MULTIDISCIPLINED INDIVIDUALS:
DEFINING THE GENRE

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Ph.D. 2010
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Much of literature is predicated upon the assumption that learning occurring inside the workplace is related to developing expertise associated with the tasks for which the individual is employed and has a background in. This research investigates those individuals who acquire expertise in other disciplines and how the application of that additional expertise changes and enhances the individual and the organisation. By combining perspectives across the disciplinary boundaries and developing multidisciplinary expertise, these individuals demonstrate better methods of achieving business objectives, leading to faster, more imaginative solutions, more frequently, and with significantly less effort.

The literature review commenced with defining “multidisciplinary” before addressing communities that cluster around disciplines such as professional societies and Communities of Practice. Aspects of organisational, team and “learning by participation” (Ashton, 2004) literature were also considered. The study took an inductive approach using an ethnographical perspective to data collection and analysis to achieve its aim of determining the existence of multidisciplined individuals and how they acquire additional disciplines. The study used interviewing as its primary method yielding both qualitative and quantitative data from a cross sectional sample set inside a medium sized oil and gas consultancy offering technical and management advice.

The disciplines inside the case organisation were mapped to ascertain boundaries where the richest learning opportunities lie. Measuring learning across the disciplines confirmed the existence of multidisciplined individuals with evidence pointing towards the integrated multidisciplined team being the ideal learning environment. The study was able to use Threshold Concepts (Meyer and Land, 2003) to demonstrate the multidisciplinary individual development process. Moreover, having examined the social interaction learning processes the potential negative impacts of Communities of Practice in encouraging this type of multidiscipline approach was highlighted.

The study concluded that developing multidisciplined individuals was worthwhile but required organisations to be willing to provide the appropriate platform for such learning by more adventurous individuals who held the appropriate underlying abilities required by the additional discipline(s).
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Acknowledgements

I would like to express my appreciation to all my friends and colleagues who have provided help and support during this research. My special thanks to Peter Gaffney and Beryl Badger for their continued support, encouragement and technical expertise throughout and without whom this would have been so much harder.

I would like to dedicate this study to my husband, Roy, son, Barry and his wife Kate in recognition of their tremendous support and understanding throughout the last five years.
AUTHOR’S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Committee.

Relevant seminars and conferences were regularly attended at which work was often presented; external institutions were visited for consultation purposes and several papers are being prepared for publication.

Publications:


Presentation and Conferences Attended:


Methods @ Plymouth 2007, 19-20 April, 2007: University of Plymouth

Word count of main body of thesis: 74,553

Signed

Date
CHAPTER ONE

INTRODUCTION AND BACKGROUND

Introduction

"It is not enough to assemble a multidisciplinary group; the individual people must themselves be multidisciplinary or willing to become so" (Kline, 1995:4).

The quote comes from Kline's 1995 book "Conceptual Foundations for Multidisciplinary Thinking" referring to a conversation with Gene Bouchard of Lockheed Aircraft who headed up "skunkworks", a well known and successful multidisciplined group handling aircraft designs. Although multidisciplinary project teams are well known across both industry (Holbeche, 2005) and the public sector, especially in the provision of health care services (Clark, 1993: Wilson and Pirrie, 2000; Payne, 2000), multidisciplined individuals are not. The emphasis on specialisation for individuals commences early and as Klein (2006:1) pointed out "it's more and more difficult for a generalist to survive in today's academic climate, which encourages hyper-specialisation by rewarding increasingly narrow, technical studies". This pressure continues throughout the individual's working life (Tealdi et al, 2006).

This research contends that these individuals demonstrate better methods of doing business, leading to both faster and more imaginative solutions, more frequently, and with significantly less effort. They offer scope for improvement to established processes by offering better solutions, speed and completeness. In establishing recognition of the existence of multidisciplined individuals this research seeks to bring attention to their value and to encourage industry to provide the appropriate environment for their development.
The literature relating to individuals acquiring additional disciplines is very limited. As with formal learning, it would appear that much of the literature surrounding informal learning is predicated upon the assumption that learning occurring inside the workplace is related to developing the knowledge and skills associated with the tasks for which the individual is employed. This study differs from existing literature in that its general focus can be expressed as being simply about individuals acquiring knowledge and skills in disciplines which lie outside of their core discipline. Furthermore it seeks to demonstrate that the application of that additional expertise changes the individual, often leading to significant improvements in their work performance.

This Introduction sets out the general background to the study including the research aim and objectives. It then moves on to provide a brief review of earlier unpublished research completed for a Masters Degree (Rogers, 2005) which primarily explored the concept of multidisciplined teams. That study contained some data which referenced multidisciplined individuals and also indications of the learning environment which facilitated their development. This earlier study was more in the nature of an initial exploration. The intention inside this dissertation is to deepen and extend insights into the learning processes associated with multidisciplined individuals. The later sections discuss potential limitations and insights into the overarching philosophical stance that will be adopted. Finally, a road map to the study is provided.
1.1 Background to Study

One of the disadvantages of increasing specialisation is that it holds the potential for the individual to develop an "inability to perceive human knowledge as a whole, as a complete pattern, [and] is one of the sources of pervasive anxiety in our times" Kline (1995:3). Kline advocated multidisciplinary discourse on the basis that it would encourage innovative problem solving, facilitate "holism" (Smuts, 1926) by enabling "emergent properties" of a social interaction process (Lewes, 1875; Blitz, 1992) and, at its simplest level, provide for a better understanding between the disciplines. Multidisciplinary teams are often viewed as the mechanism to address these issues (Lovelace, 2000). Individuals who are able to "understand the core principles and concepts of each contributing discipline and ... are familiar with the basic language and mindsets of the various disciplines" (Clark, 1993:220) would better fit Kline's requirement.

This research is set inside an organisation which contains both multidisciplinary project teams and individuals. Although both are discussed, the focus is on the development of multidisciplined individuals. It is not the intention of the research to suggest that every individual should become multidisciplinary, rather that recognition be given to the processes inside the workplace which result in individuals acquiring additional disciplines and thus being able to provide employers with added value.
1.2 Purpose of Research – Aims and Objectives

This study is not in the nature of finding a solution to an existing problem or duplicating in a new field an approach that has been utilised previously in another field of study. It is more about examining factors involved in “learning by participation” (Sfard, 1998; Felstead et al, 2005) which in the past have been largely overlooked in the literature (Livingstone, 2003). This research is focussed upon looking at multidisciplinary individuals, a subject that features little in the existing literature. Therefore, the aim of this research is to determine the existence of multidisciplined individuals and how they acquire additional disciplines. As there are no formal education courses relating to multidisciplinary development then the emphasis will be on learning undertaken inside the case organisation and which will include both formal and informal learning processes.

To achieve this aim, eight objectives have been arrived at as follows:

- Compare and contrast the participants to determine any shared characteristics which facilitate the acquisition of additional disciplines;
- Assess, by means of measuring, informal learning levels within the organisation and identify any multidisciplinary individuals;
- Identify what informal learning processes are present in the workplace and their individual contribution to the overall learning process;
- Assess environmental factors such as ethos and working practises in the workplace to determine their contribution to the individual learning process;
Illustrate by means of mapping what disciplines are inside the organisation and how they fit together;

Define boundary areas in the mapping exercise to identify difficulties that might exist for individuals crossing disciplinary boundaries;

Assess factors which may arise during data gathering to determine if there is dominant factor influencing the individual to acquire additional disciplines; and lastly,

Develop a model to illustrate the factors involved in the development of additional disciplinary expertise by the individual.

These objectives are focussed on gathering data about the individuals employed in the case organisation; the work that they do; the methodology employed to complete that work; the case organisation itself; their disciplines and lastly, the process whereby they “acquire” the additional disciplines. These aspects are discussed in more detail below.

1.2.1 Individuals

It should be noted that it is not the intention of this research to provide an in-depth psychological profiling of a multidisciplined individual. If the discussion focussed more on the individual's particular qualities, all that would be necessary would be a list of traits and characteristics that a potential multidisciplined individual should possess. While there is already a substantial body of literature on competencies and traits, as well as the theory connected to team working, none of these lists relates to what it takes to make a good multidisciplined individual. Therefore, this study will focus on what the individual
does rather than what he or she might be. What will be useful to include inside the population profile is some indication as to why the individuals chose to enter their specific discipline and the industry sector. Both aspects might provide pointers as to the nature of the discipline itself, and highlight any shared specific underlying characteristics across the population which may give a predisposition towards the acquisition of additional disciplines.

It is appropriate in this research for the individual profiles being compiled to include details of any other formal organisation (including professional societies) to which the individuals belong. This is a necessary step to ensure that those individuals who are acknowledged within the case organisation as being "multidisciplinary" have not acquired their additional disciplinary knowledge through other avenues. Examples of such avenues are formal training or educational programmes, through individual involvement with professional societies and their education programmes or any other alternative method. It is recognised that individuals may seek to augment their expertise in additional disciplines by some or all of these methods.

The material will be compiled from a number of different sources. Organisational records will be available to document details such as age, education and employment experience. Further background on the participants can be obtained through a series of interviews across the sample to obtain details on their work history prior to joining the case organisation. This can include questions concerning their discipline and career choices.
1.2.2 Acquisition of Additional Disciplines

At this stage of the research the acquisition of additional disciplines could potentially be attributed to either formal training or through informal learning processes present in the case organisation. To confirm which avenue is appropriate it will be necessary to establish what are the potential learning processes available in the workplace and how these processes apply to the learning situations being described by the research participants. Moreover, if the process is as a result of informal learning then it becomes necessary to attempt in some way to measure that learning. It might be feasible to quantify the individual expertise across a range of knowledge through the use of closed questions inside structured interviews. Using structured interviews would give the opportunity to pose questions that provide for statistical analysis thereby giving a numeric dimension to the research findings.

If, as a result of the data collection, it becomes possible to measure the individual's learning while inside the case organisation then the measurement would be demonstrable proof that "multidisciplined individuals" exist. Such measurements might provide insights as to whether there is a "scale of learning" (Erault, 2000) present and what the range of that scale might be. Multidisciplined individuals should hold a total knowledge base located at the higher end of any such scale. The scale should also indicate the level of knowledge which would be considered to be normal for an individual within the case organisation.
1.2.3 Environmental Factors – Project Teams

While it has already been established through previous research (Rogers, 2005) that the work inside the case organisation is undertaken on a project team basis, what is required here is the individual's perspective on how these teams work together. Exploring this team interaction within the technical projects has a significant role inside the study. It is expected that the data will suggest appropriate learning roles available in the case organisation. At the very least it will indicate where those aspects of the work lie which provide the individual with the greatest potential to access different disciplinary knowledge.

Evidence of this activity potentially can be drawn from other staff, data, material provided by the clients together with the various organisational databases and systems on a day-by-day basis. Further information will be obtained from a mixture of structured and unstructured interviews it is planned to undertake. Additionally, the structured interviews may enable quantum data to be obtained concerning the projects. This can then be supplemented by the unstructured interview data which will give the individual's subjective perspectives. In addition to this data, the researcher will participate as a member of project teams on two different projects so that some personal experience and perspectives are gained prior to embarking upon interviews. Moreover, participating in projects in this way will provide the researcher with a more empathic approach to framing the questions to be posed, and in understanding the responses which are more closely related to the project team experience and from a technical perspective.
Using this data it will then be possible to determine precisely what disciplinary knowledge exists and how that knowledge is being transferred. Sharing the individual's perspective in this process will again be a different reality to that of the researcher, who is most often observing from outside the teams.

1.2.4 Environmental Factors - Case Organisation

The case organisation is reviewed in detail in the following chapter and will add flavour and background to the study. As multidisciplined individuals are a feature of the case organisation, then close attention needs to be paid to the case organisation's structure, ethos and working practices. This is to identify those elements which promote or inhibit the learning experiences of the individual. The data will encompass all levels of the case organisation, in order to provide both management and individual perspectives. This exercise will also seek to surface factors relating to economic or other drivers behind the case organisation's leadership, which may not be apparent from data derived from the individual.

Information will be gathered on this aspect through a series of unstructured interviews, documentary evidence and participant observation opportunities available within the case organisation.

1.2.5 Knowledge Domains and Disciplines

In order to understand how additional disciplines are acquired it is necessary to identify and describe what knowledge domains, together with their associated
disciplines, exist inside the case organisation. Moreover, the data gathered will provide indications as to which disciplines may be more accessible than others in terms of knowledge acquisition by individuals. The key will be to gain an understanding of how individuals gain access to other knowledge domains albeit across their boundaries or through overlapping boundary edges. Conversely, there may be areas of a discipline which remain fixed and potentially not able to be acquired because their complexity through informal learning processes.

Although this area could be surfaced through individual interviews, it is more appropriate to attempt to get at "shared meanings" (Vygotsky, 1986) of the group as to what constitutes the knowledge domains and disciplines. The overall mental model (Senge, 1990) obtained in this way will provide insights into the disciplinary and organisational culture. This material can then be "triangulated" (Lincoln and Guba, 1985) by posing views expressed by the groups to individuals during a second round of individual interviews. This circumvents the difficulty of obtaining data from potentially specialised participants who may be operating in an extremely limited field and therefore are unable to relate where their core discipline fits.

If these objectives are met, then the last objective can be achieved as it sets out to develop a model to illustrate the factors involved in the development of additional disciplinary expertise by the individual. At the point when this model has been formulated it might then be possible to address the twin issues of transferability and applicability to other settings or industries (Bryman, 2004).
In terms of the literature search, the objectives above provide a starting list of subjects to be explored. By necessity, it will be wide ranging in nature since the elements described above dictate that project team based literature should be included, in addition to the extensive learning and organisational literature. It may prove more difficult to find literature relating to knowledge domains, disciplines and what might constitute those areas specifically inside the oil and gas industry. Although the industry sector has an extensive literature, provided on the whole by the professional societies, it mostly relates to technical issues with very little by way of self examination of how it is run and what drives change inside the industry. The notable exception, not unsurprisingly given its sensitivity to oil price, is information surrounding oil price movements and their subsequent effect on the industry.

1.3 Previous Research and Results

The aim of the previous unpublished research (Rogers, 2005) was to explore and provide an understanding of the background and key drivers behind the concept of multidisciplinary teams within the case organisation. This was in order to both promote and encourage individuals to adopt this approach to team working. The study was undertaken very much in the spirit of surfacing the knowledge, skills and behaviours which are important to multidisciplinary working, rather than any other purpose. References to multidisciplinary individuals were contained inside the data, but it was very much a side issue albeit an interesting one at the time.
The key objectives of the Masters study focussed on the examination and identification of the forms of working which led to project teams being recognised, both within the case organisation, and by the outside world as successful “multidisciplined teams”. Understanding how the project teams worked together, and what other influences and environmental factors influenced this process led by implication to multidisciplined individuals.

The literature search conducted for the prior Masters Study examined the extensive team and team roles material which concentrated on interpersonal skills (Katzenback and Smith, 1992; West, 2004) or Belbin-type roles (1981). All of these areas lie outside the focus of this research. The literature review highlighted the various interpretations assigned to the term “multidisciplinary” as it applied to teams, team members and individuals. The various interpretations were assembled into a “best fit” model which sought to encompass all the common influences and factors associated with this description of working.

The Masters study concluded that certain individuals were able to increase their skills and knowledge, not just in more depth within their own discipline, but across the boundaries of that discipline. In some cases, the individuals were able to perform in the “added” discipline equally as well as in their original field of expertise. These individuals were labelled “multidisciplinary” (Rogers, 2005) by other staff members and management within the case organisation, and were held in high regard for the contribution that they made to the project teams. This ability did not come about by the individuals taking “formal training” in any sense, but through their working inside the project teams. However, the initial research showed that this learning was not displayed by every member
within the same project teams, and that not every project provided the environment for the learning experience to take place. The earlier study centred on exploring what were the key drivers, but did not explore how or why these drivers interacted with each other, nor did it seek to weight the influences so as to identify the key elements. Neither did the research explore in any depth who and how the individual reacted to a particular blend of influences and drivers, nor was the additional learning and subsequent development of the individual's knowledge base a conscious or unconscious behaviour on the part of the individual.

Additionally, the data supported the "best fit model", Figure 1 which describes the various themes and influences which were associated with multidisciplinary working. Some of these themes had been suggested by the literature, but the model also incorporated additional corporate, environmental and individual influences such as eclecticism that were necessary components to achieve multidisciplinary working by both teams and individuals. These are shown in red, Figure 1.

The research undertaken to identify the factors which led to particular individuals within the case organisation being identified as "successful multidisciplined individuals" by other members of its staff suggested that to achieve this recognition required certain personality traits such as confidence, curiosity and self belief, which were encouraged by the company culture. This combination produced staff who took advantage of the knowledge and information sharing culture within the company to extend their expertise. In some cases this extension of expertise was simply at the borders of their own
discipline for example, a petroleum engineer being able to handle more readily the commercial factors involved in field development. In other people, it involved a significant understanding of two or more disciplines.

Upon reflection, the previous Masters dissertation would have been sharper and more focussed if the subject had been restricted to either multidisciplinary team working or multidisciplinary individuals. However, the research undertaken so
far clearly shows that the two working experiences are irretrievably linked as a concept, both in terms of the literature and within the case organisation. The multidisciplinary linkage between team and individual is real inside the case organisation where the more "multidisciplined" the individual, the greater value they have inside the teams and, ultimately for the case organisation.

One of the most useful aspects of the earlier research was the discussion revolving around the "bundle of meanings" (D'Andrade, 1965) associated with the term "multidisciplinary". This is summarised in Chapter Two which deals with definitions being used inside this research.

1.4 Theoretical Issues

In terms of the theoretical issues related to the project, Chapter Four discusses the research design in detail. It is proposed to provide a brief preliminary overview here.

Terminology relating to the various philosophical positions varies considerably across the disciplines (Bryman, 2004; Knox, 2004; White, 2009). The initial difficulty lies in understanding what exactly are the bundles of meanings (D'Andrade, 1965) behind the terminology, and how these address the various issues as they apply to this research. These issues revolve around the nature of the knowledge being discussed within the study. Whose reality is being described? What is the theoretical approach that the study will take? How would the research be carried out? Finally, what factors or incidents might hold the potential to affect the research either during the study or afterwards?
Lincoln and Guba, 1985). Addressing these questions formed the framework for working through the research design.

This study is looking at the “lived experiences of people” (Marshall and Rossman, 1999:112) surfacing details concerning their learning experiences at work. The philosophical paradigm that sets out “to give voice” to people inhabiting hitherto hidden areas of social life” (Seale, 1999:15) is the interpretivist approach (Bryman, 2004) and will be adopted here. The study is intended to develop an understanding of how individuals gain expertise outside their core discipline, indicating that the theory will be generated after the fieldwork has been undertaken: it is an inductive approach.

Given that the researcher has been employed within the case organisation for a number of years and is versed in the structure, ethos and working patterns then an ethnographical approach (Charmaz, 2006) which facilitates the description and understanding (Bloor and Wood, 2006) of the workplace culture would make the best fit.

There is an alternative option available which is grounded theory (Glaser and Strauss, 1967). Grounded theory requires no prior hypothesis, with the theoretical models being built alongside data collection. Adopting this approach holds a strong appeal since there is little at present in the literature concerning multidisciplinary individuals.

Nonetheless, there is a rich team and learning literature and this, combined with the model produced at the end of the previous research holds the potential to
build a framework that can later be tested in the field. This potential framework rules out the use of grounded theory since there is a high risk that theory building will be biased by being immersed in the literature at an early point in the research.

The role of the researcher practitioner combined with having undertaken previous research inside the case organisation indicates that many of the elements that contribute to individual knowledge development are already known to the researcher, stemming from a combination of long term employment and prior research in the case organisation. Thus the circumstances rule out adopting the grounded theory approach. Moreover, while this familiarity contains issues surrounding researcher bias which require handling, it also means that the preliminary analysis may be reduced.

The fieldwork will seek to provide evidence from the participants on both their own individual perspectives and the wider shared “mental model”, (Senge, 1990). Dealing with the individual’s “assumptions about social reality and how knowledge is produced about that reality,” Blaxter et al, (2001:60) confirm the social constructionist approach being taken in respect of the ontological issue. Moreover, using the social constructivism approach will allow for the participants to choose for themselves the most appropriate themes and ideas, and these can then be used to explore the concepts further with others inside the case organisation. The study will take a cross-sectional perspective, and will be more targeted to substantive theory building.
Access to staff and records of the case organisation had previously been agreed with the two founding principals who are both supportive of this research. The researcher is employed by the case organisation in a senior position, so although obtaining access is relatively simple, the difficulty will be to invite staff to participate and open up to questions. The sensitivity exists as staff may feel that they are being instructed to participate and discuss their feelings about their work, their colleagues and the case organisation.

The consideration behind the choice of participants revolves around two issues, that of getting a cross sectional sample across the disciplines employed and secondly, the availability of those candidates. The project work involves a high percentage of time out of the office by the project teams. As a consequence of this, it may not always prove possible to have the "volunteer" actually on hand when required. This could also impact the sample itself by creating a bias toward "home-based" skills such as software expertise. There has been sufficient interest expressed by staff not to make this a serious issue in terms of developing the research areas.

The objectives set out earlier provide strong indicators of which tools would be most suitable to undertake in the data collection phase so as to get a clearer understanding. The general intent is to collect data inside three separate rounds of interviewing following the opportunity to work inside two different project teams. Documentation can be gathered during the course of the data collecting rounds as prompted by the material being generated during the interviews. Each type of interview will have a pilot run prior to commencement of the full phase. This will provide an opportunity to test the questions and to
further develop the researcher's skills in terms of facilitating group interviews, one-on-one interviews, and finally, holding structured interviews. Observations and ongoing notes concerning the research will be logged in field journals, which can then be added as data itself and also be utilised as a way to organise the research.

It is intended that the data be analysed by using NVivo 8, a "capture and retrieve" qualitative data software package. This software is able to handle large amounts of data easily, and proved to be a very useful tool in the earlier research. Data from the previous Masters study will be utilised inside this research as secondary data, and will be recoded into NVivo 8 to ensure that any relevant data is captured for this study. This exercise will also provide an opportunity for development of the researcher's skills with the software package.

This Introduction has already referred to the difficulty arising out of the position held within the case organisation by the researcher and, in addition to how it might influence the data collected, there is also the ethical consideration concerning the treatment of the participants. Human resource issues are among the researcher's specific responsibilities, so care must be taken throughout the research to ensure that data collection is transparent to the participants and that information obtained as a result of the researcher's HR role is excluded inside the data. This of course, applies in the reverse situation, unless it has been previously agreed with participant.
It is intended that all transcripts or other documentation be given back to the participants for their review and approval prior to being included inside the research. It is also the intention that all names be changed, in this case to an alphabetical sequence, prior to any data being passed to any third party. This is going to be essential to maintain, since it will be necessary to have one of the technical experts inside the case organisation review the technical elements of this research. As a consequence, they will therefore have knowledge of the participants.

1.5 Road Map

This thesis is set out as follows:

Chapter Two provides an overview of the industry and case organisation before discussing the terminology to be applied inside this dissertation.

Chapter Three contains a review of the relevant literature and moves on to discuss an outline framework which will determine what data needs to be collected in order to achieve the research objectives. In determining the outline framework the Chapter also sets out the research questions that need to be answered by the fieldwork.

Chapter Four sets out the research design discussing the epistemological and ontological considerations, together with the research approach. A detailed consideration of the methods to be utilised is included, together with comments on the data analysis methods.
Chapter Five looks at the data obtained from the fieldwork drawing together the various themes that emerged from the analysis.

Chapter Six discusses the findings in terms of the conclusions that can be drawn from the research. Lastly, Chapter Seven discusses the wider issues in terms of the theoretical and practical implications of this research together with thoughts on what further research might flow from the research outcomes.

Summary

This chapter sets out the background to this study which seeks to determine if individuals with a specialist knowledge base who acquire separate expertise in one or more other disciplines address the issue of an increasing inability to transdisciplinary discourse by individuals. The chapter then moved on to summarise the earlier Master's research (Rogers, 2005) and how, as a by product of that research, interest arose in the learning processes within the case organisation which resulted in the development of multidisciplined individuals. The research aim and objectives were then explored with commentary on how those objectives might be met together with an outline of what difficulties might arise during the course of the study. The intention here is being able to build a substantive theory explaining the factors involved in the development process of multidisciplined individuals. The research theoretical position was briefly discussed concluding that an ethnological approach would be adopted.
The next chapter reviews in more detail the oil and gas industry sector, background to the case organisation and the terminology which will be used inside this research.
CHAPTER TWO

ORGANISATIONAL CONTEXT AND TERMINOLOGY

Introduction

This chapter examines the case organisation which is located inside the oil and gas industry, "the world's biggest and most pervasive business, the greatest of the great industries that arose in the last decades of the nineteenth century", Yergin (1991:13). Examining the drivers existing inside the case organisation will allow for an assessment to be made of how they affect the workplace environment. A further aspect of this review is the basis for the particular meaning being applied in terms of the key terminology used throughout this research. The terms are frequently found inside the industry sector but hold different meanings, so clarification of the meanings being applied here is necessary.

2.1 Industry Sector Background - Oil and Gas

The world has a hunger for and dependence on energy, primarily oil and gas, to meet the ever increasing demands for heat in homes, fuel for cars or aeroplanes, for uses in pharmaceuticals or any one of the hundreds of products made from crude oil. This hunger also makes the industry extremely sensitive to global political and economic factors, many of which lie outside of the industry's control but equally many of which are created because of the enormous economic power of the industry itself, which is exaggerated by the fact that oil and gas are limited natural resources.
The industry is largely a commodity business characterised by fluctuations in its fortunes which give rise to cyclical booms and depression periods (Miller, 2009). The periods are marked by the relative expansions and contractions of the industry in terms of its overall size and makeup, although generally speaking the demand for hydrocarbons continues to grow. These cycles take place in relatively short time periods, sometimes with only months between "boom" and "bust" (Strong, 1989). The cyclical nature of the business, the increasing complexity of the applied technologies (Cahoon and Rowney, 1982), the changing educational approaches from generalist to specialist, the changes in the size and nature of the companies (Tealdi et al, 2006) together with the adoption of business management theories and practices (Cahoon and Rowney, 1982; Tealdi et al, 2006) have acted as the principal drivers in the increasing use of teams within the industry.

Initial papers on what was termed multidisciplinary project teams arose as a "result of the slowdown in discoveries" (in the USA) from 1957 onwards, (Halbouty, 1967:555). The US producers were faced with increasing competition, brought about as a result of the reduction of domestic opportunities as the reserves were depleted, and coupled with the opening up of new discoveries in places such as The North Sea and the Middle East. These were the drivers forcing the US producers to find ways of cutting the cost of production to maintain profitability in the face of the lower oil prices.

As the industry was forced to look more widely in the geographical sense, in increasingly harsher environments, including offshore, and were forced to drill deeper and deeper to find reserves correspondingly their demand for
increasingly sophisticated technology grew. These two factors combined to facilitate ever closer integration of the separate disciplines (geosciences and various engineering disciplines predominantly) with all disciplines drawing information from the same data streams, although still for distinctly different purposes.

As indicated in the BP Statistical Review 2007 (Appendix 1) the early 1980's saw an increase in the number of oil companies, largely as a result of the oil spike in 1981 giving rise to one of the biggest boom periods in the industry. This expansion was quickly followed by the collapse in prices in 1986, caused by a glut of oil on the market thereby marking a significant decline in the fortunes of the industry for some time. The industry picked up again in early 1990 with the ending of the "Cold War". By August of the same year it had slipped back into depression as a direct result of the Gulf War and Iraqi oil supplies being placed under embargo. The world perceived that there would be less crude oil available in the global market. Low oil prices continued due the Gulf War and never achieved the 1980 level again until 2008 in absolute terms (BP Statistical Review of World Energy 2009).

Simultaneously, the integration of disciplines was accelerated during the 1980's with the advent of desktop and networked computing, which allowed for the transportability of electronic data (diskettes). This was one of the biggest factors behind the renewed outbursts of interest in the use of multidisciplinary project teams that occurred at that time (Miller and Pope, 1987)
Notably during the 1980’s, the numbers of professionals employed within the industry declined significantly, partially because of over staffing during the boom periods of the high oil price from the mid-1970’s through to the mid-1980’s. Many experienced personnel were laid off during the depression period and were forced to find employment in other industries. Many did not return to work again in oil and gas.

Additionally, this decade was also marked by the declining attraction of the industry in terms of recruitment. This decline resulted from:

- limited undergraduate entry in view of the increasing criticism of the industry because of the environmental impacts;
- top graduates entering the electronic and other engineering industries attracted by the higher salaries;
- the element of adventure and travel that had made oil and gas “a sexy industry” waning in the light of the major growth of the package holiday business; and
- Some geographical areas being considered too dangerous to work in and by definition, employment in the industry meant moving around, thereby making it difficult for spouses and family members to find work and pursue their own careers in an era where spouses were more inclined towards independent employment. (Edmundson, 2009)

Less staff available forced the industry to look for ways and means of doing more with less which led to an increasing use of teams. This interest was revived with John Greene (1990) identifying the main drivers behind this as:
- a combination of the changes in the traditional organisation structure;
- Increasing emphasis on the profit margins;
- fluctuating oil and gas prices;
- increasing finding, development and producing costs; and
- The requirement for the optimisation of producing properties combined with integrated databases and workstations giving access to data enabling problem solving and evaluating of projects linking geologic, geophysical, production, land and economic outputs.

At the same time, the renewed interest in multidisciplinary project teams found expression globally through the auspices of the various professional associations such as the Society of Petroleum Engineers (SPE) and the American Association of Petroleum Geologists (AAPG). These societies arranged continuing development seminars, conferences and published numerous papers on the subject which firmly announced the arrival of what was really a revived concept within the industry.

In addition to the economic, social and computing drivers, the industry had been influenced by the likes of Drucker's "knowledge workers" (Cahoon and Rowney, 1982) and the philosophy of delayering in the 1970's, the continuing influence of Lewin and Homan, Tom Peters in 1980's and Peter Senge in the 1990's; all of which are referred to in the literature.

The economic decline, combined with the overall reduction of staff led to a series of mergers as it became cheaper to buy existing oil reserves rather than explore for new oil. This initially resulted in a smaller, more consolidated
industry which in turn led to the creation of super majors such as BP Amoco and Chevron Texaco operating on a global scale.

As if to prove how cyclical the industry can be, at the beginning of this research (2005) the wheel had turned full circle with smaller independent companies appearing on the scene to pick up licences on mature fields which were perceived as being no longer economically viable for the majors to produce. One example of this was the North Sea revival. Indeed, the industry was experiencing a period of high oil prices almost unprecedented in its history, coupled with the perception of supply shortages which had in turn encouraged many merger and acquisition projects. These events, alongside a number of new stock market listings in North America, the UK and Far East were significant factors facilitating growth within the industry.

By 2009 this picture had changed dramatically once again with significant cuts across the industry as prices fell in the wake of the global recession (Hamilton, 2009). In the latter half of 2009 prices stabilised, and the industry is beginning once more to invest more aggressively. Appendix 1 sets out key dates covering the history of the petroleum industry, together with crude oil prices from 1861 to 2007 to highlight the industry's sensitivity to political and/or economic factors.

2.2 The Case Organisation - Background

The case organisation involved in the research was a wholly owned, private limited company with offices based worldwide for the first forty six years of its
life before being acquired by a global American based case organisation in 2008. The case organisation is characterised as having a cross section of skills similar to those available in an integrated medium sized oil company. Revenue is drawn solely from time expended on contracts and the need to be "billable" (working on activities which will be charged to a client) acts as a key driver for the ethos and culture within the case organisation. Strong selling points are the case organisation's ability to provide clients with practical, integrated technical and commercial advice drawn from a broad spectrum of disciplines. The disciplines can handle all aspects of the oil related industry, from initial exploration through production, refining and marketing to the acquisition or disposal of assets. This ability to service all aspects under "one roof" differentiates the case organisation from its competition, and ensures the case organisation's continued survival which is evidenced by the fact that many other similar companies have disappeared from the market place during the forty five years of the case organisation's existence.

In order to provide this service, the staff require an understanding of how the various disciplines fit together (including the non-technical elements) in order to create the scope of work which will best address the client's issue and then to carry out the work. It is this broader knowledge and how it is applied that is the main driver behind the case organisation's success. Specifically, they need to be aware of the problems and difficulties associated within the various steps of the projects in the widest sense of being able to see, and be interested in, not only the "bigger picture" but also the practical results of their efforts and how such results may be applied by the client.
This "bigger picture" approach can be illustrated using a project undertaken on behalf of a client who had contracted for a review of a mature oilfield. This was a mature field which was rapidly becoming uneconomic to produce from. The project involved reservoir engineers, drilling engineers, operations specialists and management analysts. The combined efforts of the team resulted in supporting a significant multi-million dollar reinvestment program which substantially extended the life of the field. The approach was entirely multidisciplinary based, with the resulting outcomes being that solutions to the client's problems were found which otherwise would have been difficult to discover. What was especially interesting was that this project was carried out in conjunction with the client's own staff, who also adopted the same multidisciplined approach under the general guidance of the case organisation.

A different example can be found in a project to improve the procedures set up by a worldwide oil company in managing its oil and gas reserves portfolio. Difficulties had arisen from internal company pressures to meet tight deadlines, which had been aggravated by the compartmentalisation existing inside the company. To provide appropriate recommendations, which effectively standardised approaches, for the client the project team were required to fully appreciate the complexities of the situation. To remedy those defects which had been created by compartmentalisation required the combined efforts of a multidisciplinary project team which included geoscientists, engineers and business analysts. The emphasis was on producing holistic solutions across the range of disciplines otherwise the recommendations would have been no different than those produced internally by the client.
The case organisation is consistently active with a large cross section of small and large projects. Some of the projects last for only a few days, while other projects are ongoing for a number of years. Technical staff employed on projects can be supplemented on occasion by staff drawn in from the associated overseas companies or specialist subcontractors. There is no compartmentalisation of these disciplines and very few hierarchal levels.

When contracts are awarded, a project manager is appointed with full responsibility for the project. The teams are rapidly assembled from existing resources and comprise trained, well qualified professionals drawn from a number of different disciplines. Which disciplines combine to make up the team is dictated by the project’s scope of work, and will be drawn from professionals with backgrounds in the geosciences, petroleum engineering, chemical, engineering, petrophysics, economics and business analysis.

The teams typically vary in number from two to six or more, although it is more usual to have combinations of two to four members involved on each project. Projects can last anywhere between twenty four hours to two-three years or longer, although again, more frequently they last between six to eight weeks. At any given time, an individual staff member is likely to be working on more than one project. In some cases, they can be the project manager, guiding and directing one project, while simultaneously working as a team member on other and quite different projects.

In the last few years more of the projects have required extended periods working in client offices worldwide, rather than being serviced from the “home.”
office. Some countries also make it difficult to include inexperienced professionals in the project teams. This means that many senior staff are often away with the subsequent lack of "osmosis", mentoring and informal discussion and social interaction between new and/or younger staff and the more senior, experienced staff. While this aspect is being addressed in a more formal way than previously by more formal "mentoring" approaches so as to compensate for the lack of interaction, the impact has often been to see less experienced staff grow more quickly as they were given more responsibility and exposure within the projects than they might have been otherwise.

The term "multidisciplinary" is used within the case organisation internally to describe teams and particular individuals (Rogers, 2005) and, externally within all of its published public relations material including company brochures and website.

2.3 Key Terminology

There are a number of oil and gas technical references contained within the research itself which are explained in footnotes. The discussion here relates to three terms which are used throughout the research namely knowledge domains, disciplines and multidisciplinary.

2.3.1 Knowledge Domains

Most frequently associated with knowledge management (Byosiere and Ingham, 2002) and systems engineering (Schreiber et al, 1998), the term
"knowledge domains" is widely used across the literature (Starbuck, 1997: Becher, 1989: Chen, 2004). Knowledge domain as a term is used to denote a catchment area of specific knowledge, although how that catchment area is defined changes from author to author. An example of this is Biglan's 1973 model which categorised the knowledge domains based on paradigm development; whether the subject matter was "pure" as in physics or mathematics or "applied" as in engineering, and whether or not the subject matter concerned the study of life systems. In systems engineering, knowledge domains refers to the environment in which a program operates. In knowledge management literature, the knowledge domains relate to the type of knowledge as in basic, experiential, emotional and innovation (Byosiere and Ingham, 2002). In this research the term is used in the wider sense of depicting a specific knowledge catchment area such as geosciences.

2.3.2 Disciplines

A discipline is defined as a "branch of learning" (Collins, 1995) and, in the sense of this research is used to describe the various specialised strands of knowledge which make up the wider knowledge domain. Using the geosciences example above, among the various disciplines included would be geology and geophysics. Drucker (1959) stated that disciplines were the product of crafts adopting a methodology to work by which implies that disciplines are a combination of knowledge and specific methods utilised in the application of that knowledge. In terms of this research, Drucker's description would serve to blur the demarcation between a discipline and the term "profession". Profession can often be substituted for discipline but looking at
the dictionary definition "type of work...that needs special training" (Collins, 1995), it would appear that the word "discipline" is referring to the required knowledge, while "profession" references the training required to perform the task. This distinction is applied during this thesis where appropriate.

2.3.3 Multidisciplinary

"Multidisciplined individuals" is a term frequently used to describe individuals inside the case organisation who have broadened out their knowledge base across one or more disciplines, as opposed to, or in addition to, becoming increasingly specialised inside their core discipline. Use of such localised terminology "reflects shared ideas and concepts among the narrower group to which the respondents belong and are characteristic of the specific cultural domain" (Gibbs, 2007:58). This research sets about exploring those shared ideas and concepts more fully, and in particular, the bundle of meanings individuals inside the case organisation assign to the term.

Multidisciplinary is a much used term and holds a range of meanings, both inside academia and across the wider industry spectrum. It is one of a number of words often used to describe teams where the members are drawn from different disciplines and/or professions. In terms of its application to individuals, the literature holds few references to multidisciplined individuals and this difficulty is reflected in the discussion outlined below. It is possible that the lack of references may serve to confirm the lack of recognition within the literature as well as within industry of these particular individuals, and of the unique contribution they can bring to the workplace (Kline, 1995; Clark, 1993).
In order to establish the most appropriate meaning to be applied here, various different authorities were consulted. The first step was to collect together various dictionary definitions, Table 1. These definitions revealed a number of different meanings being applied, with some dictionaries recognising multidisciplinary or interdisciplinary (the most frequent alternative term) as one word, while others preferred to define the prefix separately.

<table>
<thead>
<tr>
<th>Source</th>
<th>Multidisciplinary</th>
<th>Interdisciplinary</th>
</tr>
</thead>
<tbody>
<tr>
<td>America Heritage (2009)</td>
<td>“of, relating to, or making use of several disciplines at once”</td>
<td>“defined of, relating to, or involving two or more academic disciplines that are usually considered distinct”</td>
</tr>
<tr>
<td>Oxford Online (2009)</td>
<td>“as an adjective involving several academic disciplines or professional specialisations”</td>
<td>“between, among, interbreed, mutually, reciprocally, interaction”</td>
</tr>
<tr>
<td>Free Dictionary (2009)</td>
<td>“Of, relating to, or making use of several disciplines at once”</td>
<td>“Between, among, in the midst of, within, mutual, mutuality, reciprocal, reciprocally”</td>
</tr>
<tr>
<td>Collins Dictionary (1995)</td>
<td>“combining form, many”</td>
<td>“involving more than one academic discipline”</td>
</tr>
</tbody>
</table>

Table 1: Dictionary Definitions

From the meanings provided in the table, the term "interdisciplinary" appears to be more favoured as the definition applying to the academic disciplines; in those instances where two or more disciplines are involved. One of the definitions restricts the term "interdisciplinary" to academic disciplines which means that usage of this term within this research can be ruled out as being inappropriate since it is dealing with the business world. The disciplines that are being considered here are employed in the business world and embrace both the
more traditional academic areas such as geosciences, chemistry and physics, as well as what might be better described as the professions such as completions or facilities engineering. So, from a dictionary point of view, the choice would be to use multidisciplinary as the appropriate term.

There are a number of examples of “multidisciplinary” being used in the team context that can be explored within the literature across a number of industries. Warren (1994:1016) announced that the “fundamental idea of cross-functional teams and goals appears to surface about every 10 years with a new label (or a different set of semantics”. This remark was echoed four years later by an educationalist, Pirrie, (Wilson and Pirrie, 2000:1) when she stated “all these words [multidisciplinary, inter-disciplinary, cross professional] have come to mean something and nothing to everybody, and they’re thrown about”. In common usage, “multidisciplinary” appears interchangeable with other terms such as interdisciplinary, cross functional and cross disciplinary thus creating what Leathard (1994:6) described as “a terminological quagmire”. Most commonly the confusion lies in the use of the suffixes “inter” and “multi”.

In attempting to clarify this confusion, Wilson and Pirrie (2000:1) distinguished between “inter” and “multi” reasoning that there were “three dimensions. These are: numerical, territorial; and epistemological”. In numerical terms, Carpenter (1995) argued that more than two disciplines present within a team merited the use of multi; inter being reserved for instances where only two disciplines were present, thereby contradicting the dictionary definition.
Wilson and Pirrie (2000:2) observed that such teams working across the boundaries of their disciplines with the associated dangers created by that situation meant that many individuals could feel that they had "a lack of opportunities to consolidate their own sense of professional identity". These territorial and epistemological issues are discussed in more detail in Chapter Four. Vissers and Dankbaar, (2002:31) differentiated between cross functional and multidisciplinary teams very clearly by stating that teams may be formed which can be "cross-functional, representing different functional units, or multidisciplinary, involving several disciplines, or both". In other words, if something can be described as multidisciplinary in any way, then the description refers in some way to knowledge domains.

It is interesting to note that the definitions put forward by Wilson and Pirrie, (2000) outlining the differences they proposed between multidisciplinary and interdisciplinary focussed chiefly on the individuals. This related to the individual's "sharing role", and learning experiences within the team rather than the outcome of the team efforts. The definition also appears to have ignored the numerical basis altogether. In trying to find ways of distinguishing "amongst, between and cross disciplines" (Wilson, 2005) concluded that "interdisciplinary" was the most appropriate term to use rather than using multidisciplinary. As support for this decision they cite in their study of multidisciplinary teams in education one of their respondents as saying that in these teams "you get something that's more than the sum of its parts, you get something different, a metaperspective" (Wilson and Pirrie, 2000:4).
Wilson and Pirrie's decision to designate these teams as interdisciplinary totally contradicts Housley (2003:120), who described exactly the same characteristic of metaperspectives or "aims to provide a more holistic account of reality and truth by utilising a number of different knowledge bases as means of realising this objective" as being the defining quality of multidisciplinary teams. Holism appears to be the natural outcome of such teams.

In looking at the appropriateness of this term in respect of individuals, irrespective of whether or not the team is described as multidisciplinary or interdisciplinary, it is clear that the same defining quality of being able to combine knowledge across disciplines to present a more holistic or "metaperspective" should be present. The "metaperspective" aspect to multidisciplinary teamworking has been noted by many different writers as being a key feature, providing as it does, a catalyst type situation facilitating "novel solutions to complex problems" (Lovelace, 2000:22), and this aspect is dealt with in more detail inside the literature review that follows.

The definition of multidisciplinary given by the American Heritage dictionary expands to include "integrates concepts across different disciplines" which fits with the requirements outlined by Clark (1993) discussed in the opening paragraph of the Introduction. Multidisciplined thinking by facilitating the emergence of new and different properties (Lewes, 1875; Kline, 1995) can be more constructive in the longer term by acting as an additive to the more conventional scientific approach which has been the hallmark of Western thinking since Descartes (Goulding, 2002).
Kline (1995:4) provided an excellent demonstration of emergent thinking or being "more than the sum of the parts" (Aristotle):

"If you lay out all the bits and pieces of your car in the driveway, the bits and pieces will no longer carry out the main function of the car – to move and thereby transport passengers and their belonging. The transport function of the car is a characteristic of the structure of the systemic nature of the whole system".

The literature indicates that the use of the term multidisciplinary as being the most appropriate terminology to use here since it points to the ability to access metaperspectives by the individual. Moreover, it is in keeping with the dictionary definition which also describes individuals who have progressed to the stage of being able to offer "metaperspectives" as multidisciplined individuals.

2.3.4 Multidisciplinary Individuals

Having defined the meanings that are going to be applied to the term multidisciplinary inside this study, the next step is to determine what working definition can be arrived at to describe multidisciplinary individuals for the purposes of this research. Reference to the literature in this respect unearthed very little else other than the two references already referred to in this discussion: that of Kline (1995) and Clark (1993).

The term multidisciplinary has been defined above as holding the quality of producing metaperspectives (Housley, 2003) using knowledge combined from several disciplines (Clark, 1993). This definition can apply equally to an individual holding knowledge drawn across a number of disciplines as it can to a
team composed of a number of disciplines and it is this interpretation that will be used in this research.

What can also be established here is that the acquisition of additional disciplinary expertise is significantly different from multi-skilling which is defined as a "modest enlargement of the range of tasks required rather than a more fundamental change in the direction of skill enhancement" (Thompson and McHugh, 2002:175).

Multidisciplinary individuals can be seen as being different as they bring 'more to the table'; Holbeche (2005:154) termed them "generalists" or "boundary spanners" offering a wider ranging expertise and different perspectives. In this respect they certainly incorporate the qualities suggested in the "Thinking Performer" concept (CIPD, 2004) of delivering results, reflective, challenging, ethical, articulate and committed but perhaps not always in the way advocated within the concept. "Knowledge workers" (Drucker, 1959) are described as "employees who are involved in occupations heavily reliant on knowledge" (Suff and Reilly, 2005:52); but other researchers have noted the similar shared learning experiences inside project teams in a number of industries which include both professional and manual workers (Barrett and Sexton, 2005). Finding similar learning situations across both professional and manual workers inside project teams would serve to strengthen findings from this present research since one of its limitations is that the sample is very narrow in terms of its overall characteristics, namely that all are highly educated professional workers.
In acquiring additional disciplines during the course of their working experience, the learning experience of the individual is differentiated from those promulgated within organisations which are labelled "learning organisations" (Senge, 1990), since learning is stemming from the individual and they are not under any external pressure to learn. This is particularly important when considering Thompson and McHugh's (2002:24) observation that "learning organisation initiatives are essentially technologies of regulation aimed at facilitating change processes". This statement implies that pressure is being applied to employees by the employer to accommodate changes in work processes.

While the literature says that learning itself is self directed and self regulated, it does suggest that the more recent learning concepts relating to social interaction processes (Lave and Wenger, 1991; Yanow, 2000; Engeström, 2000; Nicolini et al, 2000) may hold the potential to account for the learning processes involved in the acquisition of additional disciplinary expertise.

Most often, gaining additional expertise across disciplines is described as "blurring the boundaries" (Nolan, 1995) and can be found in a variety of situations, although most commonly used to describe the integration of tasks and disciplines brought about by the availability of digital data. Many examples of boundary blurring can be found across a range of subject areas such as art, science and religion. Among the examples quoted by Wilson (2005) is the teacher and teaching assistant situation, where the demarcation line between the teacher and assistant is increasingly being eroded. Another example would be the practice in local Accident and Emergency departments. The Minor
Injuries Units are being increasingly run by nurse practitioners rather than by qualified medical Doctors (Horrocks et al, 2002).

Indeed, the case against encouraging multidisciplinary expertise can be found inside these examples. Encouraging individuals to cross borders could be seen to be an erosion of the specialist status. A good example of this is that of the teacher and teaching assistant (Roach, 1995), whereby the teaching assistant plans, runs and completes any follow up required in giving a lesson or series of lessons in the classroom. This could then be described as actually acquiring a new area of expertise outside of the core discipline, with the measurement being the individual’s competency to perform the work. It is perhaps true to say that many have the competency to complete the task, but equally the environment must be such that there is an opportunity to exercise the skill. Similarly, there has to be an appropriate management structure in place to oversee the development and perhaps, the courage to allow staff the opportunity, since there is a degree of risk involved in using such staff in the early stages of development. This is demonstrated by the example provided by the case organisation where there was a geologist running the IT department having sufficient experience to work full time in the IT role. In other words the acquired expertise is at a “stand alone” level but there remains an element of risk in appointing the individual to that role in the first instance rather than employing a qualified IT person.

The concept of working across boundaries is increasingly discussed in literature with the most common interpretation of crossing boundaries being that of working across cultural, ethnic, organisational and departmental boundaries;
most frequently in connection with team working processes. The greater part of
that discussion is focussed on training and developing people in interpersonal
(soft) skills and developing work processes, with the objective of enabling
people to work more effectively together, often in what could be best described
as collaborative teams.

Cesare and Thornton (1993) claimed that advancement inside a career meant
individuals were inclined to broaden out as they move up the corporate
hierarchy implying that for the individual, multidisciplinary competency is
acquired through experience rather than through formal education. Experience,
or more accurately informal learning (Dale and Bell, 1999), has attracted far
more research interest in the last decade than previously, when it was largely
overlooked. The focal point for the increased interest has been due to the
advent of work-based social interaction processes and, in particular,
communities of practice (Lave and Wenger, 1991) which have attempted to set
about explaining how informal learning processes may work in the workplace.

Summary

This chapter has established that the case organisation is a medium sized
consultancy offering technical advice to a range of clients inside the oil and gas
industry. The technical advice being formulated in response to client request
and are handled through project teams. Furthermore, the case organisation
lacks any hierarchal structure and is subject to the economic cycles
experienced by the industry itself.
The later sections dealt with the issue of clarifying the terminology to be used inside the research. Exploring bundles of meanings lying behind the terms especially in the case of "multidisciplinary" revealed the quality of being able to produce "metaperspectives" on the part of both the teams and individuals employed. This facet will be further developed inside the research.

The next chapter will review the literature available on the theme of "multidisciplined individuals". It will cover material relating to project teams, relevant aspects of organisational culture and structures, knowledge domains and their associated disciplines. Finally, it will examine the learning literature as it relates to this research.
CHAPTER THREE
LITERATURE REVIEW

INTRODUCTION

There are many titles which can be used to describe the different disciplinary roles that people are engaged in throughout their working life. These titles can be exact, describing specific aspects of a knowledge base such as a train driver, or they can be used to describe a more generic knowledge base such as a manager or geologist. On an almost universal basis, people will recognise and understand, in broad terms, the general area of work that the individual is employed in. Nevertheless, just because someone is described as a train driver or manager this does not mean that the individual it is describing is aware of all the knowledge, or all the skills sets that are available within the discipline that is generally perceived to be represented by the title nor, more importantly, is there an expectation that they would have. In acquiring additional disciplines, individuals straddle different knowledge bases, but the extent of that straddling varies from individual to individual, and is dependent upon the level of knowledge they acquire in the additional discipline.

This chapter commences by scoping out the areas to be covered by the literature review before exploring the knowledge domains and disciplines to understand how they are constantly evolving. A review of disciplinary borders and mapping alternatives is discussed, together with the mechanisms available for disciplinary interaction. These mechanisms are perceived to be the associated disciplinary professional societies and communities of practice where they exist. The chapter moves on to review appropriate sections of
organisational theory, in particular project team working. The discussion then centres on elements of organisational learning literature before dealing with how this literature exposition informs the research questions that are to be addressed during the data collection phase.

3.1 Literature Review – Scope

The aim of this research is determining the existence of multidisciplined individuals and how they acquire additional disciplines. Given the open nature of the research, it would be easy to take a number of different paths to explore and understand multidisciplined individuals. Therefore, before discussing the scope of the literature review, it is useful to examine the areas which were discarded as not being of value to the overall aim of the research.

There is extensive literature devoted to various facets concerning the individual themselves such as problem solving, critical thinking or creativity. A detailed review of these areas would lead this discussion more along the lines of what the individual is whereas it is trying to focus on what he or she does.

Furthermore, if the discussion focussed more on the individual's particular qualities, all that would be necessary would be a list of traits and/or characteristics that a potential multidisciplinary individual should possess. While there is already a substantial body of literature on competencies and traits as well as the theory connected to team working, none of these lists relates to what it takes to make a multidisciplined individual.
Moreover, it is reasonable to assume that whether or not an individual has the appropriate traits, equally as important is the individual's circumstances. It could be, for example, that an individual is open to learning and is not influenced by "status" concerns arising within their particular discipline community. That individual may simply work in a tightly controlled environment or process where there is limited or no opportunity to develop across disciplinary boundaries and would not, therefore acquire additional disciplines.

A search of the literature did not reveal any information relating specifically to multidisciplined individuals although the internet itself carries job vacancies which reference multidisciplined individuals being required. The references appear to be mostly in the IT sector for example, inside software development teams (www.dsdm.org, Jan 2010).

The literature held some instances where an individual has added a completely different expertise in some way (Cross 1991) described as:

"[firstly] that of the ability of the single individual to assess and rectify problems as they occur day by day, regardless of the nature of the problem [and secondly] the only limitations on who does what, how and when, are the skills that an individual has or can acquire, the time available to perform any new or additional tasks, and the requirements of safety" (Armstrong, 1999:335).

The first principle can be interpreted as individuals becoming multi-skilled through training or through "hands on" experience, and can be applied readily to industrial situations such as training machine operators to maintain as well as operate their machines; it is less easy to see how that would be applicable in the instance of a secretary acquiring sufficient knowledge within a company to become its computer manager.
The second principle recognises self improvement through self motivation and in the context of this study, motivation could prove to be a significant factor in understanding the processes. It is worth briefly exploring this area while trying to avoid the danger of getting too involved in the psychological aspects this entails, since it is not the intention of this research to provide in-depth psychological profiling. The question of motivation on the part of the individual is of potential interest as it could facilitate an understanding of why individuals might choose to dilute their skills in the face of pressure to develop increasing expertise.

Recognising that “motivation is something of a chimera – it’s tricky to see how it operates in principle – never mind implement it in practise”, (Levy, 2005) an initial review of the literature revealed in excess of twenty theories which may or may not apply in some degree or other to individuals in this research, Table 2.

The school of thought as laid out by Herzberg (1966), the “two factor theory” set out below is often criticised as being middle class biased and largely arrived at as a result of the questioning technique used in his research. It breaks out the key drivers into two areas, motivation and hygiene factors, Figure 2.

The motivational elements are similar to McGregor’s “Theory XY” (1960) which is based on the “complex man” showing high levels of responsibilities and self direction.
<table>
<thead>
<tr>
<th>Date</th>
<th>Type</th>
<th>Name</th>
<th>Theory</th>
</tr>
</thead>
<tbody>
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<td>Content</td>
<td>Maslow</td>
<td>Needs Hierarchy</td>
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<td></td>
<td>McGregor</td>
<td>XY Theory</td>
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<tr>
<td>1961</td>
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<td>Homans</td>
<td>Exchange Theory</td>
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<td>1961</td>
<td>Content</td>
<td>McClelland</td>
<td>Achievement/power theory</td>
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<td></td>
<td>Vroom</td>
<td>Expectancy Theory</td>
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<td>Adams</td>
<td>Social/Equity Comparison</td>
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<td>1966</td>
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<td>Value Expression/Self Identification</td>
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<td>Berlyne &amp; Scott</td>
<td>Arousal theory</td>
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<td>Heider &amp; Weiner</td>
<td>Attribution theory</td>
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<td>Hammer</td>
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<td>1978</td>
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<td>Clance &amp; Imes</td>
<td>Imposter Syndrome</td>
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<td>1982</td>
<td>Content</td>
<td>Alderfer &amp; Smith</td>
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<td>D. Ford</td>
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<td>Klein</td>
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<td>Bandura</td>
<td>Social Learning</td>
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<td>1990</td>
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<td>Kleinbeck &amp; Schmidt</td>
<td>Adaptation of goal theory</td>
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<td>1990</td>
<td></td>
<td>Locke &amp; Latham</td>
<td>High Performance Cycle</td>
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<td>1992</td>
<td></td>
<td>M. Ford</td>
<td>Motivated systems theory</td>
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<tr>
<td>2000</td>
<td></td>
<td>Deci &amp; Ryan</td>
<td>Cognitive Evaluation Theory</td>
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<tr>
<td>2000</td>
<td></td>
<td>Maes &amp; Gebhardt</td>
<td>Self-determination, autonomy and relatedness</td>
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<td>The health behaviour goal model</td>
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Table 2: Motivational Theories

<table>
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<th>Motivation</th>
<th>Hygiene</th>
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<tbody>
<tr>
<td>Responsibility</td>
<td>Supervision</td>
</tr>
<tr>
<td>Recognition</td>
<td>Salary</td>
</tr>
<tr>
<td>Promotion</td>
<td>Company Policies</td>
</tr>
<tr>
<td>Achievement</td>
<td>Relationship with colleagues</td>
</tr>
<tr>
<td>Intrinsic aspects of the job</td>
<td></td>
</tr>
</tbody>
</table>

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Figure 2: Herzberg's Two Factor Theory (1966)

These theories suggest reasons why people might want to get involved in acquiring additional skills or even "blurring the boundaries" rather than confining their activities within their own discipline.
The high performance cycle theory of Locke and Latham (1990) provides an insight stating "that motivation and performance are higher when individuals are set specific goals, when goals are difficult but accepted, and when there is feedback on performance" cited by Armstrong (1999:117) which links motivation to achieving goals. In an environment of "achievers" one way of gaining recognition would be to acquire additional expertise. These theories pave the way to understanding why individuals might want to acquire new skills, but give little insight into how they acquire new skills, apart from the obvious training and further education courses that can be either provided by companies or acquired by individuals subsequent to leaving full time education.

Included in Table 2 is the "Imposter Syndrome" (Clance and Imes 1978) which appears to be linked with peer approval among professionals in many ways. Previous research seems to have tagged it to women particularly, but when it first appeared, the business press indicated its presence within professional firms as a motivating factor (Maister, 1993). Maister claimed that professionals exhibited clear behaviour traits, requiring

"continual challenge and personal growth ... Because of their insecurity, and the ambiguity that surrounds the definition of good work in professional contexts" (1993:168).

Nonetheless, in whatever of these roles the individual is placed, a further consideration must be the ability to participate and share in the workplace (Masters, 1990) to enable development and participation, and thereby provide the confidence to grow in the various roles.

A further consideration was the appropriateness of using multidisciplined individuals as the name to be applied in the research. The literature suggests
that "polymath man" (Harper, 2001) or even "the renaissance man" (Van Doren, 1991), a term more widely known, conveyed the idea of an individual possessing knowledge across disciplines. One of the most famous examples of the Renaissance man is Leonardo da Vinci who interestingly was exposed to the relatively new science of optics at the time, and spent his apprenticeship with a master, Verrocchio, who established the use of mirrors to portray perspectives accurately. Da Vinci took this further in his work, thereby mixing technical innovations with art (Kemp, 1981). The danger in using either of these two titles to describe individuals who have abilities in more than one discipline lies in the perception that these titles carry. They both indicate a high level of intelligence across a range of disciplines which may or may not include the arts. It is not certain at this stage of the research that this perception applies in the case of multidisciplined individuals, since there has been no opportunity to measure how much learning, if any, has taken place. Moreover, the previous chapter dealt with the reasons why multidisciplinary was chosen to describe individuals, namely its ability to convey the idea of "metaperspectives" which was potentially one of the outcomes of the learning process.

In view of the above, the starting point for the literature review was to look at the case organisation to assess what factors might be included in the learning process. The entry point sets out what the individual brings with them into the environment, namely their disciplines, experience and any professional society involvement they might have. The workplace is organised into project teams and could potentially house communities of practice. Additionally there is the continued involvement by the individuals in the appropriate professional societies. Moreover, there is the overall organisational ethos and culture to
consider, Figure 3. These are all factors which are common to many working environments.

![Figure 3: Research Scope](image)

The work is organised into project teams which implies social interaction, which is linked to communities in one form or another. There are the communities clustered around the disciplines, such as professional societies and/or communities of practice; other communities are found in the form of project teams and furthermore, there is the larger community forming the organisation itself. The next chapter explores the worlds of these communities as they are represented in the literature. It is recognised that many, if not all, of these communities are, to a greater or lesser extent, within the daily experience of most of the working population, but not everyone exposed to these same drivers develops multidisciplinary skills. Therefore, it becomes more a case of "we had the experience but we missed the meaning" (Eliot, 1943) for many.
This research will seek to establish why some individuals acquire additional disciplines while others do not.

Many of the areas covered in this review such as learning and organisational structures have extensive, well documented literature available, so this review is focussed on those key issues which will provide a framework in which the appropriate research questions can be identified.

3.2 Knowledge Domains and Disciplines

The reservoir of knowledge is vast and, as the reservoir continues to grow, it requires an ever increasing division into smaller and smaller groups that drill down into deeper and deeper layers. This deepening of knowledge necessitates individuals becoming increasingly more specialised in narrower areas of knowledge. These areas of knowledge hold the potential to eventually, over a span of time, evolve into a specific discipline. Disciplines are a way of dividing up the work inside the knowledge domains (Brand and Karvonen, 2007:22).

Traditionally, the body of knowledge is divided between the sciences and the arts, with science being the long standing dominant paradigm (Lazear, 2000). This is the paradigm which has “an empirical world that can be studied objectively” (Seale, 1999:3) at its core. Having divided the literature into two categories, it can then be further sub-divided using Biglan’s classification (1973) which, in addition to the traditional divide of science and arts, added a dimension which dealt with the divide between pure academic and applied
active disciplines. Kolb (1981) added each area’s potential response to learning. Using this as a basis, Becher (1989:12) then added a further social dimension (Trowler 2006) to this classification providing insights into the character of the discipline itself:

“When academic fields are mapped on this two-dimension, (scientific and artistic, or abstract and concrete) a four-fold typology of disciplines emerges. In the abstract-active (hard-pure) quadrant are clustered the natural sciences and mathematics, while the abstract-active (hard applied) quadrant includes the science-based professions, most notably the engineering fields. The concrete-active (soft applied) quadrant encompasses what might be called the social professions, such as education, social work, and law. The concrete-reflective quadrant (soft pure) includes the humanities and social sciences”, (Becher, 1989:12).

The social dimensions that Becher added were based on the same four cell matrix using convergent and divergent on one axis to describe the level of conformity within the knowledge domain. An example of this is “engineering [which] is hard, applied, convergent and urban” (Trowler, 2006:4), implying that this particular area is populated with individuals who respond to standards, are constant in nature, are interactive and solve problems using a number of other people. The second axis was labelled urban and rural to provide smaller knowledge domains with high levels of interaction on the one hand (urban) contrasting with larger areas which require less interaction (rural) (Trowler, 2006). Becher (1989) used sociology as an example of a rural area. The Kolb-Biglan-Belcher categorising system has been heavily criticised for being too simplistic (Becher, 1989; Trowler, 2006), but it serves the function of beginning to focus on engineering and its prevailing culture.

Having found a methodology for categorising disciplines, the next consideration is how to deal with constant change inside the disciplines. The difficulty is that
of being able to apply a "permanent and enduring" label (Becher, 1989:1) with which to define a specific knowledge area. In some cases, the title remains in place for a very long time (such as lawyer), but in other cases, the knowledge domain that it is describing in the present can be very different from the knowledge domain that it was originally assigned to. For example, engineering in the late nineteenth century revolved around the invention (and applications for) the steam engine giving rise to the industrial revolution (Nuvolari and Verspagen, 2009). In the early twentieth century, engineering revolved around the internal combustion engine, generating entirely new industries such as the aircraft industry, and subsequent work on specific uses created new areas of knowledge (and disciplines). More recently engineering is facing increasing pressure to change even more as it is "becoming more complex, with boundaries established in the nineteenth and twentieth centuries between the traditional engineering and science disciplines blurring or disappearing" (Noor and Lobeck, 2005:26) eventually "converging" (ibid).

Other examples of change can be found in the growth of new sciences such as genetics in the last thirty years, or in the evolving world of the social sciences spawning more and more specialised disciplines (Sil and Doherty, 2000).

Furthermore, the knowledge domain itself becomes so fragmented that the label evolves, eventually applying to one knowledge base, whereas originally the knowledge base may have been wider, or covered a number of different bases. An obvious example of such fragmentation is the Worshipful Company of Barbers founded in 1308 who exist as a livery in the City of London today. In the nineteenth century barbers acted as "doctors" to the community in addition
to their hairdressing and shaving duties. Today the title has survived, but the members of the company are all medical practitioners; not hairdressers or barbers (Colli, 2003).

This evolution comes at a cost with "the sacrifice of breadth for depth seem [ingly] the logical price to pay for the acquisition of expert knowledge" (Brand and Karvonen, 2007:22). Moreover, as individuals grow more specialised in their particular field then the less interested they will be in other disciplines with the consequent loss of opportunities for interaction (Becher, 1989). The need to share ideas and work across the disciplines remains a difficulty (Bryans and Smith, 2000). Recognising this growing gap Sil and Doherty (2000) argued for closer integration of knowledge between the various disciplines, although later book reviews criticised the authors for not doing exactly that in their treatment of the subject (Boromisa, 2003:265). Sil and Doherty also drew criticism for not taking into account the fact that researchers in other disciplines may not be familiar with research methods used outside of their specialisation, and this may weaken any results that may be obtained in any particular study (Lansford, 2001).

Within the oil and gas industry, the progression from a long established body of knowledge, that of geology into increasingly more specialised disciplines, each ever more distant from the mother discipline (Miller and Pope, 1987), is simple to track through the literature since the industry itself is still relatively young. In its present form the industry has only been in existence since the 1850's (Yergin, 1991), and the disciplines have developed in pace with the economic demand. For example, at the turn of the nineteenth century petroleum
geologists were most likely to be university professors hired on a consultancy basis, and an engineer was mostly likely to be “merely a roughneck or a driller without formal engineering education” (Halbouty, 1976:2). Geology was regarded as a “well defined branch of science with a body of knowledge and a methodology distinctly different from other sciences” (Miller and Pope, 1987:13). The same author fixed petroleum engineering as an offspring, stating that:

"the mother science of petroleum engineering is geology .... Petroleum engineering however, emphasizes the application of science and engineering to the movement and extraction of fluid mixtures within the earth's crust; (Miller and Pope, 1987:14).

Halbouty (1963:241) described how the work was shared between the two disciplines as:

"Traditionally, geologists seek and find, and petroleum engineers develop and produce. Once a discovery [of oil or gas] is made, the geologists tend to lose interest and turn over the responsibility for the area to the petroleum engineers".

This implies a sequential chain of events with little overlap between the disciplines which would provide a learning situation.

As indicated before, disciplines change over time, sometimes widening their scope to accommodate changes as a result of new knowledge being acquired, new technology or in response to industry changes. An example of this inside the oil and gas sector can be seen in the drive to widen the scope of the "discipline of petroleum engineering to stake out a claim to address all engineering problems involving fluid transport in the earth" (Miller and Pope, 1987:13), thus moving away from the concept of petroleum engineering being limited to simply oil. Interestingly, gas is not considered within the scope of Miller and Pope's particular paper. The petroleum engineering discipline "is often viewed as being more of a technical speciality than as a fundamental
discipline" (Miller and Pope, 1987:13). Miller and Pope argued that it is something that can be applied in a number of different industries, for example, hydro related sectors as fluid would also include water. There was no evidence in the literature to suggest that the profession has indeed widened its scope.

3.3 Boundaries

Knowledge areas are contained by "boundaries" (Bergquist, 1995); the nature of which can be different according to the perspective being adopted. Sil and Doherty (2000:1) define two different boundaries, that of convention and the predominant paradigm:

"(1) the enduring, and seemingly entrenched boundaries defining and separating disciplines and subfields e.g. "political economy and historical sociology... and

(2) the boundaries that divide distinct theoretical schools or research traditions regularly vying for supremacy as "paradigms, .. i.e., the boundaries between neoralsim, pluralism and constructivism)"

These approaches can also be seen as the pragmatic solution, so that research in a given area can be carried out using the commonly agreed research methods, resulting in shared perceptions of meanings being drawn from that particular research. It is this process that makes any new knowledge acceptable within that particular school of thought (Remenyi et al, 1998).

The perspective of boundaries being used as demarcation lines between ideological camps of thought is viewed somewhat negatively by Brown and Duguid (1994) who saw them as mechanisms for containment. "Enclosed environments to embody, preserve, and represent authority" (Taylor, 1999:12) being used to describe groups creating self governing bodies with a vested
interest in maintaining the boundaries of their discipline and, through the use of change mechanisms and "boundary riders" (Taylor, 1999:11) to resist attempts to alter these boundaries. Nancarrow and Borthwick (2005:903) echo Fourneir (2000) in making the case that "construction and maintenance of boundaries is crucial to professional development and demands constant boundary work to preserve or expand them", with Rushmer and Pallis (2003) labelling any attempts to blur or cross boundaries as being a disaster.

Becher (1989) emphasised that these boundaries could be considered as "territorial possessions [which] can be encroached upon, colonised and reallocated" (ibid:37), with some boundaries being more flexible than others. One example of loose borders is geography, where "its practitioners readily absorb ideas and techniques from neighbouring intellectual territories", (Ibid:37) to "the extent that they even identify themselves with other academic professions than their own" (ibid). Becher cited economics as being almost the opposite, with practitioners who question the basic tenets being treated as outcasts, thus providing an example of the "boundary riders" in action. Moreover, economics is an example of a knowledge domain which retains a rigid hold on theories and research methodologies until such time that these are displaced by newer paradigms. This can be evidenced by Fforde's complaints concerning "the homogeneity assumption" which underpins much of economics preventing it "being more persuasive to those outside the discipline" (Fforde, 2005:63).

Not only are boundaries clearly the cause of much activity in terms of maintaining them, but they also give rise to problems when they sometimes
overlap and share common areas with other disciplines. In some cases they
do not fall neatly side by side or overlap, but simply do not match up, thereby
creating “gaps” (Becher, 1989). Becher described:

“Boundaries between the hard/soft, pure/applied knowledge cannot be
located with much precision, and even when they have been staked out,
several of the established disciplines fail to fit comfortably within them”
(Becher, 1989:1).

These gaps had already been noted by Kolb who had added it as a caveat to
his theories as to how the body of knowledge could be divided into the separate
disciplines.

Wenger (2000:223) viewed these boundaries as “areas of unusual learning,
places where perspectives meet and new possibilities arise”. These perceived
gaps act as drivers for the emergence of new disciplines. For example, in the
oil and gas sector there was recently a drive to reintroduce a discipline to span
the gap between reservoir geology and engineering. The discipline would
revolve around reservoir geochemistry, dealing with both reservoir rocks and
their contained fluids (Larter et al, 1997:12). This was a result of a shift in
industry focus from exploration towards reservoir appraisal and production
(Larter et al,1997). Geochemistry is not a new discipline but something that
was taught some 20-30 years ago, which at the time had fallen away since it did
not attract the necessary industry support. This lack of support for the discipline
was possibly due to the more readily available and accessible exploration areas
at that time than are to be found now, which meant there was less emphasis on
knowing what was under the surface.
Becher (1989:36) discusses thinking "of knowledge and its properties in terms of landscapes, and to saturate epistemological discussion with spatial metaphors: fields and frontiers; pioneering, exploration, false trials; charts and landmarks" when seeking to define adjoining areas of knowledge. Hence, mapping is commonly employed as a means of describing these borders. In mapping these boundaries there are inevitably some areas of knowledge which will overlap or be overlapped by other disciplines.

Buchanan (1966) described these as "spill in" and spill out areas and there are very few clear cut boundaries. Although Becher (ibid) described mapping in itself as having a "limited" usefulness this view is not held by all. Burke (2007) repeats Weiner's (1948) contention that mapping held out the "promise" of highlighting the gaps between disciplines where innovative problem solving would be most fertile.

Applying mapping to the oil and gas industry assists in distinguishing how the disciplines are employed within the oil supply chain. Mapping would also begin to highlight areas where there is potential for spill in and spill out to exist. As this mapping does not exist at present inside the literature to any great extent a very simple topology has been drawn up in Figure 4 to provide an overview and this mapping will be further developed during the research.
An alternative mapping structure is provided by Levorsen (1967:11) who mapped the disciplines in relation to the reservoir itself:

"the aim of academic geology may be said to be the accurate correlation of formations, the detailed working out of the geologic history, or the making of a carefully structural map. That of the exploration geophysics, on the other hand, is to measure various physical properties of the rocks underground ... The job of the petroleum engineer is to determine the reservoir data ..." (1967:10).

In Levorsen's view the data and information provided by the individual disciplines had to be "interpreted, correlated, and integrated" (Ibid) by the production geologist. Thus, the production geologist had become the pivotal discipline. Mapping in this way suggests that the only person able to move across the disciplines would be the petroleum geologist, since the other disciplines involved are only accessing specific areas of data and information, and are therefore unable to see the whole picture.
The literature does not provide any detail as to where the disciplines fit inside the oil and gas sector, so mapping the territories and their boundaries for the relevant disciplines would highlight overlapping areas which is where the potential lies for individuals to develop their expertise across the disciplinary borders. Certainly after reviewing Levorson's mapping, it would appear that there is very little overlap occurring so clarification of this aspect is required.

Relations among the various sciences and specialized fields that are utilised by the petroleum geologist. He stands between these sciences and the oil and gas pool; his chief job is to interpret them so as to locate a prospect that, when drilled, will yield commercial oil and gas – Levorsen, 1954.11

Figure 5: Levorson's Mapping of the Reservoir Activity (1967)
3.4 Communities

The following sections look at how the literature views the communities that cluster around the knowledge domains to assess their impact upon the learning process.

3.4.1 Disciplinary Communities

One of the defining attributes of a discipline is the sense of community that a discipline provides (Brown and Duguid, 1994), who viewed them as containments or "communities of practice"; a view reiterated by Lave and Wenger (1991) and Richter (1998). Becher (1989) and Taylor (1999) imply that those communities which evolve from the science based knowledge domains are perceived to be somehow more superior to those that arise from the social sciences. This view is supported by almost universal acceptance of the empirical approach which has been practised since the days of Aristotle.

The differences in perceived professional status were identified (Kline, 1995:252) as being part of a much deeper problem which he described as "tribal culture":

"examination of the way we educate and professionalise experts in the various disciplines dealing with truth assertions shows they often undergo a strong process of enculturation. This enculturation creates and reinforces schemata in the minds of experts that can and often do act as distorting filters when applied to complex systems".

In other words, "tribes" are created through the educational "rites of passage" and reinforced after full time education by belonging to the "right" professional institutions, having the "right" professional qualifications, attending particular
events, etc. Tribalism (Becher, 1989; Taylor, 1999; Sil and Doherty, 2000) is a common theme running through much of the literature concerning the development and continued evolution of specific areas of theoretical knowledge and the subsequent application of expertise.

The tribal behaviour inside disciplines is strict:

"Professionals" ethical codes require them to serve clients unemotionally and impersonally, without self-interest. Professionals identify strongly with their professions, more strongly than with their clients or their employers. They not only observe professional standards, they believe that only members of their professions have the competence and ethics to enforce these standards. Similarly, professionals insist that outsiders cannot properly supervise their activities" Starbuck (1997:152)

All of these "clubs and rites", whether or not they are within academia, the various professional societies and/or inside organisations, are designed to reinforce the sense of "belonging", to exclude outsiders and to facilitate the growth of the community by means of information and support for the individual. The sense of community can be expressed in a number of different ways, such as specialised jargon, specific research theory being applied, and interdisciplinary interaction (Taylor, 1999).

The recognition of the individual by the "club" and the strong external validation that this recognition gives to the individual is a very powerful motivational factor encouraging them to remain inside a particular "club". This is a significant factor in the conscious decision by some individuals to seek external recognition by deliberately not diluting their expertise by transcending their disciplinary boundaries however strong the argument. Increasingly in today's more complex society there is a requirement for skills that are broader based and this
requires individuals to broaden out their skill and knowledge base (Taylor, 1999).

This latter point was echoed by Holbeche (2005:9) who stressed that "it was the key to competitive advantage". Holbeche (2005:154) exhorted the need to:

"hire generalists. Let generalists combine the broad array of different skills, techniques and ideas needed to create dynamic stability. [They are] boundary spanners able to develop fresh ideas from a range of different sources".

The term "boundary spanners" is not new (Thompson, 1967; Aldrich and Herker, 1977; Bradach and Eccles, 1989) and is more usually used to describe people who cross a number of differing types of demarcation lines; discipline boundaries being just one example.

The question of whether certain disciplines attract a particular type of individual lies outside the scope of this research; however there is little doubt that the educational and associated ritual process within the disciplines provides the background framework for the individual for the rest of their life. The background framework can range in its nature from how the individual thinks as in:

"Undergraduates who go on to study law or psychology are trained not merely in the content of the discipline, but in the manner of reasoning characteristic of that discipline" (Amsel et al, 1991:247).

Or, in how they carry out their professional duties as:

"in some professions, such as psychology and medicine, career grade practitioners have a large degree of autonomy in deciding where and on what they will spend their time on", (Øvretveit, 1997:24).

With recognition, and therefore reward, coming from peers within the same profession it would be seemingly difficult for individuals to "dilute" their skills, to
become a "jack of all trades and master of none" (Minshull, 1618). Bearing in mind Starbuck's definition of a professional such a dilution of technical expertise would mean much more than simply creating derision from the appropriate peer group for the individual concerned. Depending upon the rigidity of the discipline or profession involved it would, at the very least, impede the individual's progress within the profession.

The obvious exception to this would be in the case of promotion up the chain of command within organisations where managerial, financial and interpersonal skills are normally not associated with dilution of skills in the same way. This is seemingly in general agreement with Cesare and Thornton's (1993) argument that advancement in management means that an individual moves away from their technical roots to adopt a more general approach.

**Professional Societies as Communities**

It would appear easier to identify communities clustering around the discipline in the context of the professional societies such as the Society of Professional Engineers (SPE), The Geological Society or the Institute of Chemical Engineers (IchemE). In each case these institutions seek to promote learning, to develop both their standing and that of their membership within a particular knowledge domain and, in doing so, provide for continued growth and development within this sphere. Their success in this process can be measured by the level of regard and influence that these bodies can exert at an individual level in terms of career progression, and at national and international levels. The SPE is a good example of this, since its reserves definitions are commonly accepted and
often used by the industry worldwide as the basis to define how much oil or gas is present in a reservoir. The reserves definitions provide the basis for valuing a reservoir in financial terms.

Taylor (1999) saw these groups taking action to contain the discipline itself by both looking after the territory in terms of development and also in taking care that the boundaries remained intact. There is no indication in the literature of the extent to which professional societies have been explored to determine that they do have the potential to match the dimensional and identity requirements as set out by Wenger (2000). To confirm this point an assessment was made using one of the professional societies, the SPE, present in the case organisation against those dimensions. As Tables 3 and 4 demonstrated the professional society fits the requirements appropriately. The tables have been compiled using public domain information. While the SPE makes the fit with the community of practice in terms of the dimensions, it is more difficult to make accurate representation in terms of the identity elements.

In terms of the dimensions of the community, Table 3, there are ample opportunities for engagement at every level with vision being provided by the membership through a formal structure. The society sets the standards for members of the community to conform to and there is ample communication of behaviours and knowledge to members using meetings, conferences and a technical library. The membership is updated on advances inside the disciplines through the mechanism of papers which are available for study.
<table>
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</thead>
<tbody>
<tr>
<td>Engagement</td>
<td>What are the opportunities to negotiate a joint enquiry and address important questions? Do members identify gaps in their knowledge and work together to address them?</td>
<td>Opportunities provided at local, regional, national and international level via electronic, meetings, conferences to address key issues</td>
<td>What events and interactions weave the community and develop trust? Does this result in an ability to raise troubling issues during discussions?</td>
<td>Regular membership meetings which focus on key issues to members and industry, e.g. consolidation, new technology, evolving workforce</td>
<td>To what extent have shared experience, language, artefacts, histories and methods accumulated over time, and with what potential for further interactions and new meanings?</td>
<td>Large archives of papers published by SPE which provides for a &quot;history&quot; and in continuing to provide forums to members to articulate change the Society continues to evolve</td>
</tr>
<tr>
<td>Imagination</td>
<td>What visions of the potential of the community are guiding the thought of leaders, inspiring participation and defining a learning agenda? And what picture of the world serves as a context for such visions?</td>
<td>Board of Directors and elected Presidents provide vision for society. Frequent meetings also provide for shared reality by members which is reinforced via web access and publication of papers and Society Journal</td>
<td>What do people know about each other and about the meanings that participation in the community takes in their lives more broadly?</td>
<td>Presentations and papers widely presented. Social activity very important especially for those members living and working overseas.</td>
<td>Are there self representations that would allow the community to see itself in new ways Is there a language to talk about the community in a reflective mode?</td>
<td>The society is now moving towards closer collaboration with other societies while at the same splinter groups are breaking away to form new organisations which suggested that there is an ability within the organisation to reflect and review itself.</td>
</tr>
<tr>
<td>Alignment</td>
<td>Have members articulated a shared purpose? How widely do they subscribe to it? How accountable do they feel to it? And how distributed is leadership?</td>
<td>Mission statements provided at every level of the organisation.</td>
<td>What definitions of roles, norms, codes of behaviour, shared principles, and negotiated commitments and expectations hold the community together?</td>
<td>Competence criteria for various occupations laid down by society which also sets out key definitions and understandings such as reserves estimation criteria</td>
<td>What traditions, methods, standards, routines and frameworks define the practice? Who upholds them? To what extent are they codified? How are they transmitted to new generations?</td>
<td>An executive body supports the Board of Directors which sets out the rules of conduct for staff. In terms of membership unwritten rules of conduct are followed.</td>
</tr>
</tbody>
</table>

Table 3: Dimensions of a Community

- 80 -
In terms of the boundary dimensions the professional societies engage in training and developing the individual through a constant series of meetings and events, Table 4. Individuals are encouraged both by their employers, and the society itself to pursue various activities in order to reach higher tiers of the membership. Membership of these societies is often complex, being divided into a number of different categories.

Often membership of these societies provides an alternative educational route to the more traditional university study route, with degrees, masters and fellowships based on a combination of formal education and experience with the qualification being awarded by the Society itself. They can wield enormous power since in some professions the membership of the society itself is a requisite for practicing the occupation. For example, until very recently hearing aid audiologists were required to be members of the British Hearing Aid Council in order to practice. Examples from the oil and gas industry can be found in the chartered status required for petroleum engineers in the USA, or that only members of particular professional societies can certify hydrocarbon reserves for public listing.

Inside the oil and gas industry, the professional societies have not traditionally taken this position. The major player, the SPE, for many years took the position that if it chose to introduce qualification routes into membership it would be difficult to support the diversity of worldwide membership. It did not even insist that members have a degree. There is no doubt that in some countries membership of the society can provide a certain status for the individual (Gaffney, 2007).
<table>
<thead>
<tr>
<th>Engagement</th>
<th>Coordination:</th>
<th>SPE Provides:</th>
<th>Transparency:</th>
<th>SPE provides:</th>
<th>Negotiation:</th>
<th>SPE Provides:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>What opportunities exist for joint activities, problem solving, and discussions to both surface and resolve differences through action?</td>
<td>Number of opportunities exist such as meetings, workshops, papers, conferences routinely with papers describing action taken to solve key issues</td>
<td>Do people provide explanations, coaching and demonstrations in the context of joint activities to open windows onto each others' practices?</td>
<td>Opportunities exist Via international conferences</td>
<td>Are joint activities structured in such a way that multiple perspectives can meet and that participants can come to appreciate each other's competences?</td>
<td>Emphasis laid on attempting to interact between the disciplines – exhorts multidisciplinary as one way forward</td>
</tr>
<tr>
<td>Imagination</td>
<td>Do people have enough understanding of their respective perspectives to present issues effectively and anticipate misunderstandings?</td>
<td>Yes – society endeavouring to be broad based across industry and to include all disciplines under umbrella</td>
<td>What stories, documents, and models are available to build a picture of another practice? What experience will allow people to walk in the other's shoes? Do they listen deeply enough?</td>
<td>Thousands of published papers, worldwide lecture tours by leading industry figures on a range of subjects both technical and non technical which provide for insights into allied disciplines</td>
<td>Can both sides see themselves as members of an overarching community in which they have common interests and needs?</td>
<td>Oil and gas industry is drawn together by SPE on a global basis and as such it provides for a far reaching community sense to the industry itself.</td>
</tr>
<tr>
<td>Alignment</td>
<td>Are instructions, goals and methods interpretable into action across boundaries?</td>
<td>Work in such areas as Reserve Guidelines promotes interaction across the boundaries</td>
<td>Are intentions, commitments, norms and traditions made clear enough to reveal common ground and differences in perspectives and expectations?</td>
<td>SPE sets out the basic skill sets for engineering which allows then for differences to surface</td>
<td>Who has a say in negotiating contracts and devising compromises?</td>
<td>Membership via the membership committees engage in this area as well as providing direction to the Board of Directors</td>
</tr>
</tbody>
</table>

Table 4: Boundary Dimensions
More recently in 2007, the SPE has launched a junior professional engineer accreditation scheme upon the request of the membership because:

"the environmental and consumer era of the past few decades have given the public greater awareness of pollution, energy, and the need for a high level of industry professionalism" (www.spe.org, 2009).

The professional societies are as much driven by the industry itself as they are by their members, as demonstrated by the press cutting quoted below:

"oil and gas companies continue to wrestle with the problems of consolidation, new technology, an evolving workforce, and other issues that are reshaping their business. Many of those issues were addressed during the annual meeting of the Society of Petroleum engineers in Dallas last week. And while no pat answers have been provided, some new perspectives have been explored" (Rach, 2000).

The Societies play a valuable role in providing networking opportunities and access to vast stores of knowledge, and that in itself forms very powerful incentives for the individual to participate. While this description outlines their role, what is not clear is how the individuals perceive and utilise their professional societies. Moreover, the literature also does not reflect whether or not individuals are actively pressured by their professional societies to remain inside their own discipline, suggesting that this is an area for further research.

It is clear that professional societies hold power by virtue of the fact that they create situations in which members are required to interact across disciplines on a frequent basis, providing forums for learning as well as reinforcing the "sense of belonging", both within society as a whole and within the individual. Actions that previous writers (Fourneir, 2000; Rushmer and Pallis, 2003) have thought to be essential mechanisms designed to protect the disciplinary knowledge domain and its boundaries.
In reviewing examples of professional societies within the oil and gas industry, the nature of these interactions becomes clearer. Within the industry there are a number of such organisations covering the various disciplines. The SPE publish in excess of 80 such organisations on its website which does not purport to be the total listing.

Table 5 lists those key ones that are present inside the workplace and which have developed in line with the progress of the industry itself. As with any industry, as more complex and sophisticated technology developed, correspondingly the requirement for more specialised knowledge grew to handle these technological advances. In helping to address the knowledge requirement, the societies demonstrate their usefulness to the members, thereby also profiting from the growth of specialisation.

Table 5 also sets out the membership and mission statements demonstrating the size of each society and indicating their perception of their role in protecting and preserving the disciplines they are connected with.

It shows each society staking out a claim to a particular knowledge domain, seeking both to further the knowledge within the chosen domain and to provide a recognition structure for its participants.
| Society of Professional Engineers (SPE) | 1957 - claims roots back to the 19th century via American Institute of Mining engineers (AIME) | 64,000+ members in 117 countries | USA based society with Worldwide membership | To collect, disseminate and exchange technical knowledge concerning the exploration, development and production of oil and gas resources, and related technologies for the public benefit, and to provide opportunities for professionals to enhance their technical and professional competence. |
| Society of Professional Well Log Analysts (SPWLA) | 1953 with roots back to late 1940’s | Not known | USA based society with Worldwide membership | Dedicated to the advancement of the science of petrophysics and formation evaluation, through well logging and other formation evaluation techniques and to the application of these techniques to the exploitation of gas, oil and other minerals. |
| The Geological Society | 1807 | 9000+ members | UK based | Improving knowledge and understanding of the history, structure, constitution and dynamics of the Earth and its processes. Promoting all forms of education, awareness and understanding of the Earth and their practical applications for the benefit of the public globally and Promoting professional excellence and ethical standards in the Earth sciences for the public good. |
| American Association of Petroleum Geologists (AAPG) | 1917 | 30,000+ members | USA based society with worldwide membership | Advancing the science of geology, especially as it relates to petroleum, natural gas, other subsurface fluids, and mineral resources. Promoting technology for exploring for, finding and producing these materials in an economically sound manner. Fostering the spirit of scientific research throughout its membership. Disseminating information relating to the geology and associated technology of petroleum, natural gas, other subsurface fluids and mineral resources. Inspiring and maintaining a high standard of professional conduct on the part of its members. Providing the public with means of recognition adequately trained and professionally responsible petroleum geologists. Advancing the professional well being of its members. |

Taken from Public domain information

Table 5: Selection of Professional Societies in the Workplace
### 3.4.3 Communities of Practice

Previous sections have substantially documented the care and vigilance often applied to the maintenance of the disciplinary borders, and the pressure upon individuals to conform to approved (and appropriate) rules of conduct within a particular discipline. Conformity by the individual brings its own rewards in terms of "belonging" to something and recognition of achievements within the various platforms provided within each particular discipline. It has already been noted how the acquisition of knowledge within a particular domain provides individuals with a sense of being part of a community, whether that community is disciplinary or organisationally based. Nicholson (2000:47) translated this as:

> "love of status. We create elaborate hierarchies because they are compelling motivators. A long career ladder can keep a disempowered person striving on a steady drip of increments".

Wenger (2004:1) described such communities as being "the social fabric of knowledge", labelling them "Communities of Practice". In the discussion concerning professional societies, Wenger's (2000) template to assess the dimensions and elements of a community of practice was utilised confirming the professional society's role.

The focus of the interest surrounding communities of practice is the learning process they provide to the individual members, and this has certainly captured most of the attention in the current literature.
Within these communities "knowing" information consists of two distinct elements;

a) competence or the knowledge of the community that has been built up over time and which individuals acquire from the store of knowledge by virtue of their being a member; and

b) individual experiences gained after becoming a member of a specific community.

Moreover, the individual's own experiences of contact with other disciplines and communities may result in the individual having "a new way of looking at the world" (Wenger, 2003:77). Armed with this new and/or changed perspective, the individual then rejoins their specific community with the intention of communicating and attempting to explain their changed views to their peer group so that they too can benefit. In this way the individual adds to the community's store of knowledge, and by this means, the store accessed by the whole community is continuously upgraded. This dissemination of the accumulated knowledge forms the important social learning system described, and is perhaps the most significant feature of these communities. Of course, the individual also brings prior knowledge into the community which may not simply be from their specific discipline but that which they have acquired as they went along.

One issue that needs highlighting here is that the quality of the knowledge being brought into the community can be of a variable quality depending on the individual (Wenger, 2000). It also has the disadvantage that informal learning methods have always produced; the consequence of poor practice being passed on (Lockyer et al, 1988).
Using this process, Wenger (2003:78) stated that learning could then be more clearly defined as "the interplay between social competence and personal experience". Belonging to a social learning group such as a community of practice would require engagement with others, imagination to be able share the images and ideas, together with being able to incorporate the learning alongside other ideas namely, an alignment.

In viewing the typology it is clear that within this particular framework, learning is very much centred on individual experience, which of necessity involves interaction with other individuals. Lave and Wenger (1991:53) indicate that:

"Learning involves the whole person; it implies not only a relation to specific activities but a relation to social communities – it implies becoming a full participant, a member, a kind of person. In this view, learning only partly – and often incidentally, implies becoming able to be involved in new activities to perform new tasks, and functions, to master new understandings. Activities, tasks, functions, and understandings do not exist in isolation; they are part of broader systems of relationships in which they have meaning".

Lave and Wenger (1991) proposed that there could be a number of different communities, of which each individual could be a member of for example, as part of the family, a process, a department, a discipline within the place of employment, as well as within the wider discipline community or in special interest communities.

The learning taking place inside these communities is described by Lave and Wenger (Ibid) as "situated learning". Some 20 years earlier, Fleck had identified "a community of persons mutually exchanging ideas or maintaining
intellectual interaction" (1979:22) as "the thought collective" (ibid:39), networks of individuals sharing a:

"thought style, including a shared pre-understanding between the members, which clearly facilitates internal communication, but also includes constraints that prohibit every alternative mode of thinking. The thought community easily becomes a self-contained system of opinion." (Gummessom, 1991:142).

Simons et al (2003:44) make a distinction between "communities of practice (that learn around a common practical interest) and communities of learning that have no common practice but see learning as their common interest". A view reinforced by Boud and Middleton (2003:200) who explored Wenger's (1998) 14 indicators which could indicate that a community of practice had been formed, Figure 6.

Boud and Middleton reported that as well as being able to identify communities which conformed to the indicators, they were also able to identify much more loosely tied communities existing alongside them which were marked by having less coherence and sharing of meanings.

The looser knit community members were inclined to use their existing network of contacts to solve problems rather than using the community which the authors indicate tends to imply that they were perhaps still in the process of forming a community rather than being "settled" as a community.
<table>
<thead>
<tr>
<th></th>
<th>Sustained mutual relationships – harmonious or conflictual</th>
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<tbody>
<tr>
<td>2</td>
<td>Shared ways of engaging in doing things together</td>
</tr>
<tr>
<td>3</td>
<td>The rapid flow of information and propagation of innovation</td>
</tr>
<tr>
<td>4</td>
<td>Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process</td>
</tr>
<tr>
<td>5</td>
<td>Very quick set up of a problem to be addressed</td>
</tr>
<tr>
<td>6</td>
<td>Substantial overlap in participants’ descriptions of who belongs</td>
</tr>
<tr>
<td>7</td>
<td>Knowing what others know, what they can do, and how they can contribute to an enterprise</td>
</tr>
<tr>
<td>8</td>
<td>Mutually defining identities</td>
</tr>
<tr>
<td>9</td>
<td>The ability to assess the appropriateness of actions and products</td>
</tr>
<tr>
<td>10</td>
<td>Specific tools, representations, and other artefacts</td>
</tr>
<tr>
<td>11</td>
<td>Local lore, shared stories, inside jokes, knowing laughter</td>
</tr>
<tr>
<td>12</td>
<td>Jargon and shortcuts to communication as well as the ease of producing new ones</td>
</tr>
<tr>
<td>13</td>
<td>Certain styles recognised as displaying membership</td>
</tr>
<tr>
<td>14</td>
<td>A shared discourse reflecting a certain perspective on the world</td>
</tr>
</tbody>
</table>

Figure 6: Wenger's 14 Indicators (1998:125)

Contu and Willmot (2003) discussed the evolution of the communities of practice theory focussing on how elements of the original Lave and Wenger (1991) theory have been popularised with key insights being ignored. Significant among the omissions they quote are that “learning processes are integral to the exercise of power and control” (Contu and Willmot, 2003:284) which has already been demonstrated in previous discussion on discipline boundaries. Clearly in terms of how learning might be organised and who would be able to take advantage of it within an organisation might well be dependent upon the power structure within the environment and whether or not it was formal in nature. Contu and Willmott’s discussion concludes that “Lave and Wenger are inclined to overlook the significance of the wider institutionalised contexts and media of learning in favour of a focus on relations; (2003:292) and by doing so imply that these communities are "unified and
consensual" (ibid:293) which has not proved the case in other research such as Boud and Middleton.

Cox (2005) argued that communities of practice were ambiguous, that the phenomena being described was changing as the theory evolved. Lave and Wenger's (1991) version concerned the informal socialisation of newcomers. At the same time, Brown (1991) discussed improvising knowledge in groups forming as a resistance to management. By 2002, Wenger had made "a distinct shift towards a managerialist stance" (Cox, 2005:527).

In discussing communities from the individual's perspective, participation is clearly advantageous to assist in acquiring skills and knowledge, whether it be via a vehicle such as the SPE or as an apprentice in the building trade (Dainty et al, 2004). Participation is a platform upon which to build a career, and very often forming the social background to that career.

Belonging to a community of practice may require or at least encourage the individual to surrender elements of professional independence and be subject to the politics and power plays of that community. Contu and Willmott analysed the power structure contained within a community of practice and concluded that sharing of information "may appear natural or spontaneous but this openness is conditional upon sense of trust in the other, rather than suspicion, hostility, or reservation about the use to which such information may be put" (2003:294).
3.4.4 Organisations as Communities

The above sections have discussed communities as they appear in the literature surrounding disciplines and in respect of learning in communities of practice. The notion of "tribes" and "communities" was moved across into organisations by Neuhauser (1988:5) who suggested that "anthropologically, these groups in organisations act very much like "real" tribes; they have their own dialects, ways of thinking, and rules for appropriate behaviour". This next section sets out to provide a short review of the organisation structure to ascertain if the literature can provide insights into its ethos, before looking in more depth at the project team literature. The emphasis is placed on project teams, since this is working experience for each individual, and it is therefore reasonable to conclude that this is the arena in which the individuals are developing their additional expertise.

The first issue to address here is what type of structure fits the case organisation. By determining the structure the literature may reveal distinct characteristics that would indicate a cultural predisposition to housing a learning environment. There is a significant body of literature concerning the wider aspects of post modernist organisations and their structure. This focuses on the differences between the traditional hierarchical, bureaucratic structures and the variety of forms to be found today.

Buchanan and Badham (1999) describe an alternative organisation to the traditional model as an organisation reliant upon experts; not dependent upon permanent staff, rather being happy to enter into different arrangements to handle resource issues as they arise and with no significant long term order
book to provide stability. Starbuck (1997:152-3) defines the ethos inside such organisations as:

“professionals building their own roles rather than fitting into preset roles, spontaneous internal differentiation based on work interests, competition and conflict for resources and high levels of political activity. The distribution of authority has long been identified as unique in an autonomous professional organisation because of its emphasis on collegiality, peer evaluation and autonomous, informality, and flexibility of structure”.

This view was further enlarged by Koch (2000:173):

“Disregard [ing] classic principles of management. Characterised by being fun to work in, chaotic, task and project team based, disrespectful of authority if not accompanied by expertise, and fast changing. Most suited to highly educated and motivated workforces and where work requires creativity and responsive to unpredictable and volatile customers”.

This type of organisation would seemingly fit the case organisation, but it does not provide any explanation as to how learning might occur inside the working environment. The notion of collegiality, as expressed by Starbuck (1997) inside these organisations is reflected in the learning organisation literature. Pedler and Aspinwall (1998:43) referred to “collaborative enquiry”, as being one of the key elements present when learning takes place within the relationships between team members. The outcome of these collaborative efforts being measured in what the individuals are able to create together. In saying that “collaborative enquiry forms a bridge between individual learning and the learning organisation” Pedler and Aspinwall link collaborative teams together with those working environments which are described within the literature as “learning organisations” (Senge, 1990; Argyris, 1982).

Senge (1990:94) described team learning as “reflecting on action as a team and transforming collective thinking skill so that the team can develop intelligence
and ability greater than the sum of the individual member’s talents”. This definition particularly denotes the importance of “synergy” in team learning (Power and Waddell, 2004:245), and confirms the interpretation of collaborative teams, which are called integrated teams inside this thesis.

Another example can be found in the discussion on reconceptualising learning at work, where Bryans and Smith (2000:232) emphasise “the need to share ideas and work together from different disciplinary backgrounds becomes paramount” so that knowledge does not exist in separate pools but becomes interconnected in ways that “are hard to predetermine” (ibid). An alternative view was set out by Snell (2001) who advocated exposing members of the organisation to situations, challenges and environments to enhance their capabilities.

The Learning Organisation concept (Senge, 1990; Argyris, 1982; Pedlar et al, 1991) is well known, and has a number of different interpretations which are well documented in the literature. Broadly speaking there is one set of interpretations which relates to collecting and analysing both individual and collective learning which arises out of the organisational literature (Schön, 1973). The second set of interpretations is more focussed on tools which identify, promote and assess the learning inside an organisation and is firmly rooted inside the learning organisation literature (Senge 1990). According to Örtendahl (2004:62), in reality the definition of what determines what is or is not a learning organisation is vague. Örtendahl tried by reference to the different interpretations available inside the literature to present a typology identifying
four themes that he suggested appeared to best represent the concept, Figure 7. This typology placed the various writings into one of four categories:

1. Old organisational learning or knowledge which is learnt by individuals and stored in the organisational memory:
2. Learning at Work where all the learning takes place at work, not on courses
3. Learning climate – an organisation which facilitates the learning of all of its employees
4. Learning structure - Organic structure with high degree of flexibility in order to satisfy the customers of the company" (Ortenbald, 2004)

<table>
<thead>
<tr>
<th>Old Organisational Learning</th>
<th>Learning at Work</th>
<th>Learning Climate</th>
<th>Learning Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garratt, 1990</td>
<td>Minor</td>
<td>Primary</td>
<td></td>
</tr>
<tr>
<td>Senge, 1990</td>
<td>Minor</td>
<td>Primary</td>
<td></td>
</tr>
<tr>
<td>Lessen, 1991</td>
<td>Primary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedler, Burgoyne, &amp; Boydell, 1991</td>
<td>Primary</td>
<td>Primary</td>
<td>Minor</td>
</tr>
<tr>
<td>Jones &amp; Hendry, 1992</td>
<td>Minor</td>
<td>Primary</td>
<td>Primary</td>
</tr>
<tr>
<td>McGill, Slocum &amp; Lei, 1992</td>
<td>Primary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Garvin, 1993</td>
<td>Primary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Watkins &amp; Marsick, 1993</td>
<td>Primary</td>
<td>Primary</td>
<td>Primary</td>
</tr>
<tr>
<td>Jones &amp; Hendry, 1994</td>
<td>Primary</td>
<td>Primary</td>
<td>Minor</td>
</tr>
<tr>
<td>Marquardt &amp; Reynolds, 1994</td>
<td>Primary</td>
<td>Minor</td>
<td>Primary</td>
</tr>
<tr>
<td>West, 1994</td>
<td>Primary</td>
<td>Primary</td>
<td>Primary</td>
</tr>
<tr>
<td>Pedler &amp; Aspinwall, 1998</td>
<td>Minor</td>
<td>Primary</td>
<td>Primary</td>
</tr>
</tbody>
</table>

© Ortenbald, 2004

Figure 7: Understanding the Idea of the Learning Organisation where the focus is either Primary or Minor

This typology is useful in that it provides guidance as to what to look for in the case organisation, in terms of how the organisation views learning as a whole. The learning organisation concept is of interest in this research as it provides an alternative view to how disciplines might be integrated (Senge, 1990) as a result of the social interaction taking place within teams (Kerka, 1995). It is different from the learning scenarios proposed so far, in that learning is driven by the cultural aspects of the organisation as a whole, rather than being driven from within the organisation either by the individual or by a more informal community existing within or without the organisation. This would appear to be feasible as the case organisation provides encouragement and support for individuals to
become and remain members of such societies as SPE and the Geological Society where wider professional accreditation is available. In this particular research, rather than being a pro-active member of a community of practice, the individual may well simply be responding to the organisational predominant culture, namely that of a learning organisation.

A quite separate vein of research has been working to understand how the internal structure of the organisation assists in the individual learning process (Ashton, 2004; Koike, 2002; Darrah, 1996). Independently, Koike and Darrah have produced studies which showed that if employees were instructed as to where their contribution fitted inside the organisation or process, as well as the more usual in depth knowledge surrounding their own particular tasks, then the individual skill levels improved. In addition to this knowledge which was described as “breadth of knowledge”, employees needed opportunities to practise and improve upon their skills and required feedback and reward (Koike, 2002). Moreover, the organisation itself controls what the employee is able to learn in the way it organises its work processes (Darrah, 1996). Ashton (2004) linked these two studies, drawing the threads together to develop a model depicting how the organisational processes might impact upon learning as outlined in Figure 8.
In this model individual motivation is "determined by their previous experiences" and these "experiences interact" (Ashton, 2004:45) within the limits set by the organisation, in terms of "facilitating access to knowledge and information" and then providing the necessary practice time, support and rewards. Ashton's (2004) paper concludes that there is scope for more research to further define and measure the organisation's impact upon the learning processes at work particularly, referencing the requirement for research into professional consultancies, such as the case organisation.

3.4.5 Communities as in project teams

In exploring situations where the disciplines interact, one of the most fruitful areas is that within multidisciplinary project teams. The literature surrounding teams and teamwork is vast and wide ranging, often centred around roles that
people play inside teams (Belbin, 1981), on the interpersonal skills required to be a good team member (West, 2004), or on how teams can improve performance or handle change management. This particular research is concerned with individuals gravitating across knowledge domains and as a result, it will be less influenced by the previously mentioned literature focussing instead on the disciplinary interaction within teams. This interaction is more often discussed in the literature in terms of those aspects relating to the sharing and learning processes within teams which form the nature of the disciplinary interaction inside teams.

This discussion will explore how teams can be categorised by defining the processes utilised to complete their task or function. After identifying different team types, the discussion moves on to define more appropriately the team environment most likely to create multidisciplinary individuals.

The introduction discussed the confusion that can arise from the bundle of meanings that are often applied to the term “multidisciplinary” and went on to define the meaning that would be applied to the usage of the term inside this research. This same confusion as to the exact meaning of the term is repeated inside the team work literature. There are a number of different ways that a team can work together, and this process carries a number of labels whose meaning can be uncertain. An example of this can be found in the use of the term “collaborative” which is often confused by writers with “integrated”. Although both forms are used in terms of extracting the relevant issues from the literature, the following sections attempt to clarify specifically the term
"integrated" as it is used within this study, so as to fully appreciate the implications it holds for disciplinary interaction.

In trying to distinguish between different types of team, Øvretveit (1997) is particularly helpful, in that he defined teams in four different ways:

a) Degrees of integration  
b) Membership of the team  
c) Client pathways  
d) Management teams.

In terms of this study, Øvretveit's (1997:11) first method of looking at the "degrees of integration" is most useful. He postulated that it would be possible to draw up a continuum based on how closely the team members worked together to achieve the team's purpose. The relative closeness would serve as the most appropriate measurement indicating at which point on the continuum to place any particular team:

"At one end is a loose-knit team called a network. Some people would not call a network a team at all, because membership changes and is voluntary. At the other extreme is a closely integrated team", (Øvretveit 1997:11).

To describe the project teams working inside the case organisation, Øvretveit's "integrated interprofessional team" (Ibid) end of the continuum has to be further refined to gain more clarity. In order to explore how this clarity might be achieved, a number of team descriptions drawn from various published literature over the past twenty years have been assembled into two Tables, (6 and 7). These various descriptions of teams clearly indicate the differences that can be found in team processes. An example previously used is that of Wilson and Pirrie (2000), who described two different types of teams using the same terminology.
<table>
<thead>
<tr>
<th>Author</th>
<th>Source</th>
<th>Year</th>
<th>Industry</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peter Moxon</td>
<td>Building a Better Team</td>
<td>1993</td>
<td>Business</td>
<td>Team is distinct by:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• A common purpose</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Recognition by each individual as belonging to the same unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Independent function</td>
</tr>
<tr>
<td>Wilson &amp; Pirrie</td>
<td>Multidisciplinary team working</td>
<td>2000</td>
<td>Ed.</td>
<td>- Agreed norms or values which regulate behaviour</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- bring more than two groups together</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- focus on complementary procedures and practices</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- provide opportunities to learn about each other</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- are motivated by a desire to focus on clients' needs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- develop participants understanding of their separate but inter-related roles as members of a team</td>
</tr>
<tr>
<td>Clark</td>
<td>Cited in above paper</td>
<td>1993</td>
<td>Health</td>
<td>Defined as bringing various professions together to understand a particular problem or experience... In this sense, they afford different perspectives on issues at hand, just as one sees different facets of a crystal by turning it</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Multidisciplinary team are groups of professionals from diverse disciplines who come together... They also enhance the professional skills and knowledge of individual team members by providing a forum for learning more about strategies, resources, and approaches used by various disciplines (Feb 2005)</td>
</tr>
<tr>
<td>West &amp; Slater</td>
<td>Cited by William Housley</td>
<td>1996</td>
<td>Health</td>
<td>Agreed aims, goals and objectives</td>
</tr>
<tr>
<td></td>
<td>in Interaction in Multidisciplinary teams</td>
<td></td>
<td></td>
<td>Effective communications</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Individuals roles defined and understood</td>
</tr>
<tr>
<td>Øvretveit</td>
<td>Coordinating Community care</td>
<td>1997</td>
<td>Health</td>
<td>A small group of people, usually from different professions and agencies, who relate to each other to the common goal of meeting the health and social needs of one client or those of a client population in the community</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Teams work best if they are built around well-defined tasks, where clear leadership can be defined and agreed, and where the roles of those contributing to the task are valued and well defined</td>
</tr>
<tr>
<td>Glyn Elwyn</td>
<td>Integrated Teams in Primary Care</td>
<td>1999</td>
<td>Health</td>
<td>A common objective, differential professional contribution, and a system of communication will be considered necessary for an interprofessional team to exist</td>
</tr>
<tr>
<td>Kane</td>
<td>Source &quot;Team Work in Multiprofessional Care&quot; by Malcolm Payne (2000.6-7)</td>
<td>1975b</td>
<td></td>
<td>A group who share a common health goal and common objectives, determined by community needs, to the achievement of which each member of the team contributes, in accordance with his or her competences and skill and in coordination with the functions of others</td>
</tr>
<tr>
<td>WHO</td>
<td>Source &quot;Team Work in Multiprofessional Care&quot; by Malcolm Payne (2000.6-7)</td>
<td>1984</td>
<td>Health</td>
<td></td>
</tr>
</tbody>
</table>

Table 6 Cont'd....
A team is "two or more people who must coordinate their activities to accomplish a common goal" (Plovnick et al., 1975). The common goal and the required coordination make them a team. It is not enough for people to want to coordinate because it would be nice. Coordination must be required to accomplish the task in order to be a team.

A team is a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable.

Teams are entities composed of professionals from varying disciplines and organisations. They bring a diversity of skills backgrounds and training to the (child protection) investigation, and the result is stronger than the individuals acting alone. Teams share a common mission, and the members identify themselves as part of a collective effort to protect children.

Teams are organised task groups composed of persons from differing professions or differing specialists from the same profession who work together using structured activities, processes and procedures. In addition to focussing on their tasks, successful teams attend to their process.

A group of individuals who share work activities and the responsibility for specific outcomes.

A team has five basic characteristics: the sharing of a common interest, to have a common aim and set of values, to have common objectives and/or tasks, for members to have designated roles and/or tasks; the feeling of membership and loyalty to the group.

Table 6: Integrated Interprofessional Team Descriptions
Closer examination of the descriptions contained in Table 6 which describe "integrated interprofessional teams" show variations on the theme of teams comprised of differing disciplines appropriate to the team’s purpose being assembled to carry out tasks, or to provide input based on their individual speciality as part of a process or environment. These teams can be static if the process or task is continuous in nature (with very few exceptions), with the membership of the team changing as a result of individuals moving on from their current role or, are ad hoc in nature. These are the types of teams largely utilised in the very large public and private organisations, and although often described as multidisciplined teams, are only multidisciplined because of the different areas of expertise in the membership makeup. They are described by such as Øvretveit (1997) and Sneider (1990), but more precisely described by Fatout and Rose (1995:46), as:

"organised task groups composed of persons from differing professions or differing specialists from the same profession who work together using structured activities, processes and procedures".

Learning and sharing taking place will vary from team to team upon the level of interaction. Members of these teams are often:

"specialists with narrow areas of expertise [who] typically suffer from a vertical-thinking syndrome. They tend to work in series, sequentially linked to one another", (Belasen, 2000:137).

Therefore it is not unreasonable to assume that the sharing element will often be confined to the documentation or process that is involved in the team function. Clearly the amount of disciplinary interaction inside these teams can be limited, and would not necessarily provide the environment in which any crossing of disciplinary borders might take place. Moving closer to the
multidisciplinary team at the opposite end of the continuum are the teams described by Wilson and Pirrie (2000).

Table 7 describes the integrated multidisciplined team, which sits closer to the middle of Øvretveit's continuum, where the members bring a diversity of skills, backgrounds and training, with the end result being stronger than if the individuals acted alone. It is indicative that although many descriptions were available of interprofessional teams, there were very few references to integrated multidisciplined teams. These are teams that "share a common mission, and the members identify themselves as part of a collective effort" Pence and Wilson (1994:13), but in addition provide solutions "through [the] combined efforts of highly qualified individuals focussed on a common goal or problem" Grigis et al, (1995).

They are best described by van Der Vegt et al (2003:3) as:

"representatives from all of the relevant areas of expertise are brought together [to make] team decisions and [take] actions are more likely to consider the full range of perspectives and issues that might affect the success of a collective venture ... individuals possess different information, knowledge and expertise that bear on a complex problem or issues".
<table>
<thead>
<tr>
<th>Author</th>
<th>Source</th>
<th>Year</th>
<th>Industry</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robert M. Sneider</td>
<td>SPE Paper: The Economic Value of a Synergistic Organisation</td>
<td>1990</td>
<td>O&amp;G</td>
<td>Synergy means that geologists, geophysicists, petroleum engineers and others work together on a project more effectively and efficiently as a team than working as a group of individuals.</td>
</tr>
<tr>
<td>John Grigis, Robert M. Sneider, Budiyento Thomas</td>
<td>SPE Paper: Multi-disciplinary teams - what is the &quot;right&quot; structure?</td>
<td>1995</td>
<td>O&amp;G</td>
<td>Synergy gained through the combined efforts of highly qualified individuals focused on a common goal or problem.</td>
</tr>
<tr>
<td>Gerben van Der Vegt et al</td>
<td>Learning and Performance in multi-disciplinary teams: The importance of collective team identification</td>
<td>2003:3</td>
<td>O&amp;G</td>
<td>When representatives from all of the relevant areas of expertise are brought together team decisions and actions are more likely to consider the full range of perspectives and issues that might affect the success of a collective venture. Individuals possess different information, knowledge and expertise that bear on a complex problem or issues.</td>
</tr>
<tr>
<td>Dean Tjesvold</td>
<td>Team Organisation - An enduring competitive advantage</td>
<td>1992:22</td>
<td>Business</td>
<td>Groups are two or more persons who interact and influence each other directly, who are mutually dependent, and have interlocking roles and common norms, and who see themselves as a unity in pursuit of common goals that satisfy their individual aspirations and needs.</td>
</tr>
<tr>
<td>Richard A. Guzzo, Eduardo Salas &amp; Asscs.</td>
<td>Team Effectiveness and Decision Making in Organisations</td>
<td>1995:23</td>
<td>Business</td>
<td>Team members interacting to achieve desired goals and adapt to circumstances in order to do so. Four components: performance monitoring, feedback, closed loop communication, back up behaviours... Team's self awareness and fostering of within team interdependence.</td>
</tr>
<tr>
<td>Wilson &amp; Pirrie</td>
<td>Multidisciplinary team working</td>
<td>2000:4</td>
<td>Ed.</td>
<td>Team is a group of people each of whom possesses particular expertise; each of whom is responsible for making individual decisions; who together hold a common purpose; who meet together to communicate, collaborate, and consolidate knowledge, from which plans are made, actions determined and future decisions influenced.</td>
</tr>
<tr>
<td>Brill</td>
<td>Source &quot;Team Work in Multiprofessional Care&quot; by Malcolm Payne (2000:6-7)</td>
<td>1976:22</td>
<td></td>
<td>Three strands constantly intertwine in teams and teaming: commonality of objective or purpose; belonging and being part of something successful; synergy - achieving more collectively than can be achieved by individuals acting outside a team environment.</td>
</tr>
<tr>
<td>Coelenso, 1997:11</td>
<td>Source &quot;Team Work in Multiprofessional Care&quot; by Malcolm Payne (2000:6-7)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7: Integrated Multidisciplined Team Descriptions
Clark (1993) said much the same thing about integrated interprofessional teams (Table 6). The difference between the two lies in the emphasis by van Der Vegt et al of a "collective" effort, namely not just a different view of one discipline, but a view arrived at by combining views to form a new and different view. To combine views is to share information, understand different discipline perspectives, and then integrate the understanding gained from this knowledge to be able to produce new insights and perspectives which would not have been achievable working inside an integrated interprofessional team. This may be expressed as at least "having a preference for a deep expertise in one discipline combined with enough breadth to see its connections with others" (Belasen, 2000:137). It is precisely this interaction that has been found to enhance the personal growth and professional development of team members (Hackman, 1990).

This is the meaning that is assigned to the term "integrated multidisciplined teams" as it is being used within this study, since clearly it is this combining of perspectives as an individual developmental process which expresses the cross border interaction between the disciplines.

Using teams within the working environment has long been identified as a real source of growth and innovation, particularly those teams that are composed of experts, professionals (Galbraith, 1974) and knowledge workers "knowledge workers" (Cahoon and Rowney, 1982). A decade earlier, Likert (1961:38) had already promoted their value in stating that "group forces are important not only in influencing the behaviour of individual work groups with regard to productivity, waste, absence and the line, they also affect the behaviour of the entire organisation." Writers such as Leavitt (1975) and Peters (1991:296) promoted
"modest-sized, task orientated, semi-autonomous, mainly self-managing teams should be the basic organisation building block", although in many cases these are not the self managing teams envisioned above. Nevertheless, Adler (1997:62) noted “teams have progressively replaced the individual as the unit of work organisation”. Although teams have an extensive literature dealing with a number of different aspects, there is actually little written about the effect working inside a multidisciplinary team has on the individual’s behaviour, if any.

Many writers such as Nonaka and Konno (1993) located within the knowledge creation literature recognise the link between project teams and learning. Figure 9 demonstrates their view of a “hypertext” organisation, wherein there is a bottom layer based on knowledge that is drawn from activities of the layer which deals with the processes of the organisation, and the top layer which consists of project teams assembled to carry out specific tasks.

The example quoted is that of new product design. The bottom knowledge layer is accessed through the organisation’s vision, which outlines how and where the organisation will develop corporate culture which dictates employee behaviour while “technology taps the explicit knowledge generated in the two other layers”, (Nonaka and Takeuchi, 1995:107).
Nevertheless not all writers are convinced of the importance of linking teams and learning. Examples are Power and Waddell (2004:244) who describe the link being made between teams and learning as not being significant, or Godard (2001) who has suggested that the promise of self-managed teams (Senge, 1990; Wageman, 1997) as in the learning organisation literature may have been overstated.

A different view on why teams are so successful is that provided by Nicholson (2000:1) who puts forward the evolutionary psychology perspective suggesting that “we may have taken ourselves out of the Stone Age, but we haven’t taken the Stone Age out of ourselves”. Nicholson compares project teams to self
organising teams within a community such as a tribal hunting party or entertainment troupe, identifying the factors behind their success as:

"individual contributions are valued. Experimentation is encouraged. Errors are analyzed, not blamed. People give to one another. Everyone shares a vision. The Group's work is valued by the community" (2000:19).

Again this is describing a sharing culture, where individual efforts are both recognised and rewarded.

Richard McDermott (1999) called organisations that consisted of Communities of Practice and which utilised cross disciplinary teams as "Double-Knit organisations" because of the learning loops called into play by the combination. Barrett and Saxton (2005) conducted research into small project-based firms in the construction industry in an attempt to add to the available theoretical and practical insights into project based organisations. They were able to identify workers who were "infinitely expandable in terms of their skills and abilities and the ways in which these may be deployed", (2005:10) thereby emphasising the major strengths of project teams which are their functional flexibility, and the potential for innovation.

The benefits of cross functional project teams had been defined as:

- Increased Organisational learning; members of such teams learned more about the other disciplines involved and developed themselves new technical and jobs skills because of this awareness;
Increased Creativity: by bringing together the differing disciplines with their associated differences in cultures, styles, background and orientation they were able to be more creative in handling problems; and

Increased Complexity: they were able to handle much more complex problems collectively being able to transcend the traditional confines of their disciplines. (Parker, 1994)

This illustrates accurately the cross border interaction of the disciplines involved in the project team, and the benefits that such interaction can bring about.

The disadvantage attached to the learning opportunities that arise from the team interaction is that only the team members benefit from the learning. It does not get disseminated throughout the organisation as a whole (Ancona and Cauldwell, 1992). Moreover, the individual team member’s perception of power and interpersonal risk could potentially affect the learning process (Edmundson, 2002).

Inside the upstream oil and gas industry, teams have developed in pace with other industries. During the 1960’s, Halbouty published a number of papers specifically referring to the use of multidisciplinary teams, which was something of a revolutionary call for oil and gas companies, since at that time there was very clear compartmentalisation of the different disciplines. For example, the drilling department took responsibility for much more of the set up organisation and actual drilling of the hole. In today’s world when the wells are programmed by petroleum/drilling engineers, the drilling department is often a contractor who simply executes the program (Cline, 2005). This compartmentalisation
gradually ceased, but as technology increased, it was replaced by a second stage of compartmentalisation, reflecting the increasing need to have separate professionals dealing with smaller parts of the whole.

3.5 Acquisition of Disciplinary Expertise

"Informal learning is the submerged part of the iceberg of adult learning activities" (Livingstone, 2003:363), recognising that for the majority of adults the only learning that they will encounter after leaving formal education will be in the workplace. Often this learning will take place in the context of what is commonly referred to as “Sitting with Nelly” (Livy, 1989). Informal learning by its very nature does not provide any form of verification and, because of this is often regarded as an “inferior form of learning”, (Smith, 1999:16). Informal learning is that:

“which takes place in the work context, relates to an individual’s performance of their job and/or their employability, and which is not formally organised into a programme or curriculum by the employer. It may be recognized by the different parties involved, and may or may not be specifically encouraged” (Dale and Bell, 1999:1).

Although that seems clear enough, there remains some confusion in the literature as to exactly what constitutes informal learning (Colley et al, 2002:17):

“it is possible to extract a list of 20 main criteria, [which] different writers have used to distinguish the boundaries between formal, informal and (less frequently) non-formal learning”.

Providing work based training is more efficient than sending staff offsite, especially in the light of the growing recognition of what has been identified as the “changing assessment paradigm” (Poikela, 2004:267), or the “transition from scientific measurement towards judgemental assessment” (Hager and Butler, 1994:376). This focus highlights how results are produced, rather than
simply trying to count the end results as objectively as possible. The differences between formal and informal learning has been better expressed as “learning as acquisition” of qualifications and training, verified by certificates, and, in the case of informal learning, as “learning as participation” (Felstead et al., 2005:361). Despite more intensive research being carried out in more recent years, in respect of “learning as participation”, further research is required to improve understanding of how the process works and to provide ways of measuring such learning (Hager, 2007; Ashton, 2004).

Styhre (2006:97) suggested “that one might argue that much of the organisation theory literature and management studies are concerned with knowledge and learning with the potential to codify, package and disseminate throughout organisations or organisational fields”. The workplace contains a wealth of information in differing formats such as rule books, instructions, background policy and shared software which are provided to and utilised by individuals every day. This information has been catalogued in a number of different ways so as to provide a means for explaining how it is processed and disseminated. Examples are provided in Table 8.

With the exception of Yanow (2004), these categories seem to stem from the nature of the information itself, and share similarities in treatment. For example, Polanyi (1966) is not so different in his approach from that taken by Nonaka and Takeuchi (1995), albeit the latter has added the cultural differences between Western and Japanese perceptions.
<table>
<thead>
<tr>
<th>Name</th>
<th>Year</th>
<th>Category</th>
</tr>
</thead>
</table>
| Polanyi    | 1962 | a) “objective” or abstract knowledge or  
b) tacit knowledge indicating knowledge within a specific context and  
arising as a result of the individual taking part in an activity. |
| Blackler   | 1995 | Five different categories which seem to be designed around the source of the information.  
a) encoded and embedded knowledge relating to objective sources and  
falling inside the “knowing what” dimension;  
b) embrained and embodied knowledge relating to information held by individuals and is therefore more of a subjective “knowing how” knowledge;  
c) encultured knowledge which is that information contained in the organisation's resources and covers both subjective and objective aspects. (This labelling does not take into account all the different types of information which might be available within the workplace.) |
| Nonaka & Takeuchi | 1995 | Two separate areas based on, what they believed, reflected the difference between the Western and Japanese perception of knowledge.  
a) Western perception being essentially “explicit – something formal and systematic, expressed in words and numbers, and easily communicated and shared” e.g. computer code and general rules.  
b) The Japanese perception, they described as “being primarily tacit – something not easily visible and expressible ... highly personal and hard to formalise making it difficult to communicate or share with others”. Ibid. e.g. intuition, insights and hunches Both of these forms of knowledge can be created and then used by an individual, a team or the organisation. |
| Cook & Brown | 1999 | distinguishing between types of knowledge and the ownership |
| Polanyi    | 1966 | a) explicit knowledge which is something that which can be explained using scientific terms  
b) implicit knowledge which relates more to knowing how to do something without being able to analyse it. |
| Yanow      | 2004 | a) Expert - theory based, i.e. abstract, generalised, scientifically constructed, academic based, explicit and scholarly.  
b) Local knowledge - practice based , i.e. context-specific, interactively-derive, lived experience-based, practical reasoning, tacit, everyday |

**Table 8: Knowledge Categories**

Yanow (2004) has divided knowledge on a totally different basis; that of theory and practice based information. Separating learning from knowing allowed for the building of new perspectives relating to informal learning within the workplace which will be discussed later in this chapter.

Contu and Willmott (2003) provide a very similar view, reinforcing the importance of separating out the theory from the practical information and providing for a situated knowledge transfer process which might apply within
multidisciplinary project teams in the case organisation. Figure 10 sets out how individuals might access both types of information, with the emphasis on situated learning (Lave and Wenger, 1991) being firmly placed upon social interaction in the workplace.

<table>
<thead>
<tr>
<th>Conceptualization</th>
<th>Established</th>
<th>Situated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning</td>
<td>Cognitive-</td>
<td>Interactive-</td>
</tr>
<tr>
<td></td>
<td>Passive-</td>
<td>Participative-Pervasive</td>
</tr>
<tr>
<td></td>
<td>Selective</td>
<td></td>
</tr>
<tr>
<td>Form of Knowledge</td>
<td>Canonical/codified/theoretical</td>
<td>Tacit/Embedded/Practical</td>
</tr>
<tr>
<td></td>
<td>Distilled in texts and manuals</td>
<td>Embedded in community</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and identity</td>
</tr>
<tr>
<td>Understanding</td>
<td>Abstract/Universal</td>
<td>Embodied/Context sensitive</td>
</tr>
<tr>
<td>Development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outcome of Learning</td>
<td>Acquisition of information or skill</td>
<td>Trans(formation) of identity</td>
</tr>
<tr>
<td>Transmission</td>
<td>Vertical: Instruction by authorities</td>
<td>Horizontal: collaboration with peers</td>
</tr>
</tbody>
</table>

Poikela addressed the allied issue of when does theoretical and practical knowledge (potential knowledge to the individual) become known or as she puts its “defined as knowing”, (2004:268). In Poikela’s view only after the learner has learned how to view the knowledge in the right context. This argument gets reversed inside “the emerging area of practise based theorizing on knowledge and learning [which] assumes that knowing precedes knowledge, both logically and chronologically” (Nicolini et al, 2003:3). The author goes on to suggest that knowledge arises from formal education or training, while learning happens in all other situations.
In looking at learning from an individual's point of view, the famous "double loop" learning cycle of concrete experience, reflective observation, abstract conceptualisation - active experimentation (Kolb 1984) has been the paradigm for many years. Nonaka and Takeuchi (1995) agreed with Kolb that the same processes were involved in learning by the individual, but the processes involved were rooted in shared actions, shared experiences, shared reflection, networking new knowledge and then "learning by doing". This sharing process means that individuals learn the common meanings of words applied within the workplace, together with the tacit and unwritten rules about how to behave. Crossan et al (1995) used the same phases, but expressed them somewhat differently, terming them as intuition formation, intuition interpreting, integration of interpretated knowledge and knowledge institutionalisation.

Erault (2000), widely acknowledged as providing a useful typology in this area, took a wider view, agreeing that informal learning could relate to a number of different facets of a given situation, including tacit knowledge. Tacit knowledge relates to information such as how discussions are conducted, what is the dress code, how do the other people conduct themselves. This is all information which requires more effort on the part of the individual than simply reading a set of instructions or learning a block of theory.

Focussing on the intention that individuals may have when they learn, Erault proposed an informal learning typology, Figure 11. At one end of the scale was where "the acquisition of knowledge independently of conscious attempts to learn and the absence of explicit knowledge about what was learned" (Colley et al, 2002:6) through to the high end of the scale which was marked by deliberate
learning. The range between these two ends being described as a space for “reactive learning”, or that learning which takes place spontaneously and as a response to the ongoing experiences of the individual. Erault emphasised that any analysis of learning should be primarily directed at the activity involved, and its outcomes, which then would lead to changes in the individual’s understanding or abilities.

<table>
<thead>
<tr>
<th>Time of Stimulus</th>
<th>Implicit Learning</th>
<th>Reactive Learning</th>
<th>Deliberate Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Past Episode's</td>
<td>Implicit linkage of past memories with current experience</td>
<td>Brief near-spontaneous reflection on past episodes, communications, events, experiences</td>
<td>Review of past actions, communications, event’s experience. More systematic reflection.</td>
</tr>
<tr>
<td>Current Experience</td>
<td>A selection from experience enters the memory</td>
<td>Incidental noting of facts, opinions, impressions, ideas, Recognition of learning opportunities</td>
<td>Engagement in decision making, problem solving, planned informal learning</td>
</tr>
<tr>
<td>Future Behaviour</td>
<td>Unconscious effect of previous experiences</td>
<td>Being prepared for emergent learning opportunities</td>
<td>Planned learning goals, Planned learning opportunities</td>
</tr>
</tbody>
</table>

Figure 11: Erault’s (2000:13) Typology of non-formal learning

It should be noted that these categories are close to those famously outlined earlier by Schón (1973), which were “knowledge in use”, reflection on action” and “reflection in action”. Erault thought that the last category was more related to metacognitive awareness than learning.

Although using the word “knowing” instead of “learning”, more recently Poikela (2004:271) continued work on the same basis by stating that “knowing could be characterised as a process involving decision making and problem solving,
accessing increasing amounts of tacit knowledge located in individual, group, and cultural knowing”; in other words, by sharing.

This confirms the change in the emphasis on learning in more recent years, which is shifting to the view that learning and knowledge may not after all reside inside an individual’s head as a representation of a view of the world that they might hold, namely as a mental model (Senge 1990). Learning is now increasingly being viewed as a form of social expertise, born out of the individual’s social experiences. It is taking a constructivist approach (Wenger, 1998).

Bridging the gap between the cognitive theories such as Schön (1973) and the social interaction processes is social learning theory (Bandura, 1977). Building upon Piaget’s (1995) earlier work whereby individuals construct mental models from interacting with their environment. In social learning theory the individual learns by observing the actions and their outcomes of other people, remembering those actions and outcomes which then act as a template against which the individual can replicate the behaviour as appropriate. In this way individuals can interact with and influence their environment to achieve a desired state. Social learning theory adds a social perspective to learning but “still from a primarily psychological perspective” (Wenger, 1998:280) and lacks “adequate social control or cultural dimension” (Jarvis et al, 2003:50).
3.6 Social Interaction Processes

In looking at organisations in terms of how to set about understanding the exploitation of local knowledge there are newer frameworks which attempt to explain the processes at work, and which provide a closer focus on social interaction processes. These frameworks can be differentiated by how they handle the source of information or knowledge and recognise that "learning is a social and participative activity rather than merely a cognitive activity", (Gherardi, 2000:215). Furthermore all four perspectives seek to encompass both objective and subjective information present in the workplace inside their frameworks.

These perspectives are usually referred to as:

- Communities of Practice (Situated Learning or SLT)
- Interpretative-cultural (Action Theory or AT)
- Cultural and historical activity theory (CP or COL)
- Sociology of translation or actor network theory (ANT)

One of these frameworks, Communities of Practice, has already been discussed in detail earlier in this chapter in terms of the communities that cluster around a discipline, and is mentioned again here for completeness.

These four frameworks were drawn together and presented at the Academy of Management Conference, San Diego in 1998 and although they are presented as different theories here so as to clarify the differences between them in terms of the learning process involved, in reality they are closely intertwined. They all
use a social constructivism approach to learning being focussed on “being in the world”, (Nicolini et al, 2003:9) and share themes to a greater or lesser extent such as:

➢ **Language:**

The meanings and use of words based on Wittgenstein’s (1953) "language games" where learning is focussed on knowing the right words in the correct context.

➢ **Meaning of Objects:**

Engeström and Blackler (1995) discussed the use of the Marxist theory in situated learning, in the sense that objects hold meanings, and in doing so have a life of their own or a "social presence". In understanding these meanings individuals are able to understand the role of objects such as receipts, purchase orders, drill bits or submersible pumps.

➢ **Relationships:**

Based on Vygotsky’s cultural psychology, the importance of peer relationships can be summarised as providing “a forum for mutual exchange in which an individual can achieve a sense of expertise, equality and empathy that is frequently absent from traditional mentoring relationships”, (Kram and Isabella, 1985:129).

In addition to these three themes, there are four aspects common to situated learning and centred around learning being a social process which is that
expertise can be gained from working experiences provided that the knowledge is available. Learning also requires social interaction since:

"knowledge is embedded within practice and transformed by goal directed behaviour and these aspects are also shared by the frameworks" (Tennant, 1999:170).

Having already discussed the communities of practice framework previously, the following sections will look at the remaining three social interaction processes.

### 3.6.1 Interpretative-Cultural

Yanow (2000), having categorised knowledge as being either theory or practise based, argued that organisational learning is achieved by looking at the organisation, and how it acts as a whole, as well as how the individuals within it act. Tsoukas (1996:14) provided clarification, stating that individual knowledge is possible, precisely because of the social practices with which the individuals "engage", and provided a number of examples, among which is that of a footballer out on the field. He is only playing football when 10 other men join him.

Taking this approach, the individual learns by taking into account a number of differing factors which facilitate their understanding of the whole process. These factors include:

- "The collectives"
- And their acts (including interactions)
- And the objects that are the focus for these acts
- And the language used in these acts
- Together with the site-specific meanings of these various artefacts to the actors in the situation
As well as the site (or "field" based set of interpretative methods designed to access and analyse these data).” (Yanow 2003:36)

This enables the individual to build an understanding of the workplace, its processes and their role within the organisation. The cultural aspects of this theory emphasises what is being learned, to what effect; what can be seen, who can see it and what is the purpose of the task or process.

3.6.2 Cultural and Historical Activity Framework

Within the cultural and historical activity framework theory, more emphasis is placed upon learning occurring through the action involved in undertaking work processes and dealing with the day to day difficulties that arise in that process using the people and tools present (Felstead et al, 2005). It focuses more on Vygotsky’s original work, which centred on the cultural development of children:

“Every function in the child’s cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relationships between individuals” (Vygotsky, 1978:57):

This statement puts social interaction at the heart of cognition development; a theme continued across all ages and situations since. In making this observation Vygotsky was able to propose that the level of development for children who engaged in social interaction with adults or with their peer groups was greater than that which the child could attain if they were on their own. This development was termed as the "zone of proximal development" (ZPD) and marked:

"the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration of more capable peers" (1978:86).
Problem solving as a learning technique had been previously advocated by a number of writers such as Anzai and Simon (1979), Anderson et al, (1981), and Dunbar (1993). Using problem solving as the only learning tool means that individuals learn as a necessity at the time of the problem (Borthwick et al, 2003:3), and that knowledge may be incomplete or incorporate poor practice.

This framework takes account of a number of different aspects:

- historical convention;
- rules and procedures;
- focus on the relations between individuals and the objects of their activity; and
- relationships within a community which are mediated by its division of labour and controlled by rules and procedures.

Different professions and disciplines using the same tools holds the implication that there is potential for individuals to undertake boundary crossings which can lead to greater learning of other disciplines. A simple example of this can be found in the growth of home film processing. Prior to the advent of personal computers (PC’s) and general availability of software packages on the high street people would send their holiday photographs for processing and printing. Now it is increasingly common for these processes to be done in the home without the need for the film processor.

Later work by Victor and Boynton (1998) provided a historical framework for looking at the fit between organisations, work and learning and identified five types: craft, mass production, process enhancement, mass customerisation and co-configuration. The focus being on customer-intelligent products which are
the most demanding, as learning is faster here because the product or service is custom built.


Engeström (2000) goes on to say that learning within this environment centres on new, innovative ways to meet the customer demands. Included within this is the requirement for boundary crossing, as well as multi-voiced dialogue and negotiated "knotworking" which is essentially the need to negotiate with a number of individuals rather than with one leader.

In addition to learning horizontally and inter-organisationally within such projects Engeström suggested that "besides the learning of routine-type skills of the prevailing practises directed by the vertical direction, there is need for a new type of learning appearing horizontally in networks of activity systems" (Kerosuo and Engeström, 2003:346) and which is "focussed on the collaboration networks". Problems arising during the course of work allow for people to learn through their difficulties. Moreover, peer interaction is essential to learning, since the individual needs to understand differing viewpoints in order to avoid potential conflicts (Piaget, 1995).

3.6.3 Sociology of Translation or Actor Network Framework

This framework for learning involves observing and noting how the individuals involved behave, objects they utilise, language used and in what sequence to gain an understanding of the tasks and processes. It combines the previous
frameworks, but with the emphasis on Foucault’s (1978) thoughts on the pervasiveness of power, and Wittgenstein’s (1953) notion of meaning making.

The framework is defined as:

“thinking of the world as a performative effect [which] entails acknowledgement that all entities are performed in, by and through relationships in which they are involved ...[involving] tactics of ordering in time and space” (Nicolini et al, 2003:18).

“situated in the system of ongoing practises of action in ways that are relational, mediated by artefacts, and always rooted in a context of action. Such knowledge is thus acquired through some form of participation, and it is continually reproduced and negotiated; that is, it is always dynamic and provisional” (Nicolini et al, 2003:3).

These theories are all gaining general acceptance, nevertheless one of the major criticisms levelled against them can be found in Ashton’s (2004:43) work which, while accepting the “significant advances” they represent, found that the research behind the theories had been based largely on particular groups of people. He provides examples such as Erault studying professional staff and ignoring “the wider institutional conditions and features which shape the work and learning experiences of these groups [which] fade into the background” (Ibid).

3.6.4 Social Interaction Processes In Practise

In terms of how individuals might learn through these processes as part of an ongoing process, it is useful to look at how each framework would come into play during the course of a problem solving experience. Figure 12 outlines the basic steps required to solve a generic problem, and attempts to define how those steps can fit inside each theory. It is not intended to be a definitive view
Communities of Practice (SLT)
Interpretative-cultural (AT)
Cultural and historical activity theory (CP)
Sociology of translation or actor network theory (ANT)

I have a problem do I want to deal with it?

Yes

Problem solved

Do I have the skills and/or knowledge?

No

Ask immediate colleagues (SLT)
Refer to prior history (AT/CP)
Read instructions (CP)

Is problem solved?

No

Take further action to see if it fixes the problem (ANT)
Obtain skills and/or knowledge
Watch how other people deal with issues (AT)
Network with colleagues

Problem solved
Disseminate knowledge gained by taking, writing and implementing

Tell Colleagues (SLT)
Re-write procedures (CP)

Disseminate learnings to a wider audience

Refer it to another department, supervisor, colleague, or junior

Figure 12: Problem Solving using Practice Based Theories
of how the theories interact with each other, simply as an illustration. It should be noted that the interpretative-cultural framework would not have a specific action step within the process. It would be significant in determining which actions the individual might see as potential avenues to solve the problem. For example, the cultural ethos at work within the specific workplace might mean that the individual does not attempt to solve the problem, but simply passes it onto someone else who could be their manager, their colleague, their subordinate or to a different department altogether. It is possible that an individual could take the same actions for entirely personal reasons too. In actually attempting to solve the problem, the individual can take a number of different avenues. This can be anything from discussing it with a colleague, carrying out a mini research programme or combining several different methods to solve the problem. The process followed to achieve a satisfactory solution may also be dictated by the nature of the problem and its background. For example, tying a bow can be more effectively learned by watching someone else.

Apart from the cluster of situated learning theories described above, there are other theories being put forward in an attempt to provide clues as to how the learning processes function. One example, the Virtuality and Learning process, (Styhre, 2006) is based upon organisational learning among construction workers. The individuals inside this study primarily learned by engagement with their peer group, sharing their colleagues “know how” and experience. Styhre proposed that “organisation and workplace learning is always a matter of learning in time and specific temporal horizons” (2006:93) and that the “past, present and future are already aligned and brought together when different
groups of professionals learn from another" Styhre (ibid:95). The model proposed that defamiliarising the meaning of time would enable different conceptual perspectives to be drawn on the learning situation, which may prove useful.

This is significant when considering that

"Knowledge is an ongoing social accomplishment, constituted and reconstituted in everyday practice. As such, knowing cannot be understood as stable or enduring because it is enacted in the moment its existence is virtual, its status provisional" (Orlikowski, 2002:253).

An interesting perspective which is becoming more widely used is that of threshold concepts (Meyer and Land, 2003) and "troublesome knowledge" (Perkins, 1999). This could potentially be significant in this research, as the theory has potential to explain how knowledge is absorbed. Threshold concepts can be envisioned as being the doorway between not understanding and understanding new knowledge representing a "new way of looking at things" (2003:1). As an understanding of the new knowledge is mastered then the journey between the two states is completed. This can be connected to "conceptual gateways" or "portals" that exist between disciplines.

Threshold concepts contain the following aspects:

**Transformative:** a shift in perspective is likely to have major changes upon the individual;

**Probably Irreversible:** in that once the perspective has shifted it cannot be undone;

**Integrative:** "it exposes the previously hidden interrelatedness of something", although a cautionary note is added to the effect that this may be limited and does not always happen; and,
Possibly bounded: “in that any conceptual space may have terminal frontiers”
(Meyer and Land, 2003:4-5)

In exploring the final aspect, Meyer and Land suggest that such “boundedness” may, in some cases, mark the demarcation lines of the discipline involved.

The second part of this concept deals with “troublesome knowledge” (Perkins, 1999) which relates to the new knowledge requiring mastering, and which often emanates from a different discipline or background. Troublesome knowledge can be described as:

- that which is routine, such as dates or names (ritual),
- more meaningful information but which needs to be remembered (inert)
- complex theoretical or alien knowledge which may be contrary to the individual’s own beliefs or understanding; and finally,
- tacit knowledge (Perkins, 1999).

Combining these two aspects, the concept is described by Meyer and Land (2003:1) as:

“akin to a portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something”.

The Meyer and Land 2003 study included the example of the heat transfer concept (physics) being applied to cooking to show how the threshold principle worked in practice. Once individuals understood the principles of heat transfer and applied them, then they would begin to focus on what pots and pans were being used to make a particular recipe. This would be a different perspective altogether than the one they had applied in the past, where they focussed on the ingredients and methods for making the recipe. The additional
understanding of the concept of heat transfer being the threshold concept in this instance. Furthermore, barbecuing was used as an example of “troublesome knowledge” since the method of cooking would be different again as it uses radiation.

Meyer and Land’s later study (2005) looked more at the understanding and use of language specific to a discipline as being one way of handling troublesome knowledge. In addition, there was further elaboration on what they termed as “luminal space”, the space between understanding and not understanding new concepts. Threshold concepts are gaining ground inside education as a way of opening up teaching in difficult areas as in “Teaching and learning uncertainty in science: the case of climate change” (Hall, 2006:48). No examples of the use of threshold concepts were found in literature outside of their use in higher education.

The changing perspectives approach to open up new or previously hidden ideas has been previously explored elsewhere in the literature. Tillema, for example referred to the “shifting perspective; this relates to conceptual change” (2005:85), but applied it in the context of an individual making a conscious decision to open up to new ideas. Tillema’s study found that the individual’s view of the “situational understanding” hampered the process by which individuals allowed this shift to take place (Engeström, 1994; Brookes, 1994). It was suggested that this would be less of a problem if there was some process in place for building a model to explain concepts being interchanged through the collaboration process.
The threshold concept holds the potential to be viewed as a stepping stone between spontaneous learning and the deliberate acquisition of expertise on the part of the individual. Clearly this is not a "one-way street", the individual has to be interested in the interaction and subsequent learning but also the environment is such that knowledge domain interaction takes place, thereby creating the learning environment. As far as the individual is concerned, it may simply be a case of their willingness to share information, to listen and learn from colleagues and perhaps having the courage to move away from the traditions of their own discipline if necessary.

It may potentially be possible to map this dual aspect using Erault's classifications (2000) against the learning opportunities available within the environment, Figure 13. This scale would then provide some meaningful measurement in terms of how much additional expertise individuals might acquire.

The fieldwork could be targeted to understanding if any of the individuals were aware of the opportunity to learn and if so, did they then supplement the learning by additional measures more commonly associated with "learning by acquisition" (Ashton, 2004).
Summary

The latter section focussed on the transfer of knowledge process taking place between individuals. By its very nature this transfer process is situated in the working environment, is informal and would appear, on the surface, to be much more the result of social interaction than a formal learning process. “Learning on the job” is a familiar, everyday term which surprisingly, like many other areas reviewed, reveals a complex and uncertain structure upon closer inspection. It is clearly deemed to be the poor relation in terms of education and inferior to formal education or training (Smith, 1999) and the least understood (Livingstone, 2003). There is confusion within the literature as to what it really consists of (Colley et al, 2002), although there is an increasing recognition that “learning by participation” or informal learning is equally as significant as “learning by acquisition” of certificates (Ashton, 2004; Poikela, 2004).

Source: Adapted from Boulton Typology 2000

Figure 13: Learning By Acquisition (Ashton, 2004)
Regardless of the learning process mechanics, there is no methodology suggested by the literature which attempts to measure how much learning is taking place, in terms of additional skills or knowledge (Ashton, 2004). Erault (2000) proposed a typology focussed on the individual's approach to learning, which ranged from the individual having no intention to learn through to a deliberate intention to learn. It is noted that although there may be no intention to learn on the part of the individual, there is always an element of spontaneous learning present. Erault's typology was discussed as being a possible basis for the development of a suitable methodology to measure the acquisition of additional disciplines by the individual.

Most significantly, Yanow (1998), and more recently, Contu and Wilmott's (2003) differentiation between theoretical and practical knowledge has allowed for the development of social interaction theories which seek to explain in more depth what "learning" in the workplace consists of, and how that learning takes place. These theories allow for an individual to "know about" before they have "knowledge of". For example, a geologist may know that it is possible to model the geological complexity of a reservoir before they learn how to model it simply by observing or later utilising in some way the work of their colleagues around them.

The social interaction theories were presented together at a Symposium held at the 1998 Academy of Management Meetings in San Diego revealing a number of different ways to view the "learning" taking place within the work environment. Although each focuses on different aspects of learning, they share common
themes relating to language (Wittgenstein, 1953), meaning of objects
(Engeström and Blackler, 1995) and peer relationships (Vgotsky, 1978).

These theories are gaining ground rapidly, with communities of practice
perhaps the most popular, even though there are major criticisms levelled, such
as Ashton's (2004) point that the research behind these theories is based
largely on specific groups of people. An example being Erault's study involving
professional staff only. In the case of communities of practice, that is rapidly
becoming no more than a tool for management, and ignores the effects of
power play that they contain (Contu and Willmott, 2003).

Alternative learning processes put forward by Styhre (2006), who looked at how
individuals learned through looking at their peers and more significantly, the
work of Meyer and Land (2003; 2005) looking into threshold concepts and
"troublesome" knowledge (Perkins, 1999) has been reviewed in this chapter.

There are a number of different learning processes suggested within this
chapter which attempted to explain how individuals expand their knowledge or
shift their perspective, thereby utilising knowledge that they were not aware of
knowing. The case organisation contains a blend of these processes, but it is
not clear which blend of processes best fit and can represent what "learning on
the job" is actually about.
3.7 The Way Forward

The literature suggests that many of today’s disciplines operating in the oil and gas industry appear to have had their foundations in one single mother discipline, that of geology (Miller and Pope, 1987). This, coupled with the fact that there are very few separate degree courses handling the specialist areas within petroleum engineering has led to the tentative conclusion that perhaps the real knowledge transfer process within the project teams relates more to an understanding of what is already knowledge held by the individual, but is not “known” to them up to that point.

Teams are organised according to the type of organisation they are working in and the function that they are expected to perform. In the case organisation, project teams are assembled to complete discrete tasks, and consequently access information available within the organisation. Individuals can learn not only from being within the project team, but from the business layer itself hence the inclusion of the literature concerning organisations and ethos. It is not clear from the literature how significant a role the organisation plays in providing appropriate learning mechanisms. For example, it could well be that the organisation itself promotes multidisciplinary working by the virtue of having the appropriate leadership in place, and therefore the individual expectation is that they will conform to this. Another aspect of this could well be peer pressure, both in the role models available within the workplace, and the requirement to be seen to be of a certain status. Moreover, it is entirely possible that the individual does not perceive that they are crossing boundary lines at all. Perhaps it is more that they are perceived to be “multidisciplined” by their peers.
In discussing the different forms of communities that may exist inside the organisation this review has endeavoured to highlight the individual and their role within teams, as well as to provide some focus on the potential learning avenues which they may be taking within their working experiences.

When discussing the hypertext organisation Nonaka and Konno (1993) proposed a model depicting knowledge flows through an organisation, and it is possible to adapt this model by adding an additional layer to accommodate the professional societies and other informal communities of practice that may exist. This adaptation then provides a process which accommodates the various factors that have been discussed here, Figure 14. This model shows the suggested information flow, but as yet it does not confirm where the learning processes actually exist.

Nevertheless, it could be utilised to build the framework for the data collection phase, since it points to the interaction between the various layers present inside the organisation as providing the background to the learning processes being utilised by the individual.
The literature review has pointed to four key areas which require further research and which this study will seek to contribute to. The areas can be described as:

a) providing recognition in those cases where informal learning has provided individuals with additional knowledge and skills lying outside of their core disciplinary expertise rather than inside it;

b) adding to the body of literature in respect of how individuals behave and learn inside multidisciplined project teams;

c) responding to the requirement for further research to be carried out in professional consultancy firms, assessing the learning by participation levels to broaden the existing research (Ashton 2004); and,
d) responding to the lack of appropriate methodologies for measuring learning by participation (Ashton, 2004).

Having identified within the literature areas where this research can make a contribution the next sections deal with the issues of determining the appropriate research questions and objectives. These will facilitate the achievement of the overall research aim of determining the existence of multidisciplined individuals and how they acquire additional disciplines. The initial step is to set out focussed research questions which can then used as the basis for the research objectives.

Jennifer Mason (1996) referenced research questions as an intellectual puzzle to be solved. In this instance the puzzle revolves around the individuals, and how the nature of their working processes provides learning opportunities that allows for the development of additional disciplinary expertise. These aspects will form the main areas inside further research which give rise to a number of questions. How many research questions should a researcher attempt to tackle has been the subject of some debate. This research will address eight primary questions. This is more than the four main questions suggested by White (2009), or the one or two suggested by other writers (Creswell, 1998; Stone, 2002) as being the ideal number. There are no supplementary questions involved here although White (2009) supplements his suggested four main questions by the addition of supplementary questions. These additional supplementary questions then puts the number of research questions here into a more appropriate context. Table 9 sets out the research questions together with the corresponding objective or objectives.

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Research questions need to be focussed in order to facilitate good research (Bryman, 2004). Saunders et al (2003:25) goes further saying that in order to provide a “clear sense of purpose and direction” research questions should be refined and re-stated as objectives. Objectives are “more generally acceptable” (Saunders et al, 2003:25) as evidence of robust and rigorous research to the wider academic community than research questions.
The first objective relates to the individuals comprising the sample population. Factual details for each individual such as age and qualifications combined with more descriptive data will be compiled. This data will then enable comparison between the participants to ascertain what, if any, qualities they have in common. Moreover, such detailed information assists in providing flavour (Silverman, 2001) to the study and helps to ensure transparency in the sample selection; both aspects are discussed in more detail in the next chapter.

Although this study is not concerned with building a traits and competency listing for what it takes to be a multidisciplined individual the first objective also considers whether or not there are any underlying traits found across the population of interest which might influence the predisposition to learning across boundaries.

The second objective seeks to address the fundamental issue of establishing that informal learning is actually taking place inside the case organisation. Measuring learning will take a quantitative format and therefore provide some dimensional data about the extent of learning.

Having established that informal learning is actually taking place the third objective seeks to establish ways in which disciplinary knowledge is being transferred between individuals. The data will seek for clues to establish how and what social interaction theories are being applied inside the workplace and their impact upon the levels of learning being achieved.
Objective four relates to organisational aspects both in terms of the case organisation itself and also how individuals view their present working experience. A section of the data will concern itself with looking at how the case organisation accommodates the various communities after establishing which communities are active within the workplace, and how they function. Furthermore, the question concerns itself with highlighting the management and ethos of the case organisation to understand how the environmental factors interact inside the learning processes.

There is also scope to include the individual's perspective in terms of how they work and where they believe their learning opportunities occur. It will also surface any supplemental learning that they may be undertaking to support the informal learning process. To some extent these individual's perspectives could be repeating information already obtained through addressing the organisational questions above, but they will be useful to ensure that it is the staff shared perceptions that are being addressed.

Objective five and six are two separate, albeit inter-related, objectives concerning the disciplines contained within the case organisation. Addressing these objectives will provide information relating to where the border interaction is most likely to take place leading to learning. Determining the nature of the knowledge domain itself, will show whether or not it is predisposed towards allowing border interaction. This determination will be based upon the views expressed by the sample population, and will therefore represent their shared mental model.
Objective seven seeks to explore the question of why the individual moves across disciplines thereby in many senses diluting their professional standing. What is not clear is although individuals inside the case organisation are aware of "multidisciplined" individuals, is there any understanding of how that process works and what might be the driver behind the individual's broadening out and away from their core discipline.

The last objective relates to developing a research model which identifies the multidisciplinary individual development process to facilitate its adoption in other organisations if appropriate. This can be assessed by undertaking in-depth interviews within the workplace to gain a better understanding of the advantages, or otherwise, of multidisciplined individuals. From this it will be clear whether or not this process should be encouraged further, both inside and outside the case organisation.

Addressing these objectives will hopefully meet the overall research aim and thereby allowing for the development of an explanatory theory to describe the multidisciplinary development process.
Summary

This chapter commenced by providing a review of what facets of the literature would not be included inside the research in an effort to provide a focus on what individuals did inside the workplace rather than what they were. Moving on it briefly touched upon motivation theories which could potentially explain why individuals might want to get involved in acquiring additional disciplines.

The chapter provided an assessment of the factors which might be involved in multidisciplinary development present inside the workplace thereby scoping out the literature review beginning with knowledge domains and their associated disciplines. The importance of mapping the disciplines highlighting their disciplinary borders was noted. The borders being areas where there are opportunities for disciplinary interaction and, therefore potentially rich learning opportunities.

Communities in different forms such as communities of practice, professional societies, project teams and the wider organisation itself were reviewed before the discussion moved to looking at how and what learning was available in the workplace. This discussion provided a critique of the various learning processes including the more recent social interaction processes and more recently threshold concepts and their application inside learning situations.

Finally, the chapter reviewed the four key areas which the study set out to make a contribution to before setting out to determine the appropriate research questions and objectives to achieve this.
The next chapter addresses the issues arising from the research study design, and provides a detailed outline of the methods to be utilised in the collection and analysis of the data obtained during the fieldwork phase.
CHAPTER FOUR
RESEARCH DESIGN AND METHODOLOGY

Introduction

One of the difficulties of any research is to understand the issues surrounding the choice of research philosophy, and how that choice influences every aspect of the research (Bryman, 2004; Knox, 2004; White, 2009). For the novice researcher methodology can be confusing, easily misunderstood and runs the danger of being dismissed as having little consequence upon the research itself:

"linking quantitative and qualitative research method[s] with the understanding and interpretation of philosophy (positivism and interpretivism) the research process becomes a quagmire, often too difficult for many researchers or students to fathom successfully", (Knox, 2004:119).

Much of this confusion can be attributed to authors using a range of different terms, depending upon their core discipline, to describe identical aspects (Goulding, 2002). Many writers advocate using the research strategy which best addresses the research questions (Bryman, 2004; Seale, 1999). Research in itself is a "craft skill" (Seale, 1999:17) with the emphasis being placed on the researcher being aware of how each philosophical approach influences both the research design and its eventual outcomes (Easterby-Smith et al, 1991; Remenyi et al, 1998). Given the significant body of existing literature debating the advantages and disadvantages of each major philosophical approach, it is not the intention to enter into the wider philosophical debate in this chapter, but
rather to focus on how the research design for this particular study was arrived at.

In order to select the appropriate research design, this chapter begins by addressing five questions:

- What is the nature of the knowledge outlined here? (Epistemology);
- What is the reality that is being described? (Ontology);
- What is the theoretical approach? (Theory);
- How is this research being carried out? (Research Strategy); and
- What is going to affect the research? (Values) (Lincoln and Guba, 1985).

Epistemological and ontological considerations can create confusion and divert attention away from the main issues inside the day-to-day research process (White, 2009; Bryman, 1988). However, "a sound theoretical basis upon which to base interpretations can ... give the practitioner credibility" (Goulding, 2002:10). Establishing that the results obtained from a piece of research are trustworthy is an essential requirement for the research's successful outcome.

Having addressed the issues of research design and its values, the Chapter then reviews how the data collection tools were utilised in the field, and problems from their implementation.
4.1 Research Design

One way of addressing the five questions outlined above is to utilise the "research process onion" (Saunders et al, 2003:83), Figure 15. This describes the various considerations which need to be resolved in order to arrive at the research strategies and methods appropriate to the individual research topic. The outer layers of the research onion deal with the nature of knowledge, and what constitutes the reality being described. The middle layers consider how the research will be carried out, and in what time frame. Finally, the inner layers of the onion deal with alternative data collection methods. Although not included as such in the research onion, how the data collected is analysed may also have associated credibility issues, and therefore the discussion includes this aspect, together with the steps taken to arrive at the research conclusions.

<table>
<thead>
<tr>
<th>Research Philosophy</th>
<th>Positivism, Realism, Interpretivism</th>
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<tr>
<td>Research Approach</td>
<td>Deductive, Inductive</td>
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<tr>
<td>Research Strategies</td>
<td>Experiment, Survey, Case Study,</td>
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<td></td>
<td>Grounded Theory, Ethnography,</td>
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<td></td>
<td>Action Research</td>
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<td>Time Horizons</td>
<td>Cross Sectional, Longitudinal</td>
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<td>Data Collection Methods</td>
<td>Sampling, Secondary data,</td>
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<td></td>
<td>observation, Interviews,</td>
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<td></td>
<td>questionnaires</td>
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Figure 15: Research Onion Process (Saunders et al, 2003:83)

Using the research onion approach to resolve the issues surrounding research design has the support of academia (Remenyi et al, 1998). Knox (2004) argues that the very act of classifying the different philosophical approaches creates an artificial linkage of tools to particular philosophies which may be detrimental to
the purpose of the research itself. While this weakness is acknowledged, the Saunders et al (2003) approach was utilised as a process to assess each choice within the context of this research, and determine how those choices fitted into the wider philosophical debate.

4.1.1 Epistemological and Ontological Issues

The initial consideration concerns itself with the "paradigm question" (Lincoln and Guba, 1985), which relates to the nature of the knowledge contained inside the research. Saunders et al, (2003) indicate three alternatives: positivism (Comte, 1856; Hunt, 1991), realism (Hammersley, 1992; Altheide and Johnson, 1994; Bhaskar, 1989) and interpretivism (Boas, 1920) as the available avenues. These three alternative epistemological approaches present on the face of it a clear set of choices, but often researchers end up with research designs which straddle these different areas (Bryman, 2004).

Positivism is "working with an observable social reality and that the end product of such research can be the derivation of laws or law-like generalisations", (Remenyi et al, 1998:32). It is the prevailing paradigm (Goulding, 2002) with its roots in the work of:

- Mach (1897) in avoiding metaphysical concepts and relying on senses only;
- Hume (1739) in stating that conclusions can only be arrived at from deduction and direct observation and lastly,
- Wittgenstein's (1953) "verifiability principle" which is to say that statements can only be true or false.
This philosophy is closely related to research carried out by natural scientists which dictates that knowledge is objective, and the researcher is detached from the phenomena being studied (Saunders et al, 2003). Researchers using this tradition accept that there is a measurable tangible reality "out there". Their results are obtained using predominantly statistical methods, thus providing for the necessary objectivity on the part of the researcher. Moreover, statistics can allow for replication of results by other researchers given the same set of circumstances and the same analysis approach; a process which can provide "confirmation" of truth. The major weakness with Positivism can be summed up by stating that the statistical approach it advocates "works with concepts of averages which are far too general to do justice to the subjective variety of an individual life" (Jung, 1995 cited by Remenyi et al, 1998:33).

The present research is exploratory and descriptive in nature, seeking as it does to understand how social actors (Weber, 1991) are changing their world view (Annells, 1996) inside their working environment. Although the previous chapter concluded with an outline of what elements might contribute to the learning process, there is no a priori hypothesis to be tested in the field. Until data collection and analysis takes place it will not be possible to define the end product, or determine whether the phenomena is likely to be found elsewhere, assuming at this stage that it exists at all. Any working model emerging from this research may then hold the potential for testing in other locations, or by other researchers.

Using a positivist approach, with its dependence upon statistical evidence to test causality (Hunt, 1991) in this particular research may well produce a
number of generalisations based upon statistical frequency, but these would provide little insight into the dynamics of the learning process (Remenyi et al, 1998). Furthermore, given that the researcher is employed by the case organisation, the role of a “detached observer”, researching knowledge being shaped outside of the world independent of people and social realities (authority) would be difficult. These issues are sufficient grounds for ruling out using the positivism paradigm to achieve the research aims of this study.

The second alternative, lying between the two opposing principles of positivism and interpretivism, is realism (Popper, 1959). Sharing features of positivism (Bryman, 2004), realism has an underlying philosophy which says that there is a reality which exists independently of mankind and its beliefs, but which also contains large scale forces affecting individuals who may not necessarily be aware of them (Saunders et al, 2003). Although inside this philosophy intangibles are recognised (Bryman, 2004), using this approach would be inappropriate in this research for the same reasons as carrying out positivist research.

The third philosophy, that of interpretivism describes research as “fundamentally an act of interpretation” (Locke, 2001:4). The principle being that the social world is much more complex and richer than that of the natural sciences, and is therefore open to different interpretations. Interpretivism recognises that it is not possible to detach the researcher or theory (Seale, 1999) from the world. Shipman (1997:18) states that “most researchers probably accept that humans, including social scientists, construct their own knowledge of the world around them and that there is no detached position for
neutral observation”. This outline provides greater clarity to the philosophical stance.

By recognising that particular situations can be unique, interpretivism accepts that it is not always possible that research conclusions can be readily replicated by other researchers (Saunders et al, 2003). By accepting that the research is inside the world, interpretivism allows for the use of qualitative methods, including interviews, observations, stories, etc. among its data collection tools. Above all, it is “pragmatic, interpretative, and grounded in the lived experiences of people”, (Marshall and Rossman, 1999:2). This research is concerned with the lived experiences of individuals, the choices they have made and how those choices affect their development over time. It is therefore entirely appropriate that given the requirement for individual insight into their developmental process, this study will adopt an interpretivism perspective.

Having accepted that the researcher is “inside the world”, interpretivism as such does not address the issue of exactly what the reality is that is being described here. Falling inside the interpretativism paradigm, Bryman (2004) distinguishes between two different views of reality, “Objectivism” (Rand, 1961) and “Social Constructivism” (Berger and Luckman, 1966). Bryman (2004) illustrates the difference between the two viewpoints using the examples of an organisation and culture. Adopting the objectivism view means that the organisation or culture would control the individual, that such structures are “pre-given” (ibid:17) and that the individual does not exert any influence. Social constructivism provides the individual with the ability to change or influence the organisation or the culture.
Social constructivism provides an arena where "people are likely to share interpretations of their socially constructed environment", (Saunders et al, 2003:84) and shape the social reality of the world in which they live (Bryman, 2004). People interact with the environment and other individuals around them by using shared meanings and ideals to make sense of what is happening to them. The constructionist approach that this study is adopting impacts upon the design significantly, since it is not necessary for the researcher to know if the answers to the questions are true or false, but to look for "displays of perspective and moral forms" (Silverman, 2001:112). This allows the researcher to accept that the individual's views "are part of the world they describe" (Hammersley and Atkinson, 1995:107).

Obviously what constitutes reality differs from individual to individual, creating multiple realities, "there are always multiple realities. Depending upon where a person is in the world, he or she sees things differently" (Krueger and Casey, 2000:xiii). To address this point this research will seek to identify what constitutes the shared "mental model" (Senge, 1990) in the workplace, thereby indicating the nature of the reality that is being described in the study.

4.1.2 Research Approach and Strategy

The next choice depends upon how the fieldwork is being approached. If there is an a priori hypothesis to test in the field this is, in essence, taking a deductive approach which is typical of the positivist paradigm. Although there is a preliminary framework upon which to construct the fieldwork available, it is not informed by the literature and does not constitute a hypothesis. Consequently,
this research is primarily focussed upon generating a theoretical model to understand and explain the learning process. The generation of theory is the primary purpose of the inductive approach.

Tools commonly used when taking a deductive approach, such as experiments and surveys have already been ruled out on the grounds that the results obtained from these methods will not provide appropriate insights into the complex and rich organisational environment available for study. The philosophical choices made now point towards two research strategies mostly closely associated with the interpretivist paradigm; action research and ethnography.

Action research (Lewin, 1946) "attempts an interactive cycle between practical struggles" (cited in Seale, 1999:10) as the researcher is working with the client or community actively involved in identifying problems and finding solutions (Bryman, 2004; Saunders et al, 2003). Commonly found in environmental, community and urban planning studies, action research would be inappropriate inside this particular study. Here the focus is to explain what already exists in the case organisation but is not known externally, rather than an attempt to introduce or change a process as a response to a problem situation. Intervention and action by the researcher is neither required nor desirable in this case.

The research requirement is to develop theory from the data itself, rather than from the literature which suggests adopting the grounded theory approach (Glaser and Strauss, 1967; Strauss and Corbin, 1998). Grounded theory holds
the ability to tease out new relationships and is an acceptable ethnographical research approach (Chamaz, 2006).

Grounded theory asks the researcher to "enter the worlds of those under study in order to observe the subject's environment and the interactions and interpretations that occur" Goulding (2002:39) and is "a method that aims to penetrate the phenomena by moving through various levels of theory building, from description through abstraction to conceptual categorisation, in order to prove underlying conditions, consequences and actions" Goulding (ibid). It requires a "continual cycling back and forth between theory construction and examination of data" (Seale, 1999:90) and this cycling process requires flexibility and sensitivity to the data on the part of the researcher.

Usually, grounded theory means that data collection commences in the very early stages of a research undertaking (Strauss and Corbin, 1998) so as to begin theorizing early. It is held that this process lessens the possibility of the researcher's view being influenced by the data coding and subsequent theory building (Silverman, 2001). Using this option becomes less viable in this particular study when taking into account the extensive literature review already undertaken prior to data collection. More significantly, the researcher has been employed by the case organisation for over twenty years progressing to a senior management position with the UK operation. Given these circumstances, it is inevitable that the researcher's experience and relationships will play a role in both data collection and analysis. This point is discussed in more detail in the sections relating to the research values.
Figure 15 indicates that the options of ethnology and case study remain to be considered. Yin (2003) suggests that these two approaches are often confused; the major difference being that case study research is not dependent upon lengthy observation in the field. Indeed, Yin (2003) goes further, in suggesting that case studies can be conducted in the library, based on secondary data, and need not necessarily rely on direct experience of the participants. The researcher being immersed in the field over a period of time indicates a strong basis for adopting a particular ethnological approach; "micro ethnography". This term is often applied to ethnological research where there are modest numbers of individuals or organisations involved (Goulding, 2002). This fits with this research study where it is limited to one location involving less than 100 staff.

Ethnology is not considered a popular approach in business because of the longer periods of time in the field expected of the researcher (Saunders et al, 2003) in comparison with other approaches such as grounded theory or case studies. The lengthy period is often required to facilitate the researcher gaining an understanding of the environment. Clearly time in the field is not a problem in this case, since there already exists an intimate understanding of the case organisation, its processes and staff. What the researcher is missing is the detailed understanding of how the disciplines fit, how the staff perceive disciplinary interaction and how that influences the learning processes. The concern, which is expressed at a number of different points throughout this discussion, is that the researcher will have a tendency to make assumptions rather than allowing the data speak for itself.
Ethnology is:

"participating, overtly or covertly, in people's lives for an extended period of time, watching what happens, listening to what is said, asking questions – in fact, collecting whatever data are available to throw light on the issues that are the focus of the research" (Hammersley and Atkinson, 1995:1).

Furthermore, ethnology has:

- A strong emphasis on exploring the nature of a particular phenomenon rather than testing an hypothesis;
- A tendency to work with unstructured data;
- An investigation of a small number of cases; and
- An analysis involving interpretation of meanings and functions of human actions
  (Hammersley and Atkinson, 1995)

Goulding's assessment of ethnology included an important additional point that ethnography "always involves the use of emic (outsider perspective) and etic (insider view) data", (Goulding, 2002:27). These are elements which fit the proposed research more appropriately than other considered approaches. It is interesting that these two perspectives could be thought to be contained within the participant-observer role, which provides the insider view but the observer role forces objectivity, which facilitates the outside perspective. It was certainly educative for the researcher to gain an objective view of the workplace and its processes.

One further refinement of ethnology, not featured in the research process onion, is analytic induction, a close cousin of grounded theory (Bloor and Wood, 2006:13). This is focussed on looking for "universally true causal laws" (Seale,1999:22), sometimes referred to as the "deviant case analysis" (Boor and Wood, ibid) requiring a theoretical model be drawn up, with the subsequent data used to extend the model until it fits all the instances found. Seale (1999) advocates this approach as an alternative to grounded theory, stating that it is
better suited to the post modernist era, being more open to ideas and self awareness by the researcher. These qualities will be required inside this research, in view of the close association between the researcher and the case organisation, which should strengthen credibility.

4.1.3 Time Horizons and Data Collection Methods

The term “practitioner-researcher” (Saunders et al, 2003) is used to describe a researcher who is working inside the case organisation which is the study subject. This is the case in this research. Being a practitioner-researcher inside an organisation where the study is endorsed and supported by the founding Principals means that it is possible to collect evidence from any number of different sources. It also means that this research does not face many of the access difficulties commonly found in other studies. Moreover, although it gives rise to issues concerning bias which affects credibility, being employed inside the same establishment for a number of years means that the researcher has had personal exposure to many different areas, and at different levels of the case organisation. Being immersed inside the research setting (Delbridge and Kirkpatrick, 1994) provides for an understanding of the shared symbolism, both in language and more generally. It also leads to less difficulty in identifying significant relevant information (Charmaz, 2006).

It is important to recognise that the researcher's qualifications and profession means that the majority of their personal experience relates primarily to administrative and Human Resources roles. Effectively, prior to the commencement of the research, the interrelationships between the disciplines
were not well documented in the literature and the researcher had limited knowledge of the technical disciplines. From that perspective, the researcher was in no better (or worse) position than any other researcher embarking upon field work inside the case organisation in terms of knowing how they worked together.

Moreover, the term "multidisciplinary" was commonly used in the case study work environment to describe two aspects of project life. The first usage was in respect of teams, which were comprised of different individual disciplines, and secondly, with individuals who were able to perform across a spectrum of disciplines. The initial research undertaken in 2005 was the researcher's first attempt to put a term used in a specific way inside the case organisation into a more theoretical framework in order to define and extend out its usage.

In terms of time horizons, the actual research is cross-sectional, so will take a slice through the case organisation, looking at the phenomena inside a short time frame rather than investing over a period of years, as is the case with longitudinal studies. The data does include a series of interviews and notes taken during the course of the initial research (2005) covering multidisciplinary team working which provides secondary data here. Using such secondary data will therefore provide a longitudinal element to the research. One of the main criticisms of secondary data is that there is not usually an opportunity for the researcher to question the material or the interviewees again in the event of queries or confusion (Szabo and Strang, 1997; Goulding, 2002). In this case, some of the original interviewees are still employed and available for further interviewing should the need arise.
4.1.4 Data Collection

Ethnology has a number of data collection tools associated with the strategy, which include participant observation, documents, diagrams, maps, photographs, interviews and questionnaires (Goulding, 2002; Charmaz, 2006). Yin (2003) explored the various strengths and weaknesses of different data sources which are provided in Table 16. These are discussed as they relate to the tools used in this research in the section that follows.

<table>
<thead>
<tr>
<th>Source of Evidence</th>
<th>Strengths</th>
<th>Weaknesses</th>
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<tbody>
<tr>
<td>Documentation</td>
<td>• Stable – can be reviewed repeatedly&lt;br&gt;• Unobtrusive - not create as a result of the case study&lt;br&gt;• Exact – contains exact names, references and details of an event&lt;br&gt;• Broad coverage - long span of time, many event, and many settings</td>
<td>• Retrievability – can be low&lt;br&gt;• Biased selectivity, if collection is incomplete&lt;br&gt;• Reporting bias – reflects (unknown) bias of author&lt;br&gt;• Access – may be deliberately blocked</td>
</tr>
<tr>
<td>Archival Records</td>
<td>• Same as for above for documentation above&lt;br&gt;• Precise and quantitative</td>
<td>• (same as above for documentation)</td>
</tr>
<tr>
<td>Interviews</td>
<td>• Targeted – focuses directly on case study topic&lt;br&gt;• Insightful – provides perceived causal inferences</td>
<td>• Bias due to poorly constructed questions&lt;br&gt;• Response bias&lt;br&gt;• Inaccuracies due to poor recall&lt;br&gt;• Reflexivity – interviewee gives what interviewer wants to hear</td>
</tr>
<tr>
<td>Direct Observations</td>
<td>• Reality- covers events in real time&lt;br&gt;• Contextual – covers context of event</td>
<td>• Time-consuming&lt;br&gt;• Selectivity – unless broad coverage&lt;br&gt;• Reflexivity – event may proceed differently because it is being observed&lt;br&gt;• Cost – hours needed by human observer</td>
</tr>
<tr>
<td>Participant-Observer</td>
<td>• Same as above for direct observations&lt;br&gt;• Insightful into interpersonal behaviour and motives</td>
<td>• (same as above for direct observations)</td>
</tr>
<tr>
<td>Physical Artefacts</td>
<td>• Insightful into cultural features&lt;br&gt;• Insightful into technical operations</td>
<td>• Selectivity&lt;br&gt;• Availability</td>
</tr>
</tbody>
</table>

Figure 16: Six Sources of Evidence: Strengths and Weaknesses Yin (2003:86)
Interviewing

Inside this research, interviewing was utilised in three different ways: in groups to identify “shared mental models” of what knowledge domains and disciplines consisted of (Craik, 1943; Senge, 1990); with individuals using an in-depth unstructured format to confirm data obtained from the group interviews, and to further explore individual’s views on the case organisation and the projects. Lastly, structured interviews were held to obtain quantitative data to yield a more precise understanding of the elements involved, as well as helping to confirm data drawn from other sources.

Group Interviews

One of the early objectives of the research was to map the disciplines inside their relevant knowledge domains since an existing, up-to-date typology had not been found during the course of the literature review. Mapping was a necessity to determine disciplinary borders which would facilitate the identification of multidisciplinary skills held by each individual. The plan was to take a “horizontal slice” (Saunders et al, 2003) across each of the knowledge domains represented in the workplace by holding group interviews (Bryman, 2004).

Group interviews are more commonly used inside research in the form of focus groups, typically consisting of “five to ten individuals” (Krueger and Casey, 2000:10). This was not an option here given the limited availability of individuals at any given time. It was essential that at least one group interview consisted of junior staff, only with little exposure to professional societies or the
organisational culture. The objective was to ascertain if any differences existed between the age groupings in their interpretation of the relevant knowledge domain characteristics and their borders. Furthermore, junior staff would not be overly influenced by the organisational culture which may lead to different perspectives in respect of how they observed organisational processes working. It would also deal with the separate issue of junior staff feeling inhibited by having senior staff involved in the same discussion (Morgan, 1997; Morgan and Krueger, 1993).

Gaining the appropriate technical detail at the beginning of the fieldwork was essential since the "voices of participants are an important source of data and should be allowed to be heard in the written end product" (Goulding, 2002:27), which meant that the researcher had to have at least a superficial understanding of some of the "jargon" employed in later interviews by individuals.

Bloor and Wood (2006) suggest that discussion groups are valuable as the initial pilot "to collect data on group norms, on everyday language". Such discussions should also surface shared, or otherwise, attitudes and perceptions concerning the prevailing ethos of the discipline and the case organisation. This data should reinforce the results obtained through other research methods being employed within the study (Bloor and Wood, 2006). The shared "mental model" (Craik, 1943; Senge, 1990) would provide an "understanding based on discussion as opposed to testing a preconceived hypothesis" (Krueger and Casey, 2000). Any conclusions drawn from data obtained at this stage could
then be tested during the course of the individual interviews which followed completion of the group interviews.

Morgan (1997) indicates that it is better to hold a more informal and unstructured discussion when seeking to explore a topic. This was the intent of the group interviews. To provide a discussion framework, a short list of questions to act as prompters, was drawn up (Appendix 2) and this was subsequently amended following the pilot discussion. "Brainstorming" (Osborn, 1948) the subject with "information-rich" cases (Patton, 1990) enabled these discussions to work well in practice.

The selection of individuals to take part in interview groups is fraught with difficulty as Krueger and Casey (2000) noted. This holds true for small group interviews. Selection can be tainted, as members may be drawn from people who have expressed interest or concern in the topic. Other ways of tainting the sample selection are if they are drawn up simply from researcher's memory, they are of the same nature and/or background as the research supervisor, or perhaps they are not in the mainstream of the topic under discussion. These issues are controlled in this particular case, since selection is almost always predetermined by the availability of suitable staff in the case organisation at any given time, due to project and associated travel constraints.

This constraint also brought an element of randomisation in the selection of the individuals, which meant that on occasions the interviews were run with available staff inside the discipline, rather than early volunteers. A number of individuals agreed to participate on relatively short notice which gave little time
for reflection prior to the discussions. This worked in favour of the discussions, providing spontaneity, and upon reflection, meant involving a wider number of individuals than perhaps was originally intended. It certainly assisted in avoiding a biased selection of participants.

**Unstructured Interviews**

Following the group interviews, it was planned to hold a number of unstructured in-depth interviews with a representative sample of the population. Individual interviews are the "gold standard" (Lambert and Loiselle, 2008) of the qualitative techniques and form the basis of this research. Three of the individuals who had taken part in the 2005 data collection were still available for interviewing. This was useful since any questions stemming from the secondary data could be addressed and secondly, a second interview could take place seeking detail on any changes to their views in the intervening period. This was useful in providing an element of longitudinal data to the research.

Additionally, the sample included some staff already holding a reputation for being "successful multi-disciplinary individuals". To obtain the long term management perspective, both senior partners took part in the research. One as a participant responding to the same questions as the employees to provide insight into one of the founder's view. The second partner was interviewed to gain historical perspective on the key drivers behind the case organisation's continued growth over the last forty years, and to gain insight as to how resources were handled to meet the profit and loss objectives. Other senior management figures such as the previous CEO and current regional manager
were included so as to gain insights into their management perspective and technical expertise.

The decision to use in-depth interviews as a second phase hinged on the requirement to explore the individual's perspectives on the case organisation's multidisciplined teamwork approach to projects, and how their personal experiences related to that approach. This situation calls for the use of in-depth interviews, rather than structured or semi-structured techniques "since it allows the content to be more controlled by the interviewee" Saunders (2003:245). These in-depth interviews allowed for anecdotal evidence to be gathered by exploring the individual's thoughts and feelings which can often become wider based than the interviewer initially anticipated.

Saunders et al, (2003:248) postulated that "in exploratory research in-depth interviewing is more frequent". A view promoted by Merton et al, (1956) who pressed for a more focussed interview technique using "predominantly open questions to ask interviewees questions about a specific situation or event that is relevant to them and of interest to the researcher". By using the same questions in each interview it is expected that one individual will confirm or refute the data generated in the other interviews undertaken. The use of open questions of course means that each interview will cover slightly different aspects each time. Both Merton (1956) and Saunders et al (2003) favour the use of interviews as the best way forward.

Each interview was recorded and transcribed, as recommended by Bryman (2004), to facilitate the discussion by allowing the researcher to concentrate on
running the session. Recording the sessions enables close examination of “the processes whereby meaning is collectively constructed”, (Bryman, 2004:349). It is more accurate to record the discussions, and it also shows how the individuals have interacted during the session to reach a shared understanding of the discussion topic over simply making notes.

**Structured Interviews**

Prior to conducting the interviews, an interview guide was prepared (see Appendix 3) outlining the issues to be addressed and a pilot interview conducted to assess the effectiveness of the guide. Based on the outcome of the pilot interview, the interview format can then be refined if necessary.

**Participant Observation**

Although not technically qualified in any of the technical disciplines, the researcher has previously worked on some of the projects as a support team member. During the course of the research, there was an opportunity for the researcher to participate in two projects:

- A project concerning field rehabilitation, which has been ongoing for ten years, where the researcher’s role involved administrative and tax liaison with the client. This included travelling as part of the project team to the Asia-Pacific region and working in the client offices.
• A project concerned with providing an opinion letter relating to a technical oil production problem. The task was to assist in independently reviewing the final opinion letter before it was sent to the client. This involved considerable editing to ensure that the response was understandable to the non-technical individual yet properly addressed in a clear fashion the original question.

Both of these events provided "experience" of working inside a project team, rather than being simply an observer. Working on the projects highlighted the differences in how teams worked together and provided personal experience of the learning process. Project exposure led later to the inclusion of questions relating to where in the team individuals felt the best learning opportunity lay so was useful in the sense of helping to construct the structured questions.

Other Data Sources

Physical equipment in the environment is limited to computer hardware and software so has limited value to the researcher, further data was obtained from the following sources:

a) Documentation

Documents such as company forms, resumes, organisational brochures and ISO 9001 manuals were utilised together with a variety of meeting reports. These were a rich source providing data on individuals; disciplines present
inside the case organisation; insights into organisational culture as well as project range and types.

b) Archival Records

Although there was a variety of historical documentation available for reference, more insightful was the information obtained in the form of anecdotal stories from long serving members of staff obtained during interviews.

c) Direct Observations

The practitioner-researcher is present during many of the daily, weekly and other meetings in a functional capacity, and is able to observe first hand staff reactions. It is also common for the researcher to be involved in day-to-day administrative and organisational problem solving across the case organisation, which makes for frequent contact with individuals at all levels. This provided a deeper understanding of how the processes interacted for the researcher.

4.1.5 Data Analysis Software

The data obtained from these various sources was analysed using Nvivo 8, a "code and retrieve" program which facilitates the researcher's ability to organise raw data, to build category coding structures and to "query data" (Bazeley, 2007). Bazeley (2007:8) identifies four "issues" for the researcher to consider in choosing software for analysis:
1. Using computers can give the researcher a sense of detachment from the data;
2. "Coding and retrieving" may be the only analytical tool used;
3. The study might be more biased toward positivism because of the more automatic nature of computers or the software employed; and
4. The perception that computer software is either limited to grounded theory approaches or assumes a life of its own in the sense that continually refining the categories may lead away from the raw data itself.

The four issues have been addressed inside this research and discussed further in the following Sections. The initial step was to take the raw data from the 2005 research and using open coding to construct the initial coding structure. This pilot allowed the researcher to develop the skills necessary to use the qualitative software and begin to scope out the more specific data collection requirement. It also provided an opportunity to test the issues outlined in the previous paragraph to assess how they might be addressed inside this particular research.

The discussion above addresses the first four questions in research design. It has identified that this research is interpretivist and, of necessity, it did take an inductive approach in generating theory to explain the phenomena. As the researcher was immersed in the research environment it was ethnographic in nature and of a cross-sectional design. The data collection tools were primarily different interview formats and participant observation but also encompassed
documentation, observations and archival records. Finally, the data collected by these various methods was analysed using qualitative software.

4.2 Research Values

This Section looks at what issues might arise during or associated with the whole research process, and which hold the potential to affect the research in some way. These issues require the researcher to attempt to define them and then to establish processes to follow in the conduct of the research to either reduce the issues or better still, remove them altogether. The processes set to overcome these difficulties establish the research values which are critical in establishing the credibility of the work, and ensuring that no one is deceived by any of the outcomes (Saunders et al, 2003). Positivism looks to the reliability and validity of the work as evidence by identifying a number of threats to the work. Examples of such threats are participant or observer bias; replication of results using another researcher or settings and incorrect assumptions.

Lincoln and Guba (1985) argued that for interpretative research credibility of inductive research needed to be assessed differently from deductive research. Table 10 sets out their revised terms applicable to inductive research set out in 1985, to which authenticity was added at a later date. The values which apply within this research are discussed in the following sections using this approach.
4.2.1 Credibility

Silverman (2001) highlighted the fact that all qualitative studies suffer from credibility problems. How can the researcher prove that the “fragments of data” being used within the study are objective and have not been selected simply to support the researcher’s arguments. To overcome this obstacle, Silverman suggested that the researcher should create data which allowed the “flavour” to flow through to the reader. Moreover, credibility also concerns itself with unforeseen events that occur during research such as timing, changes and unforeseen incidents. Credibility can be affected if ambiguity or bias exists in the linking of the causal relationships between variables (Hammersley, 2000).

<table>
<thead>
<tr>
<th>Conventional inquiry</th>
<th>Naturalistic Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Truth Value</strong></td>
<td><strong>Credibility:</strong></td>
</tr>
<tr>
<td>(Internal validity)</td>
<td>• Persistent observation</td>
</tr>
<tr>
<td></td>
<td>• Prolonged engagement in the field</td>
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<tr>
<td></td>
<td>• Search for negative instances</td>
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<tr>
<td></td>
<td>• Disinterested peer review</td>
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<tr>
<td></td>
<td>• Member checks</td>
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<td></td>
<td>• Triangulation exercises</td>
</tr>
<tr>
<td><strong>Applicability</strong></td>
<td><strong>Transferability:</strong></td>
</tr>
<tr>
<td>(External validity)</td>
<td>• Thick description</td>
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<tr>
<td></td>
<td><strong>Dependability:</strong></td>
</tr>
<tr>
<td><strong>Consistency</strong></td>
<td>• Documenting Research Decisions</td>
</tr>
<tr>
<td>(Reliability)</td>
<td>• Audit trial</td>
</tr>
<tr>
<td><strong>Neutrality</strong></td>
<td><strong>Confirmability:</strong></td>
</tr>
<tr>
<td>(Objectivity)</td>
<td>• Tracking data and analysis throughout the research process</td>
</tr>
<tr>
<td></td>
<td><strong>Authenticity:</strong></td>
</tr>
<tr>
<td></td>
<td>• Ethical considerations in respect of the participants and the research itself</td>
</tr>
</tbody>
</table>

(Developed from Seale, 1999:45; Agostinho 2004:9)

**Table 10: Lincoln and Guba’s (1985) Translation of Terms**

A confirmatory framework to “demonstrate” rigour in the research has been provided (Lincoln and Guba, 1985; Cresswell, 1998) which has been widely
used to discuss credibility issues. This suggested framework is used here to assist in proving credibility in this case as follows.

**Disinterested Peer Review**

In terms of formal peer review, one paper was published in 2008 following a presentation at a Symposium which discussed the aims of this research together with the problem of having little literature available upon which to establish a hypothesis prior to fieldwork. Feedback from the audience was requested on any aspect of the concept and resulted in one discussion with a member of the Plymouth science faculty regarding the use of the terminology in the scientific arena.

**Member Checks**

The main area of concern for the researcher was in ensuring the accuracy of the transcripts. Individuals were happy to participate, on the understanding that their identity would remain confidential to the researcher and not be utilised inside any management discussions. To ensure confidentiality each participant was given an alphabetical designation and this is used throughout. Full details are provided in Appendix 4 which also sets out the role each played inside the research. As a matter of routine, interview transcripts were returned to the interviewee for accuracy checks and secondly, more importantly, to provide the opportunity for the individual to modify their commentary or to withdraw remarks entirely from the research. No one withdrew; the more usual reaction being to correct perceived "gaps" in the transcripts or to add comments. Additionally,
many individuals involved in the structured interviews have since held more informal conversations pointing out examples, providing evidence or pointing the researcher towards different avenues.

Informally, there has been the opportunity to engage in a long term, ongoing discussion with one of the Founding Principals. This discussion has been invaluable, acting firstly as verification and triangulation (Remenyi et al, 1998: Krueger and Casey, 2000) for other sources used. Secondly, it ensured the accuracy of the technical aspects covered in the research where it relates to the working of the disciplines within the oil and gas industry value chain.

**Triangulation Exercises**

One method of ensuring credibility is to include triangulation (Denzin, 1989) inside the research.

"In its broadest sense, triangulation refers to the use of a combination of methods to explore one set of research questions ... in the process you can judge the efficacy or validity of the different methods and sources by comparing the products ... to get an accurate reading or measurement of it" (Mason 1996:148).

Using different methods, it is argued, does not always mean that data from one method will confirm data drawn from another. Nonetheless, different methods of data collection will be employed so as to better ensure validity and to extend and deepen the research. Moreover, using different data gathering activities is a necessity, enabling the researcher to obtain a thorough understanding of the subject. In this case, the fieldwork will be conducted in three major phases. The first phase is to hold group discussions which explore what disciplines lie in the knowledge domains, and how the individuals view their discipline. The data
from these interviews will then inform the questions to be posed during the
course of the in-depth interviews, which will also move on to discuss the
individual's "story" in more depth. From this, it will be possible to draw up the
structured questions for a wider cross section of the staff to complete. Pilots
are frequently held to provide an opportunity to test out the appropriateness of
the questions with a small sample. In this case, each phase will commence
with a pilot to check the relevance of the questions.

Moreover, the structured interviews will enable quantitative data to be collected,
adding value to the data (Bryman, 2004) and will also assist in triangulating the
qualitative data obtained during the preceding two phases of interviews.

Persistent Observation

In addition to the eleven months it took to complete the interview phases, the
researcher has spent the last three years working from time to time on one of
the case organisation's major projects. Moreover, in the course of routine
duties, the researcher has been engaged with the sample population for a
number of years. On this basis, it is believed that persistent observation can be
demonstrated to support the research.

Prolonged engagement in the field

Similarly, all aspects of the fieldwork have been conducted by the researcher
during the five year period of this current research with an ongoing engagement
in this particular area of research since 2004.
Search for Negative Instances

Although not the main thrust of the research, a small number of such instances did emerge. Negative instances occur in one case where the interviewee did not believe that they had actually acquired any learning during the course of their employment, and some instances where individuals deepened their skill set deliberately. These examples are discussed in more detail in the next chapter.

4.2.2 Transferability

Transferability relates to the requirement to have a "thick" (Lincoln and Guba, 1985; Geertz, 1973) or detailed description of the research. In this particular study, both detail and flavour (Silverman, 2001) will be provided by giving a detailed background on each of the participants and the case organisation itself, together with any other elements which may emerge during the course of the research. Flavour can also be obtained by detailing responses to specific issues which had been identified during the fieldwork or during the literature review. Providing such details moreover, may convince the reader of the "reality of the events and situations described", (Bryman, 2004:501).

By providing these detailed descriptions of the various research elements, other researchers can judge the results of the research. It may also then provide the possibility to more accurately judge whether or not any conclusions drawn from it are applicable in any other setting, organisation or industry. This judgement is not possible until after the research has been completed and accepted.
4.2.3 Dependability

The question of dependability centres on the methodology used by the researcher to generate data in a reliable and consistent manner. This covers the philosophical decisions as well as research strategy. In terms of the actual data collection tools used, dependability might have been more readily shown by, for example using a questionnaire with limited answer options. Since the requirement here is to explore, generating this type of questionnaire would not enable the researcher to gain insights. The results of the survey would be superficial at this stage, since there is insufficient understanding until fieldwork is completed on the part of the researcher to frame the appropriate questions.

Another example whereby dependability can be demonstrated is to use the same themes throughout all the interviews so that, although the interviews will vary in content, depending upon the individual's perceptions, all respondents will discuss the same themes. This technique was utilised within the interviews and assisted with alleviating potential bias. The caveat here is simply that all interviews are open to bias: it may be that there is little or no rapport between the two parties; the interviewer may pose the questions in such a way as to guarantee specific answers or the interviewee may only give those answers that they perceive should be given, rather than what they really think.

In order that the research process is transparent throughout, and to provide an "audit trail" (Lincoln and Guba, 1985) details of both fieldwork and subsequent data analysis are discussed in detail in the last section of this chapter. This documentation of the procedures will assist in proving dependability.
4.2.4 Confirmability

In order to confirm the findings from the research, it is important that the data and subsequent analysis, together with decisions made can be tracked throughout the research. To this end a journal, partially hard copy, partially electronic (on Nvivo 8) was maintained containing notes from discussions and thoughts related to the research progress. Additionally, electronic memos were introduced at the analysis stage cross referencing ideas in respect of the coding process and items that needed to be followed up (Glaser, 1978; Gibbs, 2007). This system of documenting thoughts facilitated objectivity on the part of the researcher throughout the research.

The major exercise carried out to strengthen this aspect of the research was during the course of the data analysis itself. The preliminary framework set out areas on which to focus during the course of the fieldwork. Many of these same themes surfaced during the primary data analysis (assisted by the use of open coding in Nvivo 8). In order to confirm the results and to avoid potential researcher bias, the data was printed out in hard copy and then cut up and reassembled thematically with the relevant strips of paper being stapled to cards. This could have been achieved electronically, but the physical approach provided a better review environment. In essence, the major themes remained the same, although the exercise did throw up more examples of specific cases.

4.2.5 Authenticity

Authenticity is centred on the responsibility the researcher has for the research, its outcomes and for the participants (Lincoln and Guba, 1985). Bazeley (2007)
suggests that the way to overcome both prejudice and other assumptions, including those arising from the philosophical approach of the researcher was to "recognise them, record them, and become aware of how they might be influencing the way you are thinking about your data" (Bazeley, 2007:23). Being continually aware of the long term involvement with the population made this a significant aspect of the research. One example of how this was handled was in the use of electronic memos, serving as a tool to record the researcher's reactions to particular interviews because of the awareness that "data obtained from an interview are as likely to embody the preconceived ideas of the interviewer as the attitudes of the subject interviewed" (Rice, 1931:561).

Saunders et al (2003:129) described ethical concerns as "the appropriateness of your behaviour in relation to the rights of those who become the subject of your work, or are affected by it". This general statement is expanded to cover four main areas: harm to the participants; lack of informed consent; invasion of privacy and deception (Diener and Crandall, 1978; Bryman, 2004).

In practice, the ethical issues associated with this research were complicated by the researcher's employment role, which involves a significant responsibility for the organisation's HR aspects. Initially, some staff expressed discomfort at the thought of being requested to respond to questions which required them to comment upon other colleagues and work processes. This could have had serious impacts upon their responses to the questions, but the saving grace was simply the nature of the research itself. Learning is essentially an area that can be perceived as a "neutral" subject, serving in the best interests of both the case organisation and the individual. Moreover, in the workplace, pay and
benefits are not linked to learning goals, so staff did not perceive any impact upon their peer status or management perception of their value.

In fact, many individuals were interested in discussing the technical disciplines and their development within and across the disciplines. For many their technical expertise is subjective, in that it is what they do to earn a living. Many do not have the opportunity to objectively assess their discipline and its development. Equally, some of the more interested individuals were unfamiliar with the interpretivist paradigm, and were fascinated with the emerging theory. There was no lack of volunteers to answer questions, provide feedback and, in one or two cases, to review the research prior to submission.

Most of the staff were aware of the research throughout, although care was taken prior to the fieldwork not to disclose the aims and objectives of the study, so as to avoid prejudicing the outcomes. In fact, one of the major problems experienced by the researcher was to refrain from intervention in working processes until after the fieldwork was completed. Once the interviewing commenced and the individuals were made aware of the nature and scope of the research, more open discussion was possible. The research itself does not centre on individual performance or individual relationships with management. For many individuals the discussions revealed some surprising information about their own knowledge base. In some cases it was wider than they had previously believed it to be, and in other cases more limited. Many enjoyed the opportunity to discuss how they viewed their disciplines and the role of the professional societies; in some cases how they personally had contributed to the growth of their society. Other individuals were interested in the changing
organisational processes and for many, it was an opportunity to refresh and remind themselves of the value of some of the processes in place. These discussions came about naturally, and were not prompted, which came as something of a relief given that the researcher is employed full time in a senior management role within the case organisation. This was particularly so, since one of the major concerns at the beginning of the research was how this role might have affected participation, making individuals overly cautious throughout the fieldwork.

Peer review has already been noted as being significant, in terms of credibility, and in this case the research will be "peer reviewed" internally, prior to submission by senior technical advisers, so as to confirm technical accuracy and ensure that the case organisation is in agreement with the release of information concerning their working practices. To protect the individuals, all names were removed from the thesis prior to this review, so that no one person could be identified within the text.

Given the above, and the fact that many staff have completed both Masters and PhD dissertations themselves, and so are more aware of the ethical issues involved than in many other research settings, this research can be confident in its claim to have informed consent from the participants. Equally, it is difficult to see how the participants can be harmed by the research, either during the research or after publication. Indeed, should the outcomes conclude that multidisciplinary individuals are a valuable resource, then their individual reputation could be enhanced.
In some senses, use of subjective questioning to obtain details of experiences, in an attempt to gain data on individual characteristics could be construed as invading the individual’s privacy (Saunders et al, 2003). In view of this, the plan was to use the first interview as a "pilot", so as to ascertain if this was going to be a difficulty or not. It proved not to be an issue with the participants once they were informed of the research subject.

Deception is the last issue and probably the easiest to address. Since 2005 it has been widely known within the case organisation that research is taking place and therefore no requirement for deception existed or was possible. A briefing was provided to each individual prior to commencing each fieldwork phase along with the opportunity to review the results of the interaction, whether that was in the form of a transcript or a chart. It is planned to hold a debriefing session with all staff presenting the research following completion of the dissertation.

4.3 Issues arising from the Fieldwork and Subsequent Analysis

Data collection commenced as planned with analysing secondary data available from previous research. This material consisted of ten unstructured interviews with a range of technical staff, revolving around their perception of the "multidisciplinary" concept as it was used in the case organisation for describing both teams and individuals. These transcripts had previously been coded into an earlier version of NVivo. This program was no longer available for use, and it proved impossible to import the existing coding structures into NVivo 8. As the hard copy analysis and notes were available, it became necessary to recode both the original transcripts and associated memos and notes into open
coding. Recoding proved to be a valuable exercise since it provided the opportunity to use "line-by-line" coding (Gibbs, 2007) to revisit the material and obtain new and different insights. The recoding exercise was very useful in assisting with the development of necessary skills in the newer qualitative software prior to coding the primary data.

At the same time as recoding the secondary data, the first round of interviewing commenced. The four phases are set out in Table 11, with details of the timing involved in each discussion.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1: Group Interviews</td>
<td>Each discussion lasted for approximately 1 hour.</td>
</tr>
<tr>
<td>3 senior geoscientists in one discussion</td>
<td></td>
</tr>
<tr>
<td>5 junior geoscientists in second discussion</td>
<td></td>
</tr>
<tr>
<td>2 senior facilities engineers in third discussion</td>
<td></td>
</tr>
<tr>
<td>Phase 2: Individual unstructured interviews</td>
<td>Interviews generally lasted approximately 1.5 hours.</td>
</tr>
<tr>
<td>1 senior geoscientist</td>
<td></td>
</tr>
<tr>
<td>3 senior chemical engineers (1 senior global manager)</td>
<td>Spaced out over a period of three months immediately following the last of the group interviews</td>
</tr>
<tr>
<td>3 senior petroleum engineers</td>
<td></td>
</tr>
<tr>
<td>1 senior reservoir engineer</td>
<td></td>
</tr>
<tr>
<td>Phase 3: Structured Interviews</td>
<td>Each Interview generally took approximately 30 minutes each.</td>
</tr>
<tr>
<td>1 lawyer/strategy adviser</td>
<td>Spaced out over a period of 3 weeks, two months after the individual interviews were completed.</td>
</tr>
<tr>
<td>6 petroleum engineers</td>
<td></td>
</tr>
<tr>
<td>9 geoscientists</td>
<td></td>
</tr>
<tr>
<td>3 reservoir engineers</td>
<td></td>
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<tr>
<td>3 facilities engineers</td>
<td></td>
</tr>
<tr>
<td>2 economists</td>
<td></td>
</tr>
<tr>
<td>Phase 4: Secondary Data Interviews</td>
<td>In-depth unstructured interviews lasting in excess of 1.5 hours, completed in 2005.</td>
</tr>
<tr>
<td>1 lawyer/strategy adviser*</td>
<td></td>
</tr>
<tr>
<td>1 economist</td>
<td></td>
</tr>
<tr>
<td>2 petroleum engineers*</td>
<td></td>
</tr>
<tr>
<td>3 geoscientists</td>
<td></td>
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<tr>
<td>1 facility engineer</td>
<td></td>
</tr>
<tr>
<td>1 chemical engineer*</td>
<td></td>
</tr>
<tr>
<td>*also participated inside the primary data collection</td>
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</tbody>
</table>

Table 11: Data Collection Processes
What is interesting about the sample population is that it includes four staff based in overseas offices and who were either visiting the UK office during the fieldwork or, had participated in the earlier Masters degree. It also included four staff that have since left the case organisation. 41 technical staff became involved in the fieldwork which is actually more than the 37 technical staff employed on a permanent basis currently inside the case organisation.

The sampling used here was primarily aimed at “theory construction” (Charmaz, 2006). It was not intended that the sample would represent the staff as a whole. This form of sampling was much easier to do in practice than it first appeared. Using the group interviews to draw up the nature and territory of the domains, and allied issues surfaced a number of questions which were readily addressed inside the individual interviews. An example of this was with the description of the geosciences disciplines as an active community of practice. Surfacing this early in the first phase of group interviews enabled the topic to be introduced in other group discussions, as well as with individuals. Out of that one question grew a number of issues surrounding the treatment of disciplines inside the case organisation together with the identification of other, far less apparent communities.

At the beginning of the interview process, there was some concern about ensuring that staff understood that it was an invitation to participate and not an instruction. This could have proved a sensitive issue in view of the researcher’s connection to the workplace but in fact, the interviews went well. In most cases at some point during the interview, individuals took the opportunity to raise other issues unrelated to the research. In some cases this was simply because it was
a good opportunity to air their particular idea or grievance and, in others, because they thought that the interview itself had not covered the appropriate ground in their view, and so supplemented the information. Examples of this can be found in the group interview with the younger geoscientists who wanted to discuss the cyclical nature of the industry and its potential impacts upon their careers or, the senior manager who had thought that an ideal candidate profile could be drawn up based upon the results of the interviews.

The availability of staff affected the size of the group interviews. Saunders et al, (2003) advocate membership levels anywhere between four to eight while others state that it is more usual to work with six to eight people (Krueger and Casey, 2000). In the context of this research, it should be recognised that the available population was limited. The discussion groups were held over luncheon, using one of the smaller meeting rooms; familiar territory to participants. The aim was to ensure that the participants were comfortable (Krueger and Casey, 2000) and also that the researcher was in a different context than usual. Participants were placed around a circular table facing each other (Saunders et al, 2003) to facilitate discussions.

A pilot group discussion was undertaken with three senior geoscientists. Fortunately one geoscientist had been involved in the previous research and was enthusiastic about being further involved. This enthusiasm communicated itself to the other participants, which meant that the discussion was lively from commencement. Although the discussion went well, and did provide good data, there were several points which needed addressing prior to holding any subsequent discussions. The researcher had mistakenly described this
discussion to the individuals as a focus group. This term was not favoured by
the individuals, although no reason for this was put forward. An alternative
reason might be that the dislike of the term is an expression of the difference
between the scientific disciplines, which do not use focus groups as part of their
research methods toolbox, and social sciences increasingly do. In the interests
of this research, the researcher subsequently chose to substitute the term
"small discussion group" (Krueger and Casey, 2000) instead of focus groups in
invitation to participants; this met with no objections.

The opportunity to test the questions and their order was important. Data from
such discussions is generally analysed across the groups to identify
commonalities (Krueger and Casey, 2000) which indicated a need to retain the
same questions. The pilot indicated that the questions needed refining and
reordering sequentially from broad based questions to those where more detail
was required. As expected, the initial set of questions required more definition,
so as to ensure discussion flowed more readily. The adjustments made to the
questions, and their running order proved more successful in later discussion
groups. On the practical side, the pilot also proved that the use of a flip chart to
list points, where appropriate, would prove useful in confirming items, and
enable the discussion to progress faster. A similar finding was made in the
interview rounds when one participant insisted on note taking rather than taping.
Taking notes unfortunately, meant that less attention was paid to how the
participant reacted, and more to just writing.

The pilot also highlighted the need for fast improvement of moderator skills by
the researcher. It proved difficult to keep notes and maintain the discussion,
which is highlighted by the failure to obtain individual agreement from each attendee on points where there was general group agreement. During the discussion, consensus appeared to be driven by empathy with the speaker, and did not require probing but, upon reflection this may have been an assumption on the part of the researcher.

All of the interviews were taped. This worked well with the exception of the second group interview where much of the discussion was not audible, and subsequently the transcripts were incomplete. This meant that the researcher was forced to re-visit over the transcript with each individual in order to fill in the gaps. Although this solved the problem at the time, nevertheless, there was a considerable amount of time lost. In addition to this, there were the usual problems of poor recording quality, batteries and microphones not working properly despite having taken appropriate precautions, including carrying spares batteries and tapes. Transcription was completed by the researcher, with each interview transcription taking between four to seven hours each. The tapes were typed verbatim with indicators where the interview was interrupted, or the conversation wandered away from the actual research itself onto other more general areas.

4.4 Data Analysis

The data collected consisted of both text and numeric data. Firstly, the transcripts from the group and individual interviews would be analysed using NVivo 8. Secondly, the data from the structured interviews yielding both text
and numerical information would be analysed using both NVivo 8 and Excel spreadsheets.

In terms of NVivo 8, a data-driven approach (Glaser and Strauss, 1967; Gibbs, 2007) was adopted using open coding. This began with the secondary data interviews producing a number of codes, which expanded as the subsequent interviews were transcribed and then coded. As bias was considered a significant factor to mitigate in this research, more time was spent on open coding early in the analysis, in an endeavour to lessen any researcher bias. This concern with bias to some extent contradicts the constructivist nature of this research since here the data should “equally reflect the interplay of the researcher’s and the participant’s constructions” (Gibbs, 2007:7). This contradiction can be reconciled by the requirement to ensure that it is the respondent’s views that are being reflected, rather than the researcher or indeed, the software program itself. Once the transcripts began to be included inside the coding, then a coding hierarchy began to emerge; the full listing can be found in Appendix 5.

This listing seemed to simply reflect the starting point of the research, in terms of the variables involved in the actual learning process. This was of some concern. The implication being that the researcher had simply used the data to confirm the original loose framework upon which the research design was hung. This implication was significant, and to ensure that this was not the case, the data was turned into hard copy and analysed using card and scissors to cut it into segments, and then reassemble it under different themes. With hindsight, it is not surprising that this exercise did serve to verify the earlier outcomes. So in
some senses this exercise could be deemed to have been time wasting, but it provided a sense of security and allayed some of the concerns relating to researcher detachment, bias and software limitations. An additional exercise undertaken to confirm findings was to "query data" (Bazeley, 2007). Running keyword and wildcard searches across the data pool helped to confirm the themes being used inside the research. Bazeley (2007:170) quotes an example, whereby the theme was in fact being contributed by the researcher and not the participants. Fortunately, that did not seem to be the case in this research, but as confirmation, various data queries were run across the database. One such query looked at the 100 most frequently used words, which surfaced interesting words like "because" and "probably", indicating reasons for taking some action or reaching a conclusion about an incident.

Although memo writing is regarded as an essential part of "grounded theory", and is a way to record thoughts concerning the material being collected inside a certain category and how that might affect other categories (Charmaz, 2006), it was a useful tool to apply in the data analysis. At first, memo writing was a chore but during the later stages of the analysis, it became more a valuable tool. Similarly, the field notes and journal were all useful to note developments to theory making, and to refer back to during the closing stages of the analysis.

4.5 Revisiting the Literature throughout the Research Process

Prior to commencing the fieldwork, the concept of continually reviewing the literature to keep up to date with changes, and also to interrogate as new areas
surfaced, appeared a major undertaking at the outset of the research. In practice it became a focussed activity as the various elements emerged.

Summary

This chapter has focussed on the research design, discussing the philosophical considerations which lie behind the choice of methodology, and methods employed to carry out the study. Having chosen an interpretative, inductive approach which led to adopting an ethnographic perspective to data collection and analysis, the later sections dealt with the research values, detailing how the field-work was carried out, and issues arising out of the fieldwork.

Saunders et al, (2003:83) research onion process was utilised as a template to work through the various choices available in terms of both the methodology and methods to be utilised in the course of this particular research. During this process it became clear that how the data would be finally analysed also potentially affects its value and consequently the research onion should be adapted to include this process lying, as it does, at the heart of research.

At the same time the research onion could also be adapted to clarify where the quantitative and qualitative data lie predominantly inside the various paradigms, Figure 17.
Detailed notes of how this research dealt with the various processes undertaken to deal with issues arising around its design and conduct has hopefully made the whole process transparent to the reader. This transparency will assist in enhancing its credibility and eventual acceptance by a wider audience. The next chapter deals with the findings from the data analysis which elaborates upon the themes related to multidisciplinary working inside the case organisation.
CHAPTER FIVE

FINDINGS

Introduction

Strauss and Corbin use a "conditional/consequential matrix" (1998:182) to emphasise the necessity of analysing data in context tracing connections where appropriate between micro and macro conditions. This is where small events affecting individuals are often the result of events that are occurring or have occurred on an international and/or national scale. The data collected inside this research covers an approximate fifty-year period during which the oil and gas industry itself has undergone many economic cycles (Appendix 1). Additionally, there have been significant changes in areas such as computing, technology and communication as well as inside the disciplines themselves. These events have impacted both the participants and the case organisation involved in this research. The data includes references to macro conditions and these have been noted in the findings where they have impacted the case organisation or participants (Strauss and Corbin, 1998).

The research was undertaken in a medium sized internationally based oil and gas consultancy between August 2008 and July 2009. The fieldwork itself consisted of group interviews, individual unstructured interviews and structured interviews. Additionally, nine individual unstructured interviews taken from earlier research were included as secondary data. At the same time, a series of discussions with one of the founding partners was undertaken to both confirm accuracy in respect of the technical aspects of the research as well to confirm management approaches across the life of the case organisation.
In conjunction with the interviewing activities, an examination of the professional disciplines was undertaken, project analysis and a review of curricula vitae. Furthermore, data sources such as organisational brochures, archival records and ISO 9001 quality assurance documentation were also referred to as appropriate.

The research in this case was undertaken from a practitioner-researcher perspective which led to first hand observations and participation inside a limited number of projects thus expanding and enriching the data available for analysis.

All of the interviews were recorded, transcribed and checked by the participants prior to use. The data was then analysed using Nvivo 8, a “code and retrieve” qualitative programme, along with other pertinent data. To ensure confidentiality, each participant was given an alphabetical designation, for example “A”, and this is used throughout the research. Where quotes from the individuals are used in the text the single designation is used, for example (D). Full details concerning the participants are provided in Appendix 4 which also sets out how each participant was involved inside the research.

It is acknowledged that there are a number of different ways to set out the findings from the fieldwork, for example it would be possible to present the outcomes from each different phase or to follow the same sequence as the research objectives. In this case the findings are presented based on the core categories that emerged during the data analysis (Charmaz, 2006).
The discussion commences with a review of the multidisciplinary approach taken by the case organisation, followed by examining the meanings ascribed to "multidisciplinary individuals" and "multidisciplinary teams" inside the workplace. The next section looks at what knowledge is held by the participants and across what range in order to establish that multidisciplined individuals exist. After establishing that such individuals do exist the discussion then looks at the workplace itself commencing with a detailed review of the project team environment before looking at the organisational management structure together with other potential information sources. Lastly, the discussion turns to the individuals themselves to determine if there are any shared characteristics across the population before examining the disciplines themselves to gain an understanding of their nature and territory.

5.1 Multidisciplined Approach

The organisational ethos was set by the two senior partners who have both owned and managed the case organisation for more than 40 years. Among ISO 9001 quality assurance documentation is their mission statement:

"encouraging the staff to excel at what they do best regardless of their training or prior skills and experience" (Mission statement, 2008).

Encouraging staff to broaden out their skill base was an integral part of organisational policy. "It's all coordinated towards an approach which is multidisciplined and where we are trying to look at the thing holistically" (D). This multidisciplined approach provided access to learning opportunities by individuals while, at the same time, enabling the case organisation to position itself differently from its competition and its clients.
"At the beginning it was almost an apology for multidisciplinary because we did not want to be jack of all trades - masters of none - not a happy label. Then we recognised the virtues of this. Even the other parties appreciated it a lot then we began to promote it, make a point of it - expanding on virtues of this approach" (K).

The approach was practiced from very early on and detailed in the organisation's brochure (1984) as a positive benefit. This was at a time when most companies in the industry were organised into distinctly separate departments. These differing client departments were often located in different buildings with little communication between the separate units. (K) discussed the frustration experienced in trying to bring the different client strands together, with the case organisation almost functioning as a communication device for the clients in the early projects.

Examples were drawn together of the perceptions expressed by the staff during the interviews as what they meant when they used the term "multidisciplinary". Their comments have been broken into two main sets; the first set relates to individuals who were perceived to be multidisciplinary. The second set of comments deals with perceptions on what makes multidisciplinary teams.

5.2 Individuals

Table 12 sets out how staff perceived multidisciplined individuals and attempts to identify and define what qualities differentiate them from other staff. Examples are provided of the processes involved in individuals acquiring additional disciplines together with an understanding as to what extent the
Definition: "there are clearly people with a wide range of experiences and ability and so on" (I)

Definition: "an individual is able to work on, within various different fields ... within maybe the realm of project work that [organization] does. It doesn't mean that everything but certainly more than one. Rather than being a specialist in log analysis, petrophysics or something they are able to work in other fields as well" (F)

Definition: "multidisciplined is where you have disciplines working together or a person with multiple capabilities. It is very rare but there are some. Cross discipline is, I refer to, is when there are a number of disciplines working together towards a common goal and then again people can have knowledge of those cross disciplines but they may not be themselves multidisciplined" (U)

Definition: "multi-disciplined is the concept and practice of individuals not limiting themselves to working, and corporately not attempting to organise work, such that people work only on their own specialised area, but as individuals and as part of a team cooperate on addressing the problem, rather than just their notional part of the problem" (E)

Definition: "a reasonably accomplished professional whose views are practical and not stymied by the tar of one particular discipline. Right and are able to understand the whole problem and therefore able to provide advice broad based and are also able to select the right people and technology for taking any one matter further" (D)

Learning Process: "people are not working absolutely in their own discipline; they are listening and participating on the broader front" (D)

Learning process: "it spreads out as your experience grows and almost like you start in the middle and get some comfort and get to know a fair bit about something" (J)

Learning Process: "because the resources were such that if you did not have anything to do in your own discipline then you, if you were a more senior guy, then you worked as a junior in another discipline. Which largely that side of it has probably gone which in a way is a shame because that is really how you learn so many other disciplines. Regardless of what your age and status in the company is that you are prepared to work with somebody, who is ostensibly your junior giving you advice as to how to go forward" (Y)

Learning Process: "in fact really it is the environment, the way the company works that promotes the ability to look across/ work across the disciplines" (F)

Learning Process: "if they can spread their capability and their interests wider than the fields in which they had previously worked or been trained" (D)

Knowledge level: "but I have been able to contribute to projects involving everything from geology and geophysics through reservoir engineering, through reserves work, through surface engineering. Been involved in operational work and have been seconded to a company to start an exploration company" (Y)

Knowledge level: "at the very least you need to be able to understand the edges of your area and how your area relates to another area" (U)

Knowledge level: "he may only have a kind of a certain level of knowledge but it is more the character of the person willing to step out and try something that may not be in his particular area of speciality. It is a characteristic of the individual." (D)

Table 12: Multidisciplined Individuals - Perceptions

Learning process is effective. These examples are limited to expertise in terms of knowledge or software skills since this research involves "knowledge" workers only.
The key learning for everyone joining the case organisation is that they:

"need to be able to recognise and understand their skills, their strengths and weaknesses and where that fits within the project deliverables" (B).

Primary or core expertise is a necessity as the case organisation provides very little specialised training. Simply having an appropriate degree with a recognised “oily” university department does not mean the functional expertise can be taken for granted since there still can be “massive gaps in understanding” (I). It can also take some time for new joiners to be accepted and integrated into the staff (B). Notwithstanding how it was worded, it was generally accepted by the participants that multidisciplinary indicated the practice of individuals not limiting themselves to working within their disciplines or specialised areas, but being prepared to cross boundary lines. The degree to which they move away from their core discipline being limited more by their own personality and goals rather than by management or work processes. In some cases it was described as working at the fringe of their discipline (C) and in others, as staff acquiring a totally new skill as described above (F). Note discipline and skill are used interchangeably by participants.

The comments provided in Table 12 indicate that the multidisciplined individual displays problem solving abilities drawn from one or more disciplines, in addition to their core discipline. They are able to approach problems in a holistic way because of the wider technical knowledge they hold and it is implied that this provides for a more practical approach,

"get a lot of ideas, lot of solutions if you like come from stepping outside of the box and seeing it from another angle" (A).
The additional knowledge base is acquired through a combination of being open to learning, e.g. listening, participating, moving outside their comfort zone and an environment which enables these behaviours. For the multidisciplined individual there are difficulties. Among these is the requirement to maintain knowledge levels for example:

"there is certainly more specialisation in all the disciplines and the trick is how to keep abreast with what is going on inside the different disciplines so that you can retain the idea of being multidisciplined" (C)

Another problem which arose concerned the fact that all staff were happy to be flexible and adaptive to the requirement to broaden their knowledge base in this way. (J) described it as being "jack of all trades: master of none". This particular expression had also been used by one of the Senior Partners when describing his reaction to the introduction to multidisciplinary working by the case organisation. In a couple of interviews comparisons were drawn between staff who could be called "multidisciplined individuals" and other staff focused exclusively on their specific discipline contributions to the projects. Generally staff felt that either way of working was acceptable to the staff and the case organisation. The multidisciplined individuals tended to become the best project reviewers and project managers as their wider background made it possible for them to both review project deliverables such as technical reports across a broad spectrum, and to add value to the projects in which they were involved.

5.3 Project Teams

There were fewer mentions of what were perceived to be multidisciplined teams although definitions did exist, Table 13. One participant (H) identified one of the
differences between project teams inside the case organisation and client teams as being the lack of common objectives.

Definition

"using a multidiscipline team they are getting more value for their dollar if you will in the activities that are involved in completing those projects. It either means we have the capacity to do the project quicker, or in more detail, than other organisations that might compete with us" (E)

Definition

"one of the characteristics of a good multidisciplinary group is that people are not tunneled visioned into one specialty ... actually, in my own experience the very best multidisciplinary approaches will come up with solutions which no individual has even thought of ... And that I think you could say is one of the characteristics of a very good multidisciplinary approach. People may come with preconceived ideas but because of the interaction actually come up with a solution that no single person has even conceived of. That's maybe a rather roundabout way of defining it as I see it - the multidisciplinary approach" (I)

Definition

"a multidisciplinary teams consists of a number of people who are all able to contribute to data collection, analysis and the end product regardless of their own discipline background" (D)

Definition

"The diverse nature of [Case organisation] consulting activities, from primary exploration through to refining and product disposition, has ensured the development of professional teams with a high level of multidisciplinary abilities. This interface capability at the professional level allows a logical progression from accurate analysis and interpretation to practical, decision oriented, conclusions, suitable for direct management application" (Extract Company Brochure, 1984)

Table 13: Multidisciplined Team - Perceptions

Without these, the teams are "just a bunch of guys who have different skills [knowledge]".

All staff taking part in the research were aware of the term "multidisciplinary" although not everyone described the way that the project teams worked together in the same way. Multidisciplinary teamwork was described as needing:

"interaction so that the whole is greater than the sum of the parts. And, actually, in my own experience the very best multidisciplinary approaches will come up with solutions which no individual has even thought of" (I).

Variations on this were repeated in other interviews. More than half the comments made referred specifically to "more than the sum of the parts" (Kline, 1995) type teams.
The alternative description provided what would be better termed a collaborative team approach:

“I think it describes an environment, or a project environment, where you have to bring together people with different skills and meld those skills to get a deliverable” (A)

This statement points to the project manager being the one to draw the various threads of the project together and provide solutions from these. There was no correlation in terms of age, core discipline, or years of service with the case organisation in the two participants who identified collaborative teams. In fact one had been previously described as being a good example of a “multidisciplined individual”.

Fifty percent of the interviewees raised the issue of being able to take a wider view of the individual discipline and how it fitted into the project. The words used to express this varied: “being able to think outside the box” (F), “having an eye to what he can contribute” (D), “wider understanding” (D) or “being able to cross disciplines” (MM). This ability can be differentiated from the concept of “more than the sum of the parts” as it relates to the individual being able to think laterally in respect of problem solving and lacks the element of interaction between team players to arrive at the solutions.

Another way of expressing this would be to say that the ability for interaction between project members must exist in order to leverage a different, better result out of the combined work effort: “an individual may eventually get to an answer but it is unlikely that he will get that answer in the same timeframe as a team would” (C).
It is much more clearly expressed as:

"People may come up with preconceived ideas but because of the interaction actually come up with a solution that no single person has even conceived of". (I)

Comments like "you need to have people who have wider understanding of the problem and can bring to bear some multidisciplinary view to the answers" (D) stressed that these teams needed multidisciplined individuals not only to ensure any project deliverable remains achievable in the event of a member dropping out, but also in order to enhance communication and interaction. It is interesting to note that few made the link between being able to see the bigger picture and "more than the sum of the parts".

Project teams operate in different ways. If the team operated as an integrated team then all team members will have opportunities to exchange knowledge in the various project team meetings and client discussions. On the other hand, some project managers treated the projects as a series of individuals handling separate packets of work which the project manager would then pull together into one report. There were examples of each type of team working inside the organisation.

5.4 Informal Learning

One of the major aspects that the fieldwork sought to explore was the range and depth of knowledge available inside the workplace in order to confirm individuals with additional disciplines did exist and the extent to which they were multidisciplinary. To achieve this objective a questionnaire was devised which listed the major work areas, or sub sets, inside each disciplinary area, Appendix
3. For example, reservoir engineering covered the four main sub sets of classical engineering, history matching, simulation and production forecasting. These areas were set out in consultation with the participants and represent major items of work as they are set out along the petroleum industry value chain. In other words, the scale commences with exploration for hydrocarbons and ends with the strategic end of the industry as represented by expert witness work. These are all major items of work regularly carried out by project teams and/or individuals (particularly in the case of expert witness) inside the case organisation. The questionnaire was deliberately split with the emphasis on the major task elements where this was possible rather than using the more usual disciplinary headings such as reservoir engineering or geologist. This split was designed to encourage the participants to think beyond their usual disciplinary borders. It would also highlight where the individual had developed into the overlapping disciplines or had acquired new disciplines quite separate from their primary discipline.

This task list was then broken out into five boxes; one of which was described as primary discipline and then a further four boxes which indicated the level of understanding the individual possessed in tasks which lie outside their expected knowledge and/or skill range. As described in Table 14 each box was given a numeric weighting based upon the individual’s assessment of their competence inside the work area. The scale used in the scoring system area is as follows:
<table>
<thead>
<tr>
<th>Primary discipline</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competent, do frequent work in this area</td>
<td>20</td>
</tr>
<tr>
<td>Can do some work in this area, but not often</td>
<td>15</td>
</tr>
<tr>
<td>Have a general understanding</td>
<td>10</td>
</tr>
<tr>
<td>Do not know or require any information</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 14: Questionnaire Scoring**

The different levels were described in terms commonly used inside the workplace to facilitate understanding. Each respondent was asked to complete this section of the questionnaire personally, with the remainder of the questionnaire being completed by the researcher on a question and answer basis. As part of the analysis each set of responses was graphed on an individual (Table 15) and then on a collective basis (Table 17). Using this method it was possible to quantify the level of knowledge held by each participant and across the sample population. The graphs for each of the participants serve to illustrate the breadth and depth of knowledge for each individual and are provided in Appendix 7.

It should be noted that one questionnaire was left out of this section as the participant had marked it on the basis of the subjects covered in his Master's degree rather than learning during the course of his employment with the case organisation. A second questionnaire was incomplete and therefore could not be used.
Table 15: Participants total knowledge across oil value chain
By adding the score for each participant it was possible to quantify their knowledge across the discipline sub sets with the highest scoring participants most likely to be "multidisciplinary", Table 15. Based on the scoring system (Table 14) any participant with a score of more than twenty five held some level of knowledge in an additional discipline as twenty five was the score assigned to the primary discipline. There were three participants who had marked their primary discipline only; V, BB and R. Two of whom fell into the classical subset of reservoir engineering and the last participant (R) being a junior chemical engineer.

The results indicate that participants scoring plus fifty and above would hold expertise across the disciplines, and would therefore be identified as multidisciplinary individuals. Generally speaking these individuals have core expertise combined with a general knowledge and understanding across a number of disciplines.

The question arises as to how accurate this table is. It is first and foremost a subjective view by each individual on their abilities and this will tend to produce some bias in the results. How much bias is difficult to estimate, for example, the facility engineer who talked about being the "glue holding together the projects" was surprisingly narrow in the fields he could work in. Others were surprised at how much they knew but hesitated as to the degree of expertise they thought they held. An example of this was the chemical engineer who could run adequate cashflows, but was concerned about the level of detail he thought clients required.
Table 16 looks at the detail provided by the six highest scoring participants which more aptly demonstrates which additional disciplines the participants hold. In these cases the acquisition of disciplinary knowledge and skills is across a broad range of the case organisation’s work. Geologist (0) demonstrates competencies across the whole of the geosciences sub groups as well as various aspects of economics and strategy. He possesses an understanding across the engineering disciplines and appears to be lacking knowledge only in the more specialised areas of chemical engineering. What is interesting in this example is that the participant has scored acquisition and divestment work at the same level as his core discipline of geology. Similarly the petroleum engineer demonstrates a general understanding in many areas with competencies across a variety of sub sets such as production geology, economics and strategy.

Table 16 also demonstrates that the level of knowledge acquisition varies across the tasks for each individual. Using the same example of Geologist (0), the participant holds an understanding in some tasks, whereas in others he is competent to carry out the work. Although as individuals, geoscientists feature heavily in the number of multidisciplined individuals the results show that across the sample population petroleum engineers held a broader base of knowledge. Using the results from the same question an amalgam of the participants’ expertise can be built to understand the total knowledge store residing inside
<table>
<thead>
<tr>
<th>Core Discipline</th>
<th>Exploration</th>
<th>Production</th>
<th>Geology</th>
<th>Volume Estimation &amp; Reporting</th>
<th>Seismic Interpretation</th>
<th>Geophysics</th>
<th>Log Analysis</th>
<th>Core Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geosciences</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>20</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>10</td>
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<tr>
<td>Petrophysics</td>
<td>15</td>
<td>0</td>
<td>15</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Reservoir Engine</td>
<td>Classical Reservoir engineering</td>
<td>10</td>
<td>10</td>
<td>25</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reservoir Engine</td>
<td>History Matching</td>
<td>10</td>
<td>15</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Reservoir Engine</td>
<td>Simulation</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Reservoir Engine</td>
<td>Production forecasting</td>
<td>10</td>
<td>20</td>
<td>25</td>
<td>15</td>
<td>15</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Engineering</td>
<td>Drilling</td>
<td>10</td>
<td>0</td>
<td>15</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Engineering</td>
<td>Completion</td>
<td>10</td>
<td>0</td>
<td>15</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Engineering</td>
<td>Workover</td>
<td>10</td>
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<td>15</td>
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<td>Artificial Lift</td>
<td>10</td>
<td>15</td>
<td>10</td>
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<td>Development Planning</td>
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<td>25</td>
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<td>15</td>
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<tr>
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<td>Flow Assurance</td>
<td>10</td>
<td>15</td>
<td>0</td>
<td>15</td>
<td>15</td>
<td>15</td>
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<td>15</td>
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<tr>
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<td>Global Gas</td>
<td>15</td>
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<tr>
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<td>Project Financing</td>
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<td><strong>500</strong></td>
<td><strong>470</strong></td>
<td><strong>520</strong></td>
<td><strong>455</strong></td>
<td><strong>425</strong></td>
<td><strong>465</strong></td>
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</table>

**Scale:**
- **25** = Primary Discipline
- **15** = Can do but do not use often
- **0** = Do not know or require
- **20** = Competent, frequently work in this area
- **10** = Have a general understanding in this area

*Table 16: Extract from Questionnaire*
the case organisation matched against each disciplinary subset, Table 17. This represents a significant organic database for individuals to draw on. It is clear from the group values the case organisation's knowledge base in seismic interpretation and volumetrics is low while review production and expenditure and cashflows reflect a much higher collective expertise. Cashflows used inside the case organisation refers to the more normal economics work and is not limited to simply cashflows themselves; this point is discussed in more detail in the later section on vocabulary. The graph actually reflects accurately the shortage in geophysics (created by transferring senior geophysicist to another region combined with delayed arrival of replacement with similar expertise). The high level of knowledge in the review production and expenditure element reflects an overlap area inside several disciplines while cashflows is a direct result of a number of disciplines which encompass these two elements (S). Similarly, there is a high level of expertise in classical reservoir engineering which reflects the fact that PVT\(^1\) equations are part of chemical engineering and this is simply reflecting the overlap in the disciplines.

The higher profiles inside the strategic elements reflect the fact that many individuals have a different core expertise, for example the geologist who is now employed most frequently on strategic projects.

\(^1\) Pressure, Volume and Temperature
Table 17: Participants Expertise Levels
Having established that there are individuals inside the workplace who have acquired additional disciplines albeit at varying levels of knowledge and competency the next section looks at the project teams and the potential they hold for individuals to learn.

5.5 Project Teams and their learning potential

All the participants, with one exception of a part time reservoir engineer, confirmed that the learning opportunities were available inside the project environment. Very few staff had received formal training either externally (5%) or internally (6%) during their employment with the case organisation. The lack of formal training indicates that any additional knowledge and expertise being acquired is via informal processes. The following sections look at project work in detail to identify where and how learning takes place.

5.5.1 Projects – the learning environment

The work inside the case organisation is organised into project teams based upon:

"What does the client need and where we are starting from in terms of data, and information and we will match the two up with the appropriate skill sets and with the time and budget that is available" (J).

Working among the projects is very attractive to staff since there is the:

"the international dimension of the job, the variety and the wider scope I guess in terms of looking at the whole picture which is a characteristic of the projects" (C).
These teams combine the technical expertise of their members and the practical day-to-day experiences that they share during the life of each project. The mix of expert and local knowledge-practice based knowledge described by Yanow (2004). One participant noted that issues arising out of the project work itself demanded a wider functional background since:

"a lot of the issues that we deal with are not really technical, they are not purely geology ... there is a commercial ... business component ... a strategy component to it ..." (A).

The projects provided ideal learning situations as a result of the range and exposure of the work they covered. Individuals developed because of the "projects they have come into contact with or had the opportunity to do" Interviewee A, and they provided "the greatest place to learn for someone trying to get multidisciplined experience" (D). It was suggested that the way to develop the company culture and ethos with new joining staff was to allocate them a variety of projects, combined with differing roles within those projects (F). Another interviewee (I) actually cited the opportunity to learn as being one of the reasons why he joined the case organisation in the first place. The outcome of this learning was defined as "expertise", not "qualification" (EE).

The learning experience inside the projects was described as a challenge being dependent upon the individual taking the initiative by setting their "own goals and targets ... If they are waiting for others then it won't happen" (R). This view was supported by management who saw learning as an attribute of self-starting or self-motivation, "people's career and knowledge development is largely in their own hands" (B). In providing resources for each project the management approach was to "accommodate people with some skills in the area which can be developed and broadened with project work" (B).
This appeared to be accepted by staff recognising that they needed to be proactive and get involved in those projects and other areas that they were interested in developing in. These requests appeared to be actioned over time in a variety of ways. For example:

I was asked to do some literally data input for x case and the moment I started doing it turned out that it was all about gas contracts ... went straight down to the project manager and said I haven’t done this specifically in the past, ... but in one of my previous jobs I was actually one step away from that so it was more I learnt by the average lunchtime discussions ... I am not an expert but I know the terminology, I have a friend who can give me a bit of input and I am quite interested if you need any help ... I went very quickly from just a spare pair of hands doing data input for them to two months later I was down at the lawyer’s offices drowning in data and actually working on the job proper and it was great” (J)

Although this was not the only way to acquire experience, it was presented as being typical of the initiative staff displayed and indeed, were expected to display. Staff are exposed to projects in order to aid development, but only to the extent that management felt they could deal with the work; the project deliverable being the prime concern.

When questioned the staff felt that learning was directly attributable to their project work as it was “a high exposure opportunity” (M) and was a direct result of a combination of:

- volume of projects individuals were exposed to (83%);
- variety in the nature of the project work (70%); and
- exposure to other disciplines (83%)

Additionally “proximity and freedom” (O) meant that there were no barriers to learning. The same individual went on to describe the lack of barriers in any sense the case organisation’s “hidden secret”. Staff made comparisons on
several occasions with friends employed by other organisations who frequently complained of being frustrated by distance and departmental boundaries within their organisations (GG).

5.5.2 Projects – Dealing with Jargon

One of the major barriers to learning is dealing with the jargon associated with a particular knowledge domain or discipline (Cunliffe, 2000). Given the mix of disciplines inside the project teams this could pose problems although:

"the awful truth is that most of what we do is incredibly simple. There is jargon and in order to give credit to it we reproduce the jargon when in fact the concepts are very, very simple"; (CC)

There is no doubt that “each discipline has its 'its pathway of language' unique to its endeavors” (K) and the vocabulary contained inside each of the knowledge domain appears to create problems in two different ways:

a) in the difficulties experienced by more junior staff who have not worked alongside the different disciplines; and

b) in the divide between geosciences and the remaining engineering disciplines.

The “jargon divide” was commented upon by the less experienced geoscientists who had problems with using geosciences terminology. They quoted the example of clays and horizons which held different meanings for engineers. It was also noticeable that during the group discussion with the junior
geoscientists the terms "hard rock" and "soft rock" were used when discussing
t heir choice of industry sector in which to work. This terminology did not occur
in similar discussions held with the more senior geoscientists although the same
ground was being covered.

During the structured interviews the jargon divide became more apparent, for
example, fluid flow to both the geologist and petroleum engineer meant
permeability in the rocks whereas to the facilities engineer (and sometimes to
the petroleum engineer) it meant oil running through the pipeline. The different
interpretations of this term were not picked up on by the majority of participants
taking part in the structured interviews.

There were a number of comments which indicated that the real issues lie
between the geosciences which were described as "jargon related" and "a
whole different language of its own" (U) and engineering of any description.
What seemed to be the prevailing view was as expressed as:

"it comes back to a philosophy if you like of almost any discipline in the end is
60% common sense, 20% is getting to know the jargon and only 20% really is
having a really deep experience ... On the engineering terminology 80% is the
same across all disciplines but geology is a whole new world and you almost
found difficulty getting to grips with it until I could talk to a geologist is terms or
he could talk to me in terms that I can understand" (Y)

Participants gave three different ways of dealing with this issue. Firstly, there
was an expectation that people would have "the right approach they will ask
you, [say] I don't understand it" (MM). Secondly, using "access to the internet
[which] allows you to resolve that very quickly" (U). Thirdly, there were a
number of people who indicated that they would read the appropriate book.
Indeed several people were "reading up" on allied disciplines in their spare time

2 Soft rocks are sedimentary rocks which hold hydrocarbon accumulations
in order to supplement their working experience and enhance their personal contributions to the projects. This was actively encouraged within the workplace with several recommended textbooks available from the Library. For many individuals it was an issue which disappeared relatively quickly as they gained experience and knowledge from the projects. For many engineers it was a case they "explored [geosciences] enough to converse and discuss but not have in-depth knowledge" (K). One participant (F) indicated that the level of understanding of terminology enjoyed within the case organisation did not extend to clients and other people within the industry with whom he had contact with.

5.5.3 Projects – how they are organised

Looking at the project work in more detail it was apparent that for many projects the pattern of working is very similar. The designated project team is tasked with a scope of work for each client. Initial data is provided by the client either delivered to the office, or more often the team, or several members of the team, travel to the client's office. This trip is followed by a period of intense activity back at the office analyzing the data and producing a report with the appropriate recommendations for action. At this point a further visit to the client offices may be required in order to present the findings and recommendations. On many occasions the project team is required to work inside the client offices, or nearby, for the duration of the project. Over ninety percent of all projects are undertaken for internationally based clients, explaining the extensive travel requirement to service the projects.
The technical staff may be called upon to play different roles in the project team environment depending upon their abilities and availability:

Project Team Member  >  Project Manager  >  Project Reviewer

The data obtained from the structured interviews indicate that each of these roles had different learning opportunities available. Sixty three percent felt that the project manager had better learning access than the project member (50%). Only six percent felt the reviewer had the best learning potential. The choice of which role was best was biased as to where the individual sat in the case organisation. For the more senior staff it was most likely that they would operate only in the project manager or reviewer roles while the younger members would spend more time as a team member with perhaps limited project manager roles.

a) Project Team Member:

In terms of the team member role many staff felt that this was best since the individual was responsible for the more in-depth initial work. Additionally, the less experienced individuals learnt far more by being integrated inside the team. It was necessary for them to keep "looking around ... keeping your eyes open" (AA) or "sit and listen, ask questions if you don't understand" (JJ). In fact there was a suggestion that it was easier to learn from the peer grouping rather than with the project managers or management.

As a team member individuals are expected to be sensitive to the needs of the projects that they are working on at any given time. Their main responsibility is
to produce agreed work deliverables within the timeframes given. This includes balancing the demands of working perhaps on several different projects at any one time (B). In order to do this, individuals have to take responsibility for their working practices, namely in the hours they work, when they take leave, and so on. In other words, they have freedom to control how they work in responding to the project demands (O).

With the case organisation focused on achieving “fit for purpose” (B) solutions for clients the fulfilment of these goals/deliverables provide team members with a “tremendous feeling that we had accomplished something”. This is an important motivating factor and acted as encouragement for staff to repeat the behaviour on the next and subsequent occasions (D). The recognition of this by staff was evidenced being described as a “key thing” (H) in one case and “emphasis relates to the end result” (E) in another.

b) Project Manager:

“Everyone thinks of project management as being time and budget and this is absolutely true and it is fundamental, but far more important is understanding the requirements and adding clarity of purpose and knowing who is going to do what to achieve that purpose” (II)

The project manager co-ordinates the team, the client and is held responsible for the successful outcome of each project. Managing a project includes the administrative and financial aspects such as invoicing; data control and client follow up. Invoicing can involve negotiating for additional budget from the client, and debt collection.
Others chose the project manager role as the best learning opportunity since they were drawing together all the different items of work and would have the responsibility of identifying and then "fill in any gaps" (U) in their understanding in order to finalise the reports and present to the clients. Indeed their success lies in understanding what and why individuals had completed particular work items throughout the projects.

c) Project Reviewer

In terms of the project reviewer, it was generally felt that this was an excellent opportunity to be exposed to a broad range of distilled work solving a variety of problems involving other disciplines and international reservoirs. This opportunity was limited to senior staff members.

This part of the challenge process was discussed in the context of providing a "safety net" for learning. Senior members of the case organisation act as a "devil's advocate" for projects, challenging the decisions and final outcomes of each project prior to the final recommendations being presented to the client.

It is common for all staff to be involved in more than one project at a time and often as a team member on one project and as project manager on another. The more experienced, longer serving staff members act as reviewers challenging a project report while being a team member for the same project manager in another project. This constantly changing interaction "promotes a very healthy environment of mutual respect which is something that matters"
Under such a situation, hierarchal considerations would be difficult to implement and maintain.

Having explored the internal structure of the project teams this next section explores the detailed background to the projects including size, nature and duration of projects. In looking at some of the difficulties staff face on a daily basis, the nature of the team working becomes more apparent and provides for insights into the drivers present in the workplace. Furthermore, there is exploration into attributes which made for effective team behaviour and what factors might encourage staff to replicate these behaviours.

5.5.4 Number and Duration of Projects

The data collected on this aspect included questions on the numbers of projects, the size of the teams involved, the numbers of disciplines generally involved in each project and composition of the teams. Table 18 sets out their responses to these questions revealing an element of standardisation across the case organisation.

<table>
<thead>
<tr>
<th></th>
<th>No. Projects for previous 12-month period</th>
<th>Average size of teams</th>
<th>Average Number of Disciplines inside teams</th>
<th>Same Team Members</th>
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<tr>
<td>Totals</td>
<td>327</td>
<td>-</td>
<td>-</td>
<td>13 No.</td>
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<td>Average</td>
<td>10.9</td>
<td>4</td>
<td>3</td>
<td>17 No.</td>
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</table>

Table 18: Projects

Individuals estimated that collectively they had been involved in 327 different projects during the previous 12-month period. For each individual the actual
involvement with projects varied between 3 and 30 projects, Table 18. There are a number of possible reasons for the variations:

- The length and nature of the projects, for example, acquisition transactions may only take a few days if the potential purchase is less than optimal, and a few weeks if the acquisition goes ahead. A reservoir engineer, on the other hand, may take months to complete simulations to finalise a high standard model.

- The seniority and capability of each individual. The higher numbers indicate that the individual was involved in projects as a reviewer. Reviewing a project usually takes hours rather than days or weeks.

- The internal reputation of the individual. Past performance record means that individuals who turn in work on time and of a good standard are regarded as a good team player by project managers. In these cases the individual is always kept busy.

Table 18 also indicates that on average three different knowledge domains are generally involved in each project:

"the G&G – subsurface, petroleum engineering and economics. That’s the breakdown on many, many projects" (B).

In responding to this question, some interviewees described sub-disciplines inside the same knowledge domain rather than drawing on disciplines from across the knowledge domains. For example, using seismic interpretation and static modelling; both of which lie inside geosciences.
With the constantly changing project demands, it would be expected that membership of each team would differ to the extent that everyone inside the environment was working with a mix of people. It was interesting to note that for fifty six percent of the population this was true. A relatively large proportion (46%) remained working with the same individuals on different projects routinely. A portion of this can be attributed to individuals working on a single long term project but that did not totally account for the sizable percentage.

Although the majority of projects last for a relatively short time, there are exceptional projects which run for a number of years, for example one project has been running for over ten years with staff being rotated in and out of overseas client offices. It is notable that many staff remained keen to continue working on this and other longer term projects. This is possibly due to the opportunity they offer for individuals to get involved in far more detailed technical work than would normally be the case (F), and to see the results of their recommendations.

As the vast majority of projects average two to three months the constant change ensures that staff have access to a variety of work on a routine basis. The "thing about how we work is that there is always another one (project) coming up, it’s always there on the horizon" (J). Even on the longer term projects time spent in the home office as part of the rotation was utilised for different projects. The ever-changing project environment was expressed simply as "just the nature of the business. Our revenue is time driven therefore we have to be much more precise" (B). This environment in itself creates opportunities for staff to be far more proactive and broaden their range of skills.
This in turn would improve their career prospects, both internally and in the job market.

5.5.5 Project Conditions

In addition to the Mission Statement already quoted, a second statement stated that the case organisation was all about "Undertaking profitable, rewarding and interesting work". One participant indicated that this was how the founders had approached life and as a consequence they had developed projects which fitted into this mode and this had served to attract more, "that's the chemistry of it" (A).

Teams are put together to provide "the skills necessary to individual project requirements ... not there for teamwork sake as such" (B) and their work was most appropriately described as problem solving based upon what solution was most likely to be successful in the proposed environment and not just simply the current high-tech solution. To achieve this goal the project team "has to integrate a lot of pieces of knowledge to do that" (II) and this inevitably brings pressures to bear upon the teams. Project teams are put together by the management team based upon project requirement and resource availability. However it is not uncommon for senior project managers to bring pressure to bear on selection so that they can include the more capable members, or to approach these individuals directly to interest them in the project so that they then volunteer for inclusion in the team. These are all aspects which are explored further in this section.
a) Pressure to work on Client Projects ("Billable")

What the case organisation is selling is the total knowledge bank of its staff combined to produce practical solutions to a wide range of industry problems. There are no tangible products to underpin the case organisation's finances so every hour of available professional time is a saleable product. The need to earn revenue produces internal pressure upon individuals to remain "billable" in order to sustain the company. Bonus schemes are the financial reward for sustaining high billing rates, but there are more intangible rewards in the shape of status and expert power.

One of the fundamental challenges of the case organisation is the requirement to keep technical staff utilised on client work, or being "billable". There is an internal market for staff to work on particular projects, and one of the primary aims of management is to ensure that all staff are kept equally employed. This was clearly easier in the earlier days when the case organisation was more "multidisciplined" in its approach:

"You did this job or that job as it came through the door. It was all part and parcel if you like of the non-departmental, non functionary type of approach to doing technical projects" (Y).

The interviewee concerned here was one of the most senior managers (as well as one of the most experienced) who went on to describe the perceived increasing specialisation of the disciplines. Symptomatic of this trend was that in more recent years it sometimes took a team to visit with a client to cover all aspects of the project, whereas in the earlier years it took one individual who could "talk to the reservoir engineer, talk to the facilities guy, talk to the operations guy all in the same day" (Y).
In speaking to individuals who had broadened out their expertise, it was clear that they were focused on the benefits which might accrue the individual in terms of peer recognition, ensuring project variety, and ongoing involvement within projects. Comments such as "staying gainfully employed" (F) or as "I like to do well, and feel that I have done well, I like to be paid well and I like to be well enough respected in that I have some input into what happens to me" (J).

From the case organisation's perspective, there were obvious advantages in these attitudes:

"They are extremely valuable. They are the kinds that you want to put on every project even though you know that you can't" (A).

b) Time Pressures:

Pressure upon individuals arises from the requirement to meet the various project deliverables, especially meeting report deadlines. The effects of this are reflected in comments made such as it is "all hands to the pump" (A), "move your people around to meet the demands at the time" (D), or "not working in a smooth environment" (A) emphasising the requirement for teams to be flexible in every sense in order to achieve the project goals. (B) viewed the team environment as being:

"exclusive to the organisation ... in oil companies there are less time pressures and probably more latitude to spend great lengths of time"

Individuals are expected to hold a flexible approach to their work. This was expressed in terms of the expectation that staff would travel and assist with whatever tasks are necessary (including copying, formatting, etc.) to achieve project deliverables. The deliverable deadlines formed an essential element of the day-to-day life of team members. It required them "to be responsive" (B) to
both other team members and as the project demanded; the “environment that we work in promotes that and requires it (flexibility)” (F).

c) Travel Requirement:

Social interaction that occurred between staff particularly during time spent outside of office hours arising as a result of overseas travel facilitated not only social contact, but also an exchange of knowledge and experience which was of value in other projects (H). The constant travel and changing out of projects and the subsequent change of travelling companions for some enhanced this “osmotic” process.

One of the other important features of project life was the requirement for travel. Of the participants only one (R) had not been involved in some travel associated with project work. In exploring this aspect, it emerged that it was something that many staff enjoyed and thought brought benefits both to the project and project members. Forty percent indicated they believed that improved client relationships resulted from travel. “Working face to face with client” (A), “Better able to define client goals and objectives” (N) as well as enabling staff to focus upon the client relationship itself was identified.

The most obvious benefit of “social bonding” (BB) stemming from travel was identified by a number of staff (33%). Not everyone was supportive of its importance. One individual (KK) mentioned the loneliness involved, and when questioned, explained that he usually travelled on his own rather than as a
member of a team. Another saw the actual time involved in travel as a "waste of time" (S), preferring to spend all available time inside the office environment.

d) Working with different people:

"Integrated working" surfaced in the data, in the sense of individuals joining the case organisation and taking time to be accepted by their peer group, as well as becoming familiar with the working processes:

"In some ways coming into an organisation like this can be quite difficult even for experienced professionals and I would say that experience shows that it takes anywhere between 3-8 months for even very senior professionals to become fully accepted ... not necessarily the right word, but fully integrated into the way we work" (B).

This is an essential element contributing to the project teams' success since it will promote the ability to share information and to learn from the project.

Integration at the individual level was also recognised as being vital in the cross-fertilisation of ideas throughout the life of the project. Not only do they need to understand where they fit but also from the management perspective be aware of:

"the strengths and weaknesses of the other team members; be responsive to direction they are given by project manager but not necessarily in a submissive way but if there is areas that they want to raise then they should do it in a constructive way" (B).

This can be achieved by the individual:

"listening, application, having to know about things, interfacing and looking for how the answers are derived in order to do the work I do better, following it back and answering questions" (Y).
This does not describe a complicated process but it does describe individuals who are constantly questioning their team members, the material they are working with and proactive in their daily working role.

Factors which motivated staff to replicate this behaviour varied. In one case "There is recognition and respect of your peer group in the most general sense" (MM). Another interviewee quoted:

"a tangible success factor if you like, I was pleased to move up to senior professional level ... because that was an actual yes, we noticed that your work is of a quality to justify this. It was an actual, almost numerical indicator" (J).

It was the quality of being recognised by the peer grouping that provided the pressure felt in the morning meetings. To be seen as being continually less than fully utilised implied a judgement on the technical skills and character of the individuals. One interpretation of this behaviour could be that the environment is more competitive than it appears in reality or is generally accepted to be by management:

"you [the individual] need to understand that your peer group needs to want you to be successful ... It is not competitive, I think peer group appreciation is a critical thing. Everybody I think in the company is looking to be, they need to be needed so to speak, to feel that they have the necessary skills either in their specific discipline or multi disciplined. The most unhappy people are those who don't get automatically chosen for jobs. The ones who fail to get peer group appreciation" (D).

e) Accommodation

Individuals expressed a general agreement that putting teams together in project rooms provided the ideal environment for sharing ideas and information, thereby facilitating interaction between the members. "We have project rooms set aside for major projects so that we can get the right interface between
people” (B). Having “project rooms” aided the team’s ability to focus on the project deliverables.

Communication was perceived more in terms of staff feeling that they could contribute ideas on any aspect of the project, and that they were sufficiently comfortable in their environment to participate without the danger of being denigrated or overawed by their colleagues. Physical proximity was recognised as being important in creating a sharing and learning environment. Knowledge and experience gained from one project could be transferred to future projects, enhancing individual effectiveness. This transfer of knowledge was important even if it was just learning how the separate disciplines of the project fitted together.

Not commented upon by any of the interviewees was the ability to run “virtual” teams interacting, sharing information and learning via the use of technology although this has been done by the case organisation when the resources have been allocated from different time zones.

f) Challenge Process:

The case organisation has a review process for all outgoing communications which has been referred to earlier in discussing the project reviewer’s role inside the project teams. This process has been in force since the case organisation’s beginnings in the early 1960’s. It serves a number of purposes, not least of which is ensuring the outgoing material, including the recommendations being made, meet legal and other statutory or regulatory requirements.
Notwithstanding these requirements, individuals referred to the review process as the "safety net" that the case organisation provided, allowing staff to cross disciplinary boundaries without getting into trouble (Y). One of the essential elements of this is the project review process itself. It effectively is a challenge process to the project manager and project team's efforts in bringing a project to a successful conclusion, which is normally providing the client with appropriate and effective results within a technical report (I). All outgoing documents, including reports, require a review completed by a senior technical manager not connected to the project team (project reviewer) before they are issued to clients or anyone outside the case organisation.

There were three different interpretations for the introduction of this process, Table 19.

| Strategy | "not a peer review ... One of the reasons that every report has to be reviewed was firstly, because it's too easy to make a mistake. No matter how good the individuals are it is too easy to make a mistake. Secondly, you have a house approach to how you wanted the company to be perceived and how the company wanted to carry out certain types of work and so we wanted to be sure that this report went out in a particular way ... We wanted to be sure that was a [organisation] report written as [organisation] would be expected to write it ... and by having relatively few reviewers who are all on the same page you ensure that happens" (D) |
| Business Development & Retention | "the skill of reviewing is to undertake to ask questions about something if you don't understand what the report is about. The organisation's style of reporting is/was that the guy you are writing for is not necessarily in your discipline. He is a highly intelligent person who can understand what you are telling him if you tell it in the appropriate way. So the review process was to read and the bits that you did not understand you needed to ask the question and asked that it be explained more fully" (Y) |
| Implementation of policy | "what happens is that a project runs its course and if the deliverable is a report that comes in for somebody to review it and to be honest as that project has continued nobody has challenged what has been going on just the project leader and so you finish challenging right at the very end when there are tight deadlines and the budget is almost fully used up" (I) |

Table 19: Project Challenge Process

The senior principal primarily saw the challenge process as a strategic measure acting as a mechanism for ensuring consistency and accuracy across the case
organisation. Enhancing reputation would not work if contrary opinions on the same issues were given to differing clients. This was, and remains, an important consideration on those occasions when staff are called upon to work more on projects that lie outside their core expertise. Establishing a credible reputation was the key to long term survival and expansion of the case organisation. Of equal importance in this respect was the requirement to establish the market "brand", which is achieved by issuing reports using uniform house styles in terms of how the reports looked and house approaches in establishing best practices within the case organisation.

The view the CEO (B) expressed was focused more on credibility issues. The need to convey detailed technical information to clients who may not on many occasions be in a position to understand it but who needed to understand the logic behind recommendations being made. Then in order to satisfy this requirement, he used the project review process as a forum for challenging the project team client deliverables.

In practical terms, the comments by the senior technical manager implied difficulties within the often very tight project deadlines. The implication being that the review process was much more difficult to implement given that the reports were normally produced close to the project deliverable deadline. In more recent years the project reviewers are appointed in the early weeks of a project and are more heavily involved through the life of the project. Moreover:

"Regular project meetings, regular review meetings are ways of stimulating the fit for purpose solution, the alternative solution" (B)
Project reviews provide the safety net that individuals require when working in their "fringe" areas, and enabled them to broaden out their skill sets without feeling they were being asked to move too far outside of their own personal "comfort zone". An aspect that is recognised within the staff, "The way we work we have always got a safety net if you like in the review process" (J).

5.6 Other Learning Opportunities

This section sets out to describe ways in which the case organisation provides information sources, which staff can access to assist with project work. In line with every aspect of modern life the most significant feature has been the immense impact of computing. There are a number of different information sources available within the case organisation. These are set out together with staff usage in Appendix 8.

The requirement to provide the support umbrella meant that the case organisation as a whole had to focus on providing rapid telecommunication facilities between its senior management (wherever they were located globally) and its project managers operating out of the various international bases. One methodology for this was computing power and the ability it possessed to run ever increasingly complex software programs across the entire spectrum of the case organisation's activities, promoting both fast and regular communications including data. Each generation of computer development was reflected with investments continually made in leading edge equipment as the case organisation:

"tried to be near the top end or front end of technology as it developed. We had one of the first faxes, cross-Atlantic communication ... compatible computers that talked to each other" (D).
The first computer used inside the case organisation was a self-built analog computer completed in 1962 and used to demonstrate artificial lift\(^3\) to potential clients. Ongoing projects related to this field provided the impetus for the acquisition of the first digital computer (IBM 1130) in one office which then led to installation of computers worldwide. The UK office began life as a staging post and had a computer in place although in the late 1960's the philosophy of the case organisation was:

"very much in those days, get on your bike and go and support the other regions. If necessary, go and live there" (D).

In addition to the hardware aspects, the case organisation also developed in-house software programs for its specific operational needs such as project analysis, cashflow programs covering most major petroleum sectors, reservoir engineering programs, administrative timesheets and accounting programs, together with major databases containing information concerning projects, reports and general industry data. For a number of years the case organisation had little or no IT support which meant that all new joining staff had to learn Fortran to operate the machines with system updates (D). Many of these programs were abandoned in more recent years as more sophisticated commercial programs became available although some of these databases are still accessible.

Although software and technological proximity forms a significant component in enabling the exchange of data and ideas in team working via shared access, these subjects were not raised as issues during the research. The omission

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\(^3\) Artificial lift is any method that is used to lift oil out of underground reservoirs e.g. gas lift
may simply be due to the existing provisions made in this respect by the case organisation and the staff simply takes them for granted.

Other development opportunities raised included attendance at conferences, assisting New Business Development (sales), internal presentations, one on one dialog and web based training.

In response to the question raised on what sort of things the case organisation could implement to foster the development of staff, not unsurprisingly the majority of answers centred on areas which had already been tried and tested. Examples of these are working on new and varied projects where possible or getting involved in selling the business in one way or another; resumption of lunchtime training sessions which were given on various technical and projects subjects from time to time; attendance at conferences; rotating new staff around the various international offices and specialised training where necessary to allow staff to work on new areas. Other ideas included seconding staff to client operations (as has been done at very senior levels in the past), more formal methodology for development processes within the case organisation, training for staff to provide "challenge" skills such as being able to challenge and defend own expert position with coaching/mentoring as being perhaps the way forward.

It was interesting to note that during the course of the structured interviews, one individual noted that it was only when employed in a training capacity at one stage in his career that he realised just how much he actually had learned while in the field (N). It is interesting to note that many individuals were surprised at their perceived knowledge range or, in some cases, the lack of range when completing the questionnaires (II).
5.7 Organic Database

Tapping into the expertise and experience, "the organic database", of other staff remains one of the favoured sources of information and is universally considered part of the routine. The sharing of information through formal and informal discussions was a significant feature and was identified in two separate ways. One set of comments being directed at the aspect of individuals being prepared to discuss opinions and ideas with other staff; another set focused on individuals looking to see how they could contribute to work efforts of others.

It was also acknowledged that not all staff are able to or want to share. This was usually the case where the staff member was trying to acquire recognition externally as a "leading expert". This was found to be generally acceptable behaviour provided that the individual made a full contribution within their discipline. It was also noted that other people were unable to fully contribute because of their personality. Exhibiting a number of negative behaviours was clearly not acceptable. Such behaviours were identified as:

"being sullen, quiet, withdrawn, maybe going for coffee breaks or would start on working on another project or doing their own thing, doing their e-mail when they have a whole bunch of things to do" (H).

The biggest reward to be obtained from sharing was expressed as:

"The highest form of work you can get for the most part, not all, but for the most part ... is working across the disciplines and seeing your ideas implemented through the efforts of other people" (D).

Participation is sharing in a different form, and it is important to recognise that participation in the context of this discussion is taken to mean contributing to the
common goals, but it does not necessarily follow that it also includes sharing with other team members.

5.8 Professional Societies

The research was interested in exploring how these communities which stretched across case organisational boundaries promoted or inhibited the development of multidisciplinary experience. The data revealed the thirty individuals inside the structured interviews held sixty six different professional society memberships between them representing at least two memberships per person. Given the cost of each membership, which is borne by the case organisation, their value is worth exploring inside this research. Professional societies are perceived to “form a bridge” (MM) between industry and academia and as such their usefulness inside the case organisation may provide some insight into the interaction surrounding the knowledge domains.

5.8.1 Professional Societies Present

Table 20 sets out which societies are present in the workplace. The multinational membership of the workforce is reflected here where many of the memberships listed under “Other” inside the table are in fact organisations that exist in either the individual’s home country or which they joined during a previous secondment. An example of this would be membership of the Trinidad and Tobago Petroleum Engineer’s Association. There are an equally significant number of UK-based societies reflecting the geosciences and chemical engineering interests inside the sample.
Table 20: Professional Memberships

The SPE has by far the largest membership (83%) with many individuals (44%) holding membership of both their specific discipline professional body and the SPE. The proliferation of memberships is accounted for by the fact that the case organisation encourages its staff to join the SPE since it:

"lent credibility to career [being the] industry’s primary professional society for the upstream and downstream sector ... more relevant to the work of the organisation" (CC).

This was a view endorsed by other staff and particularly relevant for those staff working more on the strategic aspects of the projects. This is because the SPE is partially responsible for publishing the industry standard guidelines which define how reserves in the ground can be valued for acquisition or divestment purposes. The SPE also provides the major reference source for the majority of technical searches conducted by staff and which involve every aspect of the relevant subsurface and surface arena.

5.8.2 Utilisation of Professional Societies

How people use the professional society is dependent upon what they specifically want to achieve inside this particular forum. The structured
interviews asked both how the individuals utilised the societies and then secondly, what needs were being addressed by society membership. Table 21 aligns the responses to these two questions:

<table>
<thead>
<tr>
<th>Actions</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attend meetings</td>
<td>Networking/Learning</td>
</tr>
<tr>
<td>Read articles</td>
<td>Learning/Research</td>
</tr>
<tr>
<td>Present papers</td>
<td>Peer Recognition/Research</td>
</tr>
<tr>
<td>Hold office</td>
<td>Peer Recognition</td>
</tr>
<tr>
<td>Edit Journal</td>
<td>Peer Recognition</td>
</tr>
<tr>
<td>CPD</td>
<td>Learning/Peer Recognition</td>
</tr>
<tr>
<td>Charteredship</td>
<td>Learning/Peer Recognition</td>
</tr>
</tbody>
</table>

Table 21: Professional Society – Actions and Outcomes

This list is not meant to include all the possible reasons why individuals chose to undertake certain actions, for example it is already known that the case organisation encourages participation in the SPE so career advancement might also feature among the motives although not identified as such during the interview sessions. In exploring each of the actions identified in the data it is possible to gauge how effectively the societies respond to individual needs and the importance of that response.

a) Attending Meetings

The most popular activity (66%) was attending society meetings although at the individual level there was a very mixed reception to the quality of the meetings. Networking was used for new business development since:

"you get exposed to how things are moving in the industry but also the functions side of it is a good way to network and it makes common sense" (Y).
A function recognised and supported by senior management who believed it was good for business. Societies give members a convenient social gathering providing a "way to keep in touch with mates" (H). Providing such a forum is an important factor inside an industry when the majority of individuals spend much of their time either travelling, or on three-year secondments to various overseas postings.

The quality in terms of the services the societies offered varied from society to society. For example, the chemical engineers meetings were described as being "just full of academics trying to sell" (U) who went on to say that meetings should be more of a forum for the "academic world [...] to move into the real world". Other individuals found the same meetings useful since they saw "some good presentations" (J) and that they "keep us in touch with academia and keeps your finger on the pulse" (GG). SPE meetings were thought to be better generally.

b) Reading Material

Although actually reading society material ranked low in response to forms of society participation, many individuals ranked learning as a key requirement for their participation in society activities. Societies play an extremely important role in disseminating information, keeping their members "up to date" with their discipline and industry.

The data holds a number of references to individuals reading the monthly society journals, attending presentations at meetings and other workshops on a
local, national and international scale in some examples. Staff had experienced a range of learning initiatives and communications from the societies and held disparate views as to how effective they were. For example the various monthly journals received a mixed reception and were "always browsed through it" (NN) but did not spend any substantial amount of time reading them. On the other hand, the SPE ran applied technology workshops which were held to be "good forums for exchanging information and learning" (S).

In talking about sources of information available inside the case organisation there were a number of references made in respect of the extensive use of SPE papers and its website indicating that this repository of information is an extremely useful function to the case organisation and they are accessed on an extensive basis.

An important aspect of information dissemination relates to the younger society members who not only require and want professional accreditation but also use societies as a means of keeping in touch with their University peer group. This allows them to keep abreast of salary reviews and industry expectations, as well as comparing their work experiences across the industry.

c) Peer Recognition

There are a number of activities which provide opportunities for peer recognition available within the societies, namely following their professional accreditation schemes, publishing and presenting papers, holding office or serving on committees. All of these activities are pursued by individuals within the case
organisation. Societies provide "recognition and respect of your peer group in the most general sense" (MM).

d) Professional accreditation

Societies pursue the route of providing qualifications for members but these are not held in any particular regard by staff. One interviewee quoted his particular society sending out a notice to members reminding them that a fellowship was available but it was felt that "everyone knows that you have only got to remain in the industry for five years ... don't consider it that much of an achievement" (NN). This view is not shared among the younger members of the same discipline who were keen to achieve Fellowship or Charteredship status and had joined certain societies because of their ability to provide such qualifications.

The more senior geoscientists discussed the cultural impact of such qualifications and decided that the use of such qualifications was something that was not particularly culturally acceptable inside the oil and gas sector as it was in others for example, accountancy. The group assumed it was because "oily" professionals had academic degrees whereas in other professions the actual qualification to practice is the purview of the relevant professional body.

e) Publishing and presenting papers

Publishing and presenting papers is a significant activity for many staff (46%). It is encouraged by the case organisation as it constitutes "significant role in
publicity for the Company" (Y) as the case organisation which does not market itself by more conventional marketing methods. This activity provides a "platform to individuals ambitious to make a name for themselves" (Y). In fact a number of individuals had used this platform during the case organisation's history to become recognised leading experts inside their field.

f) Holding Office

There were a number of examples of individuals becoming Presidents of international based societies, as well as a number at the local and national level. This had provided a sense of achievement and provided satisfaction for those individuals long after retiring from active involvement, "several of the initiatives that I help to promote ... still exists" (C). The commitment to this activity varied, for example one individual stressed that they "did not go looking for this ... involvement: I got involved and once you get buried in something it tends to move forward" (D) perhaps this reflects his disciplinary training to be methodical and meticulous in his approach to work regardless of its nature.

There is also the enjoyment to be obtained from networking with other experts in the same field. One interviewee (reservoir engineer) mentioned that he was helping to organise the setting up of a local chapter of a particular discipline in London. The local chapter would hold the distinction of being the only chapter outside of North America in this field. This objective had attracted all such experts here in the UK to get together to accomplish this.
In reviewing the role that the professional societies play inside the environment it is clear that their value lies in being a major source of data. Moreover, they provide the approved methodology standards for the industry and are important to the multidisciplinary individuals who have a reading source which describes how others have tackled problems in a very practical sense.

They give their members a sense of community which, in many senses, is stronger than the sense of community provided by being an employee within an case organisation. Membership of a professional society more often than not starts at University and continues for the rest of the individual's working life.

5.9 Workplace Structure and Ethos

References have been made throughout the work to how the case organisation is structured and its prevailing ethos. The early sections set out briefly some of the historical background in order to anchor the processes that are in use today. Equally as important is to reflect how events such as the industry cycles have impacted the case organisation and its employees forcing through changes which have contributed to the richness of the environment (Strauss and Corbin, 1998). This section looks specifically at the elements using the participant's perspective in order to gain further insights on the processes and their effectiveness.

The initial management approach was described more as "firefighting", essentially dealing with each event as it happened more on a collegiate basis than a formal management structure. This strategy was defined by one of the
founders, and frequently expressed by other individuals throughout the data as follows:

"In a small concern you talk every day and ideas for change and growth come out by osmosis. You rarely have the time to sit down to think about the so called bigger picture and as we were not reporting to a Board ... this integrated management approach worked and works quite well with smaller concerns – you also co-opted others with valued opinions into the discussion" (D).

It was not until 10 or more years had elapsed following the initial company registration that more formal systems were put into place but these did little to change the basic approach which is still much the same today.

5.9.1 Background

The case organisation began life in South America during the early 1960's becoming a formal organisation in 1962. This was at a time when "oil companies did everything for themselves [and there was a] relatively small role for contractors" (K). Consultancy was still a relatively new phenomenon at that stage:

"In the early stages, I think it was really almost basically a new business. It was being able to talk to people, convince people that we could help them more or less independently with whatever it was their problem was. It even included things like developing heating and ventilation, computer programs; working on things like process subcontracting. All of these were things that just came along so it was a wide variety" (Y).

There was no serious attempt at formulating processes and procedures for the case organisation until 1971, when the owners "put in place a tighter control system, formal policies, etc." (D).

Life inside the case organisation from 1962 until the mid-1970's was described as "organic" and a "massive growing stage". An environment where:

"Things happened because they had to happen and what you needed was a lot of common sense and the ability to see where things were going ... recognise opportunities, but it was not a formal management system. In fact it was from
about '73 to about '75/'76 the company was growing and at that stage, there was considerable resistance (that is the only way to describe it) because we had to formalise a bit more how the company worked. Prior to that [time] with 15 or 20 people around everybody could know everything that was going on and have a finger in every pie" (Y).

The economic cycles experienced by the industry have also been instrumental in forcing through changes at both organisational and individual level. The extent of the impact of this can be measured simply by the fact that economic events are frequently cited as drivers for an array of changes frequently in the research by the participants. The major economic downturn occurring during 1985-91 being described as "really hard times" (Y) forcing the case organisation to make longer term strategic decisions affecting its future. One of these was the desire to have at least one major project, where possible, running continuously to financially underpin its activities as:

"this is what makes the company survive. You got to see at least 2-3 months ahead because for the first 25 years if you could see a positive cashflow for more than about 30 or 40 days ahead it was quite something" (Y).

The case organisation’s strategic direction became broader:

"At the time the company was still very much largely petroleum engineering and development geology albeit upstream and down but there was big opportunities to move ... from that to other things while keeping the basic disciplines working as well. So, there was an objective of trying to get broader in terms of the overall company" (Y).

At the same time, the oil companies were outsourcing more work as they cut their own resources:

"They brought in contractors to work on a competitive basis for costs that they could not produce themselves, particularly new ideas from contractors to increase their share so service component of the total industry was very competitive and acted as a stimulus to technology needed in the costly marine entrapments" (K).

This provided a growth opportunity for the case organisation leading to the expansion of both staff and offices in the early 1980’s with the consequential
downturn taking place in 1985 cutting back on growth. The same chain of events repeated themselves again during the economic cycle occurring in the 1990’s.

The case organisation has a number of pressures. There is the pressure to meet the deadlines for deliverables to the client; to remain “billable” (working on client project) inside an environment where time is literally money and, to acquire skills and knowledge to complete projects to the appropriate standard. These pressures combine to create an environment where status is acquired, not through position in a defined hierarchy, but through peer approval (Casey, 1996; Sewell, 1998).

5.9.2 Managing the Case organisation

From the early beginnings, an emphasis was placed on having a flat structure with few, if any, management tiers (D). It is a major influence on working processes since there are fewer people involved in decision making processes. In the early years this was simply a necessity but even after a “more formalised system” was put in place this approach did not change. For many individuals the reporting structure has two steps; project manager>regional manager (leader of the 3-man regional management team). The flat structure of the case organisation:

“has always been one of its strong points because of the flexibility that it engenders, its ability to deal with one-man projects and multi-man, multi-month projects. It is not a widgets factory” (C).

The lack of formal management tiers dictates the atmosphere of the environment:
"organisation is ... very flat and has got an almost cooperative methodology. Everybody works in one big pool and very little airs and graces and no real hierarchy. There is nobody pulling rank. Everything is done by consensus, agreement and discussion. Fortunately we have the people here who work on that principle. There are a few exceptions of course but not to the point where they impact upon the overall business ethos" (U).

In addition to flexibility, lack of tiers enables the case organisation to be nimble reacting quickly to changing events:

"Just as today you got the opportunity, you chased it but if you thought that there were a lot more opportunities there you decided to open or extend an office if the economics looked sustainable. You added staff as the opportunity presented itself; sometimes ahead of new work, sometimes behind it" (D).

At the corporate level there are references to the disadvantages inherent in a process where every major decision is forced through the regional manager route, which can create bottlenecks and hold back progress across a number of areas (A). This view was not supported by other staff (D) who claimed that it did not fully appreciate the cost effectiveness, speed of decision making and reaction of flat management approach. Neither did it take into account the constant requirement by the case organisation that individuals consult with each other (U) to make recommendations, both in terms of the projects and the case organisation (Y).

There are advantages for staff both as project team members and as individuals in that they will have less conflicting priorities (Øvretveit, 1997). Many staff report only to the appropriate project managers on the day to day work activities. Issues outside of that are dealt with by the Area Management team on an "as need" basis. From the management perspective, it places the emphasis on staff to be self-motivated with little time to deal with individuals who are not performing to a satisfactory standard. The case organisation does
not have sufficient management or processes to identify and "bring on board people who are flagging" (B). This results in greater encouragement being placed on opting into teamwork at all levels.

The lack of tiers can be, and is, interpreted as providing an element of freedom and self-management which was appreciated by staff acting as a motivational factor in many cases (U). This freedom was noted very early during employment and proved an important factor in staff retention (F).

Staff confirmed the availability and willingness of senior staff to be called upon for advice and support, particularly when trying out new areas at any time (R). This approach was reiterated from the management viewpoint:

"Because of the backup our umbrella (of support via approval process) prevents them being caught by that but those risks can be perceived as real even if they are not" (D).

The view expressed by one interviewee (J) was that the case organisation was good in allowing people to try new things and had a respect for the individual and their skills which was appreciated by the staff. The two elements of trust and respect from both sides had been repeated throughout the interviews in one form or another. Trust expressed itself as the case organisation being willing to accommodate individuals trying on new areas of work in the first instance, and also in expecting staff to highlight when they were having difficulties in coping with those areas:

"they trust you a lot as an individual to yell when you are drowning ... and I don't just mean in numbers of hours but when you are out of your comfort zone" (J).
5.9.3 Managing Communications

The case organisation has a number of forums available for communicating information between individuals as a means of engaging staff to maintain interest and involvement in its progress. They are significant to the extent that they provide forums for staff to interact and encourage cross disciplinary experience and understanding.

a) Daily/Weekly Meetings:

Each morning there is a short meeting held involving members of the regional management team together with the project managers, new business together with any individual not working on a client project. Meetings are restricted to approximately fifteen minutes and provide sufficient information to understand and set immediate priorities for the day, identify key problems and potential solutions. In this way the morning meetings effectively feed the "organic database" and allow for individuals to identify appropriate experience or knowledge existing among the staff which might prove helpful in finding solutions.

The meetings "made it much easier for everybody to get involved with day to day activities of the business" (Y) who went on to identify the opportunity for individuals as in:

"the way jobs were sorted out it was ... keeping aware with the manager in terms of what was going on, what was coming in and making yourself available for new projects"
An alternative view on the morning meeting was expressed by interviewee (H) who talked about being forced to attend a meeting that had little effect on what they were doing during the day and who subsequently felt frustrated at not being able to simply get on with their work.

Communicating across the projects allows individuals to fit their contribution, and discipline, into the wider project and organisational context. At this extended level the individual's contribution may be less critical and may be achievable using alternative staff or methods (D). From the staff perspective these meetings can be difficult if they find themselves in the situation of continually being "available" for project work and feel that they are not appreciated by their peers (C).

b) Global Meetings:

One staff member (C) discussed the annual global meetings that were held and which provided a wider forum for discussion. In addition to financial, administrative and HR related matters these forums were also utilised for presentations on industry topics to increase the level of knowledge across the company. These meetings enabled staff drawn from the worldwide pool:

"to share experiences, air some grievances and talk about the future ... it was the only time everybody got a chance to see everybody else. It provided goals for the future; it allowed people to test ideas ... to weigh up other people in the company which because of the nature of the business there is not a lot of face to face contact. This is a facet of an organisation which has a lot of value" (C)
5.9.4 Recruitment

The multidisciplinary approach meant that recruiting into the case organisation was tightly controlled especially in the early days. Recruitment prior to the mid-late 1970’s was always carried out on a personal basis and there are a number of stories relating to how individuals were approached by their friends. Nonetheless:

"even then the interviews were usually aimed to a) make sure that the guy understood what he was getting himself into but b) also to try and establish whether he was suitable for this sort of exposure and some were and some were not" (Y) who went on to say that:

"Nearly all the people we sought in the first cross section we actually worked with. They had been our clients or had been close enough to hear what other people had said about them so we knew that they were technically good or adequate and we were looking for a reasonable personality. Somebody we could work with; somebody who was excited about the opportunity; somebody who was excited about travel and somebody who could handle a wide variety of different problems, opportunities".

Since the mid-1970s recruitment has become more conventional using a variety of methods to attract candidates. Nonetheless personal recommendations have continued to be significant factor in recruitment. Those individuals recommended by existing staff who thought they had the necessary approach often did better than those who were recruited by more conventional means. Inside the sample there were several individuals who had joined before the early 1970’s attracted by the opportunities for travel and who are still working for the case organisation.

In order to provide a starting point to explore the project team perspective further, individuals were asked to identify what they did and did not like about their work, Table 22.
Table 22: Job Factors

The table indicates that the individuals find much more to enjoy in the project work than not. Working under pressure to meet timeframes within projects was clearly not enjoyed but, more surprisingly, staff would appreciate more time to develop their recommendations for clients further by monitoring and assisting the implementation. The staff experience a degree of frustration at having to make recommendations and then walk away from the project not knowing if and how many will be implemented by the client. This inevitability exists in a consulting organisation, although there were examples of projects where monitoring and sometimes helping to implement team recommendations existed. Only one individual commented on the remoteness between working inside a consultancy and therefore removed from actual reservoir operations which he expressed as “being divorced from the action” (DD).

When asked in each case what could be considered as the motivational factors there was universal commentary on the variety of work available and the enjoyment, interest and intellectual satisfaction to be gained from dealing with

<table>
<thead>
<tr>
<th>Factor</th>
<th>Liked Most</th>
<th>Like Least</th>
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<tbody>
<tr>
<td>Variety</td>
<td>28</td>
<td>2</td>
</tr>
<tr>
<td>Short Timeframes for project</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Working with different people</td>
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<td>0</td>
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<tr>
<td>Travel Requirement</td>
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<td>Working with industry cross section</td>
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<tr>
<td>Learning Opportunities</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>Lack of in-depth exposure</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Deadlines</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>
the resulting challenges. In the words of one interviewee the work is “a challenge but something that might be intellectually rewarding as well” (B).

The ability to self manage acted as an enabler for some staff:

“after a while they will realise that they have this freedom and that changes their perception of life and out of that might come somebody who you thought was the narrowest person in the world into somebody who all of a sudden you notice is drifting into other areas and they themselves might not have recognise that.” (D).

Interviewees also raised working at the front end of technology, levels of engagement, peer respect, appreciation and acknowledgement of their efforts as less significant factors.

Other reasons for retention was the lack of hierarchy, freedom and the absence of the “no, it’s not my job” (W) found among the staff. It was also clear that generally speaking, staff did not like the administrative and invoicing aspects of project management.

5.10 Individuals – The Link

The technical staff employed within the case organisation are the central players inside this research and a detailed profile of the participants is provided in Appendix 6. One of the main objectives of the research was to explore the participants’ backgrounds to understand if there were any shared characteristics which made them predisposed towards the acquisition of additional disciplines. After exploring their career choices and how those choices led to being employed by the case organisation two such characteristics surfaced. These are discussed in more detail in the next section.
5.10.1 Social and Educational Background

The data indicated that the sample was predominantly male with an average age of 50. The participants averaged 25 years working experience inside the oil and gas industry with the majority of the case organisation's staff being recruited from the major independent companies.

The precise mix of disciplines within the workplace varied from time to time as individuals join and leave the case organisation. Table 23 details comments that the participants have made during the fieldwork relating to the disciplinary and industry sector choices. All technical staff within the case organisation indicated that they had displayed natural aptitudes for the sciences at school, which had been developed further throughout the remainder of their full time education.

All held degrees, with the exception of one facilities engineer (II) who began his career via an apprenticeship. During an interview with the two facilities engineers where the two educational backgrounds were compared it emerged that the apprenticeship covered the same ground as the equivalent "degree" facilities engineer albeit without the depth of theoretical background. This had not proved detrimental over the longer term for the individual (II).
<table>
<thead>
<tr>
<th>Name</th>
<th>Discipline</th>
<th>Subjects at School</th>
<th>Choice of University Course</th>
<th>Choice of Oil &amp; Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>Pet Eng.</td>
<td>'Did not like chemistry'</td>
<td>Lots of oilfield activity around home - worked as roustabout first. Engineering perceived to be the &quot;Best Course&quot;</td>
<td>Began studying medicine (following father, grandfather) contracted long term illness so had to start again. Interested in field operations so natural follow on</td>
</tr>
<tr>
<td>F</td>
<td>Geologist</td>
<td>'I never did geology at school; I did geography. I have always been interested in that broad science'</td>
<td>'needed to do something at University... I did not feel like doing physics or maths ... I chose geology ... never had any particular reason for taking geology'</td>
<td>Not specified</td>
</tr>
<tr>
<td>A</td>
<td>Law</td>
<td>English Literature; geography</td>
<td>&quot;Something I could do because of my writing and verbal skills&quot;</td>
<td>Change from heavy diet of legal work; choice because of family connections</td>
</tr>
<tr>
<td>J</td>
<td>Chem Eng.</td>
<td>Loved chemistry, then physics, Maths</td>
<td>Chemistry small contained lab work. Teacher suggested engineering</td>
<td>Aggressive and visual recruiters/opportunity</td>
</tr>
<tr>
<td>D</td>
<td>PE/Geologist</td>
<td>Physics, chemistry, maths</td>
<td>Background - father's contact</td>
<td>Father in industry - natural follow on to childhood spent in and around international oilfields</td>
</tr>
<tr>
<td>U</td>
<td>Chem Eng.</td>
<td>Chemistry, Biology, Maths</td>
<td>Did not want to go into lab; engineering chosen</td>
<td>Attracted by image of industry - popular films of people like Red Adair</td>
</tr>
<tr>
<td>C</td>
<td>Pet. Eng.</td>
<td>Physics, Maths, Sciences, Geography</td>
<td>&quot;How things worked - general engineering degree&quot;</td>
<td>Travel (international dimension)</td>
</tr>
<tr>
<td>MM</td>
<td>Geologist</td>
<td>Geology, Chemistry and Geography</td>
<td>&quot;Loved geology&quot;</td>
<td>North Sea opened up - recruited Exxon via student referral system</td>
</tr>
<tr>
<td>OO</td>
<td>Geologist</td>
<td>&quot;Loved dinosaurs&quot;</td>
<td>Paleontology</td>
<td>Summer temp work which became permanent</td>
</tr>
<tr>
<td>NN</td>
<td>Geophysicist</td>
<td>Chemistry, Physics, Maths</td>
<td>&quot;it seemed far better to be tramping out instead of doing my sums&quot;</td>
<td>&quot;Applying those sciences in a useful way&quot;</td>
</tr>
<tr>
<td>PP</td>
<td>Geologist</td>
<td>Did earth sciences at school level because he was not good at learning facts - liked to have processes to think about</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
<tr>
<td>GG</td>
<td>Geologist</td>
<td>Chemistry, Biology, Geology</td>
<td>If you don't want specifically chemistry, biology, physics or chemistry the only option is geology; this is apply chemistry in a &quot;more real way for the real world&quot;</td>
<td>Not specified</td>
</tr>
<tr>
<td>X</td>
<td>Geophysicist</td>
<td>Broadly the same, indicated maths</td>
<td>&quot;Just fell into it. earth science is real and you can relate to it&quot;</td>
<td>wanted something that is technical but at the same time very commercial and important to world events and obviously oil and gas was that perfect fit that because we are real technical people and what we do regulate to society</td>
</tr>
<tr>
<td>CC</td>
<td>Facilities</td>
<td>Not specified</td>
<td>Interested - read father's university books from early age</td>
<td>Not specified</td>
</tr>
<tr>
<td>II</td>
<td>Facilities</td>
<td>Apprenticeship</td>
<td>Not specified</td>
<td>North Sea opened up 1969 providing opportunities as &quot;a lot of UK shipyards [who] reinvented themselves as North Sea constructors&quot; (II) and &quot;anybody who had technical training or cost estimating ... in great demand&quot;</td>
</tr>
<tr>
<td>Y</td>
<td>Chem eng</td>
<td>Chemistry</td>
<td>&quot;Best subject and engineering aspects attractive&quot;</td>
<td>International travel - second career since first one with Ministry with fixed promotion</td>
</tr>
</tbody>
</table>

Table 23: Reasons for Education and Industry Sector Choices
The remaining individuals interviewed had preferred science subjects namely, chemistry, biology, physics, mathematics and geology. The precise combination of these subjects varied between individuals, with the “favoured” subject in each case leading eventually to the choice of discipline. Which combination of subjects eventually chosen was based on a number of different reasons, varying from a positive “loved geology” (MM) or “engineering perceived to be best course” (K) approach to the more negative approach of simply avoiding certain academic subjects. The same variation in reasoning lay behind their degree course choices. For some, it was to avoid certain subjects or certain forms of work associated with the subject, for example, in chemistry it was working in a laboratory (J). In other cases it was the perception of the image as in mathematics because “pure mathematicians were extraordinary creatures” (NN).

On the positive side, individuals used their degree courses as a way to study a favoured subject/area of interest further or as a stepping stone for a “useful” (NN) career. In some cases (as will be seen in industry sector choices) individuals were following their family into the industry so the degree was more a means to an end than choice in that they had to undertake an “oily” degree to achieve their aim. The choice of which degree course was finally selected by each individual was largely dependent upon a mix of personal preference, background and opportunities available.

The significant feature to note in these choices is that all of the individuals were consistently exposed to, and continue to share, a positivist, deductive approach to
problem solving (Bryman, 1988); a feature of hard science (Easterby-Smith et al 1991) and of communities of practice (Wenger et al, 2002).

5.10.2 Industry Choices

The question of why these individuals had chosen to enter the oil and gas industry in preference to other industry sectors was examined, Table 23. This was to address the issue of whether or not there was something specific about the industry that attracted a certain type of individual and if so, could it be identified.

The popular appeal of the industry was reflected in the responses, although that popularity had a number of different aspects associated with it. For some individuals the economic power of the industry itself proved attractive. For others, it was simply circumstances that proved decisive. An example of this is the apprentice working in a shipyard at the time of the North Sea discoveries who described his transition into the industry as:

"very early I got into cost estimating and then moved over into the oil industry at a time when there was a huge demand in the UK and they would have anybody. At 23 I was a project manager at a shipyard which was building oil rigs" (II).

For some individuals the ever present requirement by the industry for international travel was the primary reason. The adventurous nature of the industry was, and remains, a major attraction, after all "they do not make movies about guys in white coats making paracetamol" (U) who moved to describe "the macho, 'boys own' type business". Adventure is implicit given the added dimension of international
travel which is an intrinsic part of the industry and is frequently the major recruitment attraction (www.Oiljobfinder.com, 2009).

Travel is an important feature of the case organisation, serving as a major motivation tool with the younger individuals who are keen to reach the level of recognition whereby they are included on international assignment teams. The more experienced individuals recognise the uniqueness of the travel experience since oil is often associated with the more remote and hostile locations:

"the oil industry enabled me to see parts of the world that I would otherwise not have gone to and I have been in parts of the world that you cannot get into without being part of an exploration exercise [for example] You can't get into the 'empty quarter' in Saudi Arabia unless you are involved in the oil" (C).

This enthusiasm is reflected in other individuals “I took a chance of going overseas, of working overseas using my degree to travel and so applied for the job” (Y).

The willingness to undertake travel is an aspect that works in the case organisation’s favour in view of the requirement for frequent worldwide trips in order to service the various projects. This was particularly so during the 1960’s when many companies inside the industry were American owned and operated policies which effectively meant that non-US residents did not get an overseas transfer (Y). As one of the founders pointed out during this period:

“we were fortunate because in that era Brits did not have the opportunity to travel on good contracts. They were locked into expatriate colonial contracts. We were in a position to give more generous contracts which were regardless of race, colour, creed, background and home base/nationality and give an opportunity to travel around the world” (D).
In this way, the case organisation was able to attract and retain very able individuals throughout its long period. It was noted during the data collection that international travel no longer appears to hold the same appeal as in the earlier years with staff "being more domestically orientated" (Y). Nevertheless, it remains a strong feature of the case organisation and continues to attract recruits.

From the data relating to the individual's education background and reasons for joining the industry it was possible to establish that there were potentially two shared characteristics. One such characteristic related to their perceived shared empirical approach as indicated above which arose as a result of their science education and background and this was common to all the participants. The second characteristic which was common, but not shared by everyone, was the predisposition to a more adventurous nature. This adventurous nature may have found expression in the individuals being more open to moving outside of their core technical discipline.

5.11 Knowledge Domains and Disciplines

This discussion explores the two major knowledge domains inside the case organisation, that of geosciences and engineering. It sets out to map the disciplines contained inside each, indicating the overlapping areas and how the disciplines flow into each other along the hydrocarbon value chain. In doing so it is possible to determine how the individual sub disciplines have, and continue to evolve to reflect the major changes that have occurred inside these domains during the life of the case organisation as a result of technology changes, business-
climate pressures and case organisational experience. Increasingly “one man

  can’t do it all now so lots of sub-specialists [have arisen] as people gravitate
towards opportunities, aptitudes and capabilities” (K). Mapping the boundaries will
highlight where borders overlap or where there are gaps between them. This will
enable an assessment to be made of the learning opportunities more easily
accessible by individuals since it is at these points individuals most readily move
across the disciplinary boundaries (Buchanan, 1966).

It should be noted that there are a number of different disciplines inside the case
organisation relating to the strategic, economic and legal work it undertakes and
which are not part of this research. Although all make a significant contribution to
the value of the projects they are on the periphery of the oil value chain.

Data was collected about the disciplines although some aspects of petroleum
engineering are limited, notably drilling which can be described as “the main
capability in achieving the ultimate objectives of finding and producing petroleum”
(D).

The knowledge domains are discussed in the same order as they are utilised to
find, develop and finally abandon hydrocarbon resources by the industry. By
using this particular sequence of events Figure 18 sets out the process together
with the disciplines necessary to accomplish each step. It demonstrates the
necessity for the disciplines across the knowledge domains to work closely
together to bring about success at each stage.
5.11.1 Disciplines

As discussed in Chapter Three the Kolb-Biglan classification (Becher, 1989) was primarily drawn up for use in academia, but it readily lends itself to mapping the disciplines found inside the case organisation, Figure 19. This highlights the five degree-based disciplines inside the hard applied science quadrant with other specialist areas arising out of industry training programs. Of the hard pure sciences, petrophysics is not available as a first degree course and only one university (Tulsa) offers a master’s degree course with the entrance qualification being a petroleum engineering degree. Classifying the sample this way reveals an empirically based case organisation heavily biased towards hard pure and hard applied science.
The geosciences disciplines in the hard pure category concern themselves with looking at what lies under the ground (the subsurface). They are primarily utilised in the early stages of finding and assessing potential hydrocarbon resources. The extraction and transport of hydrocarbons to market is the primary domain of engineering which concerns itself primarily with activity above the ground (the surface). Geosciences are challenged:

"the whole of the sub surface group is becoming more important but the reason for that is as we try to get more out of existing reservoirs we need to understand the reservoirs better and ... the fluid dynamics of those reservoirs better. That's the first reason – getting more out of existing reservoirs" (S).
Equally, petroleum engineering is currently challenged by the need to go into deeper and deeper waters since the equipment required in these more hostile environments mean increasingly higher costs for the oil companies:

"Migration of exploration activity from easy reservoirs to more difficult reservoirs and it is not just more difficult reservoirs. First of all, it is more difficult environments ... we are going into ever deeper water, and with that we are finding increasing costs ... and because of this one has to be a lot more careful about where you drill the wells and how many wells you drill. In the deepwater offshore environment we certainly try to drill fewer and fewer wells and get more and more out of each well so there is a change in the data we acquire from fields in terms of wells. The distance between wells becomes greater because of fewer wells but we also concentrate more on extracting more information from each well and so we have developed more and more sophisticated techniques of acquiring information from individual wells so there is a change, a migration away from high well density to much lower well density" (S).

Both these challenges indicate a requirement for more sophisticated and exact information and lead to greater specialisation of the disciplines as each becomes more focused and drills deeper into detail to achieve the required finer detail.

There are two forms of data which cross the knowledge domain boundary lines. These are wire line logs\(^4\) and core analysis\(^5\). For example, wire log logs are used by:

a) geologists who will look for sedimentary rocks which have the potential to hold hydrocarbons;

b) geophysicists who correlate the information with that drawn from core analyses;

c) petrophysicists to understand the reservoir and its parameters; and

\(^4\) A continuous measurement of formation properties with electrically powered instruments to infer properties.

\(^5\) The set of measurements normally carried out on core plugs or whole core (small pieces of rock from bottom of reservoir
d) petroleum engineers who need to understand the reservoir and its parameters and as well as to design the well completion. (DD)

Similarly with core analysis, the information is required by the geologists to see the rock being drilled, petrophysicists to calibrate the wire line logs and lastly, by petroleum engineers for the design process (C).

The knowledge domains are tasked with very different areas of work within the hydrocarbons chain even though there are a number of areas where they overlap at their boundaries; these are explored in more depth in the sections that follow.

5.11.2 Geosciences – Territory and Nature

Mapping geosciences requires an understanding of how radically different the knowledge domain is today when compared to that of 1962 when the case organisation was first registered. The image it portrayed then was "more of an art than a science" (H).

The development of appropriate computer hardware and software during the intervening time period has led to the increasing specialisation of some aspects of geology and geophysics such as sophisticated 3D seismic monitoring to the extent that it is replacing physical drilling (S). Computers have enabled the integration of data in one place which has had a significant impact and it is now possible to run "thousands more iterations that just the odd one or two that was possible before" (GG) with this data. It was noticeable that both senior and junior geoscientists
were concerned at the thought that it was possible to run computer models by default and arrive at an answer without understanding any of the processes that lie behind it. "Clients do it routinely" (OO) even though it does not always produce the correct answer. The concern is at the implied lack of knowledge required to run this software and the potential threat of downgrading their discipline that this poses.

More significantly, the period since the early 1950's has been marked by the development of several major theories which have had a significant impact upon the geosciences and the industry itself. The first of these theories was acceptance of plate tectonics:

"the biggest revolution academically in geology ... [geology] is the oldest science, older that physics and chemistry are as separate disciplines but it's the most recent to undergo its revolution" (DD).

Plate tectonics enabled geoscientists to understand and explain geological features providing the capability for geosciences to move on from the merely descriptive role to increasingly that of a much more numerate and precise science. The second major development was the "whole idea of basin evolution and petroleum systems" (H). Although many of the ideas behind this had been around for some time it was the drawing together of the various strands which proved significant.
These two theories, coupled with seismic stratigraphy\(^6\) enabled a "huge leap forward in terms of understanding geology in sedimentary basins" (NN). Figure 20 sets out the disciplines and sub disciplines each concerned with specific disciplines or areas of knowledge identified during the fieldwork. These areas are currently being utilised by the organisation in:

"preparing the groundwork for the engineering side of things, you are trying to identify what exists in nature so that they can then take that, you are maybe putting forward the constraints that they have to work within for solving their problems" (F).

Earth sciences itself is a much larger field with sub sub disciplines for example palaeontology which can be further divided between palaeobiology and palaeozoology. The knowledge domain can also be categorised according to industry section for example oceanography and geodesy. In the oil and gas sector the split is between hard and soft rock. For hydrocarbons it is soft rocks only.

It is important to remember that the broader based knowledge is the same across the entire geosciences knowledge domain "it's just that the focus area is different. The skills that they use are the same ... but it is just a slightly different emphasis ... and the way that they look at the data is different" (DD). Geophysical information for example provides the data on which to base exploration drilling, and later this same information, sometimes further refined, provides the reservoir engineer with reservoir limits and continuity information (D).

\(^6\) Determination of the nature of sedimentary stratigraphy through measuring movement in the earth's crust providing the ability not only to define the subsurface structure but to make some estimation of the nature of the formations and their interrelations.
So while the fundamental knowledge base is the same, increasingly the gap between the disciplines inside geosciences is growing to the extent that it is seen as a significant step to train across geosciences:

"training of younger geoscientists has now improved really significantly to give a broad breadth in geosciences so that we are creating a set of more generalists" (MM).

![Geosciences Disciplines](image)

Figure 20: Geosciences Disciplines

The data did not suggest that any one discipline inside geosciences was considered to be of a higher status than another. It did indicate that the borders of the knowledge domains between geosciences and engineering inside the case organisation lie between geophysics and reservoir engineering (MM). The static model compiled by the geophysicist from prior survey data is passed to the
reservoir engineer. The reservoir engineer then turns it into a dynamic model using real life data and by making changes to the variables sees how the producing well reacts prior to physically introducing the changes inside the reservoir (S). Other borders are shared by knowledge domains such as biology, chemistry and physics (MM).

Individuals inside the knowledge domain perceive themselves as having an "informal, casual nature of geologists who are all lads who like to go down the pub together" (H). It is agreed that it is "first and foremost a learning subject so one has to learn the facts" (S) and individuals commented upon the necessity to have the ability to "memorise" facts both inside and outside geosciences. "There is no right or wrong answer in geology very often. In maths $2+2$ always equals 4 but, in geology it might not" (H). Geoscientists "think in a timeframe of 250 million years" (II) and are inclined to consider the "big picture of what they are looking at and they are far more aware of the variabilities" (CC) although later in the interview the same individual conceded that "we do have geos here who have a broader spectrum of knowledge than geos I have come across elsewhere". These latter comments could imply that the boundaries inside geology and geophysics are not as fixed as they are inside mathematics or some of the engineering approaches.

(DD) summarised the difference between geoscientists and other disciplines by saying that "it is a different mindset. Rather than focussing on a single issue, its how does it all fit together to tell a story". This clear separation of mindsets is echoed through the comments of individuals drawn from other disciplines who held strong perceptions of geoscientists as a group:
"they just seem to have the same discussion topics and talk about the same things and occupy each other's offices on a more frequent basis just solely because they have to sit down and talk about the projects, talk about the models, how to do this and how to do that" (U).

The status of geoscientists (and that of reservoir engineering) was perceived as being higher inside the case organisation:

"Geoscientists [and reservoir engineers] are revered here and the rest of us are just add ons to make it happen ... [they] are seen as the technical gurus with all their PhD's" (II).

The knowledge domain itself is reinforced by the strong mentoring and joint training that takes place on a regular basis. "It is absolutely essential" (MM) who had previously described:

"a geoscience community that has perhaps [as] their mission ... the practice of and advancement of the science ... looking to attain the best technical excellence ... and to share learnings".

Many of the geoscientists described their attraction to the subject area in emotive terms such as the love of the outside (NN), or areas within the subject itself (MM). This emotional attachment continues through their working life and is reflected in the way individuals think and carry out the work tasks within their discipline. There are a number of examples where this attachment expresses itself in supporting and further developing the knowledge domain (MM), (S).

5.11.3 Petrophysics

Petrophysics is not presently regarded as a separate discipline inside the industry (DD) although it employs many people in this role or in various aspects of it such
as log or core analysts. Petrophysics is essentially looking at the physical and chemical properties of rocks, soil and fluids to explain how these behave in the reservoir, Figure 21. This is achieved through predominantly using two data sets: wire line logs and core analysis. The research did not specifically include petrophysics simply because there were no petrophysicists as such on the staff during the fieldwork period. Details are provided here for completeness and furthermore, both engineers and geoscientists continue to handle some of these aspects at a higher level inside the case organisation.

5.11.4 Reservoir Engineering – Territory and Nature

The geosciences broadly define the reservoir in terms of its physical size, while reservoir engineering seeks to estimate the volumes of petroleum that can be produced, and how they can best be extracted. The reservoir engineering discipline acts as a bridge between the two knowledge domains of geosciences.
and engineering. The reservoir engineers take the data from the geologists in the form of a model and then use it to predict how the reservoir will react:

"we take the static geological model and we put it into a dynamic simulator and what we do there is reproduce the production and injection into that field" (S).

This makes a link across the borders of geoscience and engineering; between the sub surface and the surface disciplines. In this area there are both engineers and geologists carrying out the work of a reservoir engineer and because of that interplay is a clear overlap area.

The reservoir engineer works at the interface between the sub surface and surface.

"There is definitely a handover from the subsurface to the surface and our models tend to stop with us. What we provide as input to the surface people is certainly not our models – it's a completely different data set" (S).

The different data set supplied to the surface engineers contain the results derived from the various geological models and mostly relate to the amounts of oil and water the surface engineers are going to have to deal with during the extraction process and the pressures, etc. likely to be involved.

Although reservoir engineering classes have been available at various universities for over 50 years it nevertheless was still regarded as a generalist task as in:

"20 years ago, there was not any reservoir engineers of course, they were just chemical engineers who had to put their hand to a different part of the business" (U).

It has subsequently evolved into a distinct discipline in its own right. It has begun to define its borders more precisely as indicated:
"Reservoir engineers don't want to consider anything above the well head. 20 years ago they used to. I don't know why all of a sudden they don't need to any more" (Y).

Figure 22 sets out what is perceived within the case organisation as the territory now occupied by this discipline.

In terms of knowledge domains, reservoir engineering shares borders with chemistry, engineering, mathematics and the geosciences. In fact "everyone can point to geologist [s] who has a maths background [and] who have become reservoir engineers" (H). Equally there are examples of petroleum and chemical engineers who have also developed reservoir engineering skills (Y).
Little was found in the data concerning the nature of reservoir engineering, apart from the constant reference to the amount of mathematics required, for example “Reservoir engineering is only a mathematical side of geology in the oil business” (S). This remark was echoed inside the discussion held with the senior geoscientist who said that the discipline brought an “understanding of the rocks to what is a mathematical discipline” (DD). Much of the work undertaken by reservoir engineers relates to devising a development plan which can be translated into operational requirements and being able to predict reservoir volumes and production profiles of oil, gas and water. They also investigate recovery which leads to methodologies in getting more oil recovery from each field and reservoir. A key matter when the average recovery around the world is typically less than 40% of the oil discovered. These comments reinforced the fact that the knowledge domain had begun to change to that of engineering (S).

5.11.5 Engineering

The second, equally important knowledge domain within the case organisation is that of Engineering. The knowledge domain itself reflects the Kolb-Biglan (Becher, 1989) hard applied science being heavily dependent upon mathematics and applying pragmatic, empirically based problem solving techniques. The disciplines are employed in all aspects of extracting, producing and transporting hydrocarbons to the refinery.

The main areas of petroleum, facilities and chemical engineering are described in the following sections. It should be noted that these areas have a number of sub-
disciplines within them and it is not the intention here to provide more than just a general overview of each area.

Generally speaking the petroleum engineer, using the data provided by the reservoir engineer, designs the down hole part of the well stream with appropriate production tubing sizes and lift systems to bring the oil and gas from the reservoir to the surface where the surface facilities engineers take over. They put together the design for producing the wells at the surface including the tankage processing, pipelines and pumps necessary to clean up the oil, gas and any water. These fluids then get separated before being shipped or disposed of. Chemical engineers found working any of these processes have become to all intents and purposes "petroleum engineers" (D).

a) Petroleum Engineering Territory and Nature

These disciplines provide the "extraction component" (K) of the field cycle. Unlike the geosciences where the individuals clearly saw themselves as part of an overall grouping, petroleum engineering did not. In some areas distinct groups emerged, while in the more general areas very little could be discovered. This section explores firstly, the more general area of petroleum engineering, focussing then on separate disciplines present within the case organisation.

The disciplines contained within this area of the knowledge domain are mapped in Figure 23. (S) described a petroleum engineer as "somebody who does surface
facilities, drilling, completions and has a working knowledge of reservoir engineering.

The "challenges in working ... petroleum engineering ... is trying to visualise what is happening one or two miles beneath your feet on a drilling operation" (C). The data has already suggested that early engineers were much more inclined to drill a well to make discoveries than depend upon the uncertain world of the geologist. They were adventurous, creative individuals handling problems as they arose, e.g.
they "dealt with forerunner of petrophysics, log interpretation by playing with the Schlumberger handbook" (K).

As with the geoscientists in the industry, it is important to appreciate that the petroleum and reservoir engineers are also dealing with in exactitudes as all of their estimates on recoverable petroleum reserves and hypothetical production rates are just estimates, even after the fields come onto production. Their numbers only get more accurate as the fields approach abandonment (D).

The broader based petroleum engineer is becoming increasingly rare given the increasing sophistication across all the knowledge domains and this is being hastened by the fact that "major oil companies no longer really train multidisciplined petroleum engineers" (D).

b) Facilities Engineering – Territory and Nature

Within the case organisation the facilities engineers are focussed on development planning and cost estimating, in other words "to conceptualise how an asset might be developed or commercialised. So it fits on the end of what the reservoir engineers do" (II). The emphasis within the discipline is on the commerciality of hydrocarbon opportunities addressing such issues as how will hydrocarbons be processed, then initially transported to refinery or gas market (CC). More frequently within the case organisation it is facilities engineers who sell the whole project to the client after input from other disciplines (D). The emphasis on

7 Schlumberger handbook refers to field engineers manual containing formulae etc for various calculations

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economics and commerciality means that on a day to day level these engineers are required to provide input into most projects because the key is financial success: "the client wants to know or we want to know – is it commercially viable?" (II).

Conceptualising the asset includes various aspects such as contracts, cost estimating, procurement specifics, health and safety as well as project management itself which makes it a wide ranging discipline. The data suggests that the areas shown in Figure 24 cover the main topics although the actual knowledge content of the discipline involves "chemical engineering; process engineering which is a subset of that: mechanical engineering; structural: controls and instrumentation; generic construction and project execution" (II).

![Diagram of Facilities Engineering](image-url)

Figure 24: Facilities Engineering

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The facilities engineers described themselves as the essential component of successful projects. "The glue between the various components that makes them stick together otherwise there is a danger of things going off at tangents" (II) and by implication, this disciplinary grouping sits over the top of the other disciplines pulling the projects together. In reality it is an iterative process as they interface with the reservoir engineers and others to see how best to produce a suitable stream flow, how to get the oil to the surface, the number of wells required, what facilities, etc (S). Interestingly, facilities engineers are not only able to understand the work of the reservoir engineer, but also to handle the more classical elements of the work such as PVT (II). Similarly, they are able to produce cashflows and deal with a variety of economics work which is more akin to the economists and strategy groupings. Their competency levels at these tasks was defined as "probably do a reasonable job of high level reservoir engineering piece just as we could do a reasonable job of economics and tax assessment" (CC).

Project management is considered as one aspect of facilities engineering as it is in chemical engineering and not a separate discipline. The concept of project management inside the discipline is very important since to a very large extent their work consists of project managing the reservoir/field development. The only major change in new knowledge coming into the discipline in the last 25 years referenced (CC) was that of critical change project management (Theory of Constraints, Goldratt 1984).

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8 PVT = pressure, volume and temperature calculations

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In discussing the differences between the disciplines, the facilities engineers identified one area related to the thought process which they applied to projects. This required an emphasis being placed on the logical thinking required to run large projects:

"even an educated engineer or scientist can assimilate so much information and so many steps of logic ... the average world can take about four steps of logic because that's all it needs to do in terms of geoscience or reservoir engineering but we [facilities engineers] tend to take fifteen steps of logic based on, as necessary, other people's expertise just by linking together a series of facts and events to come up with something that is tangible" (II)

Individuals involved in facilities saw themselves as a separate grouping, somewhat less than respectful of other individuals who "dabbled in facilities engineering but they have never had the actual experience of actually having to engineer it" (CC). The idea of a separate grouping was confirmed during the course of an interview with a senior geoscientist (MM) who perceived the individuals to act together as a group.

c) Chemical Engineering

There are a number of chemical engineers employed by the case organisation. Some of the time they are employed in chemical engineering as described in the following section; at other times they are engaged working "upstream", namely that area of work which forms part of petroleum engineering as previously described. In order to do this these people have already successfully moved outside of their core discipline and into other areas by implication. Looking more closely at the chemical engineers it is entirely feasible that their broad based education encourages them to make this transition easily.

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(Y) clearly defined the role of chemical engineering as being a "major part of the refining industry so chemical engineering would be a major discipline you know; to design operations in the refinery, technical services in refining, process engineering ... essentially straightforward chemical engineering, distillation, fluid flow, transfer." Another engineer had a more succinct description: "chemical engineering is how to manage processes, how to operate, design and keep safe industrial processes" (J). It does contain "an awful lot of maths ... and this is, of course, wonderfully applicable to engineering" (J).

The previous discussions touched upon one of the early roles for chemical engineers in the industry which was to handle the classical mathematical aspects associated with reservoir engineering. As with all the disciplines this only represented one aspect of their skills sets. The territory is set out in Figure 25 being described as:

"everything really from mathematics, design, ergonomics, health and safety, cost engineering, all the way through to what are the correct processes to make certain chemicals, how do you make them in the lab. Looking at large scale processes, working out how to change them from small to large scale. But there is also an element of management even at degree level. There is an element of management and looking at the bigger picture and of course there is always the undercurrent of mathematics behind everything there" (U).

Within the case organisation it would appear that the facilities engineers focus on the overall project and commercial aspects of the projects while chemical engineers focus more on the hydrocarbon issues of extraction, transportation and prices on the market on the whole.
Chemical engineering is a broad based area where:

"One of, if you like, the benefits of chemical engineering is that it is broad based and in many ways you are a jack of all trades. You learn a lot and have a much broader basic education than if you would be doing mechanical engineering or chemistry or whatever because you get involved in all things" (Y).

The wider range of skills acts as an enabler providing the individual with a wide "comfort zone" (U) and is "good grounding for going into anywhere on that [oil and gas] value chain" (J). It is acknowledged that there is "lot of overlap between the subject areas, you know. Thermodynamics is often quite an issue inside petrophysics" (J). Classical reservoir engineering, cashflows (economics) are

Figure 25: Chemical Engineering
other examples. The discipline was referred to as being “multidisciplined” by virtue of the many knowledge facets contained within its borders. Within the case organisation the engineers generally have a “comfort zone ... from the well head to the point of sale and beyond” (U).

What this background does is to provide chemical engineers with access to a range of disciplines:

“chemical engineering is ... in its own way petroleum engineering, reservoir engineering are in effect branches of chemical engineering. They deal with, particularly reservoir engineering, some of the more complex processes. Reservoir engineering is basically three phase flow through packed beds and that is a distinct part of chemical engineering. Surface engineering – the well bore to surface side of petroleum engineering are straight chemical engineers” (Y).

(J) of the downstream group, identified the chemical engineers as “a little standalone unit ... dictated by the kind of work that we had”. The downstream group (the chemical engineers) tended to be located together in the same office area and they discussed their workload between themselves:

“quite a lot of my accessing information involves walking down to more senior chemical engineer and say “what do you know about this?” (J).

This confirms the view held by other disciplines of a distinct and separate group of disciplines within the wider technical staff.

Having explored the world of the knowledge domains noting where staff perceived separate grouping exist inside the workplace, it is interesting to note that:

“all those communities are in agreement that the niche that the organisation is in a position to exploit is the type of project that crosses those communities of practice” (MM).
This section has set out the shared perceptions of the participants as to the nature and territory of the individual disciplines contained within the two major knowledge domains of geosciences and engineering. In exploring their boundaries through this shared mental model it has been determined that the disciplines overlap in the reservoir engineering and petrophysics areas. At these points individuals, from each domain are able to handle the work associated with these areas readily. The perceived more relaxed nature of the geoscientists has been noted in comparison with that of the engineers who tend to take a more pragmatic approach. Disciplines in all the disciplines described above deal with uncertainties and experience constant interdisciplinary interaction as they work together to explore, evaluate, develop and produce hydrocarbons.

Summary

The chapter reviewed the data obtained from fieldwork conducted inside a medium sized oil and gas consultancy. It commenced with an outline of what the participants shared mental model of the multidisciplinary approach advocated by case organisation and specifically the meanings ascribed to "multidisciplinary individuals" and "multidisciplinary teams" inside the workplace. The result of structured interviews which contained closed questions was provided confirming that multidisciplinary individuals did exist inside the case organisation. In order to establish what factors were instrumental in bringing about an environment wherein individuals could acquire additional disciplines, the workplace particularly the project teams were examined. Lastly, the discussion turned to the individuals themselves to determine if there are any shared characteristics across the
population which were determined to be a shared scientific background and an adventurous nature. Lastly, the disciplines themselves were mapped to gain an understanding of their nature and territory thereby identifying those areas which might lend themselves more readily to boundary crossing on the part of individuals.

The next chapter sets out to examine the findings to address the research objectives and provide an overall explanation as to how multidisciplined individuals develop inside the case organisation.
CHAPTER SIX

CONCLUSIONS

Introduction

The literature surrounding informal learning assumes that the learning is connected to the knowledge and/or skill that an individual requires to carry out their duties. The informal learning approach is typified by "sitting with Nelly" (Livy, 1989), the most popular interpretation of informal learning. In the case of multidisciplined individuals this popular interpretation is not the case. The proposition being put forward here is that individuals who have acquired additional disciplines exist. Furthermore, they are valuable employees and efforts should be made not just simply to recognise their existence, but to promote the development of more such individuals. In the wider context, multidisciplined individuals hold the potential to address some of the issues Kline (1995) raised in respect of the requirement to find ways to increase innovative problem solving and discourse across the disciplines.

This chapter begins by briefly setting out the background of the research. Then it moves on to outline the key points, emerging from the data in comparison with the literature, as it addresses the research objectives. The research objectives were set out in Table 9, and were constructed to address the issues relating to the participants, the workplace and its practices, the disciplines employed and finally the learning processes which were present in the environment. The participants
were given an alphabetical designation to maintain confidentiality and this is used for referencing purposes throughout this chapter, for example (A) or (MM).

6.1 Research Context

This paragraph briefly outlines the background to the research. This was conducted from a researcher-observer perspective using an inductive, ethnographic approach and set inside a medium sized international oil and gas consultancy. Both local management and staff had identified and promoted the development of what they termed "multidisciplined individuals" over a considerable period of time. This practice was considered locally as a significant feature of the case organisation producing individuals able to integrate their knowledge and intellectual skills across disciplines (Koike, 2002). Using this integrated knowledge, project teams and individuals produced "metaperspectives" which often led to innovative and creative problem solving. This was particularly relevant when they were working at the higher levels of strategic advice projects common to the case organisation.

6.2 Research Objectives

The research examined in detail a number of different factors which were present inside the case organisation in order to understand the role they played in the individual's informal learning development. The data collected indicated that each different factor had a role to play in determining how effectively individuals accessed the learning opportunities. The research determined that it required a
combination of factors, not any single one, to create the appropriate learning environment for producing multidisciplinary individuals. These factors are reviewed below in the context of the appropriate research objectives.

Objective 1: Compare and contrast the participants to determine any shared characteristics which may facilitate the acquisition of additional disciplines.

The findings revealed that the participants were highly educated, predominantly male with a distinct bias in favour of middle-late aged individuals holding significant experience inside the petroleum industry. This makeup reflects the industry sector (Ryder, 2007). Furthermore, the study was not concerned with a large population (less than 73 total workforce in the location) but with a concentrated group of individuals focussed on application of technical knowledge and skills. The data revealed four characteristics which were shared, in some cases by all of the participants and in others, by the majority, Table 24.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly educated</td>
<td>Capable of identifying and expanding knowledge base using own initiative</td>
</tr>
<tr>
<td>Education: science based</td>
<td>Share &quot;scientific&quot; approach to learning</td>
</tr>
<tr>
<td>subjects</td>
<td></td>
</tr>
<tr>
<td>More adventurous nature</td>
<td>More predisposed towards a risk taking posture</td>
</tr>
<tr>
<td>Curiosity</td>
<td>Listening, participating, questioning attitudes</td>
</tr>
</tbody>
</table>

Table 24: Shared Characteristics

Looking at each of these characteristics in detail, Appendix 6 confirms that between them, the group held 40 first degrees, 21 Master degrees and a further
seven doctorates. It is reasonable, therefore to assume that these are highly intelligent individuals very capable of expanding their individual knowledge base on their own initiative (Maister, 1993). Moreover, having completed substantial research projects during the course of obtaining their higher degrees, many of them could be thought to be self sufficient in terms of identifying their own knowledge gaps and taking steps to rectify them through various mechanisms available within or outside of the workplace.

It is likely that the concentration of likeminded individuals inside the case organisation explained the existence of higher levels of interaction evident inside some of the project teams. The higher level of interaction was evidenced in the data by comments referring to "interaction greater than the sum of the parts" (I) and echoed the literature (Colenso, 1997; Wilson and Pirrie, 2000).

Furthermore, all the participants shared a "scientific" approach (Remenyi et al, 1998; Hughes, 1990; Gill and Johnson, 1997) derived from their science orientated educational background. This shared understanding facilitated informal learning across the case organisation, as individuals were better positioned to understand the logico-deductive model (Charmaz, 2006). This meant that they could replicate behaviours and methods more readily (Senge, 1990; Bandura, 1977) than for example, individuals drawn from the social sciences anchored in the inductive, qualitative school with different data collection and interpretation tools attempting to acquire the same disciplines.
A third characteristic, which applied in the majority of cases, was the more adventurous nature of the individuals joining the case organisation, Table 23. This opened the possibility that this particular characteristic expressed itself in more ways than simply the desire to go travelling. The industry's image has been described as being "very physical, often remotely located" (McLeod, 2009:1), indicating that the risk exposure that such locations hold can be viewed as higher than that demanded by many industry sectors. Therefore being more adventurous, and subsequently less adverse to risk taking, holds the potential to explain why some participants adopted a more flexible approach in leaving their "comfort zone" (Bardwick, 1991; White, 2008) and moving outside of their core technical discipline (D). Although not stated as such, in the data there does appear to be some correlation between those individuals who discussed the appeal of travel during their interviews and their range of knowledge and skills. An example is (Y) who used his degree to travel. He also holds a wide range of knowledge and skills (Table 14): Equally the same is true of (C). There are also examples where the individual holds little or no multidisciplinary skills, and at the same time is not interested in travel, such as (BB) and (R).

The fourth characteristic implied by the data itself is that of possessing an enquiring mind on the part of the individual. There are instances, for example, when discussing jargon that the expectation is expressed that the individual will ask if they don't understand (MM) or they will look it up (U). Again, learning was described as the individual listening, participating (D), questioning and looking for the ways that answers are derived (Y): all hallmarks of curiosity. The same
connection is made by suggesting that team members should engage in "intelligent scanning of the environment" (West, 2004:1).

By comparing and contrasting the data it becomes apparent that there are shared characteristics which facilitate multidisciplinary development. Being curious and less risk adverse explains why some individuals find it easier than others to move across disciplines and the shared scientific background makes it easier to follow the thought processes behind the other disciplines inside this particular workplace. At the same time, their education background makes it more likely that the individuals concerned will be able to assess their knowledge and take necessary steps to remedy any perceived knowledge gaps.

**Objective 2: Assess, by means of measuring, informal learning levels within the case organisation and identify any multidisciplinary individuals.**

Being able to measure and subsequently chart the participants' knowledge levels across the disciplines to demonstrate the existence of multidisciplined individuals overcame one of the major inherent difficulties associated with informal learning processes. This difficulty is associated with the measurement of individual learning (Hager, 2007; Ashton, 2004). Erault's typology (2000) provided for a scale measuring from no learning through to deliberate learning only. It did not provide for any clear yardsticks to measure against, although there are several clear indications in this research that such a scale existed and learning did vary between individuals.
Figure 26 sets out the scale based upon how the participant's viewed the various degrees of learning. Inside the environment at the lower end of the scale, it was perceived that acquiring additional disciplines began with the recognition of how the individual's core discipline fitted alongside other disciplines working on a project (U). Moving along, the next significant step was acquiring sufficient understanding of the adjoining disciplines so as to understand how to tailor the individual's work output in the most acceptable format, in order that it could be more appropriately and easily used. An example is the geophysicist working alongside the reservoir engineer to facilitate the change from a static model to a dynamic model at the point where the model itself is passed between geophysics to reservoir engineering (S). This is in opposition to the geophysicist simply completing the model and sending it to the reservoir engineer. Moving further along the scale, increasingly individuals would display the ability to
participate in discussions and undertake work in new areas, either alongside their own core area as in the fringe areas (C) or, in another different area (D). An example is the engineer undertaking some aspect of economics, or being engaged in a minor role on a corporate acquisition.

Finally, the higher end of the scale would be represented by the individual who is able to fully participate outside of their core expertise in a range of projects across the hydrocarbon chain (F). In other words, the multidisciplinary development for individuals is a process through which they move, and it varies from person to person. In practice, the term was being used to describe someone who had simply moved outside of their original comfort zone, or someone who had sufficient understanding to evaluate the results of other disciplinary work and assess the impact upon their own discipline and then lastly, somebody who was doing someone else’s job.

This variation is demonstrated by the graphs in Appendix 7 and in Table 15. Figure 27 features participant (O) to show how individuals cross the discipline boundaries and become multidisciplined.
There were a number of examples provided inside the case organisation of individuals who had been successful in acquiring additional disciplines. One such was a chemical engineer starting up an exploration company or contributing to a very successful reservoir engineering project (Y). Other examples were a geologist who at one time ran the case organisation's global IT department before returning to his technical base specialising in petrophysics (F), and a petroleum engineer who was also a chartered geologist and a leading authority in organisational strategy (D).

It is likely that the acquired expertise at the higher end of the scale would contain knowledge gaps at a purely academic level but this, if necessary, can be remedied by the individual supplementing their learning through discussion with colleagues, review of similar project reports and technical library reference. All of these
activities were evidenced in the data. There were also several examples of individuals supplementing their informal learning by referring to text books in their own time (CC). Equally, as Interviewee (I) pointed out, simply because technical staff are recruited on the basis of having the appropriate degree (plus experience) it did not necessarily mean that their functional expertise could be taken for granted. He stated that "we must not assume that just because people have a qualification that they are well versed" in that field.

In looking at the various combinations of additional disciplines being described by the participants, the significant point that emerges relates to which disciplines are more open to acquisition by the individual. This issue is discussed later in the section relating to mapping the disciplines, but it is noteworthy that much of the disciplinary acquisition activity relates to disciplines inside the participant’s knowledge domain, examples are (N), (V), (X). If the individual moved outside of their own knowledge domain and across disciplines, then the movement was often to those disciplines which related to the strategic and commercial aspects of the industry, examples are (V), (S), (Q). There are a few participants who combine geology with engineering such as (C) and (D). The individuals who move furthest along the oil value chain most often hold chemical engineering as the core discipline, for example (Y), (B), (LL) and (U).

Measuring informal learning inside the case organisation confirmed the existence of multidiscipline individuals. Moreover it provided evidence of a "scale" of learning in existence. This suggests that the individual passes through various stages as they acquire further knowledge of additional disciplines. The data also suggested
that individuals broadened out within their own knowledge domain or alternatively, the movement was biased towards the strategic/economics elements rather than between geosciences and engineering knowledge domains.

**Objective 3: Identify what informal learning processes are present in the workplace and their individual contribution to the overall learning process.**

The data confirmed that there was very little formal training either externally (5%) or internally (6%) which indicated that the research should focus on informal learning processes. Furthermore, it was stressed by the participants that the learning took place inside the project teams with an emphasis on social interaction between the members. Therefore this research focussed primarily on the four social interaction processes as potential explanations for the development of multidisciplined individuals. It is recognised that social learning (Bandura, 1977) underpins the more recent social interaction processes since they also recognised that individuals observe, remember and then replicate behaviour. Nonetheless, the data here suggests that the learning process at work inside the case organisation is more proactive and these social interaction processes will provide a more appropriate lens to review learning in this research context.

As discussed in the literature review, there were four theories; Communities of Practice (Lave and Wenger, 1991), Interpretative-Cultural (Yanow, 2000), Cultural Historical (Felstead et al, 2005) and the Actor Network (Nicolini et al, 2003). These theories provide ways in which individuals learn from others or from their environment, although in themselves they do not have the necessary ability to
explain the actual process taking place. The following sections will look at the knowledge absorption process first, before discussing other social interaction processes and why individuals "step out" (D) outside their core discipline.

The data suggested that as the participant worked inside the project team they accessed the work of other team members in different disciplines and, in doing so, they encountered what might be termed as "troublesome knowledge" (Perkins, 1999). This troublesome knowledge takes the form of different terminology and/or theoretical concepts being applied to data or processes with which they may already be familiar (S). When encountering and solving these problems, the individuals enter a "portal" where they are able to see how their work and the data flows into the other discipline, and how that discipline handles the information. This knowledge they then integrate into their existing knowledge base (Meyer and Land, 2003). The individual then moves into "luminal space" (Meyer and Land, 2003) as they begin to understand and absorb the new knowledge. At some point this new knowledge becomes fully integrated with their existing knowledge base, thereby enabling the individual to cross the knowledge threshold (Meyer and Land, 2003).

This work contends that regardless of the level of learning, having integrated the new knowledge with their existing core discipline and experience, individuals are then able to offer broader perspectives drawn from this new revised pool of knowledge. Moreover, as multidisciplined individuals grow more proficient with their enhanced state of knowledge, they are not simply acquiring expertise but utilising their original discipline knowledge in a different way from those who
remained within their core discipline. This results in the individual evaluating projects on a wider basis rather than looking to their core discipline to provide the only solution, or indeed all of the solution to a particular problem, and this approach enhances and broadens their interpretations accordingly.

This process supports Kerka's (1995) contention that disciplines more readily integrate through the social interaction taking place within the team environment. More specifically, this research identified the integrated multidisciplinary team as being the ideal learning team environment.

Examples of troublesome knowledge (Perkins, 1999) occurred with disciplinary associated jargon present in the data. In terms of terminology, the younger geoscientists referenced the use of "clay" (GG) and "horizon" (OO) which were used differently by the disciplines present in the workplace. A similar issue arose on the questionnaire (Appendix 3) where one task was described as "fluid flow". To a facilities engineer fluid flow means the oil or gas flowing through the pipelines but it means fluid flowing through porous media with very different flow properties to other disciplines.

These examples also demonstrate the requirement to know the right words in the correct context (Wittgenstein, 1953) in order to communicate appropriately between disciplines.

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9 For clarity, the horizon might be one largely consisting of clay
Turning now to the social interaction processes, the data suggests that all of the social interaction processes are utilised to some degree in the workplace but the most significant was communities of practice. Communities existed externally and also in various stages of development internally.

The literature review established professional societies as external communities of practice and because of their high profile inside the workplace environment data was collected to understand the role that they had. The research focussed on how the professional societies were being utilised as a learning tool by the participants. Understanding their role would clarify how important they were in terms of the development of multidisciplined individuals. The data itself supported their importance to the ongoing welfare of the discipline to which they were tied. Individuals displayed strong ties to their professional society, particularly in the geosciences. Such societies fulfil a number of functions for their members in keeping their knowledge base up to date, providing networking forums and some level of peer group reference. Professional societies also provide a forum for their members to submit and publish technical papers. This process contributes to the societies being able to bridge the gap between industry and academia, hereby fulfilling their role of continuing to build the knowledge base of the discipline (MM). This bridge forms a useful dialogue, since as Bryson (2004) pointed out in his discussion on plate tectonic theory, oil industry geologists had been aware of surface movements for some time "But oil geologists didn't write academic papers; they just found oil" (Bryson, 2004:225).
What was interesting and pertinent to this research was the wealth of data the societies offered their members by way of their technical paper libraries. Taking the SPE as an example, their collection (which was expanded in 2007 to include a number of other upstream organisations) offered in excess of 80,000 technical papers dealing with every aspect of the field and reservoir. The papers provide examples of existing and potential technical problems with their solutions drawn from every aspect of the worldwide petroleum industry. Every participant accessed this source during the course of their technical work inside the workplace, either searching it themselves or via the case organisation’s library facilities. In other words, it proved to be an important resource to the individual by providing an opportunity to supplement their knowledge easily and readily.

In summary then, the external community of practice in the shape of the professional society provided a rich technical information source to its members supplementing the knowledge available inside the workplace. Interestingly, although there was evidence of substantial involvement by participants in societies there was no suggestion that there was any particular pressure being applied to retain disciplinary boundaries as suggested inside the literature (Taylor, 1999; Nancarrow and Borthwick, 2005).

Turning to informal communities of practice, there was evidence of three such communities at various stages of development inside the workplace. The more easily recognisable community related to the geosciences disciplines. More informal communities were found in facilities engineering and the “downstream” sector encompassing the chemical engineering discipline. The downstream and
facilities engineering groupings had been in existence for many years (D), with the stronger, more formalised geosciences group forming in more recent years (Y).

As the literature suggested, the individuals inside communities formed strong bonds (Lave and Wenger, 1991; Kline, 1995). A number of the individuals inside the workplace had previously worked together, for example (CC, II, U). Others had been aware of other participants’ reputation (MM) prior to joining the case organisation. Where participants had previously worked together or worked for the same organisation, induction into the case organisation was faster than in the case of those individuals who had not. This was particularly so in the geosciences where a number of individuals had all previously worked for the same major international organisation.

Although the case organisation has always had a preference for recruiting through staff recommendations, the stronger internal communities of practice appear to be a relatively recent innovation inside the case organisation. One participant, who had been with the case organisation from its very early years, raised this issue expressing it as increasing specialism within the case organisation. He deplored the whole concept of what he termed departmentalisation because “it then makes everybody look inward instead of out” (Y). In turning in on itself the communities appear to have a negative impact upon the organization and some loss of multidisciplinary capability.

The community’s negative impact can express itself in a number of ways, both as a group creating barriers to other disciplines and also be potentially limiting in
respect of individual activities and subsequently their long term career progression. An example is where the disciplinary head, or other members of the community, do not allocate individuals work outside their core disciplines. This situation can be complicated further if there is a lack of appropriate projects in their core discipline. Moreover, these individuals feel uncomfortable in circumventing the established disciplinary leaders. Other participants sharing the same core discipline provided anecdotes on how they had been able to widen their skill base on the back of the project work (J); but these anecdotes relate to the case organisation, as it was several years previously and not in the current climate. While it could be argued that to some extent the individual's personal characteristics may inhibit personal development, there are a number of examples across a range of personality types to mitigate this argument.

Other aspects relating to the communities of practice raised by the data are status aspects suggesting communities of practice mitigate against multidisciplined individuals as in "the geoscientists are revered here and the rest of us are just add ons" (II), deliberate intention to build strong communities (MM), or "we are a little group on own" (J). These are all aspects which can lead to barriers being erected between the disciplines, already noted by (Y).

Given these examples, one can argue that internal communities of practice are not processes which work to the advantage of the development of multidisciplinary individuals. By their very nature they prevent an "outward facing" (Y) perspective to be developed and encouraged by their members. The growth and continued development of these communities may be viewed as a way of addressing the
increasing knowledge base inside each discipline or knowledge domain (Rushmer and Pallis, 2003), but as these informal communities strengthen, then the less likely it is for the case organisation to continue to "grow" its multidisciplinary capabilities. This is particularly valid if the disciplinary heads are also in formal management positions where they can affect the resourcing of projects. They will be much more inclined to utilise individuals in particular fields where they are aware of their disciplinary expertise, and not provide opportunities for other professionals to develop knowledge and grow into new areas.

Moreover, stronger communities of practice inside the organisation could prove detrimental to the organisation itself. The case organisation has a global reputation for bringing innovative ideas to the table, and one aspect of this is generating ideas from different knowledge bases. An example was provided by the senior principal (D) who described the challenge in having other professionals accept that "you can do most of the jobs that come up with a different skill set and in a different way". He used the example of geology or geophysics not being necessary primary components of a project if there were sufficient wells, or production data to tell the engineers what the reservoirs contained, how they were configured and how best to address them. This is not a view which the relevant communities of practice would agree with since they would perceive the project in this example as requiring geology or geophysics to determine what the reservoirs contained.

Given the continuing flat structure of the case organisation, it is entirely possible that it may be able to accommodate the various communities of practice that
currently exist. As noted above, to protect the existing workplace environment, management need to ensure that stronger communities of practice do not seek to "protect" the disciplines associated with them.

Another example would be to prevent continually allocating the specialist to work on specialist projects rather than looking at the resources available and matching the project work scope accordingly where possible. Always matching individual to particular area of work is a good example of where knowing an individual's skills and abilities based upon their core discipline effectively "blind" management. This "blindness" could manifest itself in preventing the development of alternative problem solving solutions, as well as in limiting opportunities for individuals to expand their knowledge base.

There are a number of references within the data that infer that other social interaction processes are in play. One example noted was the historical cultural process which expressed itself in this study as peer pressure. Historically and culturally "multidisciplined individuals" were perceived to be the "stars" being in demand for project work on a continual basis. Although this was not raised as a significant motivator, one interviewee pointed out "the most unhappy" (D) were those staff not in "demand" by project managers looking for staff to resource their particular projects. In many cases, the project managers were looking for individuals who typically were most able to handle a variety of tasks and deliver results (A). This aspect is dealt with in more depth later in this chapter.
Other aspects related to the various processes in place such as documentation. Examples such as AFE’s (Authorisation for expenditure) were used to capture information relating to each specific client contract assisting learning as in the cultural and historical framework (Felstead et al, 2005). To clarify, AFE’s are generally used across the industry. The example inside the case organisation sets out the thought processes required to successfully price a project. This came in the shape of tick boxes, and included such aspects as “are there special insurance requirements”, “have you polled your colleagues to see if they agree with pricing?” and “is there a conflict with another project in the group?” All items which would force the individual into discussions with his colleagues on matters often outside their immediate background.

In common with many organisations, there were “lunch and learn” sessions on a variety of topics including various multidisciplinary subjects although these were more significant in terms of cultural practices rather than as a learning environment. They could however be viewed in the context of an area where jargon (Wittgenstein, 1953; Meyer and Land, 2003) and tools or “objects” (Engeström and Blackler, 1995) were explained to other disciplines thus facilitating multidisciplinary understanding. They were also useful for forming and promoting social relationships (Kram and Isabella, 1985): all aspects fundamental to learning.

Clearly, the continual problem solving processes required within the project teams is a significant learning process in itself. This interaction forms part of the cultural and historical framework (Felstead et al, 2005; Anzai and Simon, 1979; Dunbar, 1993) and facilitates the development of multidisciplinary individuals. As noted in
the data, the individuals are involved in an average of 10 projects per annum, with a number of them involved in considerably more. The number and variety of projects provide ample material for developing problem solving skills across a broad disciplinary range, and at a rapid pace. It is this availability of projects with a spread of requirements and the case organisation's approach to staffing these projects which provides the basis for the accelerated multidisciplinary approach.

In summary, it can be said that the four social interaction theories exert considerable influence inside the workplace, providing for multidisciplinary development. To a large extent this is beneficial with the external community of practice again having a role to play in providing a source of information. Only the internal communities of practice exert a negative influence in terms of restricting individuals to their own core disciplines and thereby limiting the opportunities for integrated multidisciplinary teams and individuals as advocated inside this research.

Furthermore, although not recognised in the business context, threshold concepts, dealing as they do with "troublesome" knowledge (Perkins, 1999) held the potential to explain the actual learning process at work inside the case organisation and explained the "scale" previously commented upon.
Objective 4: Assess environmental factors such as ethos and working practices in the workplace to determine their contribution to the individual learning process.

The case organisation closely fits the descriptions of post modernist organisations reliant on experts (Buchanan and Badham, 1999; Starbuck, 1997; Koch, 2000) in minimal structure, processes and ethos. Furthermore, it also matches McDermott's (1999) "double knit" organisation, wherein it contains both cross disciplinary teams and communities of practice. In this case the "double knit" does not prove particularly beneficial to the case organisation as it is trying to cultivate solutions across a broader front than many comparable organisations.

The workplace contributes to the multidisciplinary learning process by providing the platform for "risk taking" by its staff. Although not perceived as the sole reason for the institution of certain processes, these processes provided a number of "safety nets". These came primarily in the form of the review processes which had been initiated by the case organisation from early in its history as a way of ensuring that each problem posed by the client was effectively addressed albeit not necessarily from the core discipline that would normally be expected to address the issue. This may well have contributed to its reputation as being innovative and pragmatic in its approach to the key issues arising out of its contracts. The concept being that those individuals drawn from different disciplinary backgrounds were more prepared to ask key questions and required checking by third parties material which was beyond their immediate capacity to review.
Another example of safety nets was the “3-hour” rule, which meant that if an individual had a difficulty which could not be solved inside three hours, they then had to take it to a colleague, the project manager or whoever they thought could best assist. This alone promoted interaction among staff across the disciplines rather than simply forcing the problem up the chain of management.

One further aspect of the safety net which emerged was the emphasis on constant communication at all levels. There were references to individuals being available 24 hours a day to consult with (Y) and (A) as well as frequent meetings such as the daily morning meeting. These aspects all combined to keep a constant stream of information and support circulating around the members of the case organisation turning it more into a community.

As an organisation, it had survived the macro economic cycles which affect the industry as a whole by actively seeking a broad range of activities as a buffer against the downturns (Y). This broadening out of activity is reflected inside its culture, which actively encourages individuals to keep involved with projects regardless of the billing level (B) and type. The consequence of this being that senior staff will undertake work usually considered below their level on occasions (Y). This behaviour reinforces the lack of management ties, and encourages the team approach to the projects. While this is designed to keep staff employed on billable activities (a necessity for a consultancy) it is an activity which also opens up a further learning opportunity for staff in social expertise as well as technical skills.
The case organisation operated in a climate of “consensus, agreement and discussion” (U), more collegiate by dint of its informal processes (Y), (D). Its working processes drove the requirement to create an environment where status was gained through peer approval. This extended beyond the actual project work and into the strategic and commercial areas of operating the business (D). Being responsive to external economic pressures reinforced the requirement for flexibility.

The data shows that this ethos is undergoing change in the more recent years which may simply reflect the more successful business model that the case organisation has achieved. One participant (O) observed that as the organisation's database had changed, there had been a major shift in expectations as it grew into the more “elite” class. This shift, combined with increasing technical complexity referred to previously (S), had changed the underlying business model. Increasing specialisation had promoted the growth of internal communities of practice which then made it more difficult for the case organisation to “grow” multidisciplinary individuals.

This change can be demonstrated by the anecdote relating to the case organisation’s early IT development. During the early 1970's everyone in the case organisation was required to learn Fortran programming including how to operate the various machines. This was a requirement for both technical and some non-technical staff. Learning a computer language is a discipline in itself, and facilitated the multidisciplinary environment and ethos. The outcome was that all staff became, to a greater or lesser extent, conversant with the then current IT technology. The case organisation now possesses a separate IT section which
handles all hardware and software IT aspects. This means that for the majority of staff it is easier to ring IT to deal with queries, including the very elementary issues where the answer very often is to check that the equipment is actually "plugged in" and "turned on". The individual's ability, or requirement, to develop IT skills and programming related skills to some level has disappeared.

What was clear from the data was that in order for the multidisciplinary learning processes to continue, the habits and ethos behind the company structures needed to be maintained. This would require clear explanations as to their purpose and sufficient authority to reinforce as necessary. This observation leads to the conclusion that the integrated multidisciplinary team is perhaps a feature of small consultancies or small sub-groups inside larger organisations. As the case organisation has, and appears will continue, developed in the recent years, multidisciplinary development grows less likely unless the case organisation deliberately creates the appropriate learning environment. This point would require further research to generalise to other organisations.

The data proved the existence of two different types of team which had previously been highlighted in the literature review; integrated interprofessional and the integrated multidisciplinary. The integrated multidisciplinary project teams closely fitted Colenso's (1997) description, Table 7. Whether the team was formed and run as integrated and multidisciplinary was largely dependent upon the nature of the project and/or the project manager's preferences, or on occasion the limited availability of suitable multidisciplinary staff. The opportunities for learning were greater inside the multidisciplinary team, since each individual had access to all the
data and the problem solving processes that were taking place across the disciplines. In integrated interprofessional teams the learning is limited to whatever new areas such as exploration areas or types of reservoirs the individual is working on or, in the case of the project manager, as they pull together the team member’s combined work effort. This was supported by the fact that 96% of participants had reported learning through the project work with 83% stating it was through exposure to other disciplines.

The two different types of teams also have the potential to explain the disparity between writers such as Peters (1991), Nonaka and Konno (1993) who promote learning inside teams and Power and Waddell (2004), Godard (2001) who state that this aspect is over estimated.

The case organisation must look to nurture its current environment within which the integrated multidisciplinary teams can operate. This is because it is inside this type of team that the environment is such that multidisciplinary individuals can develop faster. Outside of that team environment learning opportunities are limited and as such development will focus much more on the individual’s personality.

In addition to the actual project work itself, there were a number of sources which the participants drew for information, including notably other senior staff who make themselves accessible, even though they may not personally be working on the same project, but have experience in either the disciplines required, with the specific client or a similar technical or business problem. This “organic database” is available across the wider organisational group, and is not just limited to the staff.
at the same location. Many of the staff who fell into this "consulting" capacity also had a wide experience as project reviewers across a broad range of projects, and this provided an enhanced learning experience.

**Objective 5: Illustrate by means of mapping what disciplines are inside the case organisation and how they fit together.**

As discussed in the previous chapter, the data collection focussed upon the two separate knowledge domains containing the geosciences and engineering disciplines. Although there are other knowledge domains present inside the case organisation, these two represented the majority of staff. It was apparent early on in the data analysis that mapping the disciplines inside their knowledge domains was a major task. The key was to map to the extent that there was an understanding of where the "spill in" and "spill out" (Buchanan, 1966) or disciplinary overlapping areas occurred so as to more appropriately identify the learning opportunities.

Historically the disciplines inside the oil and gas sector have evolved rapidly, pushed on by the combination of industry demand and technological and/or theoretical advancement (NN). This can be most clearly demonstrated inside the geosciences, where something of a revolution occurred during the early 1960's (DD). Previously geosciences had been considered more of a descriptive science (DD). The change came about largely due to the combination of the acceptance of new disciplinary knowledge such as plate tectonics (1963), the demand for more energy, and the increasing ability to utilise computer software. Specialism inside
the knowledge domain evolved to meet these changes (H), albeit the fundamental knowledge essentially remains the same across all the geoscience disciplines (MM).

Mapping the geosciences and engineering disciplines was interesting, holding the potential to be explored in more detail and across a wider section of the industry makeup at a later date. The initial exercise provided the disciplinary dimensions of the case organisation, together with confirmation of the complexity and multilayered nature of the knowledge domain structures, see Figure 28.

![Figure 28: Knowledge domains and disciplines – Structure](image)
This Figure also shows the role of reservoir engineering in bridging the two separate knowledge domains of geosciences and engineering. Reservoir engineering has been one of the overlapping areas, evolving into a separate discipline to fill the gap.

**Objective 6: Define boundary areas in the mapping exercise to identify difficulties that might exist for individuals crossing disciplinary boundaries**

Although not shown in Figure 28, the disciplines have sub disciplines and further layers of sub sub disciplines beneath them. In delineating the borders of the territory, it became clear where individuals had moved into either an allied discipline in the case of sub disciplines, or across the knowledge domain boundary in the case of the major disciplinary areas. It would appear to be difficult for individuals in the sub disciplines to cross knowledge domain borders, and so there is a tendency for these particular individuals to be restricted to broadening out and crossing disciplinary borders inside their own knowledge domains. These restrictions then explain how some members of the staff viewed multidisciplinary individuals as being contained within their own knowledge domain, for example within the geosciences disciplines (MM). Others took a much wider view, and included disciplines across knowledge domains such as mixing geosciences with engineering disciplines (C).

This is demonstrated by the difference between two of the interviewees (MM) and (D). (MM) indicated that the organisational circumstances “challenge individuals to grow and they grow by pushing the boundary of their comfort and that is within
their discipline and outside it". Later in the interview the same participant referred to this growth as "we talked about integrating and comfort zones across geology". On the other hand, Interviewee (D) described individuals who "spread their capability and their interests wider than the fields in which they previously worked or had been trained". He used the example of a geologist who added economics and computing skills performing at the highest levels inside the case organisation.

Movement across the disciplines is also encouraged by the fact that the disciplinary boundaries, particularly in respect of the overlapping area of reservoir engineering, are not as fixed in geology, geophysics or petroleum engineering disciplines as they are for example in mathematics, or in some engineering approaches. There are a number of such examples contained in Appendix 7. It became apparent that sometimes it was easier to make the first step outside of the core discipline to an allied discipline in the first instance. Examples provided were chemical engineers handling classical reservoir engineering, and of geoscientists moving into reservoir engineering.

The majority of cross border activity appears to take place at three different points:

1) at the point where data/information was being transferred between disciplines;

2) where the work activity in the case organisation gave the individual access to all disciplinary areas, for example in the report reviewing or as project manager of a broad based project; and
3) opportunities arising inside projects for staff to become involved because of a resource shortage within a particular discipline, or because the individual themselves have requested exposure to a different knowledge base.

Emerging from the mapping exercise was an understanding of how data information flowed through the oil and gas value chain in terms of how the case organisation uses that data, Figure 29. It should be noted that other organisations operating at different points in the oil and gas value chain would of course show variations in this data flow. The data information flow shown in this figure differs from Levorsen's (1967) typology (Figure 5) in that it does not show a clear trail leading to the petroleum geologist in producing the reserves, but rather a clear trail that runs through the disciplines in achieving production.

Figure 29 depicts the work of the geosciences, incorporating many aspects from the various disciplines, cumulating in the static reservoir model produced by the geophysicist, who then passes the model to the reservoir engineer. Having turned the static model into a dynamic model, the reservoir engineer produces a different set of data which is then handed to the facilities engineer to then produce the necessary field development plans. This is of course not the only task undertaken inside reservoir engineering, but it is the task within reservoir engineering that links it both to geosciences and engineering thus straddling the two knowledge domains. The data supports the emergence of reservoir engineering, particularly over the last twenty years, as a discipline in its own right, providing a link between geosciences and facilities engineering.
Figure 29: Knowledge Domains and Disciplines in the Workplace

The blue line indicates the information flowing through the disciplines
The red line shows the connections between the sub disciplines
In terms of evolving disciplines, petrophysics has also been identified as an evolving discipline on the cusp of being recognised as such, largely due to the increasing complexity of material being derived in that sector.

The data suggests that geoscientists with strong mathematical abilities can move across into reservoir engineering and similarly, engineers with a strong enough interest in geology can make the move in the opposite direction. Another example would be the chemical engineer dealing with what is termed "classical" reservoir engineering. Other disciplinary crossings are more difficult to make although both geologists and engineers have been able to move across into strategic and economics work.

The data suggests that a significant hurdle facing an engineer moving into geosciences lies in the substantial terminology associated with disciplines. Equally, movement in the reverse direction can be hampered by the degree of mathematics which the individual possesses:

"the problem with reservoir engineering and all engineering is that there is a lot more mathematics associated with it than there is with geology which is still to some degree is an art form that requires probably a lot more imagination. Not that an engineer does not need imagination but geology needs some skimped thought processes that do not necessarily come naturally to an engineer" (Y)

Engineering requires an individual to deal with sophisticated applied mathematics which differs from the more straight forward, albeit complex, arithmetic which is required, for example, inside economics. Equally, the geosciences require the individual to hold more visualisation skills, since they have to interpret what is
under the ground, based on data. Reservoir engineering requires a blend of visualisation and that mathematical approach. Mathematics are not exclusive to engineering, geophysicists also require extensive mathematics. As depicted in Figure 29 geophysics is closer to the borders with reservoir engineering, suggesting a stronger bias towards mathematics than those whose borders may lie alongside domains such as biology or palaeontology. This suggests that whatever precise discipline the individual chooses at formal education level, or gravitates towards during their working life, may be more a reflection of their abilities in a particular field of study such as mathematics rather than on any other basis.

This also indicates that should an employer wish to “grow” multidisciplinary individuals faster, they would firstly need to identify the dominant characteristic of the knowledge domains. Examples found in this research are learning opportunities for individuals outside of engineering in applied mathematics and, in the case of geosciences, creative thought processes. In addition to these opportunities, it would appear sensible for any workplace that holds more than one discipline to routinely ensure that the staff were familiar with fundamental cross disciplinary jargon. This would effectively speed up knowledge absorption processes.

A secondary point which mapping highlighted was the overlap areas between the disciplines. Examples of this can be found in petrophysics, which can be handled by both engineering and geosciences disciplines at the higher end level by staff inside the case organisation. Other examples are cost estimating, which is inside both facilities and chemical engineering and production and expenditure profiles.
which almost every discipline deals with in one shape or another. The evidence suggests it is the focus of each discipline that differs rather than the fundamental, underlying knowledge base of each different knowledge domain.

Furthermore, the nature of the two separate knowledge domains is very different. Individuals inside geosciences need to be comfortable with handling imprecise information across a wide timeframe (II; CC) and rely on their ability to memorise facts (S). A number of the individuals inside geosciences expressed a real "passion" for the subject (MM), and identified themselves as belonging to a group. This is in sharp contrast to engineering where individual disciplines identified themselves as such, rather than forming part of a wider engineering group. An example of this was inside the facilities engineering group who were keen to emphasise the logical thought processes required inside their discipline. They were dismissive of chemical engineers who had "dabbled" in large scale project management. This reinforced Starbuck's (1997) observation that professionals believe that only individuals inside the discipline can handle its work efficiently. Similarly, chemical engineers felt that their subject was very broad based, with its emphasis on applied mathematics. This broad base facilitated their ability to handle a number of different roles, from classical reservoir engineering, through to strategic matters (U).
Objective 7: Assess factors which may arise during data gathering to determine if there is dominant factor influencing the individual to acquire additional disciplines;

Various pressures are listed in the literature review as to why individuals remain inside their own core discipline. These pressures range from the status to be obtained from a structured career (Nicholson, 2000), being educated inside the disciplinary etiquette (Kline, 1995), belonging (Starbuck, 1997) and peer approval (Maister, 1993). Given this, there would appear little motivation for the individual to acquire additional disciplines which can be seen as “diluting” their profession (Taylor, 1999). The structured interviews did not include any specific questions in respect of motivation but there were references inside the data to the need for peer approval (Maister, 1993). This is clearly a major motivational factor inside the workplace. This is reflected in the literature which describes high achievers acquiring new skills as a way of gaining further recognition inside a workplace full of high achievers (Locke and Latham, 1990; Armstrong, 1999). Thus motivation could be attributed to individuals observing the social actors within the environment, leading to duplication of behaviour (Bandura, 1977). However, it does not fully address the issue of why the participants acquire additional disciplines.

In considering this point there are a number of issues to take into account which focus on the conditions encountered inside the workplace arising out of the project work.
These were identified as the:

- continued pressure to remain "billable" (F) as a means of gaining peer approval (J);
- the requirement for individuals to change roles easily namely, to move from being project manager on one project and a team member of the next,
- pressure to get project deliverables to the client (A) and the need to maintain flexibility to achieve that goal (F),
- Requirement for travel bringing about greater social interaction between staff (BB); and,
- The challenge process itself whereby work outputs are constantly being peer reviewed (I).

In a workplace full of professional staff that remain with the case organisation because of the variety (93%), the learning opportunity (76%) and problem solving elements (73%) of the work these pressures act as powerful incentives to move out of their discipline. It is also true to say that many professionals have broadened out because of the interest they have in the problem solving elements and are unaware of the shift in their perspective until later (D).

Objective 8: Develop a model to illustrate the factors involved in the development of additional disciplinary expertise by the individual.

At the conclusion of the literature review an adaptation of Nonaka and Konno (1993) model of a hypertext organisation was used as a way for providing a
framework for the fieldwork, Figure 14. The diagram is useful to show how information flows around the case organisation through the various layers but it does not provide an explanation of how individuals acquire additional disciplines in the workplace.

A second model was the "best fit" model from the Masters Degree (Rogers, 2005), Figure 1 which listed a number of influences associated with multidisciplinary teams and individuals. Inside this research it has been possible to provide a better understanding of the importance of each of those influences. Equally, it has been possible to compare the findings of this research with that of the earlier masters research (2005) and note that many of these influences remain unchanged. The exception to this has been eclecticism.

The evidence presented here highlights the very real possibility of declining availability of opportunities across the disciplines. This is being brought about as a result of the case organisation recruiting more "specialists" and internal communities of practice gaining ground thus reducing eclecticism inside the case organisation.
Figure 30: Factors involved in the development of additional disciplinary expertise by the individual

Figure 30 is a simplistic view of the factors involved in multidisciplinary development within the case organisation. Taking this further would mean including feed forward loops to incorporate additional influences such as peer pressure which have been noted as being significant. The aim of this research was to determine the existence of multidisciplinary individuals and how they acquire additional disciplines therefore it did not focus specifically on building an explanatory model of the development process.

The model shown in Figure 30, does emphasises the need for the individual to match the environment. Most notably, both the individual, by disposition, and the workplace, by ethos, need to be “adventurous”, namely not averse to taking risks.
This expresses itself as the individual taking on work that falls on the fringes or outside of their own discipline. In terms of the case organisation it is in terms of trusting its staff to take on such work. If there is not a match between the individual and the workplace in this respect then very little multidisciplinary development will take place, even if either party desires such development.

Second to this requirement, this study has strongly suggested that the development of multidisciplinary expertise is, risk posture apart, less about an individual's motivation, and more about the individual's abilities matching the requirement of the additional discipline or different knowledge domain. This facilitates the individual's ability to handle troublesome knowledge which arises as they cross disciplinary boundaries.

The research established that some disciplines are difficult to enter for a variety of reasons such as lack of fundamental skill sets or the ethos of the discipline itself. Although this aspect may be sufficient to act as a barrier for many individuals, for others it has not proved a particular drawback, for example (Y).

After analysing the data it is possible to conclude that a further key element in the development of multidisciplinary individuals lies in creating an environment in which routine involvement and interaction between disciplines can take place freely (Masters, 1990). In creating that environment, the case organisation must recognise that there is an element of risk involved. In unconsciously creating the various "safety nets", the case organisation safeguarded their credibility to the outside world, while at the same time producing innovative solutions by using the
skill sets they had instead of simply addressing the issues through specialists. There are a number of difficulties associated with the creation of such an environment, such as status (Nicholson, 2000), discipline and peer pressures (Taylor, 1999; Starbuck, 1997; Contu and Willmott, 2003).

Summary

This chapter reviewed the research findings to establish whether or not the research had met its objectives. It reviewing each objective it was possible to conclude that:

- there were shared characteristics inside the sample population that made some individuals more predisposed to acquiring additional disciplines;

- By measuring the disciplinary knowledge the existence of multidisciplined individuals was confirmed. It further highlighted that a scale existed which ranged from simply knowing how the individual’s discipline fitted alongside others to being able to fully participate inside another discipline;

- Social interaction processes such as communities of practice were present inside the workplace but more significantly threshold concepts
and troublesome knowledge provided new insights into how knowledge was acquired and explained the perceived scale of acquisition;

- The case organisation was identified as a "double knit" organisation and held a number of what were termed safety nets for individuals moving outside their core discipline. It was also noted that there were differences between the project teams and that these differences meant that some teams were more open to learning opportunities than others;

- Mapping the disciplines revealed the two knowledge domains of geosciences and petroleum engineering bridged by the single discipline of reservoir engineering present. Identifying the information flow through the disciplines facilitated an understanding of how additional disciplinary expertise was acquired.

- In order to acquire additional disciplinary expertise it was essential that the individual held the underlying requirement of the new discipline. For example, for engineering the individual has to be proficient in mathematics.

- There are a number of drivers which may have a role in deciding whether or not an individual moves out of their core discipline but no single factor was apparent in the data.
Taking these conclusions together it was possible then to create a model which illustrated how these various factors came together to create a multidisciplinary individual.

Having reached these conclusions the next chapter discusses the wider issues in terms of the perceived limitations of the study; its theoretical and practical implications together with suggestions for further research.
CHAPTER SEVEN
DISCUSSION

Introduction

The previous chapter outlined how the research carried out met the research objectives highlighting the conclusions that could be drawn from the data. This Chapter looks at the research itself and how it fits into the wider research arena. Saunders et al (2003) suggested incorporating an additional discussion chapter to deal with the wider issues addressing questions relating to:

➤ "What does this [research] mean?"
➤ What are the implications for organisations?
➤ What are the implications for the current state of knowledge of the topic?
➤ How does it add to the literature?
➤ What are the implications for future research" (Saunders et al, 2003:423)

The following sections address these questions by firstly reviewing the perceived limitations of the study and then examining the methodology choice. This is then followed by reviewing how the research contributes both to the existing literature and also what practical implications it might have. Lastly, recommendations for future research are suggested.
7.1 Limitations of Study

This next section examines the issue of the generalisability (Bryman, 2004) of this study. Generalisability, or external validity, (Cook and Campbell, 1979; Lincoln and Guba, 1985) relates to how far the findings from this research may apply to other people (population validity) and workplace settings (ecological validity) (Huck et al, 1974). Lincoln and Guba (1985) explored four threats to external validity outlined by LeCompte and Goetz (1982) which relate to how the researcher determined the participants (selection effects), how far the workplace affects the results (setting effects), any previous history relating to any aspect of the research (history effects) and lastly, how far the phenomenon is unique to the workplace (construct effects).

7.1.1 Population Validity

Population validity concerns itself with how do the findings of the research apply to other people. In this particular study although the participants form a cross section of disciplines, ages and different levels of the case organisation, it does consist of highly educated predominantly male population with a largely shared scientific background. The fact that the sample population fitted inside an identical grouping could limit the applicability of the findings in respect of other people (Ashton, 2004). Nonetheless, learning inside teams is well documented across industries ranging from professional workers (Erault, 2000) through to construction workers (Barrett and Sexton, 2005). What has not been the subject of research is that learning which relates to knowledge outside of the core discipline for skill set. Moreover, there is nothing in this research to suggest that multidisciplined individuals are
limited to the sciences or to consulting and are not to be found elsewhere in differing types of organisations, professions or trades.

Turning to the learning processes, using threshold concepts (Meyer and Land, 2003) with its ability to explain how individuals acquire additional disciplines is a new application of an established theory. This concept, together with "troublesome knowledge" (Perkins, 1999), holds the potential to be applied to training, both formal and informal, across industry. Moreover, by assisting in absorption of the philosophy and discourse utilised inside any new discipline and/or subject area, learning is often more effective and faster. These qualities would make it an attractive addition to industry training.

7.1.2 Ecological Validity

This section deals with the question of how far the findings of this research apply in other workplaces. The setting for this research was inside an organisation which had few hierarchal layers and which placed an emphasis on its staff being employed on work that was chargeable to the client, rather than having a product to support its activities. Furthermore, staff had always been encouraged to broaden out their work activities which engendered a more "risk taking" environment in which to work for both the management and the individual. The element of "risk" was more apparent in the early years of the case organisation when it was operating in what was a "virtually new area of business" (Y) as a multidisciplinary organisation offering both broad and more specific solutions to client problems.
It is likely that multidisciplinary individuals develop in similar consulting environments across a range of industries or alternatively, in organisations loosely bound together such as is the case in the legal professions. In order for multidisciplinary individual development to occur in other settings, the organisation would need to have already in place or build an appropriate platform. Then they would need to select individuals who were predisposed by their nature to operate inside that environment. For many organisations, particularly larger ones, there are too many procedures and processes in place limiting both practically, and the risk exposure to the organisation to enable that platform to function as effectively as inside the case organisation.

Given the wide ranging nature of this research there are clearly elements of it which are certainly applicable in other organisations, project teams being one example. Project teams are a common feature of modern industry, and therefore determining how they work together to identify the type of team and subsequently how much learning is taking place inside the team is relevant. Any organisation using such teams has the opportunity to provide the appropriate team environment so as to ensure team members have the appropriate degree of access to learn more about the other disciplines and enhance team creativity in the process.

Another area which is applicable is the mapping exercise carried out on the knowledge domains and their disciplines. In this particular case, the mapping related to the nature and knowledge containment areas of the geosciences and engineering disciplines inside the case organisation, together with their border
interaction is relevant in other organisations to better understand how to plan career development. The disciplinary nature and borders are formed inside higher education, and they remain with the individual throughout their working life. Identifying how the disciplines fit inside a workplace and where they overlap would promote insights into staff development that are not currently available inside the talent management processes.

7.1.3 Threats to External Validity

Transferability of the study was mentioned in Chapter Three which discussed the requirement of having a detailed or “thick” (Lincoln and Guba, 1985; Geertz, 1973) description of the research. In doing this, the reader may be convinced of the “reality of the events and situations described”, (Bryman, 2004:501) and therefore the research may be considered reliable (Kerlinger, 1973). External validity concerns itself with this issue by examining how and where the research was conducted to establish any factors which might have affected its outcomes.

External validity can be threatened by the possibility that the participant selection is tainted. This issue was raised in Chapter Four which established that the participant selection here held a random element in that the travel requirements of the projects controlled who was available for interviews. Fortunately, the random selection worked in favour of the research since it encompassed all age ranges and disciplines.
At the beginning of this research it was noted that gender and cultural issues did not feature as part of the research. Both male and female participants took part in the research although it was predominantly male. Additionally the participants were drawn from a number of different nationalities. Indeed, there was anecdotal evidence to suggest that it was not a relevant feature but it would need more research focussed on those issues to really determine this point.

In terms of the workplace affecting the research it should be noted that most of the research is dominated by the geosciences, facilities and chemical engineering disciplines, with little input from other engineering disciplines. Whilst this lack of input from other engineering disciplines is acknowledged here, as well as in other sections, in reality at the time of the fieldwork there was no strong representation of the remaining engineering disciplines inside the case organisation thereby always being an inherent limitation.

In reality it did not matter what disciplines were or were not present inside the case organisation, since the research focussed on the broader aspects of individuals acquiring additional disciplines. The research was not focussed on specifics such as a geologist becoming a reservoir engineer, or a production engineer becoming a process engineer; but sought to find out if an individual gained some level of understanding of other disciplines, and if so, how.

Moreover, being social constructivist in nature, the research is only interested in how the participants saw their world. It is not interested in establishing a balance
between the disciplines which did not exist during the fieldwork period inside the case organisation.

There were no obvious historical affects related to any aspect of the research. In terms of how far the phenomenon is unique to the workplace (construct effects) it is unlikely that the case organisation is the only one that is able to develop multidisciplinary individuals but it is likely to be relatively few in number.

7.2 Methodology Choices

It is interesting to note that if a realist approach had been taken this study would have been more concerned with global economic events forcing both individuals and the case organisation to make decisions based on the need to survive the industry downturns. This would have included the need to implement policies and working practices including multidisciplinary working. Taking this stance may not have surfaced the multidisciplinary individual developmental process. Social constructivism did allow for the building of a shared mental model allowing for individuals to express their interpretation of events and individual responses to such events.

Long term employment with the case organisation made the ethnological perspective the most logical choice. It was particularly useful since a number of the changes in the working practices being described by the participants were already known to the researcher. This meant that discussions with participants moved along at a faster rate than otherwise and having shared the same
experiences participants were more open in their responses. What was essential was the need for the researcher to ensure that material being used was based upon the participant's evidence and not on the researcher's assumptions.

One aspect of reliability that is applicable here is in the measurement tools used. Both unstructured and structured interviews took place during the fieldwork. Measurements were obtained through closed questions posed during the structured interviews whose primarily objective was to obtain the quantitative data. This data was useful in clarifying some dimensional aspects of the study. Additionally, these interviews were able to be used to triangulate the findings from other aspects of the fieldwork, such as the group and unstructured interviews. There are a number of more sophisticated methods using more detailed statistical analysis available to measure learning in finer detail. Certainly using these may have allowed for a greater understanding of the actual scale of learning, from simple awareness through to expertise. Moreover, it is possible that this research would have been more readily duplicated elsewhere, adding both to its transferability and reliability qualities.

The measurement took place using a relatively simple methodology which could be considered as a weakness here. Nonetheless any more sophisticated statistical tools would have been inappropriate inside this study (which had the far simpler aim of determining the existence of multidisciplined individuals and how they acquire additional disciplines) and it is possible that some techniques might have stretched the data more than was justified. For the purposes of this study it was sufficient to understand that the individuals have acquired disciplinary expertise,
albeit at differing levels, across a number of disciplines which the relatively simple methodology achieved.

Overall the selected methodology worked well and achieved the research aim and objectives.

7.3 Contribution to Literature

This next section addresses the questions which relate to how this research adds to the literature in terms of its theoretical implications and what, if any, are the practical implications. As this research has been broad based then equally it is applicable across a broad spectrum.

7.3.1 Providing recognition for multidisciplined individuals

This research set out with the relatively simple aim of determining the existence of multidisciplined individuals which it has done through measuring informal learning levels inside the case organisation. This study has strengthened the case for individuals acquiring additional disciplines, or at least some knowledge of other disciplines, noted by Cross (1991) and Armstrong (1999). Holbeche termed these individuals as "boundary spanners" (2005:154) developing ideas from diverse sources. The contention here is that multidisciplined individuals do more than simply combine ideas. The integration of disciplinary knowledge enables new and different perspectives to be drawn. The research has also been able to set out
what factors are essential for the successful multidisciplinary individual
development.

Furthermore, the research has supported Ashton's (2004) work on the
organisational structure and its impact on learning processes. It is apparent that
the participants inside the case organisation are fully aware of how their
contribution fits into the larger picture and have broad opportunities available. Both
of these factors are pre-conditions for improved knowledge levels. Moreover, the
research itself addressed Ashton's (2004) call for broadening existing research into
professional consultancy firms although exploring how the organisation supported
learning was not the main focus of the research.

In practical terms the existence of such individuals with their capacity for faster,
innovative problem solving would prove attractive to many organisations. The
previous section discussed the difficulty for a larger organisation to provide an
appropriate platform. Nonetheless, there is potential for a blended learning
environment containing both "learning by participation" (Sfard, 1998; Felstead et al,
2005) and "learning by acquisition" elements (Ashton, 2004; Poikela, 2004) to
overcome this problem.

7.3.2 Learning Processes

In examining the different factors which influence the informal learning processes
that produce multidisciplined individuals, a number of significant points have arisen
that add to the literature in the wider sense.
As a cluster of communities surrounding the disciplines, professional societies and communities of practice (Lave and Wenger, 1991) are present in many other environments. This study will supplement the literature that is already available. The project teams inside this research do not remain together long enough to form a community of practice so that lens is not available to research. What has emerged from this research is further elaboration on the power that Communities of Practice can hold in the workplace. As well as the positive impact they can also prove detrimental in individual cases. They have a negative impact in terms of multidisciplinary development since they hold an “inward” looking aspect rather than facing outwards. This attitude can make it more difficult for individuals to find opportunities to develop across the disciplinary boundaries. Furthermore, although this research identified communities of practice as being detrimental to the development of multidisciplined individuals it would also be appropriate to add that any self-interested group would have the same effect.

Linking Threshold Concepts (Meyer and Land, 2003) and Troublesome Knowledge (Perkins, 1999) to informal learning processes adds a different dimension to the discussion. This linkage, with its emphasis on providing disciplinary insights as a way of opening up new knowledge has a very practical application since it points to different ways to handle knowledge transfer both in the workplace and inside training classes within industry.

This research also measured learning by participation, an aspect which was addressed earlier in detail in terms of generalisability. Notwithstanding the
relatively simple method used in the study it did demonstrate that informal learning could be measured.

Inside this research a questionnaire was utilised for the structured interviews to assess the additional learning of the participants. Participants were firstly invited to list out the tasks along the oil and gas value chain, and which were necessary for the completion of the range of projects the case organisation undertook. Following the structured interview itself the answers were collated. This process provided management with a snapshot of exactly where their current knowledge “gaps” lay in the workforce, Table 17. Although a very subjective view by the participants nevertheless, it accurately reflected the recruitment and development needs of the case organisation at that time.

Plotting accumulated knowledge and skills required by the organisation to complete its range of work versus existing staff knowledge is a different methodology for providing recruitment requirements than that most often used. In most cases, managers indicate where their gaps lie in terms of replacement of staff or simply requesting more of the same. By using the plotting methodology it is also possible to identify where training, either by acquisition or participation, should take place. Quantifying knowledge would prove a reliable tool to reinforce management judgement and could have practical applications for industry.
7.3.3 Project Teams

By examining project teams as a whole rather than the membership and roles inside the team, this research has been able to throw additional light into learning within teams. In defining the attributes belonging to different types of project teams, it has been able to identify the difference between an integrated interprofessional and integrated multidisciplinary team. This definition has highlighted the added value that integrated multidisciplined teams, with their capability to produce innovative metaperspectives, can bring to bear to problem solving. This may prove an appropriate mechanism by which to harness the power of these groups as suggested by the knowledge management literature.

7.3.4 Disciplines and Boundaries

This research was able to begin mapping the various disciplines being utilised inside the oil and gas industry. It also made attempted to gain an understanding of the nature of the disciplines involved. Oil and gas topology is usually only available at cost from training organisations that are able to offer training across the range. Organisations are often limited in the amount of disciplines they employ. For example service organisations may not employ any sub surface employees and consequently will be unaware of who and what they are. Consequently there may be practical implications in terms of being able to produce such a tool more generally.
In a wider context, the mapping of the knowledge domains with their accompanying disciplines, shown in Figure 29 as a diagram, enabled a three dimensional model to be built. This allowed for the development of greater insights into how individuals could be developed more readily across disciplines. For example, it is easy to see how the disciplines fit neatly side by side and allow individuals to move across readily to acquire expertise. It is less easy in terms of developing a "pathway" through the different disciplines for individual development, such as a chemical engineer becoming familiar with some aspects of reservoir engineering. The model makes these pathways more readily identifiable and may hold practical implications in terms of assisting staff development across or within organisations.

Interestingly enough, there is a wider movement to map the literature itself (Shiffrin and Borner, 2004) designed to understand the structure of knowledge and one consequence arising from this study would be to add oil and gas disciplines to that movement. In terms of the literature this research would serve to supplement the work being carried out by Becher (1989), Fforde (2005) and others to understand the nature of the disciplines and their boundaries.

The literature review pointed to four separate areas where this study could make a contribution: providing recognition for multidisciplined individuals, supplementing the informal learning literature, addressing Ashton's (2004) call for broadening existing research into professional consultancy firms and addressing the issue of measuring learning by participation.
7.4 Recommendations for Further Research

There are several interesting avenues which would warrant further research being undertaken to extend the findings here (Bryman, 2004:534) and which are listed below.

1. Although already discussed in terms of generalisability, how informal learning is measured merits further investigation. Focussing on more sophisticated methods of measuring informal learning both inside the case organisation and elsewhere would prove valuable. Understanding more about the stages an individual passes through in terms of learning would enhance learning opportunities inside the workplace.

2. Applying threshold concepts inside the workplace provides an opportunity to identify troublesome knowledge within a particular discipline or environment. If this knowledge is not apparent then the process of understanding what scale should be applied commencing with individuals simply being aware of where they fitted through to full competency can be determined by surveying the workforce using an approach similar to that used in the structured interviews inside this research. The survey would enable conclusions to be drawn as to what constituted troublesome knowledge. Subsequently, measures could then be readily introduced into the workplace to enable more rapid absorption of knowledge. This whole process may facilitate informal learning processes on a much wider scale.
3. Research into the way project teams operate has been, and still continues to be extensive. More recently, the focus has been on the actual learning processes, with examples available inside industries as disparate as the oil industry (van der Vegt et al, 2003) and the construction industry (Barrett and Sexton, 2005). One of the main points arising out of this research was the definition of the type of team that aided the development of multidisciplinary perspectives, both in terms of the teams and individuals. This could usefully be extended to a range of industry settings to ascertain the validity of the definitions in the wider world. This would enable organisations to identify the type of teams that they employed and thereby promote the growth of learning opportunities as appropriate.

4. Since this research is entitled “Multidisciplined Individuals: defining the genre” it is reasonable to question whether or not it has fulfilled this requirement. The contention here is that it has lived up to its title. It has determined their existence, identified the processes involved in their development and lastly, identified those characteristics that make certain individuals more predisposed to such development. What is not clear from this research is what happens to the individual’s core discipline. Is the knowledge and subsequent change to perspectives such that answers can only come from a single integrated base or is the individual still able to clearly answer from each disciplinary base. It has been suggested inside the data that the latter is the case but it is not clear and could form the basis for further research.
Summary

This research set out with the aim of determining the existence of multidisciplined individuals and how they acquire additional disciplines. The conclusions summarised the learning process as requiring the following components:

- Most significantly, organisations must be willing to "risk" the provision of such a platform within their operations;
- Project teams must be organised in such a way as to promote interaction between their members (Van der Vegte et al. 2003);
- The individual themselves must have what has been termed here an "adventurous" nature, namely be prepared to move out of their "comfort zone" (Bardwick, 1995; White, 2008); and, lastly
- The individual needs to possess, or be willing to acquire the fundamental abilities required when working across disciplinary or knowledge domain boundaries; for instance a geologist with an ability to cope with some level of applied mathematics or an engineer with a creative mind.

Furthermore, the learning process itself can be more readily understood in the context of the threshold concepts (Meyer and Land, 2003), which hold the potential to explain how the knowledge transfer process takes place inside the organisation between individuals.
As originally contented this work concludes that multidisciplined individuals demonstrate better methods of doing business, leading to both faster and more imaginative solutions, more frequently, and with significantly less effort. They offer scope for improvement to established processes by providing better solutions, speed and completeness. By establishing their existence and value in the case organisation this research seeks to bring wider attention to their value and to encourage industry to provide the appropriate environment for their development.
APPENDIX 1

History of the World Petroleum Industry

Key Dates

A chronological summary of some of the key events impacting the evolution of the world petroleum industry

**Ancient Historical References**

450BC  Herodotus described oil pits near Babylon
325BC  Alexander the Great used flaming torches of petroleum products to scare his enemies
100AD  Plutarch described oil bubbling from the ground near Kirkuk in present day Iraq
347AD  Chinese reported to have drilled holes in ground using bamboo to extract oil
1264  Marco Polo recorded visiting the Persian city of Baku, on the shores of the Caspian Sea in modern Azerbaijan, he saw oil being collected from seeps for use in medicine and lighting
1500s  Oil from seeps in the Carpathian Mountains in Poland was burned in street lamps to provide light in the Polish town of Krosno

**19th Century**

1801  First coal powered steam engine
1807  Streets of London lit by coal oil
1807  Geological Society was inaugurated
1814  Inauguration of the Geological Society in London on 13th November 1807 with 13 founder members
1818  One of the first wells that produced oil which was marketed was drilled near Marietta, Ohio, in 1814 (Hildreth 1833, p. 64). Well was actually drilled for salt water, the oil was a useless by-product which often spoiled the well. This Ohio well was almost 500 feet deep and produced about a barrel or so of oil per week, which was worth about 50 - 75 cents/gallon
1818  In southeastern Kentucky another salt well produced oil. It was known as the "Beatty Well," named after the owner of the land on which it was drilled (Shepherd 1988). The site is on the banks of the South Fork of the Cumberland River, and the well produced upwards of 100 barrels/day according to some reports. By 1820, oil from this well was being shipped to Europe as well as several other southern states. Thus the Beatty Well seems to be the first drilled well which produced commercial oil in North America
1816  Start of the US manufactured gas industry - the Gas Light Company of Baltimore
1821  First commercial natural gas production and use in Fredonia, New York - well drilled to 27' and gas piped through hollow logs to adjacent houses
1837  Charles Babbage conceptualized and designed the first computer
1849  Abraham Gesner developed a method for distilling kerosene from crude oil
1857  Development of the kerosene lamp - provided clean burning light
1857  First drilling of oil wells at Bend, northeast of Bucharest, on the Romanian side of the Carpathians.
1858  First oil well in North America at Oil Springs in Ontario, Canada
1859  Col. Edwin Drake struck oil 69ft below the surface of the ground in Titusville, Pennsylvania
1861  First recorded shipping of oil between countries - from Pennsylvania to London on the sailing ship 'Elizabeth Watts'
1862  de Rochas of France patented the four stroke engine
1863  J.D. Rockefeller founded an oil refining company in Cleveland
1878  First oil drilling at Lake Maracaibo, Venezuela
1879  Thomas Edison invents the electric light bulb
1882  Standard Oil Trust formed
1885  Oil discovered in Sumatra by Royal Dutch
1892  Standard Oil Company of Ohio broken up by Federal Regulators
1895  Extraction of bitumen from bituminous sand using hot water at Carpenteria, California
1895  Invention of combustion engine
1896  Henry Ford's first motor car
20th Century

1901  Spindletop gusher, blew out on January 10, 1901 near Beaumont in East Texas, drilled by Captain Anthony Lucas it heralded the birth of the Texas oil industry - Gulf and Texaco
1903  Wright Brothers first flight
1903  Ford Motor Company founded
1907  Shell (British) and Royal Dutch merged to form Royal Dutch Shell
1908  Oil discovered in Persia, Anglo Persian Oil Company formed (Later BP)
1910  First oil discovery in Mexico at Tampico on the Gulf Coast
1912  Alfred Wegener publishes Continental Drift Theory
1912  British Navy converts from coal to oil
1913  American Institute of Mining Engineers (AIME) formed standing committee on oil and gas (Branch later developed into SPE)

1914-1918  World War I, the first conflict where control of oil supply really mattered - needed for tanks, ships and planes. British Forces captured Baghdad in 1917
1921  Wright Brothers first flight
1921  Ford Motor Company founded
1929  Shell (British) and Royal Dutch merged to form Royal Dutch Shell
1931  First oil discovery in Mexico at Tampico on the Gulf Coast
1933  Alfred Wegener publishes Continental Drift Theory
1933  British Navy converts from coal to oil
1934  American Institute of Mining Engineers (AIME) formed standing committee on oil and gas (Branch later developed into SPE)

1939-1945  World War II - control of oil supply from Baku and Middle East played a huge role in the events of the war and the ultimate victory of the allies. Cutting off the oil supply considerably weakened Japan in the latter part of the war
1944  Casoc became Aramco (Arabian American Oil Company)
1948  Ghawar Field discovered in Saudi Arabia - the largest conventional oil field in the world (about 80 billion barrels)
1950  Aramco agreement with Saudi Arabia
1951  Anglo Iranian Oil Company nationalized
1954  Anglo-Persian Oil Company renamed British Petroleum
1955  Egypt nationalised the Suez Canal
1956  Suez Crisis - Britain, France and Israel attempted to regain control of Suez Canal
1956  Oil discovered in Algeria and Nigeria
1957  Nuclear Power
1957  First Society of Petroleum Engineers (SPE) Board of Directors Meeting was held on 6th October 1957
1959  Natural gas discovered in Groningen Field, Netherlands
1959  Harry Hess - Seafloor Spreading theory published
1960  OPEC (Organization of Petroleum Exporting Countries) founded in Baghdad - Saudi Arabia, Venezuela, Kuwait, Iraq, and Iran. *See end for current member countries.
1960's  Transistor based, smaller, faster and more reliable computers built

Consultants not much favoured by industry during 1960's

1962  Society of Petroleum Evaluation Engineers founded
1962  Society of Petroleum Evaluation Engineers formed
1963  Global seismological monitoring commenced under the 1963 Nuclear test ban treaty
1963  Molloy-Vine-Matthews scientific testing supports Seafloor spreading theory leading to the Development of Plate Tectonics
1966  Basin evolution and petroleum system
1967  Six day War between Israel and the Arab world, Suez Canal closed
1967  Great Canadian Oil Sands Ltd (later Suncor) began production of tar sands north of Fort McMurray, Alberta, Canada - first commercial production of the largest oil resource in the world
1968  Oil discovered on North Slope of Alaska
1969  Qaddafi seizes power in Libya
1969 Oil discovered in North Sea
1971 Libya, Saudi Arabia, Algeria and Iraq negotiate price increase from $2.55 to $3.45 per barrel
1971 OPEC Countries begin nationalising oil assets - Libya nationalizes BP concession
1971 US oil production peaked
1972 Iraq nationalizes Iraq Petroleum Concession
1973 Iran nationalizes oil assets
1973 Saudi Government acquired a 25% interest in Aramco
1973 Yom Kippur War - Egypt and Syria attacked Israel
1973 Arab oil embargo on oil exports to the US for siding with Israel in the Yom Kippur War - oil prices rise from $2.90 to $11.65
1974 (March) Arab oil embargo on oil exports to the US lifted
1974 Venezuelan oil industry nationalised
1975 First oil production from North Sea
1975 Institute of Petroleum Engineering formed, now the Energy Institute.
1977 Alaska oil pipeline completed
1978 Amoco Cadiz runs aground off French Coast
1979 First significant coalbed methane drilling by Amoco in San Juan Basin, USA
1979 Shah of Iran deposed, Ayatollah Khomeini takes power
1979-1981 Oil prices rise from $13.00 to $34.00
1980 Saudis bought out the balance of Aramco from US oil companies
1980 Iraq launches war against Iran
1982 OPEC's first quotas
1983 Development of Windows software
1984 Gulf Oil acquired by Chevron after a bidding war with Arco
1985 Microsoft Windows Version 1 released
1986 Oil prices collapse
1986-87 "Tanker War" between Iran and Iraq - destroying oil tankers in Persian Gulf
1988 Cease fire in Iran-Iraq War
1989 March - Exxon Valdez aground in Prince William Sound, Alaska
1991 January - Gulf War - Operation Desert Storm, Kuwait oilfields set alight
1991 SPE London office opened
1991 November - Soviet Union collapses
1991 UN resolution to allow partial resumption of Iraqi oil exports in "oil for food" deal.
1997 Qatar inaugurates the world's first significant liquid natural gas (LNG) exporting facility
1998 Google first incorporated
1998 50 year moratorium on mining and oil exploration in Antarctica approved
1998 BP announces plans to acquire Amoco for $46.2 billion
1998 Exxon to acquire Mobil for $75.4 billion
1999 Atlantic Richfield (Arco) acquired by BP Amoco
1999 US Sanctions against Libya lifted
1999 Total Fina and Elf Aquitaine agree to merge

21st Century

2002 Construction started on Bosphorus bypass pipeline bringing oil from Baku to the Mediterranean
2002 Conoco and Phillips
2002 (December) - Chevron-Texaco planning LNG receiving facility on Gulf Coast (800Mcf/d increasing to 1.6Bcf/d)
2002 (December) - National strike in Venezuela shuts down Venezuelan oil production
2003 (February) - BP to purchase 50% interest in TNK - the 4th largest Russian oil company
2003 Energy Institute formed as a result of a merger between the Institute of Petroleum and the Institute of Energy
2003 Talisman sells holdings in Sudan following pressure from civil rights groups
2003 (March) Iraq invasion begins - Baghdad taken April
2003 (April 9) - US take Baghdad
2004 (July) - US oil imports at a record 11.3MMBO per day
2004 (Oct 25) - Oil at a record price of $55.67 US per barrel on concerns over high demand and possible supply disruptions in the Middle East and damage on the Gulf Coast from Hurricane Ivan
2004 (Dec) - Renationalising of Russian oil industry continued with Rosneft acquiring the largest unit of OAO Yukos Oil Co. Yukos has been forced into bankruptcy due to non payment of taxes.
2004 Oil production in UK sector of North Sea declined by 10% in 2004

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2005 (Mar 31) - Oil briefly exceeds $58 US per barrel on continued strong demand and concern over supply
2005 (Apr 4) - Chevron-Texaco offer to buy Unocal Corp for $16.4 Billion
2005 (Apr) - Gulf Gateway Energy Bridge Deepwater Port opened - the first offshore LNG receiving facility and the first new LNG regasification facility to be built in the USA in 20 years
2005 (July 4) - First import of LNG to United Kingdom in 20 years as North Sea natural gas production declines
2005 (July 24) - Iran and Iraq sign a cooperative oil trading agreement
2005 (Aug) - Chevron Corp acquisition of Unocal Corp finalised
2005 (Aug 29) - Oil reaches $70.80 US per Bbl
2005 (Sept 19) - Natural gas (NYMEX) at all time high of $12.33 US on fears of new storm approaching Gulf of Mexico
2005 (Sept 23) - Hurricane Rita strikes Gulf Coast
2005 (Dec 13) - Natural gas price hits a record high of $15.65US/mmbtu in the United States
2005 (Dec 13) - Conoco Philips and Burlington Resources to merge in a deal valued at $35.6US Billion
2006 (Jan 1) - Russia attempts to penalise the Ukraine by blocking gas sales - the effort failed after a few days
2006 (Jun 23) - Anadarko Petroleum Corp offers US$21.1Billion for Kerr McGe Corp and Western Gas Resources Inc.
2006 (July 13) - Oil hits a record high of $78.40/bbl on New York Mercantile Exchange on supply and world political concerns - nuclear tensions in Iran and supply concerns in Iraq, Nigeria, Gulf of Mexico; missile testing by North Korea and flare ups between Israel and Lebanon
2006 (Aug 6) - BP to shut-in part of the Prudhoe Bay Oil Field, Alaska to replace corroded pipelines, resulting in accusations of poor maintenance procedures
2006 (Aug 18) - Mexico receives first shipment of Liquefied Natural Gas at its Altamira Terminal near Tampico in NE Mexico, LNG to be used for power generation
2006 (Sept) - Russia exerting nationalistic pressures on multi-national oil companies - Shell, Exxon and ConocoPhillips
2006 (Dec 18) - StatOil and Norsk Hydro to merge to create a $92.3Billion enterprise
2006 (Dec 22) - Gazprom to buy half of the Sakhalin-2 project from Shell and partners for $7.45Billion - continuing Russian efforts to have more control over their industry
2007 (Jan 8) - Russia turns off flow of oil through Belarus to Eastern Europe on accusations that Belarus was illegally taking their oil
2007 (Jan 8) - Venezuela planning to nationalise oil refineries
2007 (Mar) - European Union introduced new environmental regulations to reduce GHG emissions by 20% by 2020
2007 (Mar 23) - Oil prices rise on tension over Iran capture of 15 British soldiers reportedly strayed into Iranian waters. Released on 4th April resulting in oil prices falling back
2007 (Mar 27) - Venezuela deal with China National Petroleum Corp to export more oil to China instead of US
2007 (Apr 9) - GECF - Gas Exporting Countries Forum met in Qatar - a group of gas exporting countries led by Russia with plans to 'strengthen ties towards cooperation and stability in natural gas markets. - Possibly the start of an 'OPEC for gas?'
2007 (May 1) - Venezuela nationalizes part of oil industry by taking over operating control of oilfields operated by ConocoPhillips, Chevron, ExxonMobil, BP, StatOil and Total
2007 (May 31) - May LNG imports to USA highest ever at 3.18cfd. Compared to 2006 average of 1.68cfd
2007 (July 9) - StatOil and Norsk Hydro to merge
2007 (Nov 20) - WTI oil price futures hit a record close of $99.29US driven by supply concerns and weakness in the US dollar
2008 (Jan 2) - WTI oil price briefly touches US$100 per barrel for the first time driven by supply concerns and the weak US dollar
2008 (Mar 18) - Venezuela announces plans to price more of its oil sales in Euros to protect against the drop in value of the US dollar
2008 (Apr 8) - BP and Conoco Phillips announce plans to develop an Alaska gas pipeline - in competition to the previously announced plan led by TransCanada Pipeline
2008 (July 11) - Crude oil hits a record high over $147.27 per barrel on continued concern over supplies and the weak US dollar
2008 (July 23) - Alaska gives nod to TransCanada Pipeline to develop the Alaska Gas Pipeline.
2008 (Sept-Nov) - Global recession fears
2008 (Nov 18) - Saudi supertanker hijacked off Somalia

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2008 (Nov 20) - Price of oil drops below $50/bbl (see July 11, 2008)
2009 (Jan) - Oil price continues to slide on world markets
2009 (Jan) - Gas exports to Europe greatly reduced as a dispute between Russia and Ukraine causes a halt to gas exports through the Ukraine

Notes:

OPEC Member Countries: Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela

Adapted from @ http://www.geohelp.net/world.html
2nd May 2009

Crude Oil Prices 1861-2007

BP 2007 Statistical Review of World Energy
@www.BP.com 8th June, 2009
Appendix 2

GROUP INTERVIEW QUESTIONS

Phase 1  Group Interview Discussion Guide

1. What disciplines make up Earth Sciences? (this changed according to disciplinary discussion being held)
2. Are they ranked in any way?
3. How would you describe your discipline in terms of its qualities?
4. What knowledge areas lie on its borders, e.g. chemistry, biology?
5. Do they use the same language, data?
6. Single significant changes in the last 25 years, tools and/or knowledge?

Phase 2  Individual Interview Guide

1. Discuss choices that led to joining the organisation – start with career choice.
2. Explore disciplines within the organisation through projects. (This to include feedback on disciplines acquired from the group interviews)
3. Explore any problems in communicating with other disciplines/people.
4. Challenging, rewarding, discouraging projects or processes they have been involved with.
5. How do they feel they fit – what has their development process been? Has any particular experience (include software and industry development) contributed to that process?

These points were sufficient to promote discussion exploring all aspects of their working life – learning was the emergent process.
### Appendix 3 - Structured Interview Questionnaire

#### ALL ABOUT YOU

1. Who are you?

<table>
<thead>
<tr>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
</table>

Age ____________________________ years

Years of experience In Oil & Gas Industry?

- [ ] NOC
- [ ] Small Ind.
- [ ] Major
- [ ] Service Sector
- [ ] Consultancy
- [ ] Other

Please indicate type of organisation you joined from

- [ ] NOC
- [ ] Small Ind.
- [ ] Major
- [ ] Service Sector
- [ ] Consultancy
- [ ] Other

Have you previously worked in another industry sector?

- [ ] Yes
- [ ] No

If yes, please identify sector/type

How long have you been with this organisation?

What is your primary technical discipline?

<table>
<thead>
<tr>
<th>1st degree</th>
<th>2nd Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhD</td>
<td></td>
</tr>
<tr>
<td>Masters</td>
<td></td>
</tr>
<tr>
<td>First Degree</td>
<td></td>
</tr>
</tbody>
</table>

Qualifications

Other, please indicate

2. What do you belong to?

- [ ] Professional Memberships
- [ ] SPE
- [ ] PESGB
- [ ] AAPG
- [ ] Other

Are you chartered?

- [ ] Yes
- [ ] No

If yes, then what?

- [ ] Yes
- [ ] No

Involvement in Prof. Assoc.

If yes, indicate in what capacities

- [ ] Yes
- [ ] No

Other professional interests e.g. informal groups, networks?

- [ ] Yes
- [ ] No

Did you belong to these associations prior to joining target organisation?

- [ ] Yes
- [ ] No

Why are you a member?

(Tick as many boxes as necessary)

- [ ] Networking
- [ ] Development
- [ ] Opportunities
- [ ] Peer Recognition
- [ ] Research
- [ ] Social Activity
- [ ] Other
ALL ABOUT YOUR WORK

1. Working on Projects
   Approx. How many projects have you worked on in last 12 months?
   Average number of team members on those projects?
   Average no. of different disciplines on each project?
   Generally work on different projects with same people?
   Do you routinely travel on project work?
   Do you think that travel enhances team work?
   if yes, how?
   If no, why?
   Who would you regard as the Guru in:
   a) Your own discipline
   b) Generally

   What information sources do you use at work?
   Library
   Prev projects files
   Other staff
   Co databases e.g. RAPS
   Internet
   Other

   What do you like most/least in project work?
   Variety
   Short timeframes
   Working with different people
   Travel opportunities
   Cross section of industry
   Learning Opportunities
   Problem solving
   Lack of in-depth exposure
   Deadlines
   Other, please indicate

<table>
<thead>
<tr>
<th>Like Most</th>
<th>Like Least</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## 2 Experience working across disciplines

Please list your knowledge areas

<table>
<thead>
<tr>
<th>Primary Discipline</th>
<th>Secondary Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competent frequently</td>
<td>Can do but do not use often</td>
</tr>
<tr>
<td>work in this area</td>
<td>of this area</td>
</tr>
</tbody>
</table>

**Geoscience:**
- Exploration
- Production
- Geology
- Volumetric Estimation & Reporting
- Seismic Interpretation
- Geophysics

**Petrophysics:**
- Log Analysis
- Core Analysis

**Reservoir Engineering:**
- Classical History Matching
- Simulation
- Production Forecasting

**Petroleum Engineering:**
- Drilling
- Completion
- Workover
- Artificial Lift

**Development Planning:**
- Facility Design
- Flow Assurance
- Process

**Facilities:**
- Cost Estimating & Schedules
- Downstream:
  - Global Gas
  - Petrochemicals
  - Products
  - Refining
  - GTL/LNG

**Economics:**
- Review Production & Expenditure
- Analysis
- Cashflows
- Fiscal Modelling

**Strategy:**
- Acquisition & Investment
- Project Financing
- Strategic Advice
- Contractual Strategy & Advice
- Foreign Private Investment

**Expert Witness**

Was this knowledge acquired in the target organisation? [ ] Yes [ ] No

How?
- a) External training course
- b) Internal training
- c) Project work
- d) Other
If project work is learning due to:
(Tick all that apply)

No. of projects
Variety
Exposure to other disciplines
If other please identify:

Do you learn more as:

Team member
Project Manager
Reviewer

Any Additional Comments?

Thank you for your time
## Appendix 4
### Individuals Involved in Interviewing Phases

<table>
<thead>
<tr>
<th>Designation</th>
<th>Core Discipline</th>
<th>2005 Masters Interviews</th>
<th>Group Discussions</th>
<th>Individual Interviews</th>
<th>Structured Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Law</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>Economist</td>
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<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>C</td>
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<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>D</td>
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<td></td>
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<td>J</td>
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</tr>
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<td>1</td>
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</tr>
<tr>
<td>T</td>
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<tr>
<td>U</td>
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<td>1</td>
<td></td>
<td></td>
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<tr>
<td>V</td>
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<tr>
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<td></td>
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<td>1</td>
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<td>GG</td>
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<td></td>
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<tr>
<td>HH</td>
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<td></td>
<td></td>
</tr>
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<td>II</td>
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<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JJ</td>
<td>Economist</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>KK</td>
<td>Petroleum Engineer</td>
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<td></td>
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<tr>
<td>LL</td>
<td>Chemical Engineer</td>
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<td></td>
</tr>
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<td>MM</td>
<td>Geoscience</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>NN</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>OO</td>
<td>Geoscience</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PP</td>
<td>Geoscience</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Appendix 5 - Nodes Listing**

<table>
<thead>
<tr>
<th>Parent</th>
<th>Child</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Variables</td>
<td>Education</td>
<td>What was learned about individual education and how it might prove to be an influence on individual ability to cross disciplines</td>
</tr>
<tr>
<td></td>
<td>Historical Developments</td>
<td>Historical (political/economic) events driving organisation's ethos</td>
</tr>
<tr>
<td></td>
<td>Internal History</td>
<td>Technological change/factors that come into play</td>
</tr>
<tr>
<td></td>
<td>Professional Societies</td>
<td>Identification of drivers and how they have changed throughout the organisation's history</td>
</tr>
<tr>
<td></td>
<td>Individual categories assigned to selected individuals</td>
<td>Identify what and how Professional societies play in the organisation and learning processes</td>
</tr>
<tr>
<td></td>
<td>Chemical Engineering</td>
<td>Individual perceptions on professional societies</td>
</tr>
<tr>
<td></td>
<td>Facilities Engineering</td>
<td>To capture any consistency displayed across a number of individuals</td>
</tr>
<tr>
<td>Knowledg domains</td>
<td>Geosciences</td>
<td>Set of categories related to specific individuals and was designed to hold information they had provided and any other material (including comments from other individuals) that specifically related to that person</td>
</tr>
<tr>
<td></td>
<td>Mechanical Engineering</td>
<td>2 categories: one for comments related to the discipline scope and boundaries. Second category for comments relating to the nature of the domain</td>
</tr>
<tr>
<td></td>
<td>Petroleum Engineering</td>
<td>Ditto</td>
</tr>
<tr>
<td></td>
<td>Reservoir Engineering</td>
<td>Ditto</td>
</tr>
<tr>
<td></td>
<td>Economics/Law</td>
<td>Ditto</td>
</tr>
<tr>
<td>Learning</td>
<td>Formal Learning</td>
<td>2 additional categories for any comments concerning how these two disciplines fitted</td>
</tr>
<tr>
<td></td>
<td>Informal Learning</td>
<td>Examples of formal learning</td>
</tr>
<tr>
<td></td>
<td>Jargon</td>
<td>All related comments</td>
</tr>
<tr>
<td></td>
<td>Multidisciplinary</td>
<td>Examples and comments re the use of jargon inside the workplace</td>
</tr>
<tr>
<td></td>
<td>Overlapping disciplines</td>
<td>How this term is used and including all references</td>
</tr>
<tr>
<td></td>
<td>Peer relationships</td>
<td>Evidence of individuals possessing additional disciplinary expertise</td>
</tr>
<tr>
<td></td>
<td>Software/Hardware</td>
<td>Individuals perception of their colleagues</td>
</tr>
<tr>
<td></td>
<td>Prof offers</td>
<td>What developments and what effects</td>
</tr>
<tr>
<td></td>
<td>Business layers</td>
<td>Capture comments re learning opportunities provided by professional societies</td>
</tr>
<tr>
<td>Target Organisation</td>
<td>Communities of Practice</td>
<td>What processes supports the actual work of the organisation</td>
</tr>
<tr>
<td></td>
<td>Company ethos</td>
<td>Evidence of the existence (or otherwise) of communities of practice</td>
</tr>
<tr>
<td></td>
<td>Company Structure</td>
<td>What characterises the organisation</td>
</tr>
<tr>
<td></td>
<td>Company View</td>
<td>What is the structure and how is it run</td>
</tr>
<tr>
<td></td>
<td>Entry conditions</td>
<td>Capturing any internal or external perceptions of the organisation as a whole</td>
</tr>
<tr>
<td></td>
<td>Individual</td>
<td>Comments about what it takes to get into the organisation and how that requirement may have changed over the years</td>
</tr>
<tr>
<td></td>
<td>Project Life</td>
<td>Any comments re individuals and their roles</td>
</tr>
<tr>
<td></td>
<td>Status</td>
<td>comments re working inside projects</td>
</tr>
<tr>
<td></td>
<td>Travel</td>
<td>Comments re perceived status of individuals</td>
</tr>
<tr>
<td></td>
<td>Teams</td>
<td>Comments re any learning opportunities in this activity – captured in excel spreadsheets separately</td>
</tr>
<tr>
<td></td>
<td>Comments</td>
<td>Comments re multidisciplined teams</td>
</tr>
</tbody>
</table>
Appendix 6
Sample Population Profile

In order to give flavour to the data this Appendix sets out the background to the individuals that formed the sample population, who were drawn from the technical staff within the case study organisation. The individuals themselves are a mix of nationalities with the majority being drawn from the UK but there are three Americans, three Venezuelans, two Australians, an Iraqi, an Iranian and a person from South Africa. Although cultural backgrounds have not been part of the research itself this does mean that to some extent that the individual's background culture is immaterial to this particular research. Below follows details of age, sex, educational qualifications, prior experience and length of experience.

1.1 Age:
The average age of the sample is 50 with the youngest participant aged 24 (O0) and the oldest participant aged 76 (K). The majority of staff (45%) are in the 40 years and over groupings, reflecting the organisation's requirement to provide "expert opinion" to its client base.

<table>
<thead>
<tr>
<th>Age</th>
<th>No. of Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-30</td>
<td>5</td>
</tr>
<tr>
<td>31-40</td>
<td>3</td>
</tr>
<tr>
<td>41-50</td>
<td>8</td>
</tr>
<tr>
<td>51-60</td>
<td>19</td>
</tr>
<tr>
<td>61-70</td>
<td>3</td>
</tr>
<tr>
<td>70+</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>41</td>
</tr>
</tbody>
</table>

Table 6.1: Population: Age

1.2 Sex:
The oil and gas industry is male dominated with females only forming 21% of the UK oil and gas industry workforce (Williams, 2009). This dominance is reflected inside the gender makeup of the case study organisation with 90% being male.
1.3 Education:
The 41 participants in the study had collectively 68 degrees together with a further 2 higher education awards.

Table 6.2: Population\text|: Education

1.4 Experience:
The organisation's reputation for quality and depth of expertise is a significant factor in attracting individuals to the organisation which is borne out by the range and length of experience of the technical staff employed. The knowledge database represented by the sample population represents a total of 1,032 years of experience within the oil and gas industry. Individuals average 25 years experience with experience inside the industry ranging from plus 50 years at the top end of the scale to 1 year at the lower end. That experience is drawn from all sectors of the industry, Table 6.3. The majority of staff (40\%) derived their original experience from the major independent companies who are engaged in finding, producing and selling hydrocarbons such as Shell and BP. These organisations provide operational experience of the reservoirs which is not available inside the organisation.
Industry Sector | No. of Staff
--- | ---
National Oil Corporations (where a Government wholly or partially owns the organisation) | 5
Major Independent Companies | 16
Small Independent Companies | 3
Service Sector | 6
Other Consultancies | 5
Other Industry Sectors | 1
F/T Education | 4

Table 6.3: Population – Previous Employment

1.5 Organisation - Service:
The average period of service with the organisation was 10.7 years; however a substantial proportion (34%) had much longer service. It was common for individuals to leave, and then later rejoin the organisation. Within the population there were four cases of this; in one of these the individual had rejoined three times. Rejoining the organisation often occurred after a period of operational experience designed to update the individual’s knowledge of practices and technology. Individuals also indicated that they returned because they enjoyed both the work undertaken by the organisation and its working environment. In the same vein, individuals retired from full time employment with the organisation but stayed as part-time consultants. There were two such cases included in the research.

In terms of the graduate intake, although there had been many graduates employed over the years, all but one had left after the initial three plus years although there were instances where they had rejoined the organisation after gaining different experience. The decision to move on is driven by the need for “operational” experience, which is often difficult for a consultancy to provide, and is necessary for career progression in the wider industry. The one graduate who did not leave (F) was still employed by the organisation some 34 years later being generally regarded as one of the best examples of a multidisciplined individual within the case study organisation.
Appendix 8

Research Base

Other sources of information inside the case study organisation were the Library, previous project files, various internal databases, other staff and the internet. The chart below indicates that the Library was the least used facility by staff and the internet the most extensively, although clearly consulting with other staff was a major source of information.

<table>
<thead>
<tr>
<th>Library</th>
<th>Project Files</th>
<th>Internal Databases</th>
<th>Staff</th>
<th>Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal</td>
<td>Frequently</td>
<td>Extensively</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8.1: Information Sources

The Library

The organisation's Library facility offers the same functionality as any other library. It houses books, journals and reference material dating back to the 1960's and
provides subscription and circulation facilities to staff. More recently there has been a significant increase in the amount of electronic subscriptions which are stored on a central server and available across the organisation. The Library also undertakes internet and other searches on behalf of the staff and projects. As indicated in the table above the facility is widely used by staff on a routine basis. The Library also has access to many of the proprietary databases and the existing project files, so staff may request these items via the Library. This indicates that in fact individuals may be accessing project files and other sources more than is indicated in the table however the general trend will be sufficient for the purposes of this discussion.

**Previous Project Files**

Project files and associated data are kept by the organisation for at least 10 years and in many cases for considerably longer. The exception to this is data that the clients require either returning or destroying following completion of the work. Copies of all reports produced from completed contracts and which date back to the organisation's early days are kept and many are available electronically as well as in hard copy. This provides the organisation with historical data on many of the major international fields which can be of considerable importance if sourced appropriately. Although past project files can be accessed and referred to there are associated confidentiality issues attached to the material which prevent extensive use. Staff review files to understand the client relationships and to refresh knowledge on a particular reservoir or operations, but it is not an automatic source of information.
Internal Databases

In addition to the in-house developed databases which have a restricted use there are also a number of proprietary databases in use. These databases cover a wide spectrum of information ranging from proprietary information covering economic, financial, geological and other technical information to various in house built packages providing details on all previous projects, presentations etc. Since the proprietary databases are specialized, their use is dependent upon discipline or project type rather than a matter of individual preference. Table 8.1 indicates less use of these sources but this may be somewhat misleading since some staff use the library to undertake the searches rather than spend time researching themselves.

The Internet

Increasingly since its launch in 1998 and, in common with many other industries, staff access "google" using it as a significant information source. Table 9a indicates that it is the most extensively used information resource inside the organisation. Staff confirmed that it had superceded the conference papers and proceedings that were previously necessary to keep up to date. In addition to this there are a number of industry specific sites which were mentioned during the interviews provided by a mix of professional societies and journals among others. During the interviews it became clear that the face to face contact with other staff is decreasing as more people become familiar with searching tools and methods.
Examples given related to understanding terminology used in reports, maps etc.
Instances where there are quick answers to the questions.

Other Information Sources:

There are a number of reports which appear on a daily basis which provide financial information in respect of the projects. These documents indicate budget, budget spent to date, invoicing etc. and all project managers are circulated with details of their specific projects to enable better project planning to take place.

In addition to the various forums outlined above the organisation also held a number of “lunch and learn” sessions which provide information on a number of differing subjects, e.g. explanations of various projects being worked on, technical and office software packages, introduction to technical skills such as petrophysics, ISO 9001:2008. In addition to this, staff who have given presentations to clients and at outside conferences will repeat them in-house to benefit all staff.

All of these different sources provide a pool of information upon which the staff can draw upon to supplement their knowledge and skills. In addition they are provided with details of the organisation’s activities so that they can feel more engaged with their environment.
LIST OF REFERENCES

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375


378


381


382


McLeod, J. (2009) 'Where are the Women in Oil and Gas?' Available at Offshore-technology.com, (accessed March 2009).


Multidisciplined Individuals
Defining the Genre

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Plymouth Business School
University of Plymouth
ABSTRACT:

My research concerns itself with the development of multidisciplinary expertise within a project based organisation operating within the oil & gas industry. Informal learning has attracted significant research attention in recent years especially in respect of the social interaction theories such as Communities of Practice (Wenger & Lave, 1991). Although there is a substantial body of literature in many of the areas covered by this research there is little which addresses this particular research focus.

As a consequence of the lack of appropriate literature it became necessary to change the research strategy adopting Grounded Theory (Glaser & Strauss 1967) being more appropriate. The ability to identify and scope out areas for investigation which grounded theory provided enabled the scope and direction of the research to be established. Further, identifying the key elements within the working environment and how they interact to provide the learning environment will enable the appropriate explanatory concepts to be developed from the data.

The intention of this paper is to discuss the difficulties encountered with the research to date and how determining the appropriate research strategy addressed these.

Keywords: Multidisciplinary, multidisciplinary individuals, communities of practice, knowledge domains, learning
INTRODUCTION:

The need for further research to augment existing literature which has not yet been "sufficiently envisioned, embedded and evaluated in the context of small, project-based firms to form a robust, grounded body of innovation knowledge in its own right" (Barrett & Sexton 2005, p.14) is widely acknowledged (Zakarian & Kusian 1998; Van Der Vegt & Bunderson 2001; Gann & Salter 2000). This research is seeking to make a contribution in this area in respect of the development of multidisciplinary expertise by individuals within project teams.

The following sections set out to familiarise the reader with the research by giving some detail on its background and context. It then moves on to review current literature discussing identified themes and areas where the literature is lacking or fragmented. The remaining sections of the paper discuss steps taken to address the inadequacies including the decision to change research strategy. Finally it will outline the research aims and objectives moving forward.

1. BACKGROUND AND CONTEXT

In the workplace individuals are often defined or 'labelled' by the knowledge domain in which they work, e.g. geologist, reservoir engineer. Generally individuals strive to obtain status and recognition from increasing excellence inside their knowledge domain. Nevertheless there are individuals who have the capability to expand their arena of expertise to incorporate one or more additional disciplines or areas of interest. In fact they wear more than one label – they are multidisciplined individuals! They have acquired the ability to work across the disciplines not through formal education/training but from their work experiences.

Such individuals have a number of advantages in resource constraint environments. They have an enhanced ability to achieve more with less combined with a more rounded view of the world enabling them frequently to put together more practical solutions across a broader range of problems. In addition, they often have an added confidence in their core discipline as the individual is boosted by acquiring additional expertise. These attributes add value for the employer since they become a source of creative problem solving and assist by differentiating the organisation in recruitment and retention of staff.
Multidisciplined individuals "provide a greater pool of folk who understand the broader aspects of the business from which to draw future leaders". (Gaffney 2007).

The research is set within the context of the Oil & Gas industry. Subject to rapidly changing economic, political and environmental impacts this sector is driven by the cyclical nature of its business; increasing complexity of applied technologies; changing educational approaches from generalist to specialist and back; changes in the size and nature of the companies and increasingly dominant, a critical shortage of manpower due to reductions during down-cycles or pressures during up-cycles such as the current one.

2. INITIAL LITERATURE REVIEW

The original research strategy to be applied to this research was that of a case study. Case studies allow for the researcher to gain an understanding of the processes at work within a limited environment and are "a worthwhile way of exploring existing theory" (Saunders 2003, p. 93). Having previously completed a Masters Degree dissertation on the same theme (MAPD 2005) it was initially thought that the major themes to be researched would emerge from the literature review with comparative ease. However, this proved not to be case and the review became more wide ranging and time consuming than it might have otherwise have been in the effort to find appropriate material.

The literature review commenced with the requirement to define the meanings to be applied to certain terms used within the research as closer investigation had revealed a number of differing meanings applying to the same terms. The themes of boundaries and the role they play; various types of communities and learning processes were also explored and are discussed in more detail in the following sections.

2.1 Definitions

This research is principally about exploring the concept of what people do at work which has meant defining a wide cross section of the terms used. This process is described within the research as labelling since labels "classify, define, describe, designate, identify, name" (Collins Thesaurus 1992, p. 256). Labels are often a convenient way to group a bundle of different ideas and act as great communication devices. However the very act of labelling creates a variety of expectations about what the label should or should not contain and this creates difficulties. Often, particularly in the case of abstract ideas, closer
inspection reveals imprecision or misunderstandings as to the actual mechanism, process or idea which the label is conveying. Examples are discussed in the following sections.

2.2 Multidisciplinary – Meanings and usage

There appears few attempts within the literature to apply the term 'multidisciplined' to individuals apart from references found inside computer expert-systems literature, e.g. Alford (1999) typically the term is more commonly applied to teams. It also became apparent that a variety of different terms are used both in academia and industry to describe teams utilising a selection of individuals drawn from differing disciplines. Most commonly the terms 'inter' and 'multi' are used as though they are interchangeable. Wilson & Pirrie (2001) attempted to distinguish between the various terms on the basis of among, between and across the disciplines finally settling on ‘inter’ to describe teams capable of producing different perspectives which combined knowledge from all disciplinary backgrounds. Two years later Housley (2003) used the same reasoning for using the term 'multi' to fit such teams. Given this contradiction it became increasingly important that a specific meaning be applied to the word in the context of the research.

'Multidisciplined' rather than any other term was favoured for use research on the following grounds:

- Kline (1995) suggested that multidisciplined thinking enabled the concept of emergent ideas to apply to creativity;
- Multidisciplinary teams are frequently attributed with the ability to produce metaperspectives which enable increased creativity (Belasen 2000)

Both points attribute the quality of creativity which is generally deemed to be the main feature of multidisciplined working and which should be associated with individuals who develop additional expertise across the disciplines.

2.3 Project Teams

The focus here is on the sharing and learning processes which may or may not be present within project teams. In terms of how project teams work together Øvretveit (1997) produced a continuum based upon how closely team members interact and it is a useful mechanism to chart interaction between members recognising that the knowledge transfer
process requires this condition to be present. At one end of the continuum sits those teams where there is no interaction; their nature being more in the way of groups with something in common. At the other end, team members share and interact routinely to achieve their goals. It is teams operating at this latter end of the continuum which provide the ideal learning situations for their members. The research fixed upon ‘integrated multidisciplined’ as the appropriate term to describe such teams. It soon becomes apparent that there are many teams described as such within the literature and industry publications but very few which contain all the building blocks necessary for learning to take place within the team.

Significantly, fully integrated teams are those teams which are recognised as being the most successful in terms of creativity (Pence & Wilson 1994; Masters 1990; Grigis et al 1995). In multidisciplinary teams this creativity is further fuelled by the ability of individuals within the team to combine knowledge across the disciplines to produce new perspectives (Belasen 2000) and it is this ability that enhances the personal development of the individual within the team (Hackman 1990).

2.4 Learning in the Workplace

“Learning on the job" is a familiar, everyday term and yet closer inspection surprisingly reveals a complex and uncertain structure. It is clearly deemed to be the poor relation in terms of education: inferior to formal education/training (Smith 1999); the least understood (Livingstone 2003) and there is confusion within the literature as to what it really consists of (Colley et al 2002).

Styhre (2006) suggested that workplaces are packed full of learning material which has been catalogued in various ways to understand how the individual makes use of it in the last forty or so years. Various writers (Polanyi 1962; Blackler 1995; Nonaka & Takeuchi 1995) have catalogued material based on the nature of the information. Significantly Yanow (1998) took a different approach separating theory from practiced based information allowing for the development more recently of the social interaction learning theories. This approach effectively separates ‘learning’ from ‘knowing’. Poikela (2004) highlighted the thorny question of when does knowledge become knowing suggesting that only once knowledge was placed inside the right context; a view reversed by Nicolini (2003) who argued that knowledge is what you are taught through formalised training and everything else is learning.
Differentiation between theoretical and practical knowledge (Yanow 1998; Contu & Wilmott 2003) has allowed for the development of social interaction theories which seek to explain in depth what "learning" in the workplace consists of and how such learning takes place.

Exploring 'labels' confirmed the confusion of ideas surrounding certain terms making it necessary to define precisely the meanings to be attached to the terms 'multidisciplinary' and 'integrated multidisciplinary teams' within the context of this research. However, a closer review of learning within the workplace did not produce any clarification on learning processes revealing instead a number of alternate theories as to what might be taking place.

2.5 Knowledge domains and Boundaries

Boundaries are utilised within knowledge domains to separate out the individual domains but they also occur in team, communities of practice and organisational literature.

The challenge within the disciplines is the constant change created by the growth of knowledge itself; disciplines are created, expand and then, in many cases, are mutated or superseded as the body of knowledge grows with traditional boundaries becoming confused over time e.g. engineering. Looking more closely at the boundaries between the disciplines, in addition to separating out the work they allow for differing research traditions (Sil & Doherty 2000). Contrary to Kline (1995) and Housley's (2003) arguments that increasing specialisation is detrimental to the development of ideas there is a strong case made for their retention and maintenance since:

- they act as containers of knowledge (Brown & Duguid 1994);
- they create closed communities of self interested groups clustered around and promoting the development of a specific knowledge area (King & Brownwell 1966; Toulmin 1972; Fournier 2000)
- Given this, boundaries must be maintained and defended with vigour (Rushmer & Pallis 2003) although it is recognised that some disciplines are more robust in defending their borders than others.
Closer examination of the evolving disciplines and their boundaries makes it apparent that the boundaries and overlap areas between the disciplines form a fertile ground creating new ideas and innovations, encouraging the growth of new disciplines and forming a rich learning environment for individuals, (Wenger 1991: Holbeche 2005).

It is possible to 'map' the disciplines to gain an understanding of how they fit together and where the disciplinary boundaries lie. Two different ways of mapping were found within the literature. Firstly a la Becher (1989) charting the disciplines by how they were utilised (in this study from reserves extraction through to refinery processing) which allowed for an almost one dimensional picture showing basic discipline groupings to emerge. These groupings provided an understanding of where overlaps might occur and, as with any map, highlighted the distance and consequent remoteness between other disciplines.

The second method based upon how the information flowed through the disciplines (Levorsen 1987) provided a more complex, multi-layered picture to emerge highlighting the lack of interaction between certain disciplines in the process.

2.6 Organisations

The review incorporated a brief discussion on 'learning organisation' (Senge 1990) and business organisations particularly post modernist organisations (Burrell & Cooper 1988) where traditional hierarchal boundaries have largely disappeared. The review focussed on organisations employing professionals and having those special characteristics stressed by Bucher & Stelling (1996) of 'collegiality, peer evaluation and autonomous, informality, and flexibility of structure'; all qualities of the target organisation.

Different types of boundaries were found in Richard McDermott's (1999) view of organisations which consisted of Communities of Practice and utilised cross disciplinary teams terming them 'Double-Knit organisations' because of the learning loops called into play by the combination. Barrett & Sexton (2005) conducted research into small project-based firms in the construction industry in an attempt to add to the available theoretical and practical insights into project based organisations and within this were able to identify workers who were 'infinitely expandable in terms of their skills and abilities and the ways in which these may be deployed', (2005, p.10) thereby emphasising the major strengths, that of functional flexibility and innovation, of such organisations.
Boundaries within the context of this research are fascinating places being utilised to control and defend territories within knowledge domains while at the same time full of opportunities for development, growth and creativity at the individual, organisational and corporate level and promoting the development of multidisciplinary individuals.

2.7 Communities

A discussion on knowledge domains noted how communities were created around them providing for long term, deep seated behaviour patterns among individuals (Neuhauser 1988: Kline 1995: Becher 1989) and providing both status and a sense of belonging. Social interaction learning processes in the form of Communities of Practice (Wenger 2000) are included both for their immense learning potential and also as they act as a containment mechanism for the discipline itself. Wenger uses Communities in the learning context however there are similarities to earlier writings in the same vein e.g. Fleck (1979). Communities of Practice attract criticism because by their very nature they can become introverted (Gummesson 1991) and are subject to peer and internal power pressures (Contu & Willmot 2003; Boud & Middleton 2003). It was recognised that sharing does not come easily to every individual and as such these communities may actually be hostile environments (Contu & Willmot 2000).

2.8 Learning

In thinking about the acquisition of additional and different discipline expertise it is clear that somewhere in the process learning forms a major component and previous research pointed to the learning available within project teams. The review looked at communities of practice as discussed above but also covered other social interaction learning theories and considered a number of alternatives.

The social interaction theories presented together at the Academy of Management, San Diego 1998 reveal a number of different ways to view ‘learning’ at work. There are four main theories; situated learning or communities of practice (already discussed), interpretative-cultural, cultural and historical activity and sociology of translation better known as the actor network theory. Although focussing on different aspects of learning they share common themes relating to language (Wittgenstein 1953), meaning of objects (Engeström and Blackler, 1995) and peer relationships (Vgotsky 1978).
Social interaction theories are gaining ground rapidly with the Communities of Practice perhaps the most popular. Major criticisms levelled at these four theories include Ashton’s (2004) point that the underlying research was based largely on specific groups of people, e.g. Erault studying professional staff only or, in the case of Communities of Practice, that it has moved away from its original stance to become no more than a management tool.

Among the alternatives considered were Kolb’s (1984) well known experiential learning cycle based on learning by experience and reflection. This work formed the basis of later work by Nonaka & Takeuchi (1995) which emphasised sharing actions, experiences and information as being fundamental to the learning process.

The work of Meyer & Land (2003) looking into threshold concepts and ‘troublesome’ knowledge is particularly interesting as they used the approach of changing an individual’s perspective to open up to new or previously hidden ideas. This area has previously been explored by other writers (Engeström 1994; Brookes 1994; Tillema 2005) and these concepts hold the potential to be viewed as stepping stones between spontaneous learning and the deliberate acquisition of expertise on the part of the individual. These two points represent the opposite ends of Erault’s (2000) continuum which noted that although the individual may have no intention to learn there is always an element of spontaneous learning present.

Clearly this is not a ‘one-way street’; the individual has to be interested in the interaction and subsequent learning but also that the environment be such that knowledge domain interaction takes place thereby creating a learning environment – a point not highlighted enough in the literature. As far as the individual is concerned it may simply be a case of the individual’s willingness to share information, to listen and learn from colleagues and then explore the concepts further on his own. This may also mean perhaps having the courage to move away from the traditions of their own discipline if necessary.

Having reviewed the findings of the literature review the next section discusses in more detail the weaknesses identified and how this changed the research strategy.
3. RESEARCH AIDS/METHODOLOGICAL ISSUES

Initially it was thought that an inductive case study approach would prove suitable to the current research but on seeking to extend the literature review from the team/learning approach it had previously taken it became apparent that the literature from the individual's perspective was diverse, inconclusive and sometimes totally lacking. To illustrate the lack of appropriate literature examples can be found in "teamwork" where focus is placed on interpersonal skills, roles a la Belbin (1981) or into promoting team work itself. Another example is Øvretteit (1997) who attempted to get to grips with how teams actually function but still not really identifying where the learning opportunities were focussed and how the individual can best take advantage of these opportunities.

The inconclusive nature of the literature meant that there was little guidance provided as to what would mostly likely prove to be key elements and how such elements may possibly interact with each other. Lack of guidance proved challenging in terms of attempting to scope out the research framework. In attempting to surface the individual perspective the initial thought was to look at such areas as multiple intelligences (Gardner 1983), creativity (Sternberg 1985), personality/trait theory (Eysenck 1991; Pinker 1998) and indeed the various, and multiple motivational theories e.g. McGregor 1960; Alderfer & Smith 1982; Shamir 1991.

It soon became clear however that investigating the predisposition/personality traits of individuals would not prove particularly constructive since if the discussion was focussed more on the individual's particular qualities all that would be necessary would be a list of traits/characteristics that a potential multidisciplined individual should possess. While there is already a substantial body of literature on competencies and traits as well as in the theory connected to team working none relates to what it takes to make a good multidisciplined individual. Even if there was some predisposition on the part of the individual the environment itself must allow for multidisciplinary growth.

The requirement to develop themes more in keeping with the focus of the research within the target organisation itself rather than within the literature pointed to the adoption of the grounded theory approach (Glaser & Strauss 1967: Strauss & Corbin 1998). An additional consideration is that many of these areas already have a substantial literature available and grounded theory will allow for "theoretical speculation [which] can be a fertile source of
ideas for practicing researchers seeking original ways of looking at problems that otherwise seem old and worn”, (Seale, 1999, p.87).

It is more usual within the grounded theory for data to be collected and coding commence from the beginning of the research with reference to the literature as required. Although literature searches can “enhance, rather than constrain theory development” (Strauss & Corbin 1998, p.49) there is danger here that having done an extensive initial literature review and adopting grounded theory as a strategy at this late stage the review may prejudice the researcher’s openness in interpreting the data. This will have to be taken into account in moving forward in this particular research.

Having discussed the requirement for grounded theory the following section looks at what this meant in practical terms for the research.

4. INITIAL STEPS

The initial steps following the change in research strategy was to look to the target organisation to provide the scope and direction for the research. The first question centred on what specific working practices of the target organisation allowed for and promoted multidisciplinary development? Isolating common activities and requirements into distinct areas would enable more precise data to be collected which may then surface how influential a role the activity/requirement plays in whatever process may be taking place.

In order to address this question it was necessary to firstly determine what common qualities/attributes new recruits brought with them before moving on to establish the common elements within the working environment. These elements can be summed up as follows:

a. Education/Experience: staff are either highly educated holding one or more degrees or had significant experience in their core disciplines/skill sets.

b. Project involvement: working inside project teams or significant involvement with the teams.

c. Professional Societies; belonging to one or more professional associations with a significant number actively participating at regional, national and international levels.

d. All staff exposed to the company ethos/structure.
An open environment where professional staff are encouraged to take an interest in any field and pursue it inside a project environment in the appropriate environment of team leaders and colleagues.

From these basic requirements it was possible to scope out an outline framework for the study which can then be refined as more data becomes available. With hindsight it is clear this framework might have been reached much earlier in the investigation had the grounded theory approach been adopted earlier. The data itself may well have indicated at least the initial coding and allowed for cycling between the literature and data as the themes developed.

It should be noted that the controlling or environmental elements identified so far may not prove to be the main, or even the only, factors involved in multidisciplinary development. The review had been by necessity wide ranging and it is acknowledged that there are a number of significant aspects which have not been addressed in the detail and which may ultimately be required e.g. problem solving, which in itself contains a significant body of literature.

Having set out the background to the research the next section looks at the aim and objectives of the present research and its current status.

5. RESEARCH AIMS AND OBJECTIVES

Within this framework of everyday, well researched areas the work of Lewes (1875), Goldstein (1999), and Corning (2002) among many writers exploring the concept of emergent properties is useful as a different perspective. Emergent properties arise from a number of different processes/elements which when working together allow new and more complex properties to emerge e.g. the worldwide web, stock market, elections. Taking this further, although there are a number of very common features to be found in the target's working environment the specific combination/interaction of these features may allow for new properties to emerge which will assist in explaining the multidisciplinary development process.

Given the discussion above the initial research objectives are as follows:
• Identify and describe the disciplines utilised within the target organisation, map the disciplinary boundaries and describe their culture.
• Investigate the nature of the interaction between key features within the working environment to identify which situated learning processes may be present.
• Explore and assess the role of professional associations and any communities of practice identified within the working environment to better understand their affect upon the individual.
• Determine if any emergent properties arise as a result of data gathered and if so, describe their nature.
• Develop an explanatory theory that could be utilised on a wider scale.

Initial coding has already commenced using data (written records) from the target organisation and secondary data in the form of interview material obtained during the previous Masters Degree research. A mix of methods including semi-structured interviews, questionnaire and participative/observer on actual projects will be utilised in the next months as fieldwork is carried out.

SUMMARY

This research concerns itself with multidisciplined individuals, i.e. specialists who acquire additional expertise across the disciplines within their working experiences. The literature revealed little or very limited material directly related to multidisciplinary individuals although each of the elements identified so far has a significant literature behind it. This lack of specific material created initial problems in a choice of research strategy which have now been resolved by the adoption of the grounded theory approach.

The most outstanding feature of the literature review is the lack of clarity behind commonplace words e.g. multidisciplinary, team processes, informal learning and the requirement to establish the meanings to be applied to such words and processes within this research. This precision is necessary since such ‘labels’ bundle together a number of differing meanings. These meanings are usually general in nature and have evolved over time and across a number of areas within the literature e.g. communities as in social development, within knowledge domains and in social interaction learning theories.
Multidisciplined Individuals hold a number of advantages in the workplace in terms of flexibility and creativity but the processes which produce such individuals are not understood and this study seeks to make a contribution towards filling that gap in the literature.

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