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*Collaboration in Scientific Research: The Views  
and Practices of Researchers in the College  
of Sciences, Massey University, Turitea  
Campus. A Case Study*

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## ABSTRACT

Collaboration in scientific research has been increasing steadily for the last thirty years and it now characterises scientific research world-wide. New Zealand is part of this trend and this study looks at the collaboration in scientific research in one tertiary institution in New Zealand. As a mixed methods study it incorporates a survey of researchers and a number of semi-structured interviews. The researchers who participated in the study cover the full array of science disciplines and range in experience from early to late career researchers. Information on the institutional context has been gathered from the university's key strategic plan, *The Road to 2020*, and from an interview with the Assistant Vice-Chancellor, Research & Enterprise, and the perspective of the funding agencies comes from interviews with senior officers of the four main research funding agencies. The findings suggest that researchers collaborate for a variety of reasons: for personal reasons because they enjoy working with others; for tactical reasons to increase the probability of getting funding; but overall they collaborate to get better outcomes. The funding agencies promote collaboration for quite different reasons. For them it is a mechanism to promote quality, to augment the science sector, and to ensure that New Zealand researchers can work with the best that the world has to offer. New Zealand researchers are members of an international community of scientific researchers and are active participants in what Martin Lord Rees calls the "*unending quest of science; as its frontiers advance, new mysteries come into focus just beyond those frontiers*" (p. 469, 2010). Just as the quest of science continues, the quest for understanding how "science is done" and finding new ways of "doing science" continues. Collaborating in research is one of those 'new ways' and whilst collaboration is now ubiquitous, the process of collaboration has not received a great deal of attention in the literature. As resources become leaner and demands for accountability stronger, there is a renewed interest in areas such as research competencies, the initial training of researchers and subsequent professional development, the composition of a research team, leadership of research teams, and management of research projects. This thesis concludes with a set of recommendations for researchers.



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## **CHAPTER ONE: INTRODUCTION**

No one can really feel at home in the modern world and judge the nature of its problems and the possible solutions to those problems unless one has some intelligent notion of what science is up to. Furthermore, initiation into the magnificent world of science brings great aesthetic satisfaction, inspiration to youth, fulfilment of the desire to know, and a deeper appreciation of the wonderful potentialities and achievements of the human mind.

(Asimov, 1987, p. 25)

Collaboration among scientists and professionals with diverse expertise and backgrounds is required to address today's complex problems.

(Bermudez, Agutter, Foresti, Westenskow, Syroid, Drews, & Tashjian, 2005, p. 282)

### **1.1 Introduction**

Throughout the last thirty years globally there has been a steady rise in collaborative approaches to scientific research (Corley, Boardman, & Bozeman, 2006; Frenken, Hölzl, & Vor, 2005; Porac, et al., 2004), as illustrated in a study by Adams, Black, Clemmons, and Stephan (2005) of 2.4 million scientific papers written in 110 top U.S. research universities over the period 1981–1999, which showed that teams of researchers have largely replaced independent researchers, and over that same period, team size has increased by 50%. However, despite the volumes of research undertaken on searching for the reasons for this increase, our understanding of the social and process dynamics of scientific research collaboration is far from complete (Bozeman & Corley, 2004; Katz & Martin, 1997; Melin, 2000).

New Zealand is experiencing the same trends in collaborative research effort and anecdotal evidence of this increase is now supported by a number of

recent studies (Goldfinch, Dale, & DeRouen, 2003; He, Geng, & Campbell-Hunt, 2009). The recently released *Global Research Report: Australia and New Zealand* (Adams, King, & Webster, 2010), points out that scientific researchers in New Zealand have been increasing the number of their internationally co-authored publications, and shifting their geographic focus from traditional European partners to Asia-Pacific partners. The report further suggests that collaboration is likely to become an increasingly important and probably dominant policy issue for New Zealand (Adams, et al., 2010). Similarly a recent government report highlights collaboration in scientific research, locally and internationally, as a key driver in the challenge New Zealand faces in improving its economic, social and environmental performance, (MORST, 2010).

A 2006 study commissioned by the Ministry of Research, Science and Technology (Baines & Associates, 2006) on collaboration between biophysical scientists and social scientists in the developing fields of nanotechnology and biotechnology in New Zealand reported that participants saw collaboration as a challenge, although beneficial. The report also noted the need for a greater emphasis on monitoring the levels of collaboration in scientific research, and on monitoring how researchers go about collaborating. The latter should include explicit recognition, particularly by the funders of research, of the interpersonal and managerial skills required in collaborative research (Baines & Associates, 2006).

There are many different drivers behind this trend to collaborate. Researchers regard collaboration as an inherently interesting way to do science (Morrison, Dobbie, & McDonald, 2003), and they see it as a mechanism for increasing visibility and advancement (Andrade, de los Reyes López, & Martín, 2009). With the costs of modern research being so high researchers often regard collaboration as the only way to get the resources to purchase the expensive instrumentation and equipment required (Bammer, 2008b; Rigby & Edler, 2005), and collaboration has become a key policy tool in directing resources towards complex research problems or “grand challenges,” such as energy and environmental issues or health related research. Perhaps above all, science and technology are being seen as important enablers of social and economic

development (Porac, et al., 2004). Empirical evidence shows that science is strongly correlated with industrial and economic development (Jaffe, Lorez, & Mascitti, 2010) and national research policies are putting increasing emphasis on problem-oriented research, which requires the crossing of disciplinary boundaries (Rinia, van Leeuwen, van Vuren, & van Raan, 1998).

## **1.2 The science sector in New Zealand and the stakeholders**

Scientific research in New Zealand is undertaken in Crown Research Institutes (CRIs), industry Research Associations (RAs), private research organisations, and Tertiary Education Organisations (TEOs). This pattern has evolved from two major reorganisations. In 1992 government research funds previously allocated through government departments were consolidated into one large contestable pool and scientists or groups of scientists from universities, government scientific research institutes and industry research organisations, or independent researchers, applied for funds to undertake research within a framework of government-specified priorities. The second major reorganisation, affecting only academic researchers, was the introduction of the Performance Based Research Fund (PBRF) which was implemented over the period 2004 to 2007. The primary goal of the PBRF is to promote excellent research in the tertiary education sector through assessing research performance of tertiary education organisations (TEOs) and then funding them on the basis of their performance (TEC, 2004).

The term 'stakeholder' was described by Freeman and McVea (2001, p. 53) as "any group or individual who can affect or is affected by the achievement of the organization's objectives." Mitchell, Agle, and Wood (1997), however, argue that entities should also be considered as stakeholders. Both views are accepted for the purposes of this study, therefore, the stakeholders in this study comprise individuals, groups, and entities. Stakeholders in the science sector in New Zealand today are the funders of scientific research, the researchers who undertake the research, the institutions employing the researchers, and the general public or users of the research. In this study the stakeholders discussed are the funders of scientific research, the researchers, and the institution in

which the participants in this study are employed – The College of Sciences, Massey University, New Zealand.

### **1.2.1 The funders of scientific research in New Zealand**

Until February, 2011, there were two separate government agencies responsible for the science sector in New Zealand. The Ministry of Research, Science and Technology (MORST) was the chief advisory body to government on science and technology, and the Foundation for Research, Science and Technology (FRST) managed the government's research funding programme on behalf of the MORST. In February 2011 these two agencies were merged and became the Ministry of Science and Innovation (MSI) which now has the overall responsibility for science activity in New Zealand. As the lead government agency, MSI is charged with increasing New Zealand's economic, environmental, and social performance by driving science and innovation. MSI works with a variety of other agencies to create an environment in which strategy, policy and investment align.

Whilst MSI has the lead role in advising government on all matters relating to science and innovation and the role that science can play in the economy, a second source of advice to government on science policy and on policy for science comes from the Prime Minister's science advisor. The office of the Chief Science Advisor is an independent body and the budget is provided via the Department of Prime Minister and Cabinet.

The second key role carried out by MSI is overseeing of government investment in the infrastructure and funding of research. The latter is through a strategically focused programme that has three funding streams, the first two of which are open to any researcher, and the latter open only to CRIs:

1. An annual contestable investment process;
2. On-demand funds which are open for applications at any time of the year; and
3. Core funding to Crown Research Institutes (CRIs).

As well as sourcing research funds from these first two MSI streams, research scientists from academia can access funds from three other government research pools. The first is the Performance-Based Research Fund (PBRF) which they can access through their own institution. As noted above, the PBRF is a component of the government funds allocated to tertiary organisations on the basis of performance and is administered through the Tertiary Education Commission (TEC).

The second research funding pool is the Marsden Fund which is a contestable fund administered by the New Zealand Royal Society on behalf of MSI. The fund was established by the government in 1994 to fund excellent fundamental research, and unlike FRST funding national strategic benefit is not required.

The third research funding agency is the Health Research Council (HRC). The HRC manages the government's investment in health research through an annual funding round open to all independent researchers. These projects are researcher-initiated and strategically focused.

There is also a number of other smaller government and non-government funded research funding pools which academics are able to access.

### **1.2.2 The researchers**

The researchers in this study are all employed in The College of Sciences, Massey University and they are members of the wider community of scientific researchers in New Zealand.

In 2008 in New Zealand, there were approximately 24,700 fulltime equivalent (FTEs) scientific research and (experimental) development (R&D) personnel. R&D is defined by the OECD (2002) as creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. New Zealand-wide researchers made up 74 percent of all FTEs, and technicians (non-research but scientifically qualified assistants) (TEC, 2011) held 16 percent of all research positions. Over half of the research population was employed by the university sector (Palmer & Laurenson, 2010).

In total research capability in New Zealand there has been a steady increase in research personnel numbers since 2000 in CRIs and universities. This increase in research capability, however, has been even more rapid in business. This has resulted in New Zealand having more researchers as a percentage of total employment than Australia, Denmark, Ireland and Sweden, and across the OECD, New Zealand is third behind Finland and Iceland (Palmer & Laurenson, 2010).

Over the period 2002 to 2007 the number of publications per year increased by 56 percent with 71 percent of those publications having authors from higher education institutions. Over that same period the scientific publication output of higher education institutions increased by 78 percent. Multi-authored publications were mainly in the fields of medicine (33 percent of total New Zealand publications), agricultural and biological sciences (21 percent), biochemistry, genetics and molecular biology (15 percent) and environmental science (11 percent). Overall, New Zealand funds 0.2 percent of world research but produces 0.7 percent of the world's scientific publications. The most prominent fields for New Zealand publications in science are agricultural and biological sciences, and environmental science, forming 33 percent of New Zealand's publications, and 13 percent of total OECD publications. Engineering, physics, astronomy and materials science publications form a small part of that 13 percent (Palmer & Laurenson, 2010).

In terms of cost of producing publications, New Zealand authors have more papers published per US\$ million gross expenditure on R&D, and per US\$ million of expenditure on basic research, than do researchers from any other OECD nation except Poland (Palmer & Laurenson, 2010).

### **1.2.3 Massey University**

Massey University, established as Massey Agricultural College in 1927, was granted university status in 1963. In 2011 the University structure comprised the five Colleges of Business, Creative Arts, Education, Humanities and Social Sciences, and the College of Sciences.

In addition Massey University hosts two Centres of Research Excellence (CoREs): the Riddet Institute, which is engaged in discovery-based scientific research into foods and human nutrition, and The Allan Wilson Centre for Molecular Ecology and Evolution, which is a network of 100 researchers at seven institutions focusing on biodiversity and improving human and environmental health. These centres are multi-disciplinary, cross-organisational, collaborative research centres and are funded by Vote Education.

The College of Sciences, Massey University has a complement of 423 researchers, engaged in research in the fundamental sciences of Chemistry, Physics, Mathematics and Biology. Many are also associated with the university institutes of Agriculture, Veterinary and Life Sciences; the Environment; and Engineering and Technology.

#### **1.2.3.1 Road to 2020**

In January, 2009 Massey University released a major strategic document entitled 'Road to 2020.' This document, which was revised in 2011 (MU, 2011), spells out the University's intent and strategy to become a leading centre of tertiary learning with a world-wide reputation for excellence in research and teaching.

One of the key elements in the strategy is collaboration at the institutional level, in teaching and in research, with a focus on establishing creative partnerships with other universities and research institutions globally, and in nurturing and building Centres of Excellence in research areas in which Massey University has specialised. The overall goal of the strategy is to enhance research capacity and capability. Included within the strategy is a wide-ranging human resources strand featuring research training, support for cross-disciplinary activity, career progression, appropriate reward for success, and instituting 'smart' workload models to ensure researchers have sufficient time and resources to pursue quality research and scholarship. A second strand focuses on establishing critical mass and effective concentrations of leading researchers, and developing a 'state-of-the-art' research infrastructure. At the institutional level effort will go into developing sustainable functional collaborations and tactical partnerships, both domestically and internationally, across disciplines

and fostering collaborative work more closely with other universities, businesses, and CRIs.

### **1.2.3.2 Assistant Vice-Chancellor, Research & Enterprise**

Research is one of the key undertakings of Massey University and a senior officer of the university is given responsibility for the area of research and enterprise. Professor Brigid Heywood, Assistant Vice-Chancellor, Research & Enterprise (AVC, R&E), in an interview (personal communication, September 23, 2011) described collaboration as a form of engagement between individuals or groups. The shape or structure of a collaborative activity, and the degree of formality of the arrangements, will vary according to the needs of the collaborators. According to the AVC, collaboration can operate at many levels within an institution and can be within and between research groups, between the university and community, between groups within the University, between and within communities of scholars, in teaching activities, across the different Colleges, and in University committees and institutes. The value of collaboration, as the AVC sees it, is that it ensures that many different viewpoints are considered but there must always be a sound reason for collaborating.

The AVC pointed out that the reasons for collaborating can be either individual or institutional. A researcher may choose to collaborate for intellectual reasons and to solve an interesting research problem which may require complementary skills, different technologies, or different expertise. As a University officer the reasons for collaborating may be to enhance the reputation of the institution, to enhance the quality of the research, to build critical mass and capacity, for efficiency, or quality assurance.

New Zealand is a small country with limited resources and institutions, and the AVC noted that by joining forces it is possible to get the critical mass to carry out research and to develop programmes to support researcher development, although such programmes would require government investment to initiate.

There are, as noted by the AVC, within Massey University a number of programmes aimed at supporting collaborative activity within and across

Colleges. This package of actions to support collaborative ventures fall into four main areas of:

- Academic workload: the workload model has been recently updated;
- Environment: the University seeks to create an environment to facilitate and nurture collaborative research at various levels;
- Financial support: support is available to host researchers and visiting scholars and support travel; and
- Recognition of achievement: collaborative research and research outcomes are taken into account in promotions and career development.

The real value of collaboration, as pointed out by Professor Heywood, is that it ensures many different viewpoints are considered and that it can help an institution build critical mass and research capacity, whilst increasing efficiency and quality assurance.

### **1.3 Research strategy and choice of methods**

There has been a limited amount of study on collaboration in scientific research in New Zealand and the aim of this study is to make a contribution to that body of knowledge as part of the recommended “investment in monitoring and studying [of] collaboration and how collaboration is done” (Baines & Associates, 2006, p. 13).

This is a case study of one group of scientists in a New Zealand university in which their views and practices on collaborative research are reviewed. The case study approach has been criticised on the grounds that it is not possible to generalise on the basis of a single case (see Flyvbjerg, 2006; Stake, 1978; Woods, 1997), whereas from a large random sample, as for example in questionnaire surveys, one can generalise. The advantage of a large sample is breadth, but the problem is depth, and in the case study approach, the reverse is true (Flyvbjerg, 2006). In this study, an attempt has been made to capture the breadth of the large sample through a survey, and the depth of a case study through interviews. The place of the case study in research is discussed by Kuhn who says:

...a discipline without a large number of thoroughly executed case studies is a discipline without systematic production of exemplars, and that a discipline without exemplars is an ineffective one. In social science, a greater number of good case studies could help remedy this situation.

(Thomas Kuhn, 1987, cited in Flyvbjerg, 2006, p. 242)

#### **1.4 The research question**

The overall question that this research attempts to answer is “What are the views of scientific researchers in the College of Sciences on collaborative research, to what extent do they collaborate and why do they collaborate?”

This research question developed out of my background in science management and governance and an interest in the development of transdisciplinary research practice. For many years I have been professionally engaged in various aspects of the science sector including working on the boundary of scientific research and industry and promoting the transfer of science and technology to industry; in a research funding agency and experiencing the process of allocating research funds; managing scientific research organisations and more latterly involved in the governance of a research organisation. Throughout that time I have observed many changes in the research sector as researchers and institutions have responded to the influences of tighter resources and a demand for greater relevance. The highly competitive and the sometimes combat-like relationship between researchers and funding authorities has evolved to a more negotiated but still competitive approach, and the relationship between researchers and the end users of their research has become much closer. Simultaneously there has been a recognition that problems need to be approached in a multi rather than single discipline fashion and the basis of such an approach is collaboration – an approach that brings differing perspectives to a problem and incorporates, to a greater or lesser extent modern management practices.

The approach to this study is from the perspective of a practitioner of science experienced in managing science and research organisations, in policy development, in research funding decision making, and governance of research organisations. In undertaking this task I hope that the findings will contribute to our understanding of the scientific research process and identify some areas where changes might make the process more effective for all parties concerned.

The transdisciplinary approach to scientific research can be traced back to the early 1970s when the concept was developed by Swiss philosopher and psychologist Jean Piaget (Nicolescu, 2010, p. 19). A colleague of Piaget, Austrian astrophysicist Erich Jantsch published the first definition of transdisciplinarity at a conference held in Nice (France) in 1970 describing it as “the ultimate degree of co-ordination” (Jantsch, 1972, p. 17). The term transdisciplinary was later popularised in the book “The new production of knowledge” by Gibbons et al. published in 1994, in which they described traditional disciplinary production of knowledge (called mode 1), and another form characterised by its transdisciplinary approach, which they called mode 2. This latter approach deals with problems that are not confined to any single disciplinary field but are socially distributed, application-oriented, and subject to multiple accountabilities. Nicolescu (2007) describes transdisciplinarity as going “beyond disciplines” and many scholars regard the transdisciplinary approach as the key issue for all future research (Balsiger, 2004; Gibbons, et al., 1999; Klein, 2004; Nicolescu, 2010).

At the heart of the transdisciplinary approach to research is the process of collaboration, which as has already been noted has been increasing globally as a way of organising scientific research. As science and innovation are now regarded as key drivers in economic development, collaboration is likely to become an increasingly important, and probably a dominant policy issue for New Zealand (Adams, et al., 2010) as it meets the challenge of improving its economic, social and environmental performance. Collaboration is, however, seen as a challenge by researchers (Adams, et al., 2010; Baines & Associates, 2006).

The following objectives are addressed in the study:

1. To ascertain the extent of collaborative research activity in scientific research in The College of Sciences, Massey University, and how the stakeholders (funding agencies and researchers) in the scientific research process view collaboration;
2. To identify the promoters, drivers, and barriers in collaboration; the reasons why collaboration is encouraged; and how scientific researchers overcome the barriers inherent in collaborative research;
3. To describe the processes of cooperation and coordination used by scientists in collaborative projects, and to identify the personal, professional and management skills and competencies researchers consider important for successful engagement in collaborative research;
4. To ascertain how stakeholders (funding agencies and researchers) evaluate the effectiveness/success of collaboration;
5. To review how funding agencies utilise knowledge of the collaboration process when designing their funding architecture, and how scientific researchers utilise their knowledge of collaboration in designing their applications for funds and their research projects; and
6. To provide a set of recommendations to support researchers working on collaborative projects.

### **1.5 Contribution of this study**

Achievement of the objectives listed above will give an understanding of the level and form of collaboration that is employed by researchers in Massey University's College of Sciences. Furthermore, the study will identify the issues that are important to the stakeholders in the research process and the recommendations will be framed around actions that will assist the researchers. Knowing how widespread collaborative research practices already are within the College of Sciences, understanding how researchers view and value collaboration, and knowing their preferences and practices has the potential to

substantially contribute to achievement of the goals of both the Ministry of Science and Innovation and to Massey University itself.

## **1.6 Structure of this thesis**

Following this introductory chapter is chapter 2, the literature review. This chapter traverses the literature in the very broad field of collaboration moving through a discussion of science, research, the scientific community, collaboration, teams, leadership, success in collaboration, and the lack of consensus on a definition of collaboration. The chapter concludes with a review of collaboration in New Zealand as the context for this study.

Chapter 3, Methodology, discusses the methodological framework for the study including the mixed methods approach to the data gathering and the ethics and approvals process. The study comprised two phases, the first a quantitative phase, a survey, which gathered data on the researcher population, the extent of collaboration in the College, and the views of researchers on collaboration. Analysis of this data also contributed ideas to the second, qualitative phase, the interviews. Description of each phase is preceded with a discussion of the particular instrument used. Description of the analysis of the data rounds out this chapter. The Findings chapter, Chapter 4, presents the results of the survey followed by the narrative developed from the interviews.

Chapter 5, Discussion, draws together the various strands of this study. The findings are discussed in relation to the literature and the key elements arising from the study are identified. This final chapter, Chapter 6, Conclusion, summarises the main points arising from this study relating to the original objectives, and following the concluding comments there is a set of recommendations on collaborative scientific research for the research practitioner. These recommendations have been drawn from the results of this study and the literature which has both informed the study and provided the context.

This thesis is a component of a professional doctorate programme, the Doctor of Business and Administration (DBA). Whilst traditional PhD programmes

and professional doctoral programmes have much in common, the professional doctorate is designed to span the academic-practitioner divide and the field of study is a professional discipline, rather than an academic discipline. The process and product are research-based and the ultimate outcome of the process is an original work in the form of a thesis, but there is a requirement for the thesis to have an orientation to practice.

Strategic research sits on the platform of basic research and for decades now, governments around the world have made enormous investments in strategic research in the hope that the outcomes will be 'usable knowledge' as a means to stimulate economic growth.

The translation of the results of that research into economic development, has, however, proved to be difficult & spasmodic. Objective six of this study comprises a set of recommendations for researchers and whilst these recommendations are an important component of the thesis per se, it is hoped they will help to bridge the gap between the academic and practitioner worlds.

## CHAPTER TWO: LITERATURE REVIEW

There is a philosophy of science, but unfortunately there is no philosophy of research. There are many representations and clichés for grasping science and its myths; yet very little has been done to illuminate research. An association was created 150 years ago for the advancement of science, but what would an Association for the Advancement of Research look like?

(Latour, 1998, p.280)

### 2.1 Introduction

The purpose of this literature review is to consider the key research on the topic of collaboration and to provide a context for the field work described in Chapter three. The nature of collaboration means that this review will traverse a wide area beginning with a discussion of science and scientific research, moves on to collaboration in scientific research, how researchers collaborate, what motivates them to do so, and how success is measured. The chapter concludes with a review of collaboration in scientific research in New Zealand.

Throughout history the scientist has been portrayed in literature in a many ways – as being evil, noble, foolish, inhuman, mad, bad, and helpless (Feist, 1998; Garfeild, 1955; R Haynes, 2003, p. 993). In more recent times these same portrayals of scientists have appeared in many films and there are the stories, possibly apocryphal, of the real life, but absent-minded scientists such as Einstein having to call his Princeton office for directions to his house, and Norbert Weiner, the originator of cybernetics, having to rely on his children to remind him of their new address.

For many people today, the word ‘scientist’ still conjures up an image of a white-coated figure, working alone in a laboratory (usually dusty and poorly lit), surrounded by an array of mysterious instruments, chemicals and stuffed animals. This image of the socially maladjusted scientist, whilst popular, is a caricature and as scientists themselves know, ‘doing’ science is fundamentally a social process (Kraut, Galegher, & Egidio, 1988; Ziman, 1999). The image of the modern scientist is more likely to be of an individual (possibly female), who is

intellectually and technically skilled, a worker as well as a thinker, well-educated, well-established, well-paid, corporate, industrial, and commercial (Dizikes, 2008). Researchers may be involved in new industries such as space exploration, climate change, bio technology, or fighting exotic disease as well as working in a laboratory investigating aspects of chemistry, physics and biology.

### **2.1.1 What is science?**

When asked, 'what is science', Albert Einstein (1936) quipped that 'The whole of science is nothing more than a refinement of everyday thinking' (cited in Hoyningen-Huene, 1999). Percy Bridgman, the internationally renowned physicist and 1946 Nobel Prize winner defined science as merely individuals "doing their damndest with their minds, no holds barred" (Bridgman, 1947, p.144). Whilst amusing, none of these definitions is very helpful. The matter is further muddied by the practice of many authors beginning their writings with the question 'what is science' and immediately morphing into discussion of topics such as scientific procedure/method(s), the structure of scientific knowledge; the value of science, and the characteristics of science, and leaving the original question unanswered (see Galavotti, 1999; Theocharis & Psimopoulos, 1987). Science is difficult to define and it has been suggested that it might be more profitable to leave the defining of science to the philosophers of science, rather than the scientists themselves (Galavotti, 1999). The boundaries between science and non-science have been debated at length by scientists and philosophers. John Ziman, physicist turned philosopher (Ziman, 1991, p.100), posits that "science is not a well-bounded, coherent thing, and scientists themselves often disagree on what it is and what it covers. Even where there is agreement, the boundaries are often ambiguous, flexible, sometimes internally inconsistent and disputed." Jerry Ravetz (1973), mathematician turned philosopher of science, noted that even though science was so important in the quality of a nation's life, there was no general agreement or common understanding of what science is. Twenty years later Wynne, in a study comprising interviews with scientists, and managers of science, research council officials, concluded that there was no unified concept of science, but rather a

series of “understandings of science” which varied from group to group (1991, p. 114).

Despite the difficulty in defining science, there are a number of characteristics often ascribed to it: it has explanatory power, testability or verifiability, empirical support, reliability, and rationality (Medawar, 1967; Popper, 1986-87). Often these are encapsulated in ‘the four claims of science’ - Rationality, Truth, Objectivity, and Realism (Gauch, 2003, p. 41). For the philosophers and sociologists the fuzziness of boundaries is simply an analytical problem, but for the scientist it is a very practical problem (Gieryn, 1983).

Perhaps the closest we have ever come to arriving at an agreed definition of science was August 18, 1986, when seventy-two Nobel laureates, seventeen state (US) academies of science, and seven other scientific organisations submitted an *amicus curiae* brief to the United States Supreme Court in which they defined and agreed upon the nature and scope of science (Shermer, 1991). The *Amicus curiae* is a 27 page document whose purpose was to clarify why creationism is not scientific and in doing so, the authors arrived at a definition of science itself:

Science is devoted to formulating and testing naturalistic explanations for natural phenomena. It is a process for systematically collecting and recording data about the physical world, then categorizing and studying the collected data in an effort to infer the principles of nature that best explain the observed phenomena.

(*Amicus curiae* brief, 1986, p. 23, cited in Shermer, 1991)

The Oxford English Dictionary (OED, 2009) notes that the word ‘science’, is derived from the Latin word, *scientia* meaning ‘knowledge’, and initially (1840) included the theological and metaphysical sciences as well as the physical and experimental. In 1860 the theological and metaphysical aspects were excluded from the definition, and today science is defined as a systematic body of knowledge, and way of looking at the world, restricting it to those branches of study that relate to the phenomena of the material universe and their laws,

comprising 'knowledge' as opposed to 'belief' or 'opinion" (Lamont & Molnar, 2002; Ponterotto, 2005).

The term 'scientist' was initially coined by William Whewell in 1833 in an anonymous review in the Quarterly Review for March, 1834 on the "increasing proclivity of separation and dismemberment in the sciences." Six years later in his book *Philosophy of the Inductive Sciences* he more seriously proposed the word "to describe a cultivator of science in general" (a student of nature) and a person with expert knowledge of a science; a person using scientific methods" (Ross, 1962, p. 72).

The nature of science has long been debated by science-educators and McComas, who has written extensively on this topic posits that the nature of science (generally shortened to NOS) is "the intersection of the issues addressed by philosophy, history, sociology, and psychology of science as they apply to, and potentially impact science teaching and learning" (McComas, 1985, cited in Gauch, 2003, pp., 377). NOS is the package of values, beliefs, and underlying assumptions that are intrinsic to scientific knowledge and is then, the epistemology of science (Gruender, 2001; Lederman, 1992).

Some assumptions upon which science is built are shared by all scientific disciplines and tentatively accepted as being true are:

- A physical universe exists;
- There may be randomness and thus unpredictability in the universe, but it is primarily an orderly system;
- The principles of this orderly universe can be discovered through scientific research; and
- Knowledge of the universe is always incomplete. New knowledge will alter current ideas and theories. Therefore, all knowledge and theories are tentative (Bell, Blair, Crawford, & Lederman, 2003; Graziano & Raulin, 2010).

### 2.1.2 Scientific method

'Scientific method' is often used to describe 'How science really works'. It is the term which describes the conduct of investigations into natural phenomena – it is the method, process and set of procedures, including systematic observation, measurement, experiment, and the formulation, testing, and modification of hypotheses, that has characterised natural science since the 17th century. Works by John Herschel, *Preliminary Discourse on the Study of Natural Philosophy* (1830), John Stuart Mill, *System of Logic* (1843), and William Whewell, *The History of the Inductive Sciences (1837) and the Philosophy of the Inductive Sciences* (1840) all reflect the general view of method advanced by Francis Bacon in his *Novum Organon*, written over 200 years earlier (Rudolph, 2005).

Some writers suggest that “there is no such thing as Scientific Method... [it] has always been part of the scientific rhetoric to be used in demarcation controversies” (Ylikoski, 1995). The renowned biologist, Peter Medawar (1969), claimed that “what passes for scientific methodology is a misrepresentation of what scientists do or ought to do” (cited in Berliner, 2002, P 18). There are, however, others who believe quite firmly (although accepting that it is controversial) that scientific method does exist and there is a set of general principles of scientific method shared by all sciences (Gauch, 2003) which can, and are being taught in education institutions.

Bonilla (2002) describes the long tradition of understanding the scientific method as a matter of careful application of logical rules, or methodological norms. These nowadays are regarded as conventions - a position supported by Popper who saw science as a game which was defined by certain rules, and scientific method a set of conventions. He added though, that in their application there must be some decision making and methodological rules alone are insufficient. He also added that in science, competition should be between theories, not between scientists (cited in Bonilla, 2002, p.53) although this is not what has always happened (see Gould, 2000; Koertge, 2007, for discussion of the science wars).

Contributing to the widespread belief in a standard model of scientific method is the way scientific papers are written which makes it look as if

everyone follows the same process or standard research plan (McComas, 1996). The scientific paper, with references (as footnotes), systematic refereeing, and date of receipt and date of publishing, first appeared in the nineteenth century, but it wasn't until after WWII that the scientific paper, with all the features we know today, appeared (Meadows, 1985).

Webster (2003) writing as editor of the *European Journal of Soil Science*, points out that "writing a scientific paper has become a ritual to be followed almost regardless of the subject" (p. 216). He laments the passing of the style of scientific papers of the latter half of the seventeenth century when, fostered by the new learned societies such as the Royal Society of London, and Academie des Sciences in Paris, they were full of excitement and sense of adventure about scientific discoveries and speculation. At that time written articles appeared in a variety of formats and contained "varying mixtures of motivation, observation, method, and discussion, with history and polemic thrown in for good measure" (Webster, 2003, p. 216).

In a BBC broadcast in 1963, Peter Medawar (cited in Webster, 2003, p.2) called the scientific paper a fraud because it rarely followed the actual way in which a problem was investigated. He claimed that the process had been both sanitised and rationalised and "*a substitution of order for the disorder and agitation that animate life in the laboratory . . . replac[ing] the real order of events and discoveries by what appears as the logical order, the one that should have been followed if the conclusions were known from the start*". Medawar often called scientific research a mixture of guesswork and checkwork and twenty years later Meadows points out that scientific papers are as carefully constructed "as any archaeological artefact and reflect the requirements of the contemporary scientific community" (Meadows, 1985, p. 30).

The American Association for the Advancement of Science (AAAS), the largest scientific society in the world, umbrella for some 300 scientific organisations, and publisher, views scientific methodology as a combination of general principles and specialised techniques as described in the following text:

Scientists have certain basic beliefs and attitudes about what they do and how they view their work..... Fundamentally, the various scientific disciplines are alike in their reliance on evidence, the use of hypotheses and theories, the kinds of logic used, and much more. Nevertheless, scientists differ greatly from one another in what phenomena they investigate and in how they go about their work.

(AAAS 1989: 25-26, cited in Gauch, 2003)

There are many models of the scientific method (Bukvova, 2009; Graziano & Raulin, 2010; Harwood, 2004; Harwood, Reiff, & Phillipson, 2005; Mobjörk & Linnér, 2006; Reiff, Harwood, & Phillipson, 2002; Susman & Evered, 1978; Wong & Hodson, 2010) and the one that is generally accepted and which all research scientists follow, was first proposed by Pearson in 1937. It has six basic steps:

1. Define the problem
2. Gather background information
3. Form an hypothesis
4. Make observations
5. Test the hypothesis
6. Draw conclusions
7. (Communicate results)

As noted earlier, this straightforward model has been described as being one of the most pervasive myths of science, (McComas, 1996), however, comparison of the various models shows that they are all basically similar across all disciplines and the variations are in the tools and techniques across disciplines. Thus the model is discipline-free, but its implementation is discipline specific (Graziano & Raulin, 2010). An often missed, but important characteristic of the process of scientific inquiry reported by Reiff et al. (2002, p. 9), and later by Graziano and Raulin (2010), is the iterative nature of the process and that some phases will run concurrently.

This general model does have its critics who argue that the model emphasises only the hypo-deductive process and alludes to the process of science being dependent on a prescribed set of steps which when completed almost automatically lead the researcher to solving 'the problem' and a new law or theory emerging (Lederman, 1998; Reiff, et al., 2002). This view supports the criticisms made by McComas (1996) and noted above.

The complex phenomenon of scientific inquiry is not yet completely understood, nor is it fully characterised and some writers have proposed that because philosophers are trained to 'think critically' about questions such as what is the nature of science, and what is the structure of scientific theory, the discipline of philosophy of science could make a much greater contribution to clarifying these issues than it currently does (Blachowicz, 2009; Griesemer, 1985).

### **2.1.3 Communities of practice**

Throughout history people of like mind and inclination have gathered together in groups. In modern times groups have focused on the widest possible range of interests, ranging from social service groups to business and professional interests, and groups simply for friendship. They can be formally established groups with well-developed internal processes for managing their activities and assets, or informal and short lived groups.

One of the characteristic of all groups, however, is the propensity for learning to take place. In some groups the learning may just be an incidental result of the activities of the group, but for other groups learning and the creation of knowledge is their specific and overt focus. These latter groups have become known as "Communities of Practice" (CoPs), a term coined by Wenger (1998a) to describe groups of people who share a concern or a passion for something they do, and learn how to do it better as they interact (Wenger, McDermott, & Snyder, 2002). These groups exist for their individual members thus they are social structures with collegial relationships between members, with an organisational structure built round the knowledge which the groups steward and create. All communities of practice have an identity and this both

effects, and helps to shape, the identity of its members as they engage in shared practice and learning (Wenger, 1998b), and plays a part in determining the effectiveness of a community of practice (Snyder, Wenger, & de Sousa Briggs, 2003; Wenger, et al., 2002).

Communities of practice and social networks are not identical. The latter are much looser sets of relationships which, whilst flexible and useful for personal interaction and support, are not as good as communities of practice for mobilising resources and focusing those resources on the achievement of specific tasks (Castells, 2000). The success of a community of practice depends on having appropriate leadership that can guide, support, and renew the community initiative over time and an infrastructure with internal mechanisms of review and sanction. For an organisation the measure is publication quantity and quality – for the individual it is knowledge.

#### **2.1.4 The scientific community of scholars**

Of recent times the term “community of scholars” has been applied to a special kind of community - a community of academics (Stablein & Frost, 2004), and whilst it shares the characteristics of all communities of practice, it does have some peculiar to itself. Most fundamentally the community of scholars is an intellectual enterprise and whereas for most communities of practice knowledge is a secondary outcome, for individual members of the community of scholars it is the principal outcome, measured by the community in terms of publication quality and quantity (Stablein & Frost, 2004, p.33). Other outcomes could be enhancement of reputation, promotion, opportunities to engage with others of high reputation, and for early stage researchers membership of a community of scholars is a socialising process (Traweek, 1988).

Specialised scientific communities of practice emerged during the 19<sup>th</sup> century in response to the fragmenting of disciplines into smaller and more specialised sub disciplines. This process was facilitated and fostered by the establishment of scholarly journals which, through their selection of articles for publication, help to identify areas of knowledge and active interest, and to

establish and maintain the boundaries of these more specialised groups (Vanderstraeten, 2010).

As scientific communities grow in size, the scientific field becomes fragmented and subgroups emerge with each new grouping representing a different orientation toward the area. The boundaries of these new groups are clearly identifiable through network analysis which shows how a CoP or discipline grows around a core of publications which disseminate the research findings (Tuire & Erno, 2001). These sub groups have been described in many ways such as "schools", "disciplines" (Usdiken & Pasadeos, 1995, p. 503), "invisible colleges" (Price & Beaver, 1966, p. 1011), and "co-citation networks" (Garfeild, 1955).

Communities generally build up over time but occasionally a community is deliberately built for specific purposes. An example of this is the initiative of the American Association for the Advancement of Science (AAAS) which is creating the world's largest multi-disciplinary scientific and engineering society with 125,000 members and approximately 260 affiliated disciplinary societies and state academies of science. The objective of this programme is to build an intellectually cohesive and sustainable community able to produce and provide theoretically grounded and empirically tested evidence to federal and state government policymakers on science and technology matters (Teich, 2009).

Another example is a collaborative project on nanotechnology co-ordinated by the University of Manchester involving research teams from 17 research institutes around the world. In an effort to create boundary spanning opportunities and identify ways in which disparate disciplines can be usefully connected, a form of speed dating, termed speed storming (as in brain storming), is being used (Molloy, 2009). This process is further explained in Section 2.5.5.

### **2.1.5 Science as an institution and the norms of science**

Science is produced through the existence of the so-called 'scientific establishment', formed by the group of institutions, persons and resources directly involved in the production of new knowledge according to certain 'internal' rules and procedures.

(Krieger, 1999, p. 104)

It has been suggested that science is best thought of as a culture, in the anthropological sense, and like any culture, it has its rules, its “norms”, practices and conventions (Ziman, 1996). It has been described as a “republic of science” with the “structure”, being provided by the disciplines and sub disciplines, and communities of practice, within which the scientists and researchers operate (Polanyi, 2000). Citizenship in this republic is dependent on an individual’s credentials being acceptable to other citizens (Weinberg, 1974) and is achieved through the processes of review and sanction, the most notable of which is the peer review process. This process has been formalised into a quality control mechanism through which judgment is passed on the work produced by the members. The strong developmental component of this process is considered to have a ‘tempering’ effect and can lead to improvement in standards (Stablein & Frost, 2004). It is through peer review that scholars gain admittance to a community of scholars, journal editors choose which articles to publish, and funding agencies allocate funds to researchers and projects (Rinia, et al., 1998). The level of adherence by members to the values and tenets of a community will determine how strong the community is (Snyder, et al., 2003).

Ziman (1994) described science as an institution, bound by a set of social practices carried out by actors performing roles, and holding the production of useful knowledge as its mission. These “rules” include the set of principles known by the acronym CUDOS (Communalism, Universalism, Disinterestedness, Originality and Scepticism), or the Norms of Science, published in 1942 by eminent sociologist Robert Merton, as a guide to good scientific research. The prominent featuring of CUDOS in Vanevar Bush’s (1945) book, *Science, the Endless Frontier*, was responsible in large part, according to (Demeritt, 2000), for the institutionalisation and embedding of the norms in the scientific culture. The norms have been updated and the modified set, outlined below, is the most widely used (Ziman, 1996).

- **Communalism:** means that scientific results are the common property of the entire scientific community (manifested today as collaboration and co-authored work (Fox & Faver, 1984);

- **Universalism:** means that all scientists can contribute to science regardless of race, nationality, culture, or gender;
- **Disinterestedness:** means that scientists should not present their results entangled with their personal beliefs or activism for a cause. Scientists should have an arm's-length attitude towards their findings; and
- **Organised Scepticism:** means that scientific claims must be exposed to critical scrutiny before being accepted.

In 1962 the following were added (Barber, 1968)

- **Rationality** – science uses rational methods to generate and validate its claims to knowledge
- **Emotional neutrality** – scientists are not so committed to an existing theory or procedure that they will decline to reject it or adopt an alternative when the empirical evidence points to it.

It has been argued by a number of sociologists that “the so-called “Mertonian norms” of scientific conduct provide a “story book image of science” (Mitroff, 1974, cited in Mulkay, 1976), and as noted by Ziman (1984) in his discussion of the scientific paper as a fraud, they do *not* guide practice. Rather, they are used retrospectively by scientists to dignify what they have done, and to impress non-scientists” (Wong & Hodson, 2010, p.1439). Accordingly a set of ‘counter norms’ has been proposed:

- **Particularism** – the personal or professional attributes of the researcher, and the status of the institution, are frequently taken into account in the evaluation of scientific contributions.
- **Solitariness** – ownership and control of distribution of scientific knowledge resides with the individual scientist (or group) who produced it. On occasions results are withheld until a patent has

been secured or delayed until their announcement will have greater impact.

- **Interestedness** – many scientists have personal agendas for engaging in particular research and may have a vested interest in the outcomes – even more so when research is funded by commercial organisations.
- **Exercise of judgement** – the expert opinion of experienced scientists plays a prominent role in the evaluation of knowledge claims. Moreover, the research of newcomers is subject to much more rigorous checks than the work of established scientists.
- **Non-rationality** – scientists do not always act in a fully functional manner and scientific advances can result from non-rational as well as rational actions.
- **Emotional commitment** – commitment to a theory is essential for its advancement; disinterest leads to stagnation. On occasions, however, commitment in spite of substantial contrary evidence becomes unreasonable (Mitroff, 1974).

Perhaps the greatest criticism of the Mertonian norms of science is that Merton extracted his 'norms' from the "highly select writings of the rare, great scientists" and did not include what Mitroff called the messy behaviour and complicated attitudes found throughout the large and diverse scientific community which has given rise to multiple sets of norms in science (Mitroff, 1974). Within the framework of Mertonian Norms scientists undertake their work – routine work of solving puzzles and accumulating knowledge, described by Kuhn as 'normal science' whose purpose is to extend the frontiers of knowledge (1962).

#### **2.1.6 Disciplines and discipline specialisation**

The outcome of scientific research is an increase in the amount and complexity of knowledge through either the addition of new knowledge, or the replacement of old knowledge (Abbott, 1988). Modern day disciplines have evolved from the

division, recombination, hybridisation and specialisation of disciplines and now number in their hundreds. This explosive growth in knowledge, measurable by the growth in journals - 10,000 in biology alone – has been accompanied by growth in discipline associations, courses and numbers of graduates from higher education institutions (B R Clark, 1996; Dogan & Pahre, 1989; Giri, 2002; Morillo, Bordons, & Gomez, 2003).

The growth of disciplines through fragmentation and specialisation is considered to be one of the defining characteristics of modern science (Dogan, 2000; Dogan & Pahre, 1989). As early as 1961, Boulding (1968) warned of the danger of specialisation and speculated that researchers would be unable to communicate across their own discipline, and be less capable of, and even unwilling, to use the knowledge produced by alternative epistemologies and methodologies (Pfau, 2008, p. 599). The difficulties researchers face when they do attempt to move outside their disciplinary boundaries has been documented by Massey, Alpass, Flett, Lewis, Morriss, and Sligo (2006). Durden and Perri (1995) point out that because of the complex nature of many disciplines it is now difficult for many scientists to know a sufficient amount about a broad range of topics to work outside of collaborative projects. This division of labour along discipline boundaries is regarded as driving collaboration and in turn, drives more specialization (Barnett, Ault, & Kaserman, 1988; Bush & Hattery, 1956; Cole & Zuckerman, 1984; Katz & Hicks, 1997; Moody, 2004).

Disciplines are the means of transmitting knowledge from one generation to the next and they play a very important role in the training of students (Dogan & Pahre, 1989; Liefner, 2003). On completion of the required period of study and research, a PhD student emerges as a fully credentialed, if not fully fledged, member of a research community (Wiles, Durrant, De Broe, & Powell, 2009), and through having been encultured into a specific disciplinary context and community of practice he/she will perpetuate the norms, values and assumptions of that particular community (Abbott, 2001; Baldrige, 1971; Gumport, 1997). As the disciplines fragment into specialities, the students, or “researchers in training”, become specialists.

## 2.2. What is research?

In the last century and a half, scientific development has been breathtaking, but the understanding of this progress has dramatically changed. It is characterised by the transition from the culture of "science" to the culture of "research." Science is certainty; research is un-certainty.

(Latour, 1998, p. 208)

The term 'research' is often used rather loosely by both scientists and non-scientists, rarely defined and assumed by authors to be self evident to the reader (see Hockey, 2000; McComas, 1996). It has, however, been described as "an attempt to increase the sum of what is known, usually referred to as "a body of knowledge," by the discovery of new facts which add to available knowledge, but also that of new relationships"(MacLeod, Clark, & Hockey, 1989) .

The internationally accepted definition of 'research' is the Frascati definition used by governments for statutory purposes in relation to research (the Frascati Manual, OECD, 2002). This definition includes 'development' as well as 'research' and defines it as "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD, 2002, p. 30).

Scientific method and research are not the same. Scientific method is a process and set of procedures and research is a programme of investigatory activity for the purpose of creating knowledge through applying the scientific method in order to develop, test, and validate or reject scientific principles (Nabel, 2009).

This definition covers three activities: (1) **Basic research**; experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view; (2) **Applied research**; also original investigation undertaken in order to acquire new knowledge however directed primarily towards a specific practical aim or objective; and (3) **Experimental**

**development;** systematic work, drawing on existing knowledge gained from research and/or practical experience directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed.

As noted earlier, scientific methodology has two components – the general principles of scientific method and the specialised techniques of a given speciality (AAAS, 1989; Gauch, 2003). The set of general scientific principles of scientific method which pervade all of the sciences are of three types: those that are peculiar to science itself, including specialised techniques for research that are used in only specific disciplines, used in the main by scientists and technologists; those that are shared by all forms of rational inquiry; and those that are rudimentary and can be described as commonsense. The common core of general principles comprises, inter alia, topics such as hypothesis generation and testing, deductive and inductive logic, parsimony (use the simplest theory that fits the facts), and science’s presuppositions (beliefs required to reach a particular conclusion, sometimes termed assumptions, a priori beliefs, axioms and so on), domain, and limits (the boundary between what science is able and is not able to discover). It is vitally important that researchers understand this core of general principles shared by all disciplines as they form a platform from which a shared view of a problem can be generated at the early stages of a collaborative project. This is a difficult but important aspect of collaborative research and has been documented by Massey et al. (2006), O’Cathain, Murphy and Nicholl (2008), and Jacobs and Amos (2010).

There are, however, critics of this view. For example, the philosopher Paul Feyerabend insists that there are no objective standards of rationality, and there is no logic or method to science (Gauch, 2003, p.4). Jaffe’s work on scepticism in science confirmed that empiricism, rather than rationality, is the basis of modern science (Jaffe, et al., 2010), and Sir Peter Medawar when discussing ‘scientific method’ asked what methods of enquiry applied with equal efficiency to stars and genes. He then concluded that the methodology used by biologists and physicists would be of little use to a sociologist (Medawar, 1969).

### **2.2.1 The researcher**

A 'researcher' is a person who undertakes research, and a 'scientific researcher' undertakes research in the natural and physical sciences guided by knowledge of science, and acting according to scientific principles (OECD, 2002). In a similar vein researchers are "professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned" (OECD, 2002, p.93).

Researcher training has always been described as a socialisation process aimed at forming the identity and professional practices of future science workers as they are immersed in, and participate in the disciplinary culture and community of scientists (Bourdieu, 1975; Thune, 2010). According to many writers the skills and competencies of 'doing research', can and should be learned throughout this socialisation process (Bromley, Boran, & Myddelton, 2007; Solmon, 2009; Willison & O'Regan, 2007). Engaging in collaborative research requires a further set of skills but very few researchers have ever had any formal training in collaborative research methods (Magyary, Whitney, & Brown; Poole, Egan, & Iqbal, 2009).

### **2.2.2 Science and the process of research**

Scientific inquiry is not a set of proscribed steps with a known outcome... but rather an exploration into the unknown, but knowable world. (Harwood, et al., 2005, p. 26)

Over the past century, there has been a major shift in the way scientific work is organised (Hara, Solomon, Kim, & Sonnenwald, 2003; Stokols, Hall, Taylor, & Moser, 2008), and the independent scientist, or "the lone wolf scholar" (Cronin, 2003), has been largely, although by no means entirely, replaced by teams of scientific specialists (Adams, et al., 2005; Andrade, et al., 2009; Chompalov, Genuth, & Shrum, 2002). The scientific researcher's role has changed from one of being highly individualistic, to one of being more social and collaborative (Glanzel & Schubert, 2004; Jones, 2011) and the organisational

units of modern science are groups rather than individuals (Ziman, 1994). Scientific research has become collaborative.

Some writers claim that because new knowledge always builds on earlier knowledge, scientific research, has always been a collaborative activity (N. Fox, 2003), but others consider that collaboration didn't start until the 17<sup>th</sup> or 18<sup>th</sup> century (Beaver & Rosen, 1978; Lorigo & Pellacini, 2007; Price & Beaver, 1966). It is true that senior researchers have always tended to collaborate, and this is particularly so of many Nobel prize winners (Mulkay, 1976; Zuckerman, 1967), however the increase in collaborative research over recent years has brought collaboration to the point where it is no longer confined to just the elite in the scientific community, but is now regarded as the norm in research practice in many scientific disciplines (Beaver & Rosen, 1978; Katz & Martin, 1997; Morrison, et al., 2003); and for academics, particularly in physics and biology, it is now the most common way of adding to a body of knowledge (Hand, 2010). These fields of research tend to be experimental, or applied and broad in their nature, and require a wider range of skills and knowledge than is possible from a single discipline approach and as a result there has been a shift from single discipline to multi and interdisciplinary projects (Hagstrom, 1964; Toomela, 2007).

Since the 1960s the collaboration phenomenon in scientific research has been systematically studied, and the increase over the last thirty years has been well documented with the evidence suggesting that the increase has been global and in every discipline (Beaver, 2001; B L Clarke, 1964; Corley, et al., 2006; Frenken, et al., 2005; Glanzel, 2002; Klein, 1996; Porac, et al., 2004; Stokols, Harvey, Gress, Fuqua, & Phillips, 2005). Analysis of the Web of Science shows that by the 1950s, 83 percent of papers in selected journals in the physical and biological sciences were collaborative efforts, compared to 32 percent in the social sciences and only 1-2 percent in the humanities (Thagard, 1997).

Further analysis also shows that in the natural sciences between 1900 and 1909 collaborative papers comprised about 25 percent of the published papers rising to 80 percent by the 1960s and since the 1970s, in some journals over 94 percent of the articles have been co-authored (Wray, 2006).

Whilst some writers claim that in the scientific disciplines collaboration has been the norm for many decades (Beaver & Rosen, 1978; Katz & Martin, 1997; Morrison, et al., 2003), much of the early 17<sup>th</sup> and 18<sup>th</sup> century research in physics and chemistry was more appropriately termed collective research as it was the result of the *collective* efforts of many people although the credit and responsibility rested with one person. In modern day 'collaborative' research the credit and responsibility are shared, to a greater or lesser degree, amongst all those participating.

Despite the volumes of research undertaken in the search for the reasons for the increase in collaboration, and the countless reasons given, it is not clear why it is growing so rapidly (Bozeman & Corley, 2004; Katz & Martin, 1997; Melin, 2000). Usually the growth is attributed to the rising costs of research and restraint on resources whilst at the same time large scale, complicated projects of scientific research today are demanding very large resources for their support (B L Clarke, 1964; Wray, 2002). Researchers are being encouraged to find more efficient ways of using those resources (Adams, et al., 2005; Black, 1997; Cavusgil, Calantone, & Zhao, 2003; Gibbons, et al., 1999; Luukkonen, Persson, & Sivertsen, 1992); and the increasing professionalization of science has also influenced the rise in collaboration (Lorigo & Pellacini, 2007).

The adjective 'big' is often used to describe the character of modern science, whether measured by the number of scientific papers published each year, the amount of money expended on research, the size of the scientific work force, or the enormous resources required to support much of it (Capshew & Rader, 1992). The term 'big science', was coined by physicist Alvin Weinberg in 1961, to describe the very large programmes such as the high-energy accelerators and programmes of the National Aeronautical and Space Administration. These programmes were ushered in by the Manhattan Project undertaken during World War II and involved the mobilization of much of the U.S. community of physical scientists in an engineering project of unprecedented magnitude . The 'big science' phase in scientific history was characterised by research projects being enormous in scope, scale, complexity, or impact requiring such large investments they were possible only through large scale

investment by the state. Often the media with its powers of persuasion, and the military with its enormous resources were essential components in the pursuit of big science (Capshew & Rader, 1992; Welsh, Jirotko, & Gavaghan, 2006).

A wider currency was given to the term 'big science' with the publication of De Solla Price's book 'Big science, Little Science' in 1963. Price's concerns with "science-in-the-large" dated from the 1940s (Price, 1956, 1961, 1963, 1986) and he stressed the importance of technological innovation (e.g. instruments, machines, automata) as an engine of scientific change, in contrast to Weinberg, who was concerned about large machines and large programmes (Capshew & Rader, 1992).

Throughout the 1990s we have seen the rise of 'big biology'. Like the 'big science' of the 1960s which focused on physics, 'big biology' is large-scale, cross and multi-discipline, and resource-hungry. The first 'big biology' project (1990-2003) is considered to be the Human Genome Project (F Collins, Morgan, & Patrinos, 2003). The 'big science' movement has been described as the "industrialisation of science" (Ravetz, 1973, p.31). The 1990s saw the beginnings of a shift from *normal science* (routine, expert driven, reductionist science) to a new paradigm termed *post normal science* (also termed Mode 2 or post-academic science). Post normal science, unlike normal science, does not claim to be certain and value-free, and is, in fact, characterised by uncertainty, multiple values frameworks, high stakes, urgent decisions, judgement, extended peer communities, and the scientific goals are largely controlled by political or societal agencies (Kunseler, 2007).

Science and scientific research seems to be entering another phase as around the world reports are coming in of governments tightening budgets, looking for greater efficiencies, questioning the size of the funding, seeking value for money and focusing the money on identified priorities. In Europe 'big science' programmes such as space programmes are being reviewed and the big programmes, such as the European Space Agency (ESA), and CERN (particle-physics laboratory near Geneva, Switzerland) are facing cuts over the next five years (Brumfiel, 2010). In Japan the competitive grants are being boosted but at the expense of 'big science' (Normile, 2011); and in the United States, despite

the feared major cuts to research funding in the 2011 federal budget, the reductions were not as bad as had been anticipated .

Within this framework of reducing and redirecting funding, governments, institutions and individual researchers are looking for ways of stretching the money going into research and at the same time pushing out the intellectual boundaries. Collaboration is being encouraged as one way of doing both.

### **2.3 Collaboration – what is it?**

Collaboration is now ubiquitous in scientific research and increasingly is being seen as a desirable way for researchers to work (Cavusgil, et al., 2003), however, our understanding of the potential scope of collaboration, the levels and situations where it should be used, how it should be initiated and set up, and how collaborative activities and projects should be managed, is still limited (Rigby, 2009).

In studying collaboration a complication is that the term ‘collaboration’ is used in a several different ways and often interchangeably with other terms such as ‘cooperation’ and ‘coordination’ (Andrade, et al., 2009; Hara, et al., 2003; O’Sullivan, Stoddard, & Klishman, 2010; Wray, 2006). This loose usage extends even to the formal government documents (see Appendix A for a range of examples), and without clarification the confusion is likely to be perpetuated in the literature and impede progress (K L Hall, Feng, Moser, Stokols, & Taylor, 2008). Calls for the development of clear definitions and operational languages have been made by a number of writers (Bruner, Kunesh, & Knuth, 1992; Hay, 2006; Salmon, 2004).

The generally accepted definition of collaboration refers to researchers working together for a common end within an agreed, and integrated methodological framework (Jeffrey, 2003; Tuomela, 2000). Collaboration in scientific research has been described as a complex social phenomenon based on researchers with diverse interests and disciplines coming together, sharing meaning, knowledge, resources, responsibility and/or power whilst working together for a common, and superordinate goal (Adams, et al., 2005; Belkhdja & Landry, 2007; Glanzel & Schubert, 2004; Goodman & Abel, 1986; Hara, et al.,

2003; Hossain & Fazio, 2009; Hoyningen-Huene, 1999; Jassawalla & Sashittal, 1998; Katz & Martin, 1997; Landry & Amara, 1998; Sonnenwald, 2006; Sonnenwald & Pierce, 2000; Traore & Landry, 1997; Wagner & Leydesdorff, 2005a). Individual researchers may bring additional, individual goals but these are subordinate to the group goals (Sonnenwald, Whitton, & Maglaughlin, 2003). A further characteristic of collaborative research is the involvement of participants, or those being studied, as partners in a process of mutual learning and co-production of knowledge (Pohl, 2008).

In this study, **'cooperation'** describes the interaction across one or more disciplines (Jakobsen, Hels, & McLaughlin, 2004) as researchers work together for their own individual ends. Collaboration, where there is a shared goal, is more complex than cooperation (O'Sullivan, et al., 2010) and requires a coordinating process to link together the various pieces of a project to accomplish the collective task.

**Coordination** of collaborative projects is a major challenge, and particularly so for geographically dispersed collaborations (Cummings & Kiesler, 2005; Ven, Delbecq, & Koenig, 1976) and the extra time, money and management efforts required to run a collaborative project make for extra costs (Beaver, 2001; Wray, 2006; Katz & Martin, 1997; Réjean Landry & Amara, 1998). As a project increases in complexity the coordinating activities also become more complex and more costly to the extent that the costs can be a significant barrier to project success in multi-university collaborations (Cummings & Kiesler, 2007; Hagstrom, 1964; Hobday, 2000; Ven, et al., 1976). The complexity of running a collaborative project has given rise to a whole new area of study, termed *'coordination theory'* (Malone & Crowston, 1994). This issue is raised in Chapter Five, Discussion.

### **2.3.1 Type or shape of collaboration**

Collaborations can be categorised in many ways: by their shape and structure; by their reason for existing; by the number of disciplines involved; and by the depth of theoretical and methodological integration (Eigenbrode, et al., 2007). The variety of forms in the shape or structure category is almost endless ranging

from informally generated collaborations to highly formal arrangements (Cronin, 2003); vertical arrangements as between students and supervisors, horizontal arrangements between researchers at the same level in the hierarchy (considered as a risk distribution strategy by Morrison et al. (2003); structures lying somewhere on a continuum of complementary parts, where the project is divided into discrete units, to a fully integrative and shared project, or somewhere in the middle with some shared components (Hara, et al., 2003; O'Sullivan, et al., 2010; Sonnenwald & Livonen, 1999). Even though they may exist on a continuum distinct categories can be recognised (Eigenbrode, et al., 2007).

Another way of looking at collaboration forms is in identifying their genesis or reason for existing. Hemphill and Vonortas (2002) provide two theoretical positions which can give rise to collaborations:

1. Cost-based partnerships, based on games theory to analyse behaviour of parties and influence of transaction costs, power dominance and maintenance of alliances;
2. Strategies-based partnerships based on organisation and management theories:
  - a. organisational theory suggests the incentive to collaborate is forming networks to increase competitive position; and
  - b. management theory suggests that incentives to collaborate are the appropriation of strategic resources to best fit one's own capacities and opportunities.

At the structural level collaborations can take place between individuals or within or between organisations but they also can be within or between disciplines ranging from shared work within a monodisciplinary situation, where specialist researchers from the same discipline work together, to researchers from different disciplines combining in a different ways. The following could be considered the main groupings of disciplines in collaborative research:

A **multidisciplinary** arrangement comprises several research programmes contributing to a given theme from a number of disciplinary perspectives. It is not problem oriented and there is little attempt to define the cognitive nature of its knowledge base (Chynoweth, 2006), and no collaboration is necessary (Balsiger, 2004; Max-Neef, 2005). Multidisciplinary is additive rather than integrative, and any synthesis is accidental, rather than by design (H K Klein & Myers, 1999);

An **interdisciplinary** arrangement, whilst the definition is still under debate, (Cooper, 2002), is generally accepted to be an arrangement where scientists collectively address the resolution of common problems through drawing on, and integrating insights from other disciplines but not connecting the disciplines themselves. This gives a more complete perspective to answer a specific question (Newell, 2000). This can be undertaken by a single researcher whereby s/he knits together tools, concepts, data, methods, or results from different fields or disciplines or by a group of researchers (S H Frost & Jean, 2003; Lattuca & Stark, 1994). Note that Balsinger (2004) prefers the term 'supradisciplinary' to ensure that the terms multidisciplinary, interdisciplinary and transdisciplinary all retain their specific meanings; and

A **transdisciplinary** arrangement is a synthesis of the disciplines by subsuming them within a single, new overarching epistemology. Newell (2000) calls this a unity of knowledge. Some writers suggest that a **transdisciplinary** arrangement has qualitatively different properties to other arrangements and as the disciplinary parts are no longer distinguishable, the sum is greater than the parts (Benatar, 2003; Flinterman, Teclerian-Mesbah, Broerse, & Bunders, 2001; Hadorn, Bradley, Pohl, & Wiesmann, 2006; Horlick-Jones & Sime, 2004; Max-Neef, 2005).

The depth can range from synthesis of disparate kinds of research results to theoretical and methodological integration where the collaborators "... accept and adopt epistemological perspectives unique to the collaborative effort and distinct from any of the collaborating disciplines"(Eigenbrode, et al., 2007, p. 56). The form or shape that collaboration takes is often determined by the field of study and/or the disciplines involved (Wagner & Leydesdorff, 2005). Whatever

that shape may be, achievement of the common goals depends on the development of relationships and clear lines of responsibility (Andrade, et al., 2009; Chompalov, et al., 2002; Frenken, et al., 2005; Leahey & Reikowsky, 2008; Melin, 2000; Thijs & Glanzel, 2009). O'Sullivan's (2010) typology of collaboration can be seen in Appendix B.

Within the collaborative structure researchers are connected by the flow of knowledge, in the form of scientific ideas, results, and methods, between them and the external environment (Calero, van Leeuwen, & Tijssen, 2007; S Kyvik & Larsen, 1997; R Landry, Traore, & Godin, 1996). Expertise is shared (Nahapiet & Ghoshal, 1998), and new social and intellectual capital is built. Individual scientists bring their own capital to the collaborative effort, but in the process gain access to new capital, both directly, from the individuals with whom they collaborate, and indirectly, through the collaborators of their collaborators (Yin, Kretschmer, Hanneman, & Liu, 2006).

Researchers are also connected through the interpersonal relationships between individuals and/or teams of researchers. Trust and conflict have been extensively studied in collaborative research and it is claimed that they have a central role in project success (Davenport, Davies, & Grimes, 1998; Davison, 2003; Dirks & Ferrin, 2001; Lin, 2001). Not all agree with this position and Shrum, Chompalov, and Genuth (2001) suggest that in big collaborations the importance of trust has been greatly exaggerated, and it is the relations between structural elements of a collaborative venture that are much more significant for the functioning of modern scientific collaborations.

The broad features of collaboration can be summarised as follows:

1. Collaboration is the bringing together of the knowledge, skills, and abilities required for the advancement of research (Stevens & Campion, 1994) and the integration of that knowledge (see Eigenbrode, et al., 2007; Massey, et al., 2006 on the difficulties of trying to achieve integration);
2. Collaboration occurs within a social context of two or more scientists and a mutually shared superordinate goal (Belkhdja & Landry, 2007;

Hossain & Fazio, 2009; Shrum, et al., 2001; Sonnenwald & Pierce, 2000); and

3. Scientific collaboration may be different from other varieties of collaboration as it is shaped by social norms of practice, the structure of knowledge, and the technological infrastructure of the scientific discipline (Hara, et al., 2003).

### **2.3.2 Collaboration by discipline**

Numerous studies have shown that collaborative practices and norms differ greatly from discipline to discipline (Beaver, 2001; Frame & Carpenter, 1979; Garg & Padhi, 2001; Moody, 2004; Toomela, 2007; Wagner-Döbler, 2001). It has been found that basic sciences, which have less clear objectives, tend to be less collaborative than the applied sciences with very clearly formulated problems (Hagstrom, 1964; Margarita, 2007; Toomela, 2007), and it tends to be more common where there is an easy division of labour along specialist lines as in biomedicine, high energy physics, biology and agricultural sciences, and unlikely mathematics (Cronin, 2003; Harris, Lyon, & Clarke, 2009).

### **2.4 Why collaborate?**

Many would argue that collaboration has been good for scientific research. It ensures that a full panoply of scientific skills is available when required, and as compensation for lack of skills, but Powell suggests that it should also be seen as “a source of ongoing synergistic partnering leading to knowledge creation” (cited in Hardy, Phillips, & Lawrence, 2003, p.326). It has been claimed that research undertaken in a collaborative manner has greater epistemic authority than that which has not and the claimant, Wray, cites five reasons and the relevant studies to support this position (2002). The increase in epistemic authority comes from (1) an increase in the quality of collaborative research (Katz & Martin, 1997); collaborative papers are more likely to be cited (Glanzel & Schubert, 2004) ; (2) by bringing together knowledge from different fields that no single scientist would have, collaboration has made possible types of inquiries that would not otherwise be feasible and made possible and some discoveries which otherwise would not have been made (Thagard, 1997); (3) collaboration ensures that

scientific findings are less apt to be forgotten or lost as the knowledge is shared between team members (Robert Merton, 1973, cited in Wray, 2002), and (5) collaboration plays an important role in training young researchers (Weil, 2001).

Collaboration is considered to be the cause of the rapid growth of scientific knowledge and for facilitating the diffusion of information and ideas (Joanne Roberts, 2000), making possible easier access to the new knowledge and to the new research tools. Because of the heightened awareness of so many researchers of what has been discovered and where information can be found, findings are more likely to be remembered (Crane, 1972; Merton, 1938; Wray, 2006). For the individual researcher collaboration offers visibility and feedback (Beaver & Rosen, 1978; Crane, 1972; Rigby & Edler, 2005) and it plays an important role in training young scientists (Beaver, 2004; Lorigo & Pellacini, 2007; Thagard, 1997; Wray, 2002).

#### **2.4.1 Motivations of the researchers to collaborate**

Over recent years a great deal of effort has gone into understanding collaboration and many studies have been undertaken to understand why researchers collaborate (Beaver & Rosen, 1978; Bozeman & Corley, 2004; Katz & Martin, 1997; Melin, 2000) and the 'drivers' fall into four main groups:

1. Those relating to the restraint on resources and the requirements of funding agencies;
2. Those relating to the professional and personal aspirations and motivations of the researchers themselves;
3. Those relating to the effects of discipline specialisation ; and
4. Those relating to the opportunities that large projects may provide.

There is conflicting evidence about how researchers regard collaboration. Many researchers regard collaboration quite positively and are actively driving the move towards it, in part because science is becoming increasingly complex (Adams, et al., 2005; Andrade, et al., 2009; Barnett, et al., 1988; J. S. Katz & Martin, 1997).

At the personal level researchers may be intrinsically motivated to collaborate, simply because they enjoy social interactions, or because they are encouraged by a challenging research question which they cannot tackle by themselves (Bozeman & Corley, 2004; Melin, 2000; Rafols & Meyer, 2007; van Rijnsoever & Hessels, 2011). Collaborations (and their outcomes) have also become an important factor in academic career progression and promotion within the university structure (Sargent & Waters, 2004) and for a researcher the importance of getting credit for the work produced cannot be overstated (Wray, 2006; Zamora-Bonilla, 2010). The allocation of credit for individual contributions has become one of the more contentious issues in a collaborative research (Galison, 2003; Wilcox, 1998).

Some of the drivers for researchers to collaborate are purely utilitarian and pragmatic (Melin, 2000). As single authored articles are rejected more frequently than are multiple-authored articles (Gordon, 1980), scientists are attempting to increase their chances of getting published by participating in more collaborative work (Herald, Hudson, Papka, & Uram, 2009; Laband & Tollison, 2000; Morrison, et al., 2003). This enables them to spread their risk and hedge against the uncertainty of being published (Barnett, et al., 1988; Herald, et al., 2009; Laband & Tollison, 2000; Morrison, et al., 2003). Collaboration also adds greater authority to a submission "...alleviating the authors of sole responsibility for errors or inadequacy in profession that so heavily depends upon those reviews" (B Y Clark, 2009, pp., 15)

Other writers suggest that researchers regard collaboration quite negatively as it promotes the creation of artificial teams, and the 'top-down' managerial process imposes structures and constraints on their work, thus encroaching on academic freedom. It can be seen to interfere with the conventional institutional and science reward systems and this may have an impact on motivation (Acedo, Barroso, Casanueva, & Galán, 2006; Laberge, Albert, & Hodges, 2009; Wray, 2006). It has also been claimed that collaboration with non-scientists makes publication in the mainstream journals difficult (Baines & Associates, 2006).

#### **2.4.2 Productivity**

The relationship between research collaboration and research output has been the subject of a number of studies focusing on the premise that specialization and collaboration should lead to efficiency gains which should result in greater productivity in terms of articles published and knowledge created. It has been shown that collaboration tends to produce an increase in the individual scientist's productivity (Adams, et al., 2005; Laband & Tollison, 2000; S Lee & Bozeman, 2005; Morrison, et al., 2003; J R Turner & Muller, 2005) and co-authoring with partners located overseas increases team output by nearly 40 percent (with all other variables constant) (Ordonez-Matamoros, Cozzens, & Garcia, 2010).

#### **2.4.3 Research quality**

It has been long claimed that collaboration enhances the quality of research as it is both the cause and effect of collaborative papers being cited more often (Adams, et al., 2005; Beaver, 2004; Beaver & Rosen, 1978; T Braun, Glänzel, & Schubert, 2001; S. & Bozeman, 2005; J R Turner & Muller, 2005; Wray, 2002). For publications with multiple authors the citation lifetime was significantly higher than that for single authored works, at 16.8 versus 11.1 years on average (Andrade, et al., 2009; Beaver, 2004; Katz & Martin, 1997; Laband & Tollison, 2000; Rigby & Edler, 2005; Wray, 2002). However, despite policy makers sometimes taking it for granted that collaboration will increase the quality of research (Beaver, 2004), the literature is ambiguous on the relationship between collaboration and quality (He, et al., 2009).

Social interaction is crucial for creativity in science (Kenna & Berche, 2010a) and novel findings in science can result from the exchange and interaction creative and non-creative inputs. It has been claimed that those working in groups are more productive than those working in isolation particularly when there is some degree of diversity, as this may stimulate divergent thinking (Laudel, 2001, p. 778). That collaboration increases creativity makes it an important consideration in the design of training and development of

independent researchers (Beaver, 2001; Guimera, Uzzi, Spiro, & Amaral, 2005; Lovitts, 2005; Ordonez-Matamoros, Cozzens, & Garcia, 2010).

A recent study by Kenna and Bershe (2010a) shows that the dominant driver of research quality is the number of researchers with whom an individual researcher is able to communicate. This explains why the average quality of bigger groups appears to exceed that of smaller groups, although above the upper critical mass, this seems to plateau. Small and medium sized groups should not be expected to yield the same quality profiles as large ones and even comparing small/medium groups to the average quality over all research groups in a given discipline would be misleading. Furthermore as Kenna and Bershe explain, group size or critical mass, is discipline specific and the model they have developed is able to determine the critical masses for many academic disciplines (2010a).

In the academic world there are many factors which will affect the quality of research and these range from the calibre of individual researchers, the strength of communication links between them, their teaching and administrative loads, the quality of management, the equipment used, whether the work is mainly experimental, theoretical or computational, the methodologies and traditions of the field, library facilities, journal access, extramural collaboration, and previous successes and prestige factors. Because the publications that result from collaboration tend to be published in higher quality journals (Laband & Tollison, 2000; Morrison, et al., 2003), and get cited more frequently (Acedo, et al., 2006; D. Beaver & Rosen, 1978), collaboration is a way of increasing visibility, building a reputation, earning peer recognition (Whitley, 1984), and gaining 'credibility' (Melin, 2000).

#### **2.4.4 Opportunities that large projects may provide**

The growing body of research on collaboration in scientific research suggests that collaborations across disciplines and between researchers and practitioners is increasingly being seen as the best way of addressing problem oriented research which more closely matches complex social and environmental real-world problems.

These complex problems or 'grand challenges', with their multiple and complex causes as seen, for example, in energy, environmental, and health areas do not come in disciplinary-shaped boxes, and providing effective solutions to them requires contributions from more than one discipline. Knowledge production therefore has to transcend boundaries - disciplinary, institutional, and national boundaries, and the range of actors involved has become large and diffuse (Bammer, 2008a; Beaver, 2001; Cooper, 2002; Eigenbrode, et al., 2007; Jewitt & Gorgens, 2000; Laberge, et al., 2009; Leydesdorff & Wagner, 2008; Maglaughlin & Sonnenwald, 2005; Nowotny, 2005; Rigby & Edler, 2005; Thune, 2010; Weingart & Steht, 2000). Funding to support research in these areas is increasingly based on thematic priorities (Porac, et al., 2004).

Despite the concerns and cautions of some writers about 'big science' (Weinberg, 1961), there are a number of valuable legacies from these large projects. Projects, such as the Human Genome Project (HGP), the Sloan Digital Sky Survey (SDSS), and the colliding beam accelerators of particle physics, where the participants may number over a thousand (Galison, 2003), have become important enablers of science and technology development and major drivers of scientific research in the development of new, more powerful, and more precise instruments, the development of new technologies, and have opened up opportunities that researchers in earlier times could only dream of (Chompalov & Shrum, 1999; Schubert, 2009; Zhang, Vogeley, & Chen, 2011).

These projects have also had enormous influence on the way that research is undertaken, and how researchers work together (Ordonez-Matamoros, et al., 2010). Collaborative activity between members of different epistemic communities is seen as one of the most important causes of the rapid progress in science and technology (S & T) in most developed countries, and the mix of scientific competence with administrative competence that supports the high degree of organisation, collaboration, coordination and teamwork required to run these large projects, has become a permanent part of modern scientific life in both large and small projects (Beaver, 2001; Capshew & Rader, 1992; Traweek, 1988). The development of new communication and computer technologies has played a large part in these projects as they have made possible the high-

throughput processing of the enormous volumes of data at low cost necessary for such (F Collins, et al., 2003; Cummings & Kiesler, 2005).

## **2.5 Barriers and issues affecting collaboration**

When scientific researchers from one discipline collaborate they start with a shared understanding of the fundamental assumptions, norms and values of that community of practice, but when researchers coming from more than one discipline collaborate, there will be an equal number, at least, of different 'world views' and success will be dependent on researchers working out how they bring these different views to the problem. Massey et al. (2006) point out that even though collaboration can contribute skills, knowledge, expertise and experience to an investigation it can also pose huge challenges to participants as the different viewpoints can be barriers to effective operation of a team.

### **2.5.1 Integrating different epistemologies**

As noted earlier, collaborations lie on a continuum from a group of discrete disciplinary contributions to a project with full epistemological integration. Two areas that collaborators must address are the degree of integration that is required, and this can vary according to the scope and scale of the problem being addressed (Eigenbrode, et al., 2007), and the nature, levels, and forms of evidence that are both necessary for the project and are acceptable to all collaborators (Stokols, et al., 2003).

At the extreme end of the collaboration continuum where integration of disciplines is expected, the most fundamental barrier to integration and successful collaboration is the conventions and practices within the disciplines themselves (Blau, 1976). Because different disciplines have very different philosophical underpinnings theoretical integration is difficult (Zahra & Newey, 2009) and for researchers having to accept and adopt epistemological perspectives different to their own, and possibly "unique to [a specific] collaborative effort and distinct from any of the collaborating disciplines" is very difficult (Leggon, 2006; Lowe & Phillipson, 2009).

In effect, the integration of different epistemologies will create a new epistemology as it now has different properties, and the disciplinary parts will be

no longer distinguishable (Hadorn, et al., 2006; Klein, 1990). As a process, integration is not well understood but is pivotal in determining success (Cooper, 2002; Newell, 2000) and poses real challenges for researchers as it requires transcendence of disciplinary boundaries (Rosenfield, 1992; Upham, 2001). This is difficult for any researcher, but, it is claimed, integration is a particular problem for even the most interpersonally competent scientist as science is at the core of their very identity (Gray, 2008; Hurd, 2009). Trusting and taking risk is a part of collaboration – difficult at the best of times, but particularly so when careers and reputations are at stake (Eigenbrode, et al., 2007).

All disciplines have their own terminology and the specialised terms used are accepted and understood by others in that community, but in other disciplines those same words may have a different meaning. Fisher, Tobi, and Ronteltap (2011) point out that one of the greatest impediments to social and natural science collaborations is that researchers do not understand each others' jargon. Writing for disciplinary colleagues might well be challenging enough, but writing, communicating and persuading peers in other disciplines requires another set of skills to navigate the norms, languages, and knowledge structures of those other disciplines. These can be impediments, and at times barriers, to communication and can slow down interdisciplinary dialogue and knowledge sharing (Baines & Associates, 2006; Massey, et al., 2006; Zahra & Newey, 2009).

### **2.5.2 Distance**

Physical distance between researchers is a key influencer in collaboration (Glanzel & Schubert, 2004). The research suggests that the greater the proximity the more likely a collegial social environment will become established and researchers, knowingly and unknowingly, will be aware of what others are doing, and out of this common ground spontaneous projects may emerge (Kraut, et al., 1988).

Evidence showing that research cooperation decreases exponentially with the distance separating the collaborative partners comes from a comparative study of domestic inter-institutional collaboration in Canada, Australia, and the UK (Katz, 1994), and from Morrison's work in New Zealand which suggests that

proximity, be it geographic, cultural, intellectual, or physical, is an incentive to collaborate (2003). The accepted 'rule of thumb' is that co-workers should be no more than 30 metres apart, and beyond this collaboration effectiveness declines precipitously (Kirat & Lung, 1999; Moodysson & Jonsson, 2007; Nardi, et al., 2002).

Offsetting the knowledge that proximity increases collaboration is the evidence which shows that increasing the number of domestic institutions involved in co-authorship significantly reduces the expected average citation rates per article (Dirks & Ferrin, 2001; Lin, 2001), and studies of international collaboration in the sciences (T Braun, et al., 2001; Glanzel & Schubert, 2005) show that the proportion of internationally co-authored papers in most countries has dramatically increased during the last two decades (Glanzel & Schubert, 2004). The explanation for this is framed in terms of structural reasons and citation patterns.

There are four main structural reasons given to explain the increase in international collaboration: (1) the "science laggard" countries, or institutions, actively seek to cooperate and collaborate with leading countries and institutions; (2) the increased specialisation of disciplines makes collaboration necessary; (3) the high costs of today's "big" science projects cannot be borne by single institutions, and (4) the professionalisation of scientific institutes which has emerged from the restructuring of the scientific community from being a loose group of individuals to many identifiable scientific communities (Beaver & Rosen, 1978; C. Wagner & Leydesdorff, 2005a).

Citation patterns are also affecting international collaboration. At the country level this is illustrated by the European Community (EC), where co-authored papers, whether co-authored by two countries within the EC, or between an EC and a non-EC country, were twice as heavily cited as papers from a single EC country (Goldfinch, et al., 2003). At the researcher level, because papers from international collaborations are more heavily cited, and have greater impact than those from a domestic collaboration, or a collaboration within a single institution, researchers tend to prefer international collaborations (He, et al., 2009). International collaborations also offer researchers a greater

flexibility to cultivate or drop collaborators more freely than might be done with local collaborators where a collaborative relationship might persist past the point of usefulness because of social or academic obligations (Hand, 2010; Leydesdorff & Wagner, 2008).

The internal dynamics of international and national collaboration systems (these are in fact networks of researchers) are different and whereas national systems probably have institutional policies that mediate, foster and promote scientific communication, at the global level these systems are really self-organizing (Gibbons, et al., 1999; Katz & Hicks, 1997; Price, 1963; Wagner & Leyesdorff, 2005b; Ziman, 1994).

### **2.5.3 Age**

Age is a variable that has long been studied in scientific productivity (S. Lee & Bozeman, 2005). Most studies, including bibliometric studies, suggest that the top scientists tend to be younger (under 46), although this could be that they are active in the “hot topics” areas where access to the top might be easier (Costas, van Leeuwen, & Bordons, 2010).

Productivity does vary across the disciplines and the peak of productivity for scientists is generally regarded as being between late 30s – early 40s (Costas, et al., 2010; Feist, 1998; Monge-Najera, Nielsen-Munoz, & Azofeifa, 2010). Others have found two peaks. The first peak in the late 30s in the more theoretical disciplines (theoretical physics), and the second at about 50 years in the more empirically based fields such as biology. In materials science, biology and biomedicine researchers attain their highest productivity in the 50-54 age bracket, and in the Natural Resources the peak is 40-44 years (C Cohen & S Cohen, 2005; S Cole, 1979; S. Kyvik, 1990).

Age-induced changes in cognitive abilities are a universal phenomenon and many studies show that productivity declines with age (S Cole, 1979; Fox, 1983; B H Hall, Mairesse, & Turner, 2007; Heller, 2007). The evidence shows that this is also true of scientists and on average they become less productive as they age, but this may be due to things other than age, such as effects of the reward system and a loss of motivation (S Cole, 1979; Levin & Stephan, 1991). The

productivity of Nobel Laureates fell immediately after the award of the prize (Zuckerman, 1967) and as more senior/older researchers tend to become involved in non-research activities such as administration, teaching, research assessment, project management, funding, supervision of PhD students, and so on, they may have less time to devote to research and the nature of their productivity is captured in documents which are not covered by the Web of Science (WoS) and therefore do not feature in bibliometric studies.

A recent study of the relationship between age and highly cited research productivity for biomedical researchers showed that the greatest productivity was between 31 to 35 years of age and then gradually decreased with age. However, almost 20 percent of the top scientific work included in this particular analysis, was from researchers who were more than 50 years of age during the year of publication (Falagas, Lerodiakonou, & Alexiou, 2008).

While earlier statistical analysis studies showed that there was a greater likelihood of both older and more senior academics engaging in collaborative activity (S Cole, 1979) Morrison's (2003) study affirms the likelihood of collaboration increasing with seniority and shows that even though the *number* of research projects does not alter with seniority, the likelihood of collaboration definitely does as researchers are able to draw on accumulated experience, contacts and funding to attract more collaborators. Some scholars suggest that collaboration becomes an essential step in moving up the science hierarchy (Beaver & Rosen, 1978; Morrison, et al., 2003)

Of particular relevance to researchers who are forming teams is that age and experience influence how a researcher goes about solving scientific problems. Psychometric results confirm that novice researchers depend more on their cognitive abilities, whereas expert researchers depend more on learning experiences and domain-specific knowledge (Heller, 2007, p.143).

#### **2.5.4 Resourcing and funding requirements**

There is a widespread assumption that collaboration in scientific research is a positive development and ought to be encouraged (Katz & Martin, 1997; Melin, 2000). Funding agencies see collaboration as a 'laudable goal' because of the

value it can add to a project and are increasingly allocating resources on a thematic basis (Cummings & Kiesler, 2005; Defazio, Lockett, & Wright, 2009; Ponds, Van Oort, & Frenken, 2007; Rigby, 2009). In one of the few studies of collaboration in New Zealand research, the author notes that many initiatives have been launched to encourage collaboration based on the assumption that collaboration is a "good thing" (Rigby, 2009). A 2008 study showed that in six of the ten cases studied, interviewees claimed that it was the funders who had demanded a collaborative approach to the research (Harris, et al., 2009).

The claim that collaboration is a good thing has been queried by a number of writers who say that the benefits of collaboration are more often assumed than investigated (S Lee & Bozeman, 2005). Funders are driven by the economics of production (Abramo, D'Angelo, & Solazzi, 2010; Morrison, et al., 2003) and whilst there is a positive relationship between government support and collaboration, there is a diminishing return on investment (B Y Clark, 2009). Collaborations do give rise to greater efficiency, but the diseconomies of scale may encourage compromise and less risk taking (Herald, et al., 2009; Van Der Wal, Fischer, Marquiss, Redpath, & Wanless, 2009).

A major issue for funding agencies is how they should spread the funds available and whether funding should be concentrated in relatively few well-resourced institutions or should it be spread more widely to those areas where there are pockets of research excellence. It has been demonstrated, from a mathematical and statistical viewpoint, that critical mass (discussed further in section 2.6) is key to improvement in research quality and whilst there are variations across disciplines, the average quality of bigger groups appears to exceed that of smaller groups. Small and medium sized groups should not be expected to yield the same quality profiles as large groups, so the conclusion for funding agencies is that medium-size groups should be promoted and small ones left to work at attaining critical mass (Kenna & Berche, 2010a).

It is claimed that governments increasingly use research funding to influence and direct scientific discovery by directing where funding should go, and by encouraging and promoting collaboration, particularly international

collaboration as a way of increasing the quality of research (Harman, 1998; Katz & Martin, 1997; Laudel, 2006; Melin, 2000, p.36-39; Smith & Katz, 2000).

### **2.5.5 Choosing a collaborator**

Collaboration does not seem to be confined to any particular group, nor is it a function of either rank or status. Nobel laureates are keen collaborators right through their careers starting early and collaborating with mentors, who either were, or were to become, Nobel laureates. The publishing record shows that in a given period, on average Nobel winners co-authored 7.9 articles, compared to a sample of non-laureates in the same sciences who co-authored, on average, only 2.9 articles (Zuckerman, 1977, cited in Wray, 2002; Wray, 2006).

The choice of a collaborator by a scientist depends on several factors (Garg & Padhi, 2001; B H Hall, et al., 2007; Kraut, et al., 1988; Ponomariov & Boardman, 2008; Smith & Katz, 2000). The type of organisation employing the researcher is an important consideration as institutions vary enormously in the flexibility and mobility they permit researchers to take. In academic settings researchers tend to have more flexibility in choosing their research collaborators and in teaching beyond their own departments (Qin, Lancaster, & Allen, 1997). Social stratification is an important factor in choosing a collaborator. In extramural collaboration the participants are usually of a similar social status, whereas in intramural collaboration there are often significant differences in the social status of the co-authors (Kretschmer, 1994, 1997). There are differences in the kind of collaborator chosen by males and females and females are more likely to collaborate with their spouse than are males (Long, 1992).

It has been argued that women are more inclined to work in groups and that men prefer to work independently, but analyses of patterns and rates of scientific collaboration show little difference and nearly identical levels of collaboration (Ledin, Bornmann, Gannon, & Wallon, 2007; Long, 1990). The recent exploratory work of Rhoten and Pfirman (2007), subsequently confirmed by van Rijnsoever and Hessels (2011), supports the view that female scientists have a greater propensity for collaborative work, and they are more inclined to step outside their disciplinary boundaries than are males. Analyses, however,

show that female scientists average similar numbers of collaborations as do men (Long, 1992; McDowell, Singell, & Stater, 2006; van Rijsoever & Hessels, 2011). There are differences in scientific output (see the discussion of the 'productivity puzzle' in Cole and Zuckerman, (1984), and whilst women might prefer to collaborate, because they tend to be more marginalized within the culture and structure of traditional science, they may not have the same access, as male researchers to the same resources, opportunities, and, in particular, to the informal networks that foster collaboration (Mahlck, 2001).

For many years now, in many western countries programmes have been instituted with the aim of increasing the participation of women in science, mathematics, and engineering. Scholars of feminist science studies claim that women are not as bound to the norms and ways of modern science and its methodology as are males (Harding, 1986; Schiebinger, 2000). Modern science disciplines, however, are based on a masculine epistemology which emphasises the principles of objective rationality, reductionism, and a separation of the social and natural worlds, and women, working within the feminist epistemology which emphasises affectual rationality, inter-connectedness, holism, and a multiplicity of ideas and truths, tend therefore to be at a disadvantage (Fehr, 2004).

Finding a collaborator can be a lengthy process and for many researchers the investment in time and effort, and the lack of guarantee of success, means that it is not a worthwhile activity in which to engage. Professionally and socially people tend to interact mostly with others similar to themselves, and to talk about subjects known to all participants (Ingram & Morris, 2007). For researchers finding potential collaborators outside of one's own discipline and professional grouping is difficult and institutions are increasingly setting up ways for individuals with diverse interests to interact and mix. As mechanisms to promote collaboration are developed and implemented, and cross functional teams are formed, organisational and disciplinary silos are reduced and innovation is fostered. One technique, normally used for strictly social purposes, has found its way into the repertoire of mixing methods and a version of 'speed dating', termed 'speed storming' is being used by some institutions. Early results suggest

that as a technique in promoting collaborative opportunities there can be high payoff for a small investment in time and effort and, whilst still in its infancy, the preliminary research indicates that it has real possibilities and should be further investigated (Joyce, Jennings, Hey, Grossman, & Kalil, 2010).

## **2.6 Teams**

At the heart of research collaboration is the team, which has been described as a group of two or more people who interact in a cooperative and interdependent fashion toward the achievement of a common goal (O'Connor, Rice, Peters, & Veryzer, 2003). Whereas groups are homogeneous with respect to roles, expertise, and responsibilities (Wray, 2006), members of teams have specific roles, functions and responsibilities to perform and the combining of their task relevant knowledge, skills, expertise, and resources enables the team to efficiently and speedily complete the necessary tasks to achieve the team goals (B P Cohen, Kruse, & Anbar, 1982). In scientific research the team has been described as the “vehicle for the integration of knowledge, efforts and capabilities for research processes” (Andrade, et al., 2009, p. 301). The individual researcher has to “play for the team” and simultaneously work to distinguish him/herself as an individual high achieving researcher (Heilbron, 1992; Psaltis, 2007; Walsh & Maloney, 2007).

Given the complexity of modern science, building a research team is an important part of designing for success in research. It is a complex process and to ensure highest performance a strategic approach should be used starting with reflection of the goals of the team and project (Adams, et al., 2005; Stokols, Hall, et al., 2008). “Hand-picking” members (Curtis & Matthewman, 2005; Harvey, Pettigrew, & Ferlie, 2002), and having a high number of senior and experienced collaborators with extensive institutional and external networks (Andrade, et al., 2009; C.Smith, 1971) should be encouraged. Kenna (2010b) points out that it is not simply the mean calibre of the individual researchers in a research team that determines the quality of output, but relationships between the researchers has a major impact on quality.

Forming a research team is a complex process and the following framework which has been developed from the work of Belbin (1981, see Appendix C); Mallon, Duberley and Cohen, 2005; Harvey, Pettigrew and Fairlie (2002); and Sapienza (2005), can be used to ensure that the five key areas of team membership generally accepted as necessary are taken into consideration.

**Table 1: Framework for the formation of a team**

KEY AREA	DESCRIPTION
<b>Roles: All team members must have:</b>	<ul style="list-style-type: none"> <li>▪ a functional role</li> <li>▪ professional and technical knowledge</li> <li>▪ a team role that is high task relevant</li> </ul>
<b>Capabilities: Necessary capabilities within the team are:</b>	<ul style="list-style-type: none"> <li>▪ idea generation</li> <li>▪ entrepreneuring or championing</li> <li>▪ project leading               <ul style="list-style-type: none"> <li>▪ sponsoring or coaching</li> <li>▪ boundary spanning</li> <li>▪ boundary management</li> </ul> </li> </ul>
<b>Size: Must have a balance between:</b>	<ul style="list-style-type: none"> <li>▪ being large enough to accomplish the work</li> <li>▪ small enough to avoid inefficiencies associated with lowered sense of responsibility</li> </ul>
<b>Membership Diversity: A team requires moderate diversity:</b>	<ul style="list-style-type: none"> <li>▪ If the team is too homogeneous, it may lack the resources to accomplish the task</li> <li>▪ If too heterogeneous, the diversity of values or perspectives may prevent a team from working together effectively</li> </ul>
<b>Interpersonal Factors: Personality and mental abilities:</b>	<ul style="list-style-type: none"> <li>▪ Some members better suited for some team roles and limited ability to play others</li> <li>▪ Team members need interpersonal as well as task-related skills</li> </ul>

Cognition is defined as structured or organized knowledge that aids a person in interpreting and responding to events (Rentsch & Small, 2007). In a sole researcher situation, cognition and expertise reside in the individual, although as Cronin cautions that does not mean “intellectual solitary confinement” as an individual researcher is enmeshed in a wide array of socio-cognitive networks (2004). In teams cognition is distributed throughout all members rather than being localized in the individual scientists involved and outcomes are reached by combining individual knowledge that is not initially

shared with the others. Rentsch and Small (2007) claim that as team members draw on their experiences to attribute meaning to team-related events, to tasks and to one another, they develop a cognitive similarity (termed a mental model). In a research team discipline and research expertise, both of which are contributing factors to cognition, collectively confer authority, which, like responsibility is distributed throughout the team. Both authority and responsibility depend on there being a high level of trust and cooperation within the team (Giere, 2002).

Team size is an important factor in determining the effectiveness of a research team and work undertaken by Kenna (2010a) shows that there is a relationship between research quality and group size. Critical mass, described as the minimum size a research team must attain for it to be viable in the longer term, plateaus at an upper limit, and then reduces when the team size is too great. In many scientific fields, about six or eight researchers seems about optimum for a research team as above this there is usually little or no extra gain per capita (Kenna & Berche, 2010b; Von Tunzelmann, Ranga, Martin, & Geuna, 2003). The size of critical mass does vary to some extent according to the discipline but the dominant driver of research quality, is the number of researchers that an individual is able to communicate with, and the existence of two-way collaborative links between the researchers. The average quality of bigger groups appears to exceed that of smaller groups (Kenna & Berche, 2010a). Small groups must strive to achieve critical mass and overall research performance of a given discipline is improved by supporting medium-sized groups over large ones. Research groups, however, are not static in terms of size and often they start out very large and gradually break into smaller groups (Zhang, et al., 2011).

Relationships between members of a scientific research team, as already noted in section 2.6 as an important factor in team functioning, are very dynamic (Davenport, et al., 1998; Rhyne & Teagarden, 1995). Good management of the relationships can result in development of commitment to a project and to the development of what is termed, 'social capital'. Social capital is defined as sum of the actual and potential resources embedded within, available through, and

derived from the network of relationships possessed by an individual or social unit (Nahapiet & Ghoshal, 1998). For a research group it is the collectively owned social capital which forms the foundation for trust, cooperation, and collective action of the research group. Trust has been identified as being one of the most important elements to contribute to the eventual success of any cooperative or collaborative venture (Corner & Normand, 2001; Davenport, et al., 1998).

Conflict, considered to be inherent in the very heterogeneity of collaborations, can arise in a research team but it is not necessarily associated with negative outcomes. The conflict does need to be harnessed and the differences managed if it is to be the stimulus to creativity that some scholars suggest that it can be (Bammer, 2008b; He, et al., 2009; Shrum, et al., 2001).

In addition to critical mass issues and team size issues, there are a number of other factors which effect the optimum size of a research team and the quality of the output: the calibre of individual researchers, the strength of communication links between them, the teaching and administrative loads of researchers, the quality of the management, the extent of interdisciplinarity, the equipment used, whether the work is mainly experimental, theoretical or computational, the methodologies and traditions of the field, library facilities, journal access, extramural collaboration, and even previous successes and prestige factors.

Reflection on experiences as a team and evaluating the outcomes of the team activity is an important contributor to good team work. The willingness and ability of team members to engage in such reflection is considered to be one of the key attributes of an effective team (Drach-Zahavy & Anit, 2001; Kayes, Kayes, & Kolb, 2005).

### **2.6.1 Research competencies**

Successful collaboration will depend on the leader of a team being able to assemble the necessary team core competence mix along with the related complementary competency and skill mix of the individual members (Poole, Egan, & Iqbal, 2009).

Over the last century the doctorate, first known in medieval Europe where it was a simply a licence to teach in universities, has established itself as a qualification recognised internationally, as the standard qualification for entry into the research and academic professions today, and as an important qualification for other labour markets (Park, 2005). It was first awarded in the United States by Yale College in 1861 (Coradsco, 1973, cited in Goodchild & Miller, 1997) and it wasn't until 1917 that the degree was introduced in the UK.

The objective of a PhD is completion of a programme of research enabling candidates to make an original and significant contribution to scientific knowledge. There is considerable variation in the detailed requirements of disciplines, institutions and countries for the award, but there is a generally understood notion or understanding of what constitutes the “traditional” PhD (*Philosophiae Doctor*) (Huisman & Naidoo, 2006).

The development of general scientific ability depends on many interlinked factors – both cognitive and non-cognitive (Heller, 2007; Shavinina, 2004) and the outcome of a meta analysis study of the personality characteristics which might predict scientific and technical achievement, showed that the best predictors of scientific success related to biographical features, followed by subject-related ability and creativity tests, with general intelligence and creativity tests having the lowest prognostic value (Funke, Krauss, Schuler, & Staph, 1987 cited in Heller, 2007).

Many writers would suggest that scientists are different to non-scientists and the literature supports this view. A comprehensive review of the literature on the psychology of science and scientists by Feist and Gorman (1998) showed that scientists compared to non-scientists are:

- More conscientious and orderly;
- More dominant, driven, or achievement oriented;
- More independent and less sociable; and
- More emotionally stable or impulse controlled (G.J. Feist & Gorman, 1998, p.26)

The review went on to say that eminent and creative scientists compared to less eminent and less creative scientists are more:

- Dominant, arrogant, self-confident, or hostile;
- Autonomous, independent, or introverted;
- Driven, ambitious, or achievement oriented; and
- Open and flexible in thought and behaviour (Feist & Gorman, 1998, p. 26)

An earlier study by Greene (1976, cited in C Cohen & S Cohen, 2005), reported that the problems faced by scientists often stemmed from their communication and interpersonal difficulties and Feist (1994) who studied academic researchers (professor level and all male), concluded that “In sum, complex thinkers about research are influential in their discipline and are well cited, but are considered by observers to be neither warm nor sociable” (Feist, 1994, p.479). On a more positive note, C Cohen and S Cohen (2005) point out that studies have also found out that scientists were emotionally stable, impulse controlled, and open and flexible in thought and behaviour, and whilst their interpersonal skills can be less than optimum, they are willing to learn and improve and that they have the capacity and motivation to do so.

The outcome of a recent international study of scientists, musicians and politicians identified a number of features about scientists including that scientists from various different disciplines within the natural sciences share a uniform personality and a set of fundamental values, skills and attitudes that seem to be related to their professional activity; science favours the development of a sceptical attitude; and sociologists are the academics less similar to natural scientists and closest to business people (Jaffe, et al., 2010).

Cognitively, the successful scientist is characterised by having highly developed formal-logical thought processes; is able to think in the abstract, is creative, sensitive, and inventive, has lots of ideas, and original ways of approaching, restructuring and solving problems. The non-cognitive characteristics of the successful scientist are intellectual curiosity and

questioning, clear interests; motivation to achieve, goal orientation and persistence, and an ability to tolerate and exploit ambiguity, uncertainty and complexity (Heilbron, 1992). In addition the successful scientist has discipline knowledge and the set of research and collaborative skills (Heller, 2007).

Researcher training has been described as a socialisation process aimed at forming the identity and professional practices of future science workers as they are immersed in, and participate in the disciplinary culture and community of scientists (Bourdieu, 1975; Thune, 2010). According to many writers the skills and competencies of "doing research", can and should be learned throughout this socialisation process (Bromley, et al., 2007; Solmon, 2009; Willison & O'Regan, 2007). Despite the widely view that understanding and being able to apply research skills is regarded as a fundamental competency required of doctoral graduates, there are remarkably few courses on research competencies available (Huisman & Naidoo, 2006; Solmon, 2009; Willison & O'Regan, 2007). Collaborative research requires a further set of skills and competencies but very few researchers have ever had any formal training in collaborative research methods (Magyary, Whitney, & Brown, 2006; Poole, et al., 2009).

There is some confusion in the usage of words relating to competencies and core competencies. Competency has been defined as set of skills and know-how (expertise) resident in individuals, teams of individuals and strategic business units (Javidan, 1998; Ljungquist, 2007), and core competency is described by Prahalad and Hamel (1990) as the area of specialised skills, knowledge, technologies, and physical, managerial and value systems, cognitive strategy, meta-cognitions, beliefs, values and attitudes unique to an organisation which gives it a competitive advantage. Core competencies are regarded as the highest level competencies as they are the collective learning of a group, (described as social capital in section 2.6) and are of the greatest value to organisations, but are the most difficult to achieve and difficult to imitate (Prahalad & Hamel, 1990). In research it is only recently that a clearly identified core of research competencies has been generally agreed as a minimum (Solmon, 2009).

Whilst there is some debate in the literature as to the value of competence models they have been widely used in industry for some years. Through analysis of behaviours it is possible to identify those which can be related to definitions of more effective and less effective performance and are then categorized under thematic headings which define the general competencies. Complicating an already complex area, in response to the demand for relevance and a research workforce capable of working in a variety of situations in a modern economy, the nature of the research degree is changing from one of achievement of a highly focused piece of scholarly research to a broader based training in research competence and transferable skills (Bromley, et al., 2007).

The increasing interest in identifying research competencies, has also extended to an interest in identifying the additional skills required for researchers to undertake collaborative research projects (see Boyatzis & Kolb, 1995; Coronini & Mangematin, 1999; Eisenhart & DeHaan, 2005; Kaslow, et al., 2004; RCUK, 2001). This trend is illustrated by publication by the UK Economic and Social Research Council (ESRC, 2001) of a framework of research competencies covering a range of discipline areas including:

1. General research skills and transferable skills;
2. Framework for research methods training; and
3. Subject and discipline guidelines.

The Research Council of the United Kingdom (RCUK) has also developed a research competency framework of the 36 competencies which the Council regards as essential for research (PhD) students graduating from UK universities (RCUK, 2001) and as potential employer requirements (RCUK, 2009). Termed The Joint Skills Statement (JSS), the 36 competencies fall into 7 domains as follows:

1. Research skills and techniques;
2. Participation in the research environment;
3. Research management;
4. Personal effectiveness;

5. Communication;
6. Networking and team working; and
7. Career management.

A further evolution of the Research Councils' Joint Skills Statement (JSS) is The Researcher Development Statement (RCUK, 2010) (see Appendix D for details) which is now the key reference statement for the development of postgraduate researchers' skills and attributes. The Framework sets out the knowledge, behaviours and attributes required to be a successful researcher and include a subset of collaboration skills, which it is claimed, is at the heart of the research model for the 21st Century. There are seven components to the set of collaboration skills:

1. Team Roles: the model used is the Belbin Team Role framework (see Section 2.6 Teams).
2. Good working relationships and understanding colleagues,
3. Working styles; understanding the type of working style that one prefers (networker, results focused; task oriented; micro or big picture person: ideas person,
4. Trust and respect,
5. Working with diversity,
6. Managing others, and
7. Managing oneself.

Two programmes which are aimed at increasing capability in collaboration are the IGERT programme in the United States and the Canadian CIHR programme. The IGERT programme (Integrative Graduate Education and Research Traineeship Programme) , which is supported by the National Science Foundation, is designed to “catalyze a cultural change in graduate education, for students, faculty, and institutions, by establishing innovative new models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries”(NSF, 2011). In

British Columbia Canada, The Canadian Institutes of Health Research (CIHR, Canada's primary health research funding body), initiated a programme in 2003 aimed at fostering interdisciplinary health research and evidence-based health policies and practices emphasising the development of research competences and related skills needed for collaborative research. Experiential learning and identification of the core competencies are features of the programme (Poole, et al., 2009).

In addition to becoming skilled in the competencies for collaborative research, students are urged to become familiar with disciplines other than their own, and it is suggested that graduate students should be trained, *inter alia*, in diverse epistemological perspectives, and diverse methodological strategies, and an interdisciplinary research orientation (Eisenhart & DeHaan, 2005; Sung, et al., 2003)

### **2.6.2 Team processes**

Over recent years much attention has been paid to the development of theoretical models of team effectiveness and though these models may vary in detail, they all share an input–process–outcome (I-P-O) framework. 'I' is the inputs that are conditions that exist prior and may include member, team, and organisational characteristics, 'P' is the processes that describe how team inputs are transformed into outputs, and 'O' is the outcomes which are the results and by-products of team activity (Mathieu, Goodwin, Heffner, Salas, & Cannon-Bowers, 2000).

Team processes has been described as "members' interdependent acts that convert the inputs into outcomes through cognitive, verbal, and behavioural activities directed toward organizing taskwork to achieve collective goals" (Marks, Mathieu, & Zaccaro, 2001, p. 357). Team success and achievement of project objectives will be an outcome of the how well the team members are able to utilise their talents and the available resources, how well they interact with each other to accomplish the work, and whether appropriate processes to support the work are developed.

The processes which support the I-P-O activities are either explicit coordination processes where team members communicate directly with colleagues to manage the multiple interdependencies, or implicit when team members anticipate the actions and needs of their colleagues and adjust their own behaviour accordingly without having to communicate directly with each other. These implicit processes are rooted in the team mental model approach (noted in section 2.6) where the shared understandings that members have of a given situation are used to generate predictions of others' actions (Rico, Sanchez-Manzanares, Gil, & Gibson, 2008). This notion is very similar to what Boreham (2004) describes as "shared competence" .

There are many taxonomies of team processes (see Marks, et al., 2001, p. 363) and the model developed by Marks is divided into two phases. The first, termed the Transition phase, focuses on the early planning activities including goal setting, strategy, evaluation, and contingency planning, and the second, termed the Action phase, comprises the tracking, the systems and the team monitoring, feedback and the activities which orchestrate the sequencing and timing management through the coordination processes .

In effective teams, members seem to be able to predict the behaviour and needs of other members (C. G. Smith, 1971) and implicit processes are part of any team decision making (TDM) where there is a shared mental model. TDM is a process involving gathering, processing, integrating, and communicating information in support of arriving at a task relevant decision. The quality of a decision is dependent on the ability of the team to function effectively as a unit and how well the members interact, coordinate, communicate, exchange information, adapt and explicate the nature of teamwork and teamwork skills

Given that the dynamics between individuals are critical to effective team functioning team composition will affect how well team members are able to develop a shared mental model of a situation and how well the implicit coordinating processes can be utilised.

## 2.7 Leadership

Science is odd in some ways. You spend all your time as a student and postdoctoral fellow learning how to become a good experimentalist. Then you become an independent scientist, and if you are successful, before long you are no longer doing experiments because you don't have any time, and personnel management becomes a major issue.

(Robert Doms, cited in Hede, 2007, p. 993)

At the heart of research collaboration is the team which has been described as a complex system of individuals each having a specific role or function to perform in the achievement of the team goals (Psaltis, 2007). One of the key processes in the functioning of a team is leadership, without which, team members are unlikely to identify with team objectives and achievement of team goals is unlikely (Burke, et al., 2006; Sivasubramaniam, Murry, Avolio, & Jung, 2002; Solansky, 2008).

The debate about leadership, and what it is, has raged for decades. Over the last century there have been five major eras in the leadership literature which coincide with the four main leadership models. These range from the "Directive model" which is hierarchical, top down (vertical) "leader as commander" and was the dominant leadership paradigm during the scientific management movement, to the emerging "Empowering model" in which leadership is 'shared', or distributed, and in between is the 'Transactional model' which emphasises trait and behaviour issues representing management interests, and the 'Transformational model' which emphasises visionary, entrepreneurial and charismatic issues. These two models have been blended into the 'Multifaceted' model which has been the mainstream model since the 1990s (Van Wart, 2003).

The terms 'Leadership', 'what leaders do', and 'headship' should not be confused. 'Headship' is simply 'presiding at the top of an organisation' (Moisan, 2004), 'what leaders do', traditionally is viewed as 'calling the shots' – setting the direction, making the decisions, motivating the workforce, and building the culture in an organisation, and 'leadership' is defined as the actions of an

individual to build and maintain a group that performs well relative to its competition (and should be evaluated in terms of the performance of the group over time) (Hogan & Kaiser, 2005). It can also be seen as a set of behaviours that frame the realities of others (Feyerherm, 1994), and as the art of “liberating people to do what is required of them in the most effective and humane way possible” (DePree, 1989, cited in Howell & Avolio, 1992, p. 49). Leaders are the designers, teachers, and stewards who challenge prevailing mental models, who foster creativity and empower, who influence, and inspire others (Goffee & Jones, 2000; Senge, 1990). The implication is that leadership is not something that ‘is done’ to others, but rather it is how an individual lets others, i.e., the followers, do what is needed to be done. Despite the volumes written on the topic of leadership, as Cammock (2003) observes, there is still no commonly held definition of the term.

In general, research has demonstrated that appropriate leadership can enhance the overall effectiveness of teams and increase the satisfaction of team members (Gray, 2008), and whilst the research has also shown that leadership and performance are positively related, it is only recently that quantitative research has been able to demonstrate which leadership behaviours actually produce positive results (Goleman, 2000; O'Regan & Ghobadian, 2004).

The notion that leaders do not have to be assigned, designated or even recognised in order to have great impact, and that they could emerge at any level in an organisation or team, was initially espoused by Greenleaf (1977, cited in Ensley, Hmieleski, & Pearce, 2006). It had been observed that high-performing groups often did not have formal leadership structures (Manz & Sims, 1984) and if there was an assigned leader the individual was more commonly treated as a peer rather than as a formal hierarchical authority. In groups such as these, the leadership function was often distributed to those with the relevant knowledge, skills or abilities and in certain situations or specific times they came to the fore as leader.

Shared leadership has been defined as a dynamic, unfolding, interactive influence process among individuals, where the objective is to lead one another toward the achievement of collective goals (Pearce, 2004, cited in Ensley, et al.,

2006). At times this model is actively engaged to ensure that those with the creativity, innovation and influence are making the necessary input at specific times. A study by Pearce and Henry (2002) showed that shared leadership was an important predictor of team effectiveness and an important ingredient in teams that are responsible for complex tasks. This same study also showed that high-performing teams seemed to exhibit “more” leadership than low-performing teams and members of these teams often had more positive images of themselves. Despite these findings, Pearce and Henry (2002) believe that as both vertical (hierarchical) and shared leadership affect team effectiveness, they both have their place and a fuller view of leadership processes and outcomes must encompass both vertical and shared leadership.

Many factors shape the development of a leader. Bruce Avolio, a very well known writer in the field of leadership, claims that the research shows that there are some traits possessed by leaders that are repeatedly associated with effective leadership, including persistence, tolerance for ambiguity, self-confidence, drive, honesty, integrity, internal locus of control, achievement motivation, and cognitive ability (2007). Some of these attributes such as intelligence are stable over time, but others can change as people learn. Formal training can provide technical skills and credibility, management knowledge, external awareness, coaching, and encouragement for reflection (Van Wart, 2003). The ability to learn from experience, termed “learning agility”, is a key attribute for a leader and this criterion is often used in the identification of “high potential” individuals who may become leaders in the future (Lombardo & Eichinger, 2000). Day and Harrison (2007) argue that leadership development, if it is to be really effective, needs to be focused on a leader’s sense of identity as this is the source of meaning from which leaders operate. This is very significant for scientists and Hurd (2009) has observed that when scientists move into management or leadership roles, they are often blindsided by the magnitude how much of their identity they leave behind and former star performers can become quite demoralized.

The notion that leaders are both born and made (Conger, 2004) is illustrated by the work of Hogan and Kaiser (2005) on the analysis of a set of

studies on personality and organisational performance. This analysis showed that (a) personality predicts leadership style (who we are determines how we lead), (b) leadership style predicts employee attitudes and team functioning, and (c) attitudes and team functioning predict organisational performance.

The competencies that leaders require can be grouped into either leadership competencies which are task oriented, related to organizational structure, design, and control, and to establishing routines to attain organisational goals and objectives, and person-oriented competencies which includes behaviours that promote collaborative interaction among team members and the establishment of a supportive social climate (Tubbs & Schulz, 2006). There are many frameworks or models of leadership competencies that are all very much the same, albeit with different words and using different indicators, but all measuring the same competencies. In the view of two internationally respected researchers and writers on leadership, Lombardo and Eichinger (2000), the important issue is not what the competencies are, but how much they matter in a particular job (2001). Competencies such as these, of course, may take a lifetime of commitment to develop (Senge, 1990).

Recent studies have moved beyond analyses of specific leadership traits toward a broader focus on the combinations of skills, patterns of behaviour, and interpersonal styles exhibited by exemplary leaders (Stokols, Misra, Moser, Hall, & Taylor, 2008) and Jim Collins in his book 'Good to Great' asserts that exemplary leaders are a "paradoxical blend of personal humility and strong professional will" (J Collins, 2001, p.80).

The research tells us that the credibility of a leader as judged by those being led, rests on four leadership virtues or themes. They are integrity, decisiveness, competence, and vision (Hogan & Kaiser, 2005; Kouzes & Posner, 1995). "Competence" includes the notion that good leaders are a contributing resource for their groups. Legitimacy and respect from team members is derived from expertise (D Frost & Stahelski, 1988).

Leadership style can be considered as an aggregation of attributes, traits, skills, and behaviours and recent studies show that different styles of leadership can have different impacts on organisations (Goleman, 2000; Idris & Ali, 2008).

The leadership requirements vary by situation and they also differ at the functional level in an organisation and at the enterprise level. Conger, who has worked extensively in this area, is very critical of the models and frameworks used for leader development claiming that they assume a static set of behaviours which are universal to most leadership situations (Conger, 2004).

The terms leadership and management are often used interchangeably, but they are not the same. This could be due either to confusion or simply to convergence but either way it ignores the different purposes of leadership and management (Jennings, Scalzi, Rodgers, & Keane, 2007). Management is concerned with taking responsibility and accountability for the performance and general working of an organisation and focuses on maintaining order, planning, organising, coordinating resources, and attending to rules and details (Kouzes & Posner, 1995). There are many definitions and descriptions of leadership and at the heart of it is the notion that leadership is a process of helping people move toward achieving a vision – of inducing followers to act. A summary of the key leadership studies identifies three major task areas for leaders: Envisioning: being able to see beyond the current situation and develop a vision of the future; Engaging: winning the support of followers and supporters and gaining commitment to involvement; Enacting: being able to motivate, inspire and bring the vision into action (Cammock, 2003). In addition to having a clear vision of what needs to be accomplished, and be able to communicate that vision, a leader needs a passion and intense level of personal commitment, and integrity or character (Bennis, 1989).

Management and leadership do share many competencies comprising (a) intrapersonal skills (regulating one's emotions and easily accommodating to authority), (b) interpersonal skills (building and maintaining relationships), (c) business skills (planning, budgeting, coordinating, and monitoring business activities) (Hogan & Warrenfeltz, 2003; Jennings, et al., 2007). The three sets of competencies particular to leadership are: (a) setting and articulating the vision (Poole, et al., 2009; Rhyne & Teagarden, 1995), (b) developing people (Fornell, Lorange, & Roos, 1990), and (c) building and motivating a high-performance team (Hogan & Kaiser, 2005). The key difference is that managers act to limit

choices, and leaders develop fresh approaches to long-standing problems and open issues to new options (Zaleznik, 1992). Like leadership, management is not taught or addressed in the academic education of scientists (Sapienza, 2005) and scientists are generally thrust into managerial roles and have to learn their management skills on the fly (Kreeger, 1997). Despite this somewhat pejorative statement, “Learning on the fly” is one of the key leadership competencies in the Lominger Leadership Framework. Without the ability to “learn on the fly”, a leader is likely to be derailed (Lombardo & Eichinger, 2000).

The leader of a scientific research project requires two kinds of leadership: team leadership, and science leadership (Klavans & Boyack, 2008).

### **2.7.1 Leadership of a research team**

Leadership is, above all, a performing art with a range of leadership roles that must be filled and enacted in different situations.

(Pearce, 2007, p. 357)

... [it] is a dance, in which leaders and followers jointly respond to the rhythm and call of a particular social context...

(Cammock, 2003, p. 17)

Leading a research team is a challenge and the leader is responsible for fostering the development of an internal group culture which is supportive and conducive to a productive environment (Ashforth, 1985). The leader is also responsible for ensuring that there is the flexibility, adaptability and responsiveness necessary to be able to deal with changing circumstances (Teagarden, et al., 1995) but still permitting the high levels of interdependence demanded by academics. The research project itself has been described by Pearce and Manz (2005) as a complex situation which has:

- No well defined form or structure;
- Dynamic and interactive structures and relationships;
- Dimensions and variables that are not known due to lack of clarity of the problem;
- Uncertainty and ambiguity;

- A dynamic environment;
- Divergent holistic systemic thinking; and
- Many possible solutions.

Adding to the challenge created by the complexity of the research project a leader also has to cope with leading a team of individuals who have a number of characteristics which are essential for doing good science, but they can be very challenging as individuals. As noted in section 2.6.1, scientists have certain personality traits that can make them difficult to manage, they see science as the core of their identity; they are independent in thought and action; they are creative and explorative; and they are technical experts (in their discipline) rather than skilled in managing people (Hurd, 2009). To this list must be added that scientists may not be well attuned to the interpersonal dynamics of a team, and are not likely to notice cues to how others are feeling and they may not even be very self aware (C Cohen & S Cohen, 2005).

In a recent study by Sapienza (2005) on how scientists define effective leadership, the characteristic of caring and compassion featured most frequently (28 percent of responses), followed by possessing managerial skills (23 percent of responses), technically accomplished (15 percent of responses), and being a good role model (11 percent of responses). Equally interesting is that those same scientists defined ineffective leadership as having a boss who was abusive (19 percent of responses), exploitative (19 percent of responses), and unable to deal with conflict (14 percent of responses). The author described how the responses revealed the powerfully negative climate that can be created when there is an ineffective leader and how this can affect productivity.

Autonomy, integrally related to academic identity (Henkel, 2005), and tacit knowledge, are both regarded as the defining characteristics of professional workers, and some researchers claim that the disciplinary culture, and its norms and values, is being challenged by a managerial culture (Harvey, et al., 2002; Morrison, et al., 2003; J Roberts & Dietrich, 1999). Wray, however, observes that even though a research team may operate in an undemocratic fashion with the

principal investigator calling all the shots, the group, and the individuals can still act freely ( 2006).

### **2.7.2 Science leadership**

Leadership in science as a discipline as opposed to leadership of research as an activity has had limited study and what there is often is part of larger studies on organisation in science (Chompalov, et al., 2002). There are three different kinds of science or disciplinary leadership. 1. Current leadership which is simply a count of current scientific publications; 2. Discovery leadership which is a summary calculation of a range of impact measures typically based on citation counts to older literature; and 3. Thought leadership, which is a new, independent indicator which measures whether current papers are building on the more recent discoveries or on the older discoveries in a field. Thought leadership can be used at the level of countries, institutions, or research groups to show where gains are being made (Klavans & Boyack, 2008; McCrimmon, 2005).

Central to all three types of science leadership is the requirement that ‘the’ leader must provide connectedness with other research communities, funders, industry etc (Harvey, et al., 2002).

### **2.7.3 Collaborative team leadership**

It has been demonstrated that appropriate leadership can enhance the overall effectiveness of teams and increase the satisfaction of team members and that different types of collaboration require different types of leadership (Gray, 2008). As teams get bigger and the scientific enterprise more significant, the managerial tasks of the leader become larger and the less time he or she is likely to spend “at the bench” (F Collins, et al., 2003). It has been suggested that collaboration is changing the very nature of managing in the current era of more permeable organisational boundaries, or what some have called post-bureaucratic organizing (Espinosa, Cummings, Wilson, & Pearce, 2003; Hodgson, 2004).

## **2.8 Measuring research performance**

The overriding goal of scientific research is the generation of new knowledge (Bammer, 2008a, 2008b) and traditionally the researchers themselves have judged the quality of the work of their colleagues (Rinia, et al., 1998).

As exploitation of the new knowledge produced by scientific research increasingly becomes a key element in the growth and development strategies that governments have developed for their various economies, assessment of the performance and the outcomes of the research funded by those governments has become an important factor in the life of a researcher (S Cole, 2000; Coryn, Hattie, & Hartmann, 2007; Schubert, 2009; Van Raan, 2000).

There are vast differences in the ways that governments fund their research programmes and there is an equally diverse range of approaches to how they evaluate the research they fund and its outcomes. Increasingly, as resources are constrained funders look for efficiencies in how money is spent, and decisions on funding, in terms of what is funded and to what degree, are being related to performance. Being able to measure performance and outcomes is now a significant component of the funding process (Geuna, 2001; Geuna & Martin, 2003; G Laudel, 2006; Schmoch, Schubert, Jansen, Heidler, & von Gortz, 2010; Schubert, 2009).

William Starbuck, (2005), writing on performance measurement in general, observed that performance measures have become a dominant and ubiquitous theme in modern society. He goes on to say that their use can dramatically improve human and organisational performance, but equally, if not carefully designed and actually measure the variables they purport to measure, performance measurement can be counterproductive and damaging. Assessing performance in scientific research is a complex process and conflicts have arisen over finding a suitable framework and methodology.

Traditionally, within the scientific community and the community of researchers in general, researchers have judged the quality of the work of their colleagues by the process of peer review or expert based judgement. Through this process scholars can gain admittance to communities of scholars, journal editors choose which articles will be published, and funding agencies allocate

funds to projects and researchers (Rinia, et al., 1998). As a process, peer review has been described as being crude and understudied (Kassirer & Champion, 1993; Ware, 2008) but it is regarded as being fundamental to scientific progress (Alberts, Hanson, & Kelner, 2008). It has been a very successful tool, but it does have its shortcomings such as subjectivity, perhaps in choice of reviewers, and bias either scientific as in institutional affiliation, or non scientific bias such as age, gender and race (S Cole, 2000; Ware, 2008).

A major limitation of the peer review process today is that in emerging fields or cross disciplinary areas colleagues and peers find it difficult to form valid opinions of performance in areas in which they are not expert (Van Raan, 2000). Furthermore as the numbers of scientific papers published continue to increase, and the papers become more interdisciplinary, peer review becomes under increasing stress. The increasing burden being placed upon the entire scientific enterprise has prompted the editor of *Science*, in 2008, to urge “The scientific community ... [to] collectively ensure that the peer review process continues to serve the loftier goals of our enterprise, which ultimately benefits us all” (Alberts, Hanson, & Kelner, 2008, p.15).

Over recent years more quantitative measures in the form of bibliometric indicators have been used to assess research performance (Garcia-Aracil, Gutierrez, & Perez-Mar, 2006; Roy, Nagpaul, & Mohapatra, 2003; Taylor & Taylor, 2003; Tuire & Erno, 2001). These indicators have been described as useful tools in the assessment of research performance providing that “they have a sufficient level of sophistication, their pitfalls are taken into account, and that they are used in combination with other, more qualitative knowledge about the units to be assessed” (Moed, 2000, p. 323). Bibliometric indicators are largely simple arithmetic measures (i.e. counting) of output in the form of the number of papers published, and the Journal Impact Factor (JIF), or “what the scientist might expect to receive in terms of citations (during a single year)” (Ingwersen, Larson, & Wormell, 2000, p. 376). Such data can be used to develop research profiles of individuals and institutes, and mapping of the data can show where individual researchers and institutions are positioned on world science maps and

demonstrate the levels of influence of individuals and institutions in various fields (Buter & Noyons, 2001; Small, 2003; Van Raan, 2000).

The level of third-party funding for scientific research has become one of the most commonly used quantitative indicators of research performance and quality. This is despite the fact that it has been shown that success in obtaining market funding is only partly related to the quality of researchers and their proposals, and it does not answer the question of what has actually been achieved with the expenditure (Coccia, 2005; M Levitt, 2005; Schmoch & Schubert, 2009). The level of third party funding now widely used as a performance and quality measure was initially used as an instrumental goal, or means of achieving an end, but as public funds available for research have become more scarce it has morphed into a fundamental goal, or the means itself (Laudel, 2005; M Levitt, 2005).

The use of indicators is still controversial and fraught with problems and there is not yet any real consensus on what indicators are best (Coryn, et al., 2007), but they do provide a more systematic approach to at least part of the assessment process, and they counter, again to some extent, the subjectivity inherent in peer review. Indicators are critical tools in understanding the performance of research institutions and research units, in evaluating the status of research fields, their role in economic systems and markets, and in the efficient allocation of public resources and it is not suggested that they should replace peer review, but rather be used in parallel with peer-based methods (Coccia, 2004; Lehmann, Jackson, & Lautrup, 2008; Schmoch, et al., 2010; Van Raan, 2004).

### **2.8.1 Measuring collaboration**

Collaboration in scientific research is often an explicitly identified objective of funding agencies and a condition to funding. It is also often used by those agencies to measure the success of a research project. To date the approaches to measuring collaboration are still quite crude. Co-authorship is considered to be an indicator of collaboration (Bukvova, 2009; Garcia-Aracil, et al., 2006; Schmoch & Schubert, 2009), although the degree to which it represents collaboration has

been questioned (Bozeman & Corley, 2004; Katz & Martin, 1997; Newman, 2004). Another measure that has been suggested as plausible way of generating a quantitative measure of collaboration is social network analysis (described in section 2.8.2) (Rigby & Edler, 2005).

### **2.8.2 Co-authorship/citation**

Authorship has been described as a “particularly thorny issue in science” as, unlike intellectual property, there is no codified body of doctrine or law, and the practices and conventions change across disciplines and institutions but generally the first person to make a discovery gets most of the credit (Biagioli, 2003). Credit for contribution is the basis of a researcher’s professional credibility and career citing the work of others is one way that a researcher can accord credit to colleagues. It is also a way of giving greater credibility to one’s own work and to show how new work flows naturally from the accepted work of others (D L Hull, 1997). The research shows that collaborative research is more highly cited (Qin, et al., 1997), and co-authored papers have longer reference lists than single-authored papers (Glanzel, 2008; Wuchty, Jones, & Uzzi, 2007) and as collaboration becomes more prevalent, allotting credit in multi-authored publications has become an important topic for researchers (Moed, 2000).

There are many individuals involved in any research venture as well as the researchers themselves but some contributors are rarely mentioned or acknowledged (Cronin, 2001b; Katz & Martin, 1997; Laudel, 2001). Being accorded credit for contribution can come about in two ways: either through being listed as a co-author or by being acknowledged as a contributor (Lorigo & Pellacini, 2007). Acknowledgement, a less visible way of being accorded credit, is described as ‘sub-authorship’ and refers to those persons acknowledged by the authors of the publication as having given substantial assistance to the project (Glanzel, 2002; Glanzel & Schubert, 2004).

The conventions regarding the allocation of credit in collaborative research are highly variable and dependent on field or subfield. At the individual level the most common systems are Alphabetical or First Place - Last Place (Beaver, 2001). Intermediate authors tend to be overlooked, or be less highly valued. At the level

of the academic unit, institution, or country there are two methods in use. The integer counting method whereby a collaborative paper and its impact is assigned totally to the contributing unit, or fractional counting whereby some fraction is attributed to each collaborator. Determining the size of individual contributions can be a contentious issue, however, (Moed, 2000).

The difficulties that the governors and managers of today's very large scale projects face regarding allocation of authorship is illustrated by the actions of the Collaboration Council of the Stanford Linear Detector (SLD). In 1988 (some years ahead of the actual opening in the 1990s), the Council, spelled out the policy on authorship. The stability of the group was the prime consideration, and the first specification related to who should be included. This policy was so rigid that even if a paper was written by one person, or originated as a thesis, the individual's name or that of the student was only in the first footnote. "For physics papers, all physicist members of the collaboration are authors. In addition, the first published paper should also include the engineers." For all the various kinds of reports, briefing papers, internal memos, conference papers and so on, the Council developed a protocol (Galison, 2002, p.332).

At the Fermilab's Tevatron with a collaboration of 424 physicists, the authorship protocol states that "all serious participants ought to be on all publications" and then goes on to elaborate what is meant by "serious participant" (Galison, 2003, p.337).

The number of papers being authored by more than one author has increased substantially. Between 1945 and 1995 the average number of authors per scientific article rose from 1.8 to 4.6 (Cronin, 2001b) and in the physical sciences there are papers that list over fifty authors (Beaver & Rosen, 1978). The number of papers with 100 or more authors (termed "hyper-authorship") has increased from 1 in 1981 to 182 in 1994. Papers with extraordinarily large number of authors can be found in some medical research fields and high energy physics (Cronin, 2001b; Cronin, Shaw, & La Barre, 2003).

These co authorship networks have been extensively studied using social, and/or affiliation network analysis (Wagner & Leydesdorff, 2005a) and results show that most scientists who have co-written papers do know each other,

although there are exceptions such as in some of the very large collaborations in high-energy physics, where co-authors can number in their hundreds, creating the 'hyper-authorship' situation mentioned earlier. There are also interesting disciplinary differences between sizes of networks with the experimental disciplines networks being large, and the networks of the theoretical disciplines tending to be smaller (Cronin, 2001b; Cronin, et al., 2003). Like the science maps discussed in section 2.8 which show where individual researchers and institutions are positioned on world science maps, social network analyses such as these show where the "core documents" in any discipline are, and thus are important nodes in the networks (Cronin, 2001b; Glanzel, 2002; Newman, 2001).

Closely related to co authorship and citation is the impact of a publication. Citation analysis, initiated by Eugene Garfield in the mid-1950s, has long been used to measure the impact and quality of scientific work (S Cole, 2000). It has been found that the highest impact comes from publishing papers from international collaborations, and the least impact from papers coming out of national collaborations. Papers from within one institution have greater impact than those from a national collaboration (Glanzel, 2002). At the individual level it has been shown that the highest performing groups of researchers, based on productivity measures, are those having the highest number of senior collaborators (van Raan & van Leeuwen, 2002).

Citation is the method by which researchers accord credit, and it is not "just a quaint tribal custom" (Ziman, 1994, p. 180), but rather a social mechanism by which reliable scientific knowledge is generated and evolves and a means of ensuring accuracy. Failure to cite hurts careers of others (D L Hull, 1997).

## **2.9 Successful collaboration**

Even though research is one of the most fundamental activities in which academics, and professional researchers engage, and a great deal of work has been done on describing what successful collaboration looks like, little is known about what makes collaborative research successful (Andrade, et al., 2009). Evaluating the outcomes of collaborative scientific ventures, and particularly

those where there is a true integration across multiple fields is enormously complex (Stokols, et al., 2003).

In a 1992 publication on collaboration, entitled “Collaboration: what makes it work” the authors ask “what do we mean by successful collaboration?” (Sargent & Waters, 2004), and they go on to list six groups of 19 factors that will influence the success of a collaboration. These groups are: 1. Environment; 2. Membership; 3. Process/Structure; 4. Communications; 5, Purpose; and 6. Resources. In more recent studies, these same concepts are identified as “success factors of collaborative research” – the same ideas, albeit under different names. These success factors, however, are not actually the criteria for deciding at the conclusion of the project if it was successful, but are, in fact, the inputs into the project management system leading directly or indirectly to the success of the project. There are many such lists (for example. Barnes, Pashby, & Gibbons, 2006; Glaser & Taylor, 1973; Hara, et al., 2003; Maglaughlin & Sonnenwald, 2005; Pinto, Pinto, & Prescott, 1993; Wray, 2000) but perhaps the most compelling one, in terms of coverage and simplicity, is that based on the work of Olson, et al. (2008, p 80). The factors are grouped under five main headings (see Appendix E for details):

1. The Nature of the Work: some independence but clarity of role;
2. Common Ground: previous collaboration, shared vocabulary, working and management style;
3. Collaboration Readiness: goals aligned, trust, appropriate competence mix and motivated to work together;
4. Management, Planning and Decision Making: critical mass, project manager, principals have time to do the work, communication plan, protocols and procedures in place; and
5. Leadership.

Determination of the success of the project is made on the basis of the achievement of the objectives of the project and is measured against a set of predetermined success criteria, often termed ‘milestones’. Project management

success is a judgement of the performance of the researchers against cost, time and quality (Cooke-Davies, 2002). Both project success and project management success are important elements in determining the 'value' of any collaborative research project, and are important in raising standards.

Unfortunately because writers on "success in scientific research" tend to use the technical terms of the discipline of assessment and evaluation in different ways, often interchangeably or assuming a shared understanding (Williams, 2006), the literature can be quite confusing. The key terms are: measure, evaluate, assess, and judge, and all have specialised meanings.

Assessment is a process of gathering different kinds of information concerning the functioning of something. In this case it is a scientific research project but it can be of an institution, student, or any kind of activity. The basic aim of assessment is to improve the functioning of whatever is being assessed (Astin, 1993) and it can comprise a whole suite of activities with information being sourced in many ways including subjective and objective methods. Measurement, frequently used to get data, is defined as the determination of magnitude or quantity against a recognised standard. The number of publications would be a measure. To 'evaluate' is subjective and means to work out the "value", "worth" or "quality" of something. Researchers evaluate professional journals and those identified as being of higher quality are the ones in which they prefer to publish. In judgement all the various objective and subjective methods are brought together and a subjective estimation or appraisal, termed a judgement, is made an opinion is formed followed by an authoritative declaration on the whole (OED, 2009). Because different kinds of data and information are being brought together and judged it is a difficult and complicated process to do well.

Developing a systematic assessment process for research is complicated and even within the natural and physical sciences, the variations in publication and citation practices, variations in importance of different communication practices or literatures between disciplines, and subdisciplines makes this difficult. In writing about the introduction of a new form of academic performance assessment and allocation of research funding similar to the

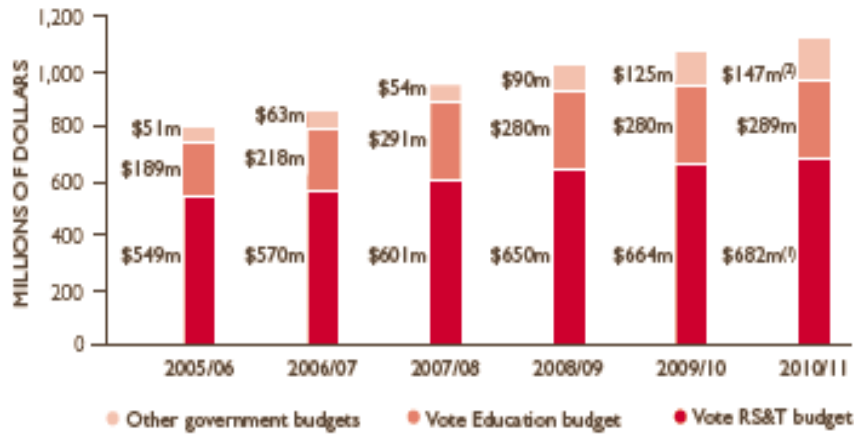
Britain's Research Assessment Exercise (RAE)—the Research Quality Framework (RQF), Butler (2007) calls for a balanced approach and notes that 'metrics' have their place, in terms of efficiency and cost-effectiveness, but peer review must be retained as a central element in any research assessment exercise. Retention of peer review is the first recommendation in the Robert's Report which was the major driving force in the development of UK policy relating to researchers (G. Roberts, 2003). Extending assessment to the processes and outcomes of scientific collaboration is even more complicated and specialised (Scriven, 1996; Vleuten, 1996).

There is a myriad of practical difficulties in research collaboration. Researchers must cope with differing epistemologies, methodologies and paradigms of different disciplines, and even when working in the same discipline, they bring different perspectives and different strengths to their shared work (Mattessich & Monsey, 1992 p. 37). Overcoming the different disciplinary specific languages was noted in two New Zealand studies, one by Baines (2006) and the other by Massey et al. (2006). Even though, as Jeffrey says, collaborative research is now almost 'de rigueur', we still do not have a good understanding of the determinants of good practice, or the effective translation of its output into policy and decision support tools" (2003, p. 539).

## **2.10 Collaboration in scientific research in New Zealand**

In New Zealand scientific research is funded, in the main, by government through either Vote RS&T (Research, Science and Technology) or through Vote Education. Approximately 30 percent of this research is undertaken in the Higher Education Sector (MORST, 2010).

Figure 1: Budgeted government funding for R&D, 2005/06 to 2010/11



(MORST, 2010)

### 2.10.1 Measuring research output

Science output in New Zealand is measured by the number of publications per year and during the period 2002 to 2007 this increased by 56 percent. Seventy one percent of authors were from higher education institutions – the sector showing the greatest sector growth with publication output having increased by 78 percent. Hendy cautions that this apparent increase in productivity is due, at least in part, to a function of the increase in researcher FTEs over the same period (Hendy, 2010).

New Zealand compares well internationally. On average, researchers produce 0.7 percent of the world’s scientific publications even though New Zealand funds only 0.2 percent of world research. New Zealand researchers have more papers published per US\$ million gross expenditure on R&D, and per US\$ million of expenditure on basic research than do researchers from any other OECD nation except Poland. They also publish more papers per US\$ million expenditure on basic research than the comparator nations Australia, Ireland, Finland, Denmark and Sweden (Palmer & Laurenson, 2010).

Relative to universities in Australia since the introduction of the PBRF New Zealand university citation rates have increased (Smart, 2009), but as this is also true of the CRIs, it is unlikely that it is attributable solely to the PBRF but more likely to be a combination of other, unidentified factors. Despite the growth in

publication rates, productivity has been stable and the increases in bibliometric output attributed to increases in researcher numbers (FTE) (Hendy, 2010).

Most of the New Zealand publications were in the fields of medicine (33 percent of total New Zealand publications), agricultural and biological sciences (21 percent), biochemistry, genetics and molecular biology (15 percent) and environmental science (11 percent). Publications in the disciplines of agricultural and biological sciences, and environmental science, are much more prominent in New Zealand's total publication output than they are in the OECD as a whole. Publications in engineering, physics, astronomy and materials science, however, were low (Palmer & Laurenson, 2010). Despite the relatively low output in physics and astronomy, and also in veterinary sciences, and various health disciplines the impact is greater than might be expected (Palmer & Laurenson, 2010).

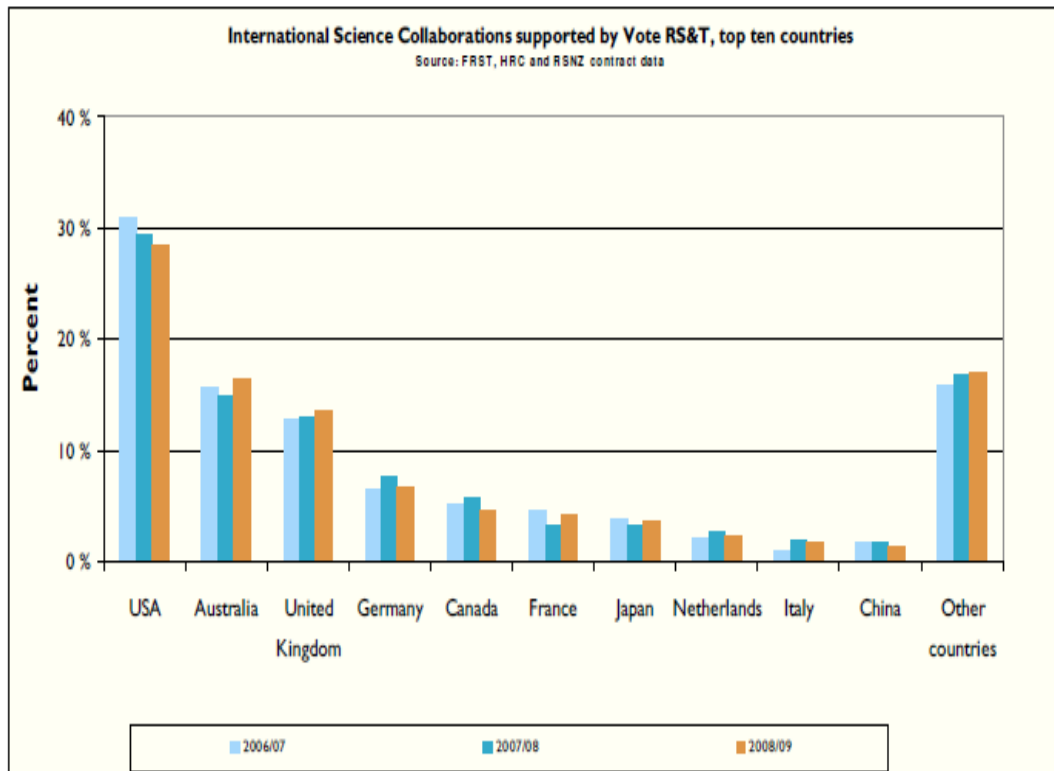
Collaboration is an important feature of the New Zealand science system. During the period 2002-2007 84 percent of New Zealand's scientific publications were multiple authored and 70 percent involved multiple institutions. An evaluative study of the scientific research journals published by the New Zealand Royal Society showed that the majority of articles published by the journals are the results of research collaborations between two or more institutions. The co-authorship network developed in this study showed a central core of four entities: National Institute of Water and Atmospheric Research (NIWA); Massey University, Otago University; and New Zealand's private businesses (the last is an artefact as it is 151 separate businesses that have published in the journals over the 2002-2009 period) (Gush, 2011, p. 10).

International co-authoring by New Zealand researchers, in the main, is with authors from the United States, Australia and the United Kingdom, and these collaborations have increased over time (Palmer & Laurenson, 2010). It has been pointed out by Adams that researchers in New Zealand (and in Australia) are increasingly co-authoring with international colleagues but are shifting the geographic focus of these collaborations. Countries such as Russia and South Africa are decreasing in importance, but there are marked increases in

collaboration with Spain and Switzerland, and more importantly with China and India (Adams, et al., 2010).

The chart which follows shows the levels of science collaboration with various countries and the recent trends.

Figure 2: Science collaborations by Vote RS&T, Top Ten Countries



(Palmer & Laurenson, 2010)

Regionally, Australia is an important collaborator with some 12.5 percent of all New Zealand co authored papers with an Australian co author (Adams, et al., 2010). The following chart shows the institutions with the greatest collaborative activity with New Zealand scientific researchers.

**Table 2: Top ten international institutional collaborators 2004-2008**

New Zealand	# of co-authored papers (2004-2008)	Avg. Cites/Paper
<b>University of Sydney</b>	404	7.47
<b>University of Queensland</b>	387	5.89
<b>University of Melbourne</b>	367	10.05
<b>Monash University</b>	232	5.42
<b>Australian National University</b>	223	6.48
<b>University of Oxford</b>	215	14.5
<b>University Victoria Canada`</b>	197	5.46
<b>University of New South Wales</b>	187	5.86
<b>University of Western Australia</b>	167	8.17
<b>National University of Singapore</b>	164	3.95

### **2.11 Summary**

Collaboration has become an important and ubiquitous aspect of scientific research today. The reasons for researchers collaborating are varied and they range from the purely utilitarian such as individual scientists collaborating to reduce feelings of isolation, to collaboration as the best approach to tackle the large scale problems facing society today. The consequence of researchers collaborating is a renewed focus on, inter alia, teams, teamwork, collaborative research competencies, leadership, and processes for coordinating the activities of the individual team members.

For New Zealand, being a small country, with a small investment in scientific research, collaboration is an important tool in augmenting the size of the research community and the available resources. Through being an active international science player New Zealand's science capabilities are extended, and in turn New Zealand is able to draw on global science activity.

The next chapter, Chapter Three the Methodology chapter, sets out how the objectives of the study are to be achieved.



## CHAPTER THREE: METHODOLOGY

Epistemology is the science of knowing and methodology the science of finding out.

(Babbie; 2010, p. 4)

### 3.1 Introduction

As was noted in chapter one, collaboration in New Zealand is increasing and whilst these bibliometric studies tell us in what disciplines this is occurring, there is no clear picture of where, i.e. in what institutions, it is occurring and why it is occurring. A 2003 study of the collaborative scientific research undertaken in the Faculty of Science at Victoria University of Wellington (Morrison, et al., 2003) showed that almost all staff in the Science Faculty were engaged in some collaborative research. Within-discipline and within-School collaborations were the dominate form and “Collaborative links with other research groups in New Zealand [are] relatively weak” (Morrison, et al., 2003, p. 290). My aim in undertaking this research is to add to our knowledge of collaborative scientific research activity in New Zealand by reviewing collaborative scientific research activity of researchers in another university, The College of Sciences, Massey University. The focus of the study is on the extent of collaborative activity that is undertaken and why researchers collaborate. This chapter begins with a discussion of the theoretical and epistemological perspective underpinning this study, the methodological approach, and discussion of the two data collection methods.

### 3.2 Framework for the study

The theoretical framework or ‘paradigm’ is the network of coherent ideas within which the researcher works. It comprises the basic set of beliefs and practices adhered to by a group of researchers, and it guides the researcher’s actions. Such a framework has three elements: ontology, the ‘reality’ which researchers investigate and upon which a theory is based; the epistemology, which is the relationship between that reality and the researcher and encapsulates the

knowledge-gathering process including developing new models of theories; and the methodology, which is the set of general principles which underlie how researchers investigate the social world and the methods and techniques they use to do so.

Research is generally described as being either quantitative or qualitative. In quantitative research the focus is on the careful control of variables, measurement, statistical analysis, and analysis of causal or correlational relationships between variables. The researcher maintains an objective stance. According to Di Nuova this does not necessarily give the whole story about an event as not even a "summing up of [the] variables give[s] us the reality in its complexity..."(Di Nuova, 2010, p.18). Not all research is amenable to measurement or quantification as is practised in the natural sciences (Maldonato & Pietrobon, 2010; Morgan & Smircich, 1980; Strauss & Corbin, 1990) and data that is collected through observation and interpretation of events and from which theory is built through an inductive process is termed qualitative research. In this research overt acknowledgement is made of the relationship between the observer and the subject and the observations which are made through the researcher's own lens or perspective, shape how the task and the approach to it are conceptualised, how the research question is framed, how the study is structured, which concepts will be studied, and how the findings are framed.

Teddle and Tashakkori (2010) maintain that complex social research questions do not lend themselves to being studied solely in either of the traditional research modes, i.e. either qualitative or quantitative methods, but can be studied by combining both approaches into the third methodological approach termed a "mixed methods" approach (2010, p. 18). By this they mean that there is an overarching question that requires a structured quantitative approach and an emergent and holistic qualitative component. The overarching question can be broken down into a number of sub questions, each of which requires a different approach to reach an answer. This is the approach taken in this study. The overarching research question is: "Do scientific researchers in the College of Sciences collaborate, and if so why?" This has been broken into a

number of sub questions framed as objectives and approached from a mixed methods perspective.

### **3.2.1 Mixed methods**

The mixed methods approach comprises separate quantitative and separate qualitative phases. It is not a mixed model in which the techniques of both qualitative and quantitative research are mixed or combined into a single phase (Johnson & Onwuegbuzie, 2004; Johnson, Onwuegbuzie, & Turner, 2007). The justification for choosing this design is that both approaches have different strengths and different purposes, and they have different weaknesses. Quantitative research focuses on deduction, theory/hypothesis testing, prediction, standardized data collection, and statistical analysis. This approach is suitable for Objective one which is to ascertain or measure the extent of collaboration in the College of Sciences. Qualitative research focuses on induction, discovery, exploration, theory/hypothesis generation, with the researcher as the primary "instrument" of data collection (Johnson, et al., 2007). This approach is suitable for Objectives two to five as they involve discovery and exploration of the ideas and perspectives of the participating researchers.

Combining the elements of both qualitative and quantitative approaches "gives breadth, depth of understanding, and corroboration" (Johnson, et al., 2007, p. 123) and Melin (2000) claims that from a mixed methods approach a fair and general picture of what the participants think will emerge. Surveys which are quantitative instruments can reveal any general patterns and interviews which are qualitative instruments and have no statistical analysis, can reveal personal or emotional details and allow participants to express opinions and ideas according to their experiences and not just express general ideas.

### **3.2.2 Interpretivist paradigm.**

The qualitative phase (objectives two to five) of this study is interpretivist and based on the assumption of the social construction of reality. In contrast to the positivist's position, the interpretivist view is one of multiple realities and it assumes that human action is meaningful and has intent. It is concerned with meaning and the researcher's attempts to interpret, or make sense of the

practices under observation in terms of the meanings and the value that individuals or social groups bring to specific events or matters (Denzin & Lincoln, 2003; Di Nuova, 2010; Schwandt, 1994).

In the physical sciences it is expected that adherence to the norms of objectivity, methodological rigour, universality and measurement will ensure that the results will be accurate and factual. Issues of reliability and validity are emphasised (Clavarino, Najman, & Silverman, 1995; Corbin & Strauss, 1990; Kvale, 1996). In the interpretivist paradigm, judgements of research quality are not so straight forward and the researcher/writer has to convince the reader that the findings are worth taking into account (Lincoln & Guba, 1990). The conventional criteria of internal validity, reliability, external validity and objectivity (Kvale, 1996), may be applied but some researchers express reservations about applying such criteria to qualitative research because of the anecdotal nature of qualitative research, and because the assumptions upon which concepts such as reliability and validity are based are incompatible with interpretive enquiry (Clavarino, et al., 1995).

There is an extensive literature on how data should be collected, codified, and interpreted and this will be returned to in Chapter Four, Analysis of the Data.

### **3.3 Approvals to undertake this study**

Approval to undertake the field work for this study was sought from the Ethics Committee Massey University, the Pro Vice-Chancellor, the College of Sciences and from the four main funding agencies – the Ministry of Innovation and Science (MSI), the Tertiary Education Commission (TEC), the Royal Society (RSNZ) (in relation to the Marsden Fund), and the Health Research Council (HRC).

#### **3.3.1 Ethics Committee, Massey University**

Historically, adherence by scientists to the 'norms of science' (see section 2.1.5) their discipline-specific codes of conduct, and peer review processes were sufficient to ensure achievement of a balance between the benefits arising from a piece of research, and the potential harm that could arise from that same research (Mulkey, 1976). Thus, both the scientific community, and the wider

community, were protected from unethical behaviour (Haggerty, 2004). This self-monitoring framework still operates but has been augmented by formal systems of oversight, compliance, and accountability put in place by governments, funding agencies, employing organisations, and professional associations.

At the heart of ethical research is informed consent, the appropriate use and protection of data to ensure confidentiality, and enable the evaluation of any risk to participants (Madden & Wiles, 2003). It is interesting to note that the 2005 interim results of a survey of existing codes of conduct and codes of ethics for scientists, undertaken by the Division of Ethics of Science and Technology of UNESCO (UNESCO, 2006), shows that in the physical, mathematical and engineering science disciplines and professional groups there are more codes of ethics and codes of conduct than in other discipline and professional groups, and that the most frequently recurring statement in these codes relates to confidentiality of information.

Like other research organisations, Massey University has a code of ethical research (2010b), the key principles of which are:

- a) Respect for persons;
- b) Minimisation of harm to participants, researchers, institutions and groups;
- c) Informed and voluntary consent;
- d) Respect for privacy and confidentiality;
- e) Avoidance of unnecessary deception;
- f) Avoidance of conflict of interest;
- g) Social and cultural sensitivity to the age, gender, culture, religion, social class of the participants;
- h) Justice.

Evaluation of the requirements to gain University approval for this project was initiated through completion of the Massey University Screening Questionnaire. This step was to identify areas where action needed to be taken, and the protocols to be adopted. Subsequently, a Low Risk Notification was

forwarded to the University Ethics Committee and approval was given (Approval dated 15 July, 2010). (See Appendix F).

### **3.3.2 College of Sciences, Massey University**

Very early in the preparation of this field work an approach was made to the Pro Vice-Chancellor, College of Sciences, Massey University seeking approval to undertake a survey of the academic staff of the College of Sciences and to interview a number of researchers. Approval was received and the documentation, comprising my letter to the Pro Vice-Chancellor requesting to undertake the survey and interviews, and the return letter of approval; letters to academic staff inviting participation, and follow up letter thanking them for doing so; Information for participants; and Participant consent form are in Appendices G – L. Thank you letters and a small token of appreciation were also sent to the office of the Pro Vice-Chancellor and Administration Manager, and to all those who had provided invaluable assistance in organising the distribution, and follow up reminders, of the survey and the organisation of the interviews.

### **3.3.3 Funding Agencies.**

The four key research funding agencies approached were the Ministry of Innovation and Science (MSI), the Tertiary Education Commission (TEC), the Royal Society (RSNZ) (in relation to the Marsden Fund), and the Health Research Council (HRC). In all cases approval to interview an officer of the organisation was received.

## **3.4 Data collection**

As noted in section 3.2.1 this is a mixed methods study with both a quantitative phase and a qualitative phase. At the beginning of the design phase of the data collection, a high level table (Appendix M) was drawn up to show the relationship between the study objectives, the data required to answer the objectives, and the method by which the data would be collected. This high level table was then detailed into the questions to be asked (Appendix N).

The aim of phase one, the quantitative phase of this study was to answer Objective one, and aspects of Objectives two and three, through a survey of the

entire population of scientific researchers in The College of Sciences, Massey University (note that the topic of response rate is discussed section 3.4.1.5 and the actual response rate is discussed in section 4.1). The survey elicited factual information about the respondents, their involvement in collaboration, and their views on collaboration. In addition to providing contextual data the analysis of the data from the survey contributes to the identification of the issues that were subsequently studied in the second phase of the study.

The aim of phase two, the qualitative phase was to answer Objectives two to five and consisted of interviews with a number of researchers in The College of Sciences, Massey University (note that the topic of sampling is discussed in section 3.4.2.7), and with officials of the four main research funding agencies, and a senior officer of Massey University. Through the interviews in-depth information was sought on the processes, behaviours and activities scientific researchers undertake when collaborating, and the perspective of the funding agencies. The official nominated by each funding agency had expert knowledge on research funding and the funding policies and practices of the particular agency.

### **3.4.1 Phase 1: Surveys**

The survey method used to address Objectives one and aspects of Objectives two and three, formed the first phase of this study. All researchers in the College of Sciences were invited to participate and over the six week period two reminders were sent out.

#### **3.4.1.1 Why use a survey?**

The survey method used to address Objective one was selected because the survey is regarded as probably the best, and the most frequently used, means of collecting original data about the characteristics, actions, or opinions of a large group of people, referred to as a population. Surveys are efficient and relatively low cost in time and effort (Coleman, 1959). Mainly factual data is collected in surveys, and for more in-depth material, interviews are better (Pinsonneault & Kraemer, 1993; E. Roberts, 1999; Stablein, 2006). The data gathered in a survey is processed and converted into information and then used to inform decision-

making, to educate and to inform (Tourangeau & Ye, 2009). For this study, the data and information derived from the survey questionnaire formed the foundation of the study findings and identified issues to be followed up in the interviews which followed.

Pinsonneault and Kraemer (1993) distinguish between “surveys” and “survey Research”. Surveys, sometimes termed “status surveys” (Graziano & Raulin, 2010), often taking the form of marketing surveys, opinion surveys, and political polls, have become a ubiquitous part of life in modern society and the practice of surveying the public has developed into a multibillion dollar industry throughout the world. Survey research, on the other hand, has the overall goal of advancing scientific knowledge through gathering data and looking for relationships among the variables.

Over the last twenty years, developments in computing and the Internet, coupled with the creation of very large databases, have transformed surveys from straight-forward fact gathering tools into very sophisticated research tools with sampling techniques and powerful analytical protocols that allow inferences to drawn about large populations (E.Roberts, 1999).

There are three types of survey research - exploration, description, and explanation:

1. Exploration: for familiarisation with the topic and establishing what concepts to measure and how to measure them. It can also used to discover and raise new possibilities and dimensions of the population of interest; a theory generating approach.
2. Description: used for finding out what situations, events, attitudes or opinions are occurring in a population and the distribution in the population. The researcher's concern is simply to describe a distribution or to make comparisons between distributions. Analysis of descriptive questions provides facts and can be considered a theory generating approach.
3. Explanation: used for testing theory and causal relations. Survey research aimed at explanation is about the relationships between

variables building on from theoretically grounded expectations about how and why the variables ought to be related (Pinsonneault & Kraemer, 1993).

The survey forming the first phase in this study is both exploratory, in the sense of enabling the researcher to become familiar with the topic, establishing the extent of collaboration, and descriptive in the sense of illuminating what situations, events, attitudes or opinions are occurring in the population of researchers (Pinsonneault & Kraemer, 1993). Furthermore it is cross-sectional, as it is an observation of the population (or a representative subset) at a defined time, rather than longitudinal, which involves repeated observations of the same items over a period, sometimes decades, with the objective of identifying patterns and trends over time (Rindfleisch, Malter, Ganesan, & Moorman, 2008).

The basic tool of a survey is the questionnaire which has a number of valuable features. Surveys are very cost effective when compared to face-to-face interviews, are easily analysed, and because of the uniformity in questions and as there is no interviewer to influence the respondent they can reduce bias (Walonick, 2010). Questionnaires are also less intrusive than telephone or face-to-face surveys and when a respondent receives a questionnaire he/she is free to complete the questionnaire on his/her own time frame prior to the close-off.

#### **3.4.1.2 Criticism and limitations of surveys**

There are many critics of surveys. Some claim that surveys are nothing more than collections of data providing nothing of theoretical value; others claim that survey research is restricted by the limitations of highly structured questionnaires, and that there are other, and better, ways of collecting data (E. Roberts, 1999). In this part of the study because the data sought was factual data about the respondents and their involvement in collaboration, a survey was deemed to be the appropriate method to use and the questionnaire the appropriate instrument to use. Information on the researchers' experiences and their views of collaborations was sought in the second or interview phase of this

study. The survey data did contribute to identification of the issues which were raised in the interviews in the second phase.

A further group of critics claim that the data collected from surveys inevitably contains a great deal of error, in the form of sampling error, coverage error, measurement error, and non response error (Lindner & Murphy, 2001, p.44).

Surveys have also been criticised for having low validity and for being unreliable (see also Hinkin, 1998; Pinsonneault & Kraemer, 1993; Walonick, 2010). Validity is the extent to which the measurements of the survey provide the information needed to meet the study's purpose (Simon & Francis, 1998, in Glasgow, 2005, p.70). Content validity refers to whether the questions measure the content they were intended to measure. In this survey, to ensure validity, the objectives, the data required, the questions asked and the method of collection were linked in a table. These linkages are shown in Appendix M. Subsequently the survey was tested in a pilot study which is described in section 3.4.1.4. Reliability refers to the extent to which a measuring procedure yields the same results on repeated trials (Carmines & Zeller, 1979; Forza, 2002; Krosnick, 1999), but as this study utilises a cross sectional survey, consistency of survey responses over time is not an issue.

In any survey there is always potential for bias and the researcher must be prepared for this. In written questionnaires because there is uniform question presentation and there are no verbal or visual clues to influence a respondent, bias can be minimised (Pinsonneault & Kraemer, 1993; Walonick, 2010). Another area of concern with surveys and questionnaires is non-response. Response rate is discussed in section 3.4.1.5.

This survey was exploratory in nature and the sample, from within the population of scientific researchers within the College of Sciences, was self selected.

### **3.4.1.3 Survey design**

Many factors have an impact on the design of a survey and the tools to be used. Costs, type of analysis, population size and sample size, data input and

processing, delivery method, the form of the report and, not least, the objectives of the exercise must be considered (Cavana, Delahaye, & Sekaran, 2001) .

Even though there has been a great deal of study on the design of surveys, and according to Morrell-Samuels (2002), the difference between a good survey and a bad one is careful and informed design, there is still no coherent theory of questionnaire design (Gendall, 1998). Principles and frameworks aimed at ensuring data quality have been developed and most writers suggest that well defined goals are the starting point for questionnaire development (Gendall, 1998, 2005; Salant & Dillman, 1994; Walonick). Defining the concepts (the ideas) and the constructs (hypothetical concepts that are not directly observable) and accuracy in measuring them is regarded by many writers as the most difficult aspect of any study (Barrett, 1972; Price, 1986; E. Roberts, 1999; Stablein, 2006).

#### **3.4.1.4 Preparation of this questionnaire**

To address Objective one and to ascertain the extent of the current collaborative practices of academic staff in The College of Sciences, Massey University, a survey with 38 items was developed. This survey, in line with Pinnosault's (1993) classification system (noted in section 3.4.1.1) is exploratory and descriptive. It is not explanatory as it is not theory-generating, and because it is cross-sectional rather than longitudinal trends cannot be identified from this data.

The following four key steps were followed in preparation of the questionnaire:

- Step 1: Item development
- Step 2: Pilot Test with another set of researchers
- Step 3: Review and modification
- Step 4: Electronic distribution of questionnaire

### *Step 1: Item development*

In the preparation of this questionnaire the following criteria were observed:

1. Focus on the objectives;
2. Keep questionnaire to about 10 minutes in length;
3. Word questions to be clear and unambiguous;
4. Use mainly closed questions.

The length of a questionnaire has a major influence on response rate. In one study the response rate to a short survey was 30.8 percent whereas the response rate to a longer survey was only 18.6 percent (Marcus, Bosnjak, Lindner, Pilischenko, & Schutz, 2007). Furthermore the length of questionnaire has been shown to influence how many potential respondents even start to answer a questionnaire (Yan, Conrad, Tourangeau, & Couper, 2011). Because people allocate their mental resources according to how long they expect a task to last, more will start if told it is 8-10 minutes long than if it were 20 minutes. If their expectations are not borne out, performances are affected accordingly (Boltz, 1993, cited in Yan, et al., 2011). There are no hard-and-fast rules regarding the optimal number of questions, but keeping the questionnaire as short as possible is an effective means of minimizing response biases caused by boredom or fatigue (T Hinkin, 1998). In general a survey should be kept to 5-10 minutes. The average respondent is able to complete about 3 multiple choice questions per minute and an open-ended text response question counts for about three multiple choice questions depending, of course, on the difficulty of the question (Qualtrics Labs, 2009). My survey comprised 36 multiple choice questions and two short answer questions and I estimated that it would take about 15 minutes to complete it. The subsequent piloting is discussed later in this section.

At the most fundamental level it is critical to ensure that all potential respondents will interpret each question in exactly the same way, and respond accurately, thus the questions were designed to be clear, unambiguous, non-leading, in familiar language, and formatted so that the questions are easy to answer.

Apart from two questions, all the questions in this questionnaire were “closed”, multiple choice questions and the respondent was asked to answer by choosing a point on a 5 point category scale (see Zikmund, 2000, cited in Cavana, et al., 2001). This is illustrated in Figure 3.

**Figure 3:** Example of the questions used. The full questionnaire is in Appendix P.

What percentage of your research time is in collaboration with other scientific researchers?					
<b>Time percentage</b>	<b>0%</b>	<b>25%</b>	<b>50%</b>	<b>75%</b>	<b>100%</b>
	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>

Closed questions such as these, whilst keeping the time required to complete the survey to a minimum, because they are designed and selected by the researcher can be regarded as representing the researchers' agenda, even though the questions may have been generated out of discussion with others, focus groups, or from formal interviews (O'Cathain & Thomas, 2004). To counter this difficulty, respondents were given the opportunity to provide comments and views in two “open” questions. Open questions are valuable as they allow the respondents to note any difficulties or to add other issues which are not covered elsewhere, but they are difficult for the researcher as answers are difficult to analyse. In some cases, questions of this nature are not analysed at all, and some scholars are adamant that if the intention is not to analyse open questions, then they should not even be asked (Boynton & Greenhalgh, 2004).

#### *Step 2: Pilot study*

Pilot studies, sometimes termed ‘vanguard studies, or ‘exploratory studies’ are regarded as an important component of qualitative research (Beebe, 2007; Lancaster, Dodd, & Williamson, 2004; Van Tijnlinen, 2001), and a pilot study of this questionnaire was undertaken at the end of November, 2010.

Often used interchangeably, the terms 'pilot study' and 'feasibility study' have different meanings. A 'feasibility study' is undertaken before the main study to see if the main study can be done, and to identify and estimate the parameters/variables and boundaries of the main study. The 'pilot study', on the other hand, is a miniature version of the main study and is used to test the components of the study and to see if they all work together (NETSCC, 2010). In the pilot study the focus is on testing the methods and other practical aspects of the proposed study (Watson, Atkinson, & Rose, 2007).

The reasons for undertaking a pilot study can be grouped as follows (Sampson, 2004; Van Tijnlinen, 2001):

1. Process: to assess the feasibility of the steps required to take place in the main study;
2. Resources: to assess time and budget problems that can occur during the main study through collecting data on such things as the length of time to mail or fill out all the survey forms;
3. Management: to identify the issues relating to carrying out the study, personnel and data management issues, to identify potential risks and to foreshadow problems;
4. Scientific: to help in developing the research question, variables, issues relating to data adequacy and analysis; to show the direction of possible research lines of inquiry.

To ensure that the pilot study provides outcomes that are robust enough to be used the pilot study should have a well-defined set of aims and objectives and the necessary methodological rigour and scientific validity and the participants should always be representative of, but not part of the sample (Boynton, 2004).

Despite the potential usefulness of pilot studies, the limited literature on the topic claims that pilot studies may often be misused, or used in a haphazard way, and little attention is paid to them in scientific research training (Lancaster, et al., 2004; Sampson, 2004; Thabane, et al., 2010). Although they can be

expensive and time consuming (Gendall, 1994), Sampson suggests that pilot studies have potential to be of much greater use than is generally made of them. The usual practice is to use them only to tweak research instruments (Sampson, 2004).

Analysis of a pilot study should provide the researcher with sufficient information upon which a judgement can be made to either not go ahead with the main study because it would not be feasible, or to continue with no modification, or to continue with modifications such as close monitoring or modifying the research protocol. Researchers must be cautious though, as Gendall points out piloting does not always reveal misunderstanding and misinterpretation by respondents and he goes on to say that plausible answers don't mean respondents have understood or interpreted a question as intended (1994).

#### *Step 3: Review and modification*

The pilot study was undertaken at the end of November 2010. Six scientific researchers from another university were asked to complete the questionnaire and provide written feedback in the following five categories: 1. How well the questionnaire focused on the objectives, 2. Identification of ambiguities and difficult questions, 3. The time taken to complete the questionnaire, 4. Logistical issues relating to accessing and returning the completed questionnaire, and 5. Any other points. Where some of the feedback was not clear clarification was sought and emails were exchanged. Analysis of the feedback identified a number of amendments required and these were subsequently made to the questionnaire.

**Table 3: Feedback from pilot study**

<b>Feedback categories</b>	<b>Amendments made</b>
<b>Focus on Objectives</b>	One question added
<b>Identification of ambiguities and difficult questions</b>	One duplicate question was eliminated. Two slightly ambiguous questions were rephrased.  The type of scale used in one question was altered to one more appropriate to the question.
<b>Time taken for completion</b>	No amendment
<b>All questions answered</b>	No amendments had to be made
<b>Logistical issues</b>	No amendments had to be made

*Step 4: Electronic distribution of the questionnaire*

The questionnaire had been developed on proprietary on-line survey programme software known as Qualtrics (Qualtrics Labs, 2009). This software, which is licensed to Massey University, is an easy-to-use package of sophisticated functions with which one can design, test, distribute, and analyse a survey. Distribution of my questionnaire took place through the administration offices of the Schools within the College of Sciences, and was sent by email to all academic members of staff in The College of Sciences, Massey University. Attached to the email was the letter of invitation to complete the questionnaire, the URL to the survey, and information relating to approvals from the Ethics Committee of Massey University and the Pro Vice-Chancellor of the College of Sciences. As noted these documents can be found in Appendices F - L.

Surveying by email is very convenient, and evidence from various studies suggests that electronic and print data collection methods are comparable in many respects, including standard measures of reliability, and in terms of aggregate, descriptive information (Boyer, Olson, Calantone, & Jackson, 2002; Truell, 2002). Research also shows that electronic surveys have a few advantages such as convenience, lower cost (Simsek & Veiga, 2000), ease of data input,

flexibility in format, ability to capture additional response-set information, and reduced turnaround time (Franceschini, 2000).

Electronic studies also have a number of drawbacks such as the inability to maintain total anonymity (Shannon, Johnson, Searcy, & Lott, 2002), the upfront time investment required to develop the tool (Shannon, et al., 2002), and sampling limitations (Simsek & Veiga, 2000). Some critics, although by no means all (see Sax, Gilmartin, & Bryant, 2003) suggest that their major drawback, is that they do not achieve the same response rates as do mail surveys (Sheehan, 2001; Truell, 2002).

The email inviting participation was distributed at the end of January 2011 and, as the research shows that follow up increases the response rate (Kaplowitz, Hadlock, & Levine, 2004; Paxson, 1992), two reminders were sent. The survey was closed off March 31, 2011.

#### **3.4.1.5 Response rates**

Apart from government-sponsored population censuses, surveys are generally voluntary and their success rests on what Tourangeau terms, “a delicate and complicated relationship between those who conduct surveys and those who take part in them” (2004, p. 776). Response rates to questionnaires have declined over recent years brought about by over-surveying (Dillman, et al., 2009; Porter, 2004; Rogelberg & Stanton, 2007). Baruch and Holtom (2008) report that in academic studies, the average response rate for questionnaires used as the basis for published academic studies, during the period from 1975 to 1995 declined from 64.4 percent to 48.4 percent. They go on to argue that as high response rates generally ascribe greater credibility among key stakeholders it is critical that researchers understand response rate issues. Others argue that response representativeness is more important than response rate, but if the response rate affects the representativeness of the sample, it does become an issue (Cook, Heath, & Thompson, 2000).

The need for a minimum response level in surveying has generated a great deal of discussion and debate with figures ranging from 50 percent as a minimum (Baruch & Holtom, 2008; Dillman, 1991); 60 percent as a minimum (Fowler,

1984); and 80 percent as a minimum (Isaac & Michael cited in S.M.Cummings, Savitz, & Konrad, 2001). Babbie suggests that for mail surveys a 50 percent response rate is adequate, 60 percent is considered to be good and 70 percent is very good (2010, p. 262), and Guest argued that fifteen is the smallest acceptable sample size in qualitative research (Guest, Bunce, & Johnson, 2006). Justification for any of these figures is hard to find, and Baruch (1999) is concerned that all these suggestions are based on assertions rather than on data. He has suggested that a set of norms for individual and organisational response rates be developed.

The level of interest potential respondents have in the topic has a major effect on the response rate, and the term 'salience' is given to the association of importance and/or timeliness a person ascribes to the topic of a survey (Martin, 1994). Many studies have shown a strong positive correlation between perceived salience with response rates for all kinds of surveys, whether they are postal, web based or email. It has been shown that the odds of receiving responses to a survey that is highly salient are 1.87 times higher (19.0 percent to 30.3 percent) than to a survey that is of lowly salience (Marcus, et al., 2007). It was hoped that salience would play a role in ensuring a good response rate to this questionnaire and the email was worded to encourage completion but as the questionnaire was completed by 120 academic researchers giving a 28 percent completion rate salience did not have a major effect.

The effect of questionnaire length on response rates has already been discussed in section 3.4.1.4. Detailed results of the survey are discussed in chapter Four.

### **3.4.2 Phase 2: Interviews**

The interview method used to address Objectives two to five and formed the second phase of this study. This comprised a set of semi-structured interviews with three groups of key stakeholders – the researchers, the funders, and Massey University. The interviews were aimed at eliciting detailed information from the researchers on why and how they collaborate, from the funders on why they do or do not encourage collaboration and the interview with the AVC

Research – Enterprise was to ascertain the views of Massey University on collaboration in scientific research. As identified in Table 3 the interviews addressed all objectives and followed up on certain issues that had been identified in the analysis of the responses to the questionnaire.

Arrangements for the interviews were as follows:

- Researchers: On receipt of approval from the Pro Vice-Chancellor of the College of Sciences, arrangements were made to interview a sample of researchers (sampling is described in Methodology, section 3.4.2.7);
- Funding Agencies: Contact was made with the Chief Executive of each agency and I was directed to contact specific individuals; and
- Massey University: Contact was made with the office of the Assistant Vice-Chancellor, Research & Enterprise and an appointment made to meet.

#### **3.4.2.1 Why use an interview?**

The interview, like the survey, has been described as the most widely used data collection strategy in qualitative research (Lambert & Loiselle, 2008) and whereas the survey is used to explore, describe, or explain (Pinsonneault & Kraemer, 1993), the interview is a means of gathering descriptions, understandings, and interpretations of the world of an interviewee (Patton, 2002). In other words, the interview is a means of exploring how others understand and describe their worlds and as this was the focus of Objectives two to five in this study, the interview was deemed the most appropriate instrument to use.

The interview has been referred to as dialogue in which there are mutual interests in a conversation, as a negotiated text or neutral exchange of asking questions and getting answers (Denzin & Lincoln, 2005). In this basic model of the interview it is the job of the researcher to extract information from the interviewee and as such it is a powerful method of producing knowledge of the

human situation. Because an interview is face to face it does allow either party to clarify questions and to clear doubts, and the very presence of the interviewer is said to decrease the number of “don’t knows” or “no answer” (Babbie, 2010).

The issue of quality in interviews is the subject of much debate. Mishler (1990) suggests that rather than the researcher trying to determine the “truth” in a situation, it is preferable for the researcher to make a judgement on the relative plausibility of an interpretation when compared with alternative interpretations. In section 3.1.4 in the discussion of the assessment of research, plausibility was defined as how well the writer of the text connects the reader and the subject's world (Golden-Biddle & Locke, 1993). Quality of an interview is multifaceted and extends to the appropriateness of the interview as a data collection tool, the ability of the interviewer, how questions are asked, how studies are designed, and the relationships between the interviewee and the interviewer. A ‘best practices’ summary was developed by Kvale (1996) who proposed six criteria for judging the quality of an interview:

1. The responses from the interviewee are spontaneous, rich, specific, and relevant answers;
2. The interviewer’s questions are short and the subject’s answers are long;
3. The interviewer follows up and clarifies meanings of the relevant aspects of the answers;
4. The interview was to a large extent interpreted throughout the interview.
5. The interviewer verified his or her interpretations of the subjects’ answers in the course of the interview.
6. The interview was ‘self-communicating’ – it is a story contained in itself that hardly requires much extra descriptions (*sic*) and explanations (*sic*) (Kvale, 1996).

### 3.4.2.2 Criticism and limitations of interviews

The interview is not as straightforward as it appears at first sight and is fraught with difficulties. As a data collection tool it does have its critics. As noted earlier, the interview has been described as a 'dialogue' (Kvale, 2006) and this suggests mutuality, egalitarianism, unassuming, non directive approaches, and authentic personal relationships between the researcher and the interviewee. Conversely the interview has also been described as a one-way dialogue - the interviewer is the expert who defines the interview situation, determines the time, initiates the interview, decides the topic, poses the questions and has the monopoly of interpretation (Kvale, 2006). Interviews have also been described as being exploitative (Burman, 1997), exhibiting faked warmth and friendship (Mauthner, 2002, cited in Kvale, 2006), and having very asymmetrical power structures (Briggs, 2007).

There are claims that responses from interviewees may not accurately reflect their genuine beliefs, opinions or actual behaviour, and advocates of interviews as a research method do acknowledge that there is a possibility that interviewees may provide "alternative" answers deliberately to thwart the intent of the interviewer who wishes to generate truthful or credible data (Glesne, 2006; Roulston, 2010). Kvale (2006) suggests that it is illusory to see interviews as open conversations and exchanges of ideas as they are not dominance-free dialogues between equal partners. The interviewers are not simple conduits for answers but are deeply involved in the process and therefore influence the shape of the answers (Atkinson & Delamont, 2005; Schneider, 2000; Silverman, 1998).

The difficulties of interviewing (and any other observational types of study) of scientists and other specialised professions and occupations has been well studied and the extent to which an interviewer must understand scientists' work *scientifically* in order to explain their behaviour *sociologically* or to competently interview a scientist has been asked many times (Laudel & Gläser, 2004; H. Zuckerman, 1972). An interviewer can be described as either "naïve", meaning that the interviewer has no knowledge of the particular science field or as

“informed” meaning that the interviewer has knowledge that is relevant in the field.

Laudel & Gläser (2004) claim that “informed interviewing” is necessary for three reasons:

1. Epistemic reasons: the interviewer seeing the world as a scientist sees it not as a sociologist does.
2. Operationalisation reasons: identification of the phenomena to be investigated and information needed to answer the research question requires a shared understanding of situations, language and definitions.
3. Probing reasons: deep probing requires the interviewer to use the language and discipline-specific terminology of the interviewee. Laudel & Gläser suggests that a “limited understanding [of the discipline] is sufficient to conduct in-depth interviews” (2004, p.14).

The act of becoming an “informed interviewer” does bring with it further problems as the interviewer can no longer stay the “stranger” in a scientific environment.

As noted in chapter one my own background is in science and because I have experienced working in scientific research communities in various capacities, I was able to comfortably slip into this community. I was at ease with the researchers I was interviewing and comfortable with the scientific terminology and scientific examples they used to illustrate their responses. I felt like an “informed interviewer” as described by Laudel and Glaser (2004). Seeing the world as a scientist sees it and sharing an understanding of situations, language and definitions.

In addition to the philosophical issues as noted above, there are many practical difficulties and problems that might be encountered in undertaking the qualitative interview. These have been extensively discussed by writers such as Kvale (2006), Rubin and Rubin (2005), Silverman (1998), and summarised by Myers and Newman (2007) as:

- Artificiality of the interview (it is a conversation between complete strangers);
- Lack of trust (it takes time to develop rapport between interviewer and participant);
- Insufficient time (time pressures can effect answers);
- Level of entry (interviewing individuals at one level in the organisation may inhibit interviewing higher or lower in the organisation);
- Elite bias (interviewing only senior people may give an inaccurate picture);
- Hawthorne effects (the interviewer may intrude and influence the social setting);
- Constructing knowledge (interviewers may not realise they are not just collecting data but creating knowledge in the process);
- Ambiguity of language (understanding of the language and terminology may not be shared by interviewee and interviewer) ;
- Interviews can go wrong (unintentional offending);
- ‘Leading questions’ (includes, either explicitly or implicitly, the expected answer); and
- expressing personal opinions and experiences can influence responses.

As social science researchers have come to better understand the power asymmetry in interviews and how that can affect the data (Hoffmann, 2007), they have moved towards an “active” model for the interview in which the power is shared by interviewee and interviewer. This allows for the development of a contextually bound and mutually created story (Holstein & Gubrium, 2000) or “shared task of collaboration” (Gubrium and Holstein, 2002, cited in Hoffmann, 2007).

### 3.4.2.3 Approaches to interviews

There are two main theoretical positions in relation to interviews: neopositivism and romanticism (Roulston, 2011). Alvesson (2003) adds a third position termed *localism* (2003).

The *neopositivists* take a quantitative-like approach to the interview and use protocols and procedures intended to minimise researcher bias and influence in order to create a transparent research process, characterised by objectivity and neutrality with the purpose of generating credible knowledge concerning the beliefs, perceptions, experiences and opinions of the authentic self of the interviewee (Alvesson, 2003; Foddy, 1998; McLellan, MacQueen, & Neidig, 2003). Critics of this approach assert that it can lead to superficial and cautious responses (see Roulston, 2011, p. 79).

The *romantics* or '*emotionalists*', on the other hand, try to establish rapport, trust, and commitment between the interviewer and interviewee. The interviewer, through interacting with the participant, sets out to understand, interpret and transform the opinions and feedback into knowledge, rather than to objectively 'capture' the views of the interviewee (Alvesson, 2003; Roulston, 2010). This has also been termed "active interviewing" as the researcher's interventions transform the interview subject from what is termed a repository of opinions, reasons, or emotions, into a productive source of knowledge (Holstein & Gubrium, 2000). It is also constructivist in the sense of it being a co-construction by interviewer and participant of one cultural event within the life world of the participant (Holstein & Gubrium, 2008).

The third approach is that of the localist position which emphasises that interview statements must be seen in their social context. "The interview is an empirical situation that can be studied as such, and it should not be treated as a tool for collecting data on something existing outside this empirical situation" (Alvesson, 2003, p. 16). Alvesson goes on to describe the interview as being an event/situation like any other event/situation in the life of the participant and should be studied as such, rather than as an external event being reported. This view challenges the assumptions of those wanting to use interviews as tools, and

Alvesson (2003) criticises this view on the grounds that it comes close to denying that interviewees can communicate important insights about their social reality.

#### **3.4.2.4 Structure**

The amount of structure in an interview is imposed by the interviewer and it can range from very little, as in the spontaneous, unstructured discussion that would take place in a behaviour observation study, to the highly structured, detailed schedule where questions, usually closed questions, are asked in a specific order, and the responses are recorded on paper (sic) by the interviewer (King, 1994). Between these extremes lies the semi-structured interview which is regarded as a balance between the fixed response interviews which restrict interviewees' replies, and the potentially unwieldy, difficult to analyse, open-ended interview (Patton, 2002).

For this study the semi-structured interview was selected rather than a tightly structured interview or the laissez-faire approach. The semi-structured interview is regarded as being a good instrument to use in the early stages of a project when the researcher is seeking to understand the broad concepts and issues (Thomas, 2003). As noted earlier, this study has an exploratory component as the aim is to solicit ideas, concepts, viewpoints and information from the informant on their experiences and views of collaboration in scientific research.

One of the important features of the semi-structured interview is its flexibility which permits the interviewer to clarify issues through probing, from which very rich data can emerge. The interviewer can go into greater depth than is possible in other ways of gathering data and explore complex issues which can be difficult for the respondent to articulate without prompting (Cavana, et al., 2001). Whilst flexible, the semi-structured interview does retain threads of consistency as the researcher can ask key questions in the same way each time, can sequence the questions in the same fashion, and can probe and explore.

The nature of semi-structured interviews means that large amounts of data in non-standard formats are generated (B A Turner, 1983) and this was true of the interviews in this study. Analysis of all this material was through a thematic approach as discussed in 3.5. for discussion.

### **3.4.2.5 Interview process**

The intent was for the interviews in this study to follow the four stage pattern for interviews described by (Cavana, et al., 2001):

1. Entrance (getting comfortable and setting the scene);
2. Rapport (the interview proper);
3. Intimacy (a complex and 'connected' period in the interview); and
4. Exit time (space to tie-off, check for any 'loose ends', preparation to leave).

Whilst the use of these stages was planned, on later reflection it was interesting and gratifying to note how clearly identifiable were the stages and how smoothly we moved through them.

### **3.4.2.6 Interviewer**

A good interview depends on the willingness of participants to be involved (Hoffmann, 2007) and this, at least in part, is a function of the relationship between the interviewee and interviewer. Amongst the range of skills required to be a good interviewer is the requirement for the interviewer to have good inter-personal skills, to be able to put a subject at ease, and to be non-judgmental in approach (Willis, 1999).

The basic interview model suggests that the interviewer takes a neutral stance (Denzin & Lincoln, 1994) but other scholars assert that an interview is a social interaction and a good interviewer will take an active role in promoting the interaction (Rapley, 2001). The interviewer needs to be skilled at listening (not just a good listener), and to be an active observer in order to correctly note, and later interpret, the words and non-verbal behaviours of the informant (Cavana, et al., 2001; Eisenhardt & Graebmer, 2007). Interviews are good tools for extracting honest, clear and consistent views from informants, but they consist of multiple layers of meaning and the interviewer must be able to conceptualise and understand what is going on (Alvesson, 2003).

In some situations maintaining a neutral stance, as required by the 'basic' interview model, or engaging in the shared task of collaboration of the 'active' model, is not always easy (King, 1994). The difficulties that can arise when interviewing the high-status interviewee have been studied by Smyth and Mitchell (2008) who point out that whilst there is a significant body of work on researchers crossing moral and political boundaries (e.g. Blee, 1998; Campbell, 2003; Ezekiel, 2002; Ostrander, 1993), there is very little on relationships between interviewer and interviewee, or the researcher's personal orientations towards the topic. The issue of the "informed" or "naïve" interviewer (Laudel & Gläser, 2004) has already been discussed in section 3.4.2.2.

Probe techniques were utilised in these interviews as a way to develop the informants' responses (Glesne, 2006; Patton, 2002). Probes are defined as essentially "requests for more explanation, clarification, description and evaluation" (Glesne, 2006, p. 96), and usage is recommended when the answers proffered are very brief or shallow. Silence is also recommended as this is an invitation, or cue, to the informant that more is wanted on a particular subject (King, 1994).

At times informants do not let the interviewer control the interview and they may use a number of ways to counter the power imbalance. They may be over-communicative, choose to not answer or to deflect a question, they may talk about something other than what the interviewer asks for, or merely tell what they believe the interviewer wants to hear. The informant may also act in his/her interests and use the opportunity to advance their own cause (Blee, 1998; King, 1994).

As my background is in science, throughout these interviews I felt comfortable interacting with the scientists and that I shared an unstated understanding about "what it is to be a scientific researcher". My interviewing was "informed interviewing" as described in section 3.4.2.2 and although I used probing to elicit information, I actively tried not to lead the interviewee or judge what was being said. The interviewees were open, reflective, stayed on track, and although they indicated a willingness to extend the interview beyond the allotted time of 30 minutes, rarely did this happen.

### 3.4.2.7 Preparation of interviews

*Step 1:* Preparation of the Interview Guide: An interview guide (these guides can be found in Appendices Q, 1 - 4) was prepared for each of the four groups of informants. An interview guide is essentially the list of the topics to be covered in the interview and because the topics varied from group to group in this study separate guides were needed. Each guide, or set of questions, was developed from the relevant objectives as set out in Appendix O. These interview guides were not intended to be formal schedules of questions as one would use in a tightly structured interview, but literally as guides to the topics to be covered in the semi-structured form. King (1994) points out that guides are continually modified throughout a series of interviews by adding probes or issues that originally were not included or that emerge throughout the process, and this was true throughout the interviews conducted in this study.

The questions in the interview guides were also intended to act as stimulus questions with the purpose of stimulating the informants thinking, but not to prescribe the shape or boundaries of the interview or to influence the information proffered. The questions were also open questions and whilst such questions have been criticised (Dohrenwend, 1965) as being less efficient than closed questions, they do permit the informant to do a verbal tour of something they know well (Leech, 2002). The phrase "*grand tour question*" was coined by Spradley (1979) as a technique to get respondents talking, but in a fairly focused way. As informants can wander off track when responding to questions such as these, the interviewer needs to be able to impose direction without causing offence (King, 1994).

#### *Step 2:* Sampling

Sampling is a process of selecting a number of individuals from a population (termed elements) and studying that group to form an understanding of the properties or characteristics of that population, and then generalise from the sample to the entire population (Cavana, et al., 2001). Representativeness is therefore important and the parameters of a subset must be established at the outset (Pinsonneault & Kraemer, 1993). This form of sampling is known as

Judgment Sampling, termed so because the subjects chosen are “in the best position to provide the information required” (Cavana, et al., 2001, p. 263). It is regarded as the only viable method of obtaining the information required from very specific groups of people who possess knowledge. Determining the sample size and number of individuals required to be able to generalise from the sample to the entire population is not straightforward as there are many factors which influence the number in a sample and “there are no published guidelines or tests of adequacy for estimating [the] sample size required...” (Morse, 1995, p. 147). Making tight recommendations is very difficult and there is enormous variation in size. Morse goes on to say that “the greater the cohesiveness of the sample, the faster saturation [data adequacy] will be achieved” (p. 149) and Guest, Bunce and Johnson (2006) claim that data saturation is for the most part achieved after twelve interviews. Expertise in the chosen topic can reduce the number of participants needed in a study according to Jette, Grover and Keck (2003) and most importantly, as Guest (2006) points out it is not the sample size that is the issue but rather the quality of the data.

In this study interviews were undertaken with a representative from the four key research funding agencies, with the Assistant Vice-Chancellor in charge of research at Massey University and two subsets of researchers. The first set comprised researchers who had been members of collaborative research teams, and the second comprised individuals who had been leaders of collaborative research teams. Both leaders and members were interviewed as they have different perspectives, require different competencies and they have different needs. All interviewees were selected because of their expert knowledge. The researchers came from a range of disciplines. Two other parameters were applied to ensure that the sample had a similar ratio of female to male as in the population of researchers as a whole, and that there was a mix of researchers in terms of seniority and experience as a researcher.

There was an element of ‘Convenience’ sampling as those selected all came from easily accessible locations (Cavana, et al., 2001). As the survey in phase one was anonymous, it is not known if the researchers interviewed had also completed the survey.

**Table 4: Interviews: Numbers and types**

Type of interview	No of interviews
<b>Funding agencies</b>	
MSI: Marsden Fund; TEC; HRC	3 interviews, 1 written response
<b>Researcher interviews</b>	
Previous membership of a collaborative research team	5
Previous leadership of a collaborative research team	3
Female researchers similar to the staffing ratio	1
Range of experience in years	Early through to very experienced
Disciplines represented	veterinary sciences biological sciences mathematics chemistry environmental sciences physiology nutrition
<b>Assistant Vice-Chancellor, R &amp; E</b>	1 interview
<b>TOTAL</b>	13

*Step 3: Documentation*

The documentation relating to the interviews (see Appendices F – L) comprises:

- Massey University Low risk assessment approval letter;
- Letter to PVC Anderson and response
- Letter to participants
- Information Sheet for informants; and
- Participant Interview Consent form.

*Step 4: Undertaking the interviews*

Each interview was held in the office of the informant and 40 minutes was allocated for completion of all aspects of an interview. A total of 13 interviews were undertaken, 9 were electronically recorded and later transcribed, three

individuals did not wish to be recorded and notes were taken in the interview. In the case of one individual who lived out of Wellington, written answers to the questions were provided.

### **3.5 Analysis of the data**

The use of two research instruments, in this case it was a survey and interviews, and a convergence of the data from the two phases is a process called triangulation (Brannen, 2005, p. 176). The purpose of triangulation is to ensure that the results have greater credibility and thus improve the conclusions drawn from the study (Scandura & Williams, 2000). Triangulation can have a number of possible outcomes;

- Corroboration: the results from different methods are the same;
- Elaboration: the quantitative data exemplifies the qualitative data;
- Complementarity: the qualitative and quantitative data differ but together generate insights; and
- Contradiction: the qualitative and quantitative data differ.

Triangulation is becoming increasingly important and a consistent theme running through the recent literature on research methodology is the call for the use of triangulation in qualitative research as a means of enhancing the quality of results (Brannen, 2005; Johnson, et al., 2007; Kan & Parry, 2004; Parry, 1998).

The quantitative data from the survey was subjected to basic (univariate) analysis with the overall aim of providing factual biographic data, data on the collaborative activity of the respondents, and quantitative information on respondents views on collaboration. The data, i.e. responses, are displayed in the Findings chapter in charts, frequency tables, or for open-ended text response questions, in narrative form.

Qualitative research which normally produces large amounts of data requires good organisation, and good processing of the data (Patton, 2002). The interviews, and the two open ended questions in the survey in this study were subjected to thematic analysis in order to make sense of the data. This process is

adapted from Glaser and Strauss 'grounded theory' approach (Burnard, 1991) and is regarded as convenient and efficient (Thomas, 2003), but is also described as being a rich, messy and complex process (Cavana, et al., 2001).

Thematic analysis is an inductive process comprising a number of steps in which a template of codes or themes derived from the research objectives and the interview guide is used as the framework for sorting and resorting the raw data as often as necessary into groups of similar ideas or themes (see Cavana, 2001). A theme is defined as a recurring comment that "captures something important about the data in relation to the research question, and represents some level of *patterned* response or meaning within the data set" (V Braun & Clarke, 2006, p. 10). Throughout the process the analyst should be continually asking the questions – "what does this mean?", "what is the perspective?", and "what is the evidence provided?" (Patton, 2002).

The final step in the process links the description phase to causal interpretation and links are made between events, actions, and concepts, and a set of provisional explanations is developed (Patton, 2002). From this, a model or framework is developed that captures the key themes and shows the relationships between them (Thomas, 2003). A good theoretical framework identifies the important variables and logically describes the interconnections among these variables. It will also identify the independent variables, the dependant variables, and the moderating and intervening variables if they exist (see Cavana,2001; Gibbs & Taylor, 2005).

A fully emergent process means that the themes which emerge are not bounded by any artificial structure or construct that has been imposed at the beginning of the study. They are judged by their substantive significance rather than their statistical significance as in quantitative research (see section 3.2.2 for the criteria against which qualitative research is judged) (Patton, 2002). In this study a template based on the research objectives and the interview guide is used as a framework around which the material is sorted.

Coding, or giving a label to groups of similar ideas makes the large quantity of data easier to handle and these coding schemes can take a variety of forms.

The following could form the basis of a coding scheme:

Themes	Topics
Ideas	Concepts Terms
Phrases /Keywords	Key-words-in-context
Metaphors	Analogies
Connectors	Missing information

The steps used in the coding process are those that Thomas (2003) suggests should be used in inductive analysis:

1. An initial read through the data;
2. Identification of specific segments of information;
3. Labelling of the segments to make categories;
4. Reduction in the overlap and redundancies; and
5. Creation of a model incorporating the most important categories.

Whilst throughout the process of analysis the analyst is continually asking "What is the person saying?" the following two basic rules must keep in mind:

1. Maintenance of accuracy by reporting "in the voice of the source' by using the actual words, and
2. Reporting the logic of the interpretation used to come to a particular conclusion.

Categories, defined as "group[s] of words with similar meaning or connotations" (Krippendorf, 2004, p. 37) which "must be mutually exclusive and exhaustive" (GAO, 1996, p. 20), are formed as the groups of similar ideas are further refined. Thomas notes that most inductive studies report only 3-8 main categories; however, inexperienced researchers may go up to 12 indicating that they have not finished the process of sorting and resorting the smaller categories (Thomas, 2003).

In this study rather than undertaking a fully emergent analysis, King's template approach (1994, 2004) was used and the codes or themes which form the basic framework of analysis were derived from the research objectives and interview guide. The data was sorted on that framework and the resulting themes form sections in the Discussion chapter.

The final step in this study is the integration of both the quantitative and qualitative phases. There is very limited literature on the analysis of data in a mixed methods approach to research and although Onwuegbuzie and Teddlie (2003, p.375) have developed a seven stage model in which techniques of both qualitative and quantitative analysis are used either concurrently or sequentially. Adequacy of the resulting information is based on "representation" and "legitimation" with the former referring to the ability to extract information from the underlying data and the latter referring to the validity of the data.

1. Data reduction: The goal is to organise the data into forms from which conclusions can be drawn. For quantitative data this may be statistical analysis and for qualitative data it may be thematic analysis;
2. Data display: Converting the data into configurations that can be easily understood. Numerical data can be displayed in graphs or charts and qualitative into lists or narrative form;
3. Data transformation: Quantifying or qualifying the data;
4. Data correlation: Correlating the quantitative data with the qualitative data;
5. Data consolidation: combining both types of data into one new or consolidated set;
6. Data comparison: comparing data from different data sources; and
7. Data integration: integrating all the data into a coherent whole.

Thomas (2003) proposes various procedures for assessing the trustworthiness of the data analysis and these include consistency checks (another coder compares the category descriptions with the text), credibility or stakeholder checks (asking

people with a specific interest in the research to comment), or comparisons can be made with previous research on the topic). The data from both phases of this study have undergone the activities identified in stages one – three and the resulting graphs and narrative are displayed in the Chapter Four, Findings. Stages five - seven are discussed in Chapters Five the Discussion, and Chapter Six the Conclusions.



## **CHAPTER FOUR: FINDINGS**

### **4.1 Introduction**

In the previous chapter the data required for this study, the phases and processes for gathering that data, and how the data was to be analysed was described. In this chapter, the findings are presented.

Data was sourced in two phases. The first was a quantitative phase comprising a survey of researchers in the College of Sciences. The questionnaire used in the survey can be found in Appendix P. The second qualitative phase consisted of interviews with three researchers who had led collaborative research teams, five researchers who had been members of collaborative research teams and a senior staff from each of the four main research funding agencies. Data was sought from Massey University strategic planning documentation (MU, 2011), and an interview was undertaken with the Assistant Vice-Chancellor - Research & Enterprise, Massey University. The interview guides are in Appendix Q 1-4.

The survey of academic staff of The College of Sciences, Massey University was undertaken throughout February, 2011. The College of Sciences comprises a number of Schools and Institutes based on the fundamental sciences of chemistry, physics, mathematics and biology. The teaching and research activities also cover the areas of Agriculture, Veterinary and Life Sciences; Land, Water and the Environment; and Industrial Innovation via Engineering and Technology.

The College of Sciences (<http://science.massey.ac.nz/structure.asp>) has an academic staff of 423 and the questionnaire was completed by 120 giving a 28% completion rate. This is a disappointing completion rate particularly as the timing of distribution of the questionnaire was carefully considered in relation to other activities researchers were likely to be involved in, and three follow up reminders were distributed. Of the 120 respondents, 29% were female, which approximates the proportion of female researchers in the School of Sciences. It must be pointed out that the number of staff absent during the time of the survey is not known and whilst 28% of the staff responded to the questionnaire not all

questions were answered by all respondents; therefore the ‘N’ number varies for some questions. Survey response rate is discussed in Chapter Three, section 3.4.1.5.

Data from phase 1, the quantitative phase of this study, is set out in graph form and in frequency tables, and material from open-ended response questions, and from the interviews with researchers, the funding agencies and Massey University sources is in narrative form.

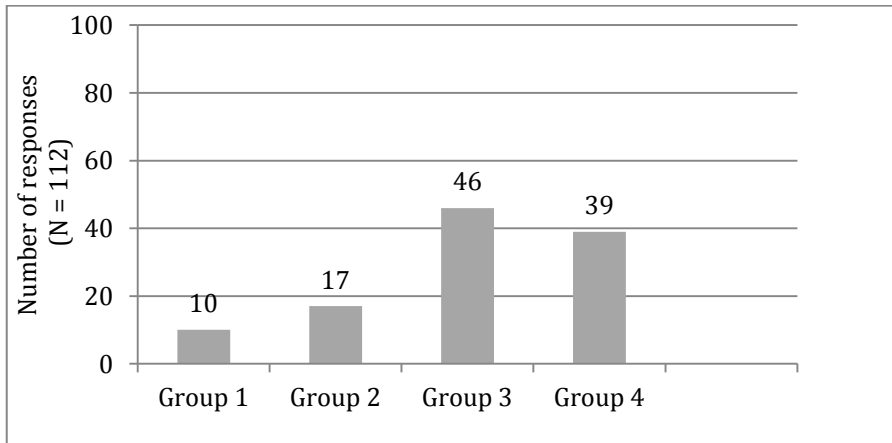
## 4.2 Phase 1: Quantitative Phase: Survey

(The questionnaire can be found in Appendix P)

### 4.2.1 Demographic data of respondents

The material in this section is contextual and provides a description of the attributes of the respondents to the questionnaire.

Figure 4.2.1.1: Respondent Position in the College of Sciences Massey University

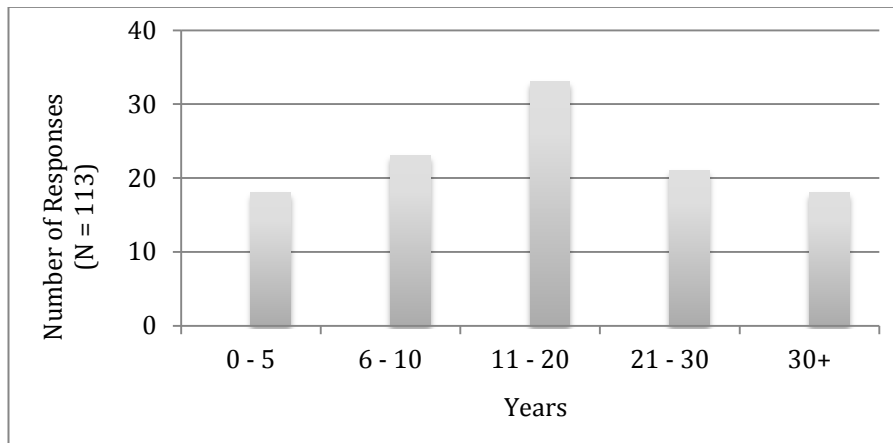


- Note.
- Group 1: Post doc Fellow/Tutor/Senior Tutor/Junior Research Fellow
  - Group 2: Assistant Lecturer/Lecturer/Research Officer
  - Group 3: Senior Lecturer/Senior Research Officer/ Practising Veterinarian/Professional Clinician
  - Group 4: Associate Professor/Professor/Senior Practising Veterinarian/Senior Professional Clinician

The groupings have been derived from the Massey University Collective Employment Agreement (MUCEA10, 2010, Clause 4.9) by job title as an indicator of seniority in research.

Most respondents were from the more senior rankings. The relationship between age and collaborative research activity is considered in the Discussion chapter.

Figure 4.2.1.2: Number of years as an Active Researcher Following Terminal Qualification



Survey responses were received from researchers with varying levels of experience; however, most respondents were very experienced researchers with eleven or more years of experience. Seniority, position and engagement in collaborative research is further explored in the Chapter Five, Discussion chapter.

Table 5: Gender of respondents

	Number of Respondents	Percentage
Female	32	29
Male	80	71
N = 112	112	100

The proportion of female respondents (29%) corresponds roughly to the proportion of female researchers (28.3%) in The College of Sciences, Massey University. As noted earlier not all questions were answered by all respondents and the 'N' number varies for some questions.

**Table 6: Disciplines to which respondents are affiliated**

Discipline	Number of Respondents	% of Respondents
Biological sciences	31	28.3
Mathematics	19	17.9
Chemistry	14	13.2
Vet/animal sciences	13	12.3
Engineering	10	9.4
Ag science	9	8.4
Geology/Earth sciences	5	4.7
Computer sciences	5	4.7
Sport and exercise	3	2.8
Physics	3	2.8
N = 112	112	

The Schools and Institutes comprising the College of Sciences are not single discipline based thus there is no direct correlation between discipline and School or Institute. Comment on the respondents' disciplinary variation in the propensity to collaborate appears in the Discussion chapter.

**Table 7: Types of collaboration involvement reported by respondents**

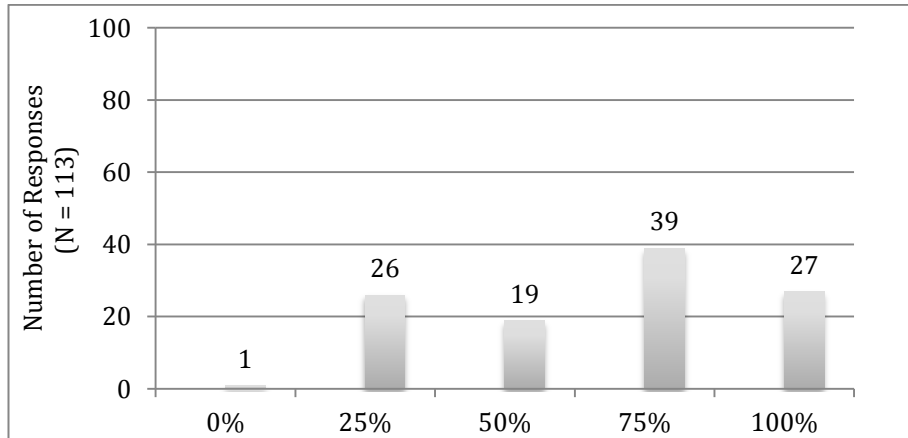
Type of collaboration in which respondent has been involved	Number of Respondents	%
Jointly publishing a journal article	107	95
Jointly carrying out a research project	99	88
Jointly preparing and presenting a paper at a conference	96	85
Jointly preparing and submitting a research proposal	95	84
Jointly supervising a graduate student	93	82
Jointly receiving a research grant	71	63
Jointly publishing a book or part of a book	54	48
N = 113	113	

The most common type of collaboration that respondents have been involved in at some stage in their career is the production of a journal article subsequently published, and the least common is the production of a book or part of a book.

#### 4.2.2 Collaboration within Massey University

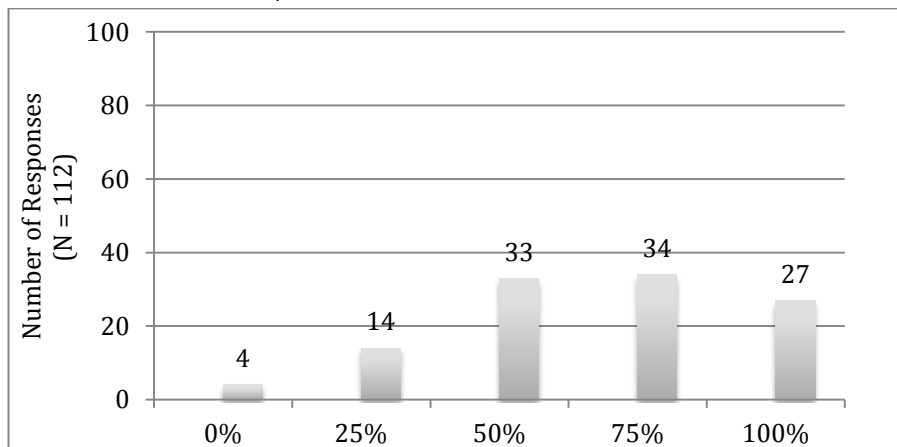
The material in this section describes how much time researchers spend in collaborative scientific research and with whom they collaborate.

Figure 4.2.2.1: Percentage of research time spent in collaboration with other scientific researchers



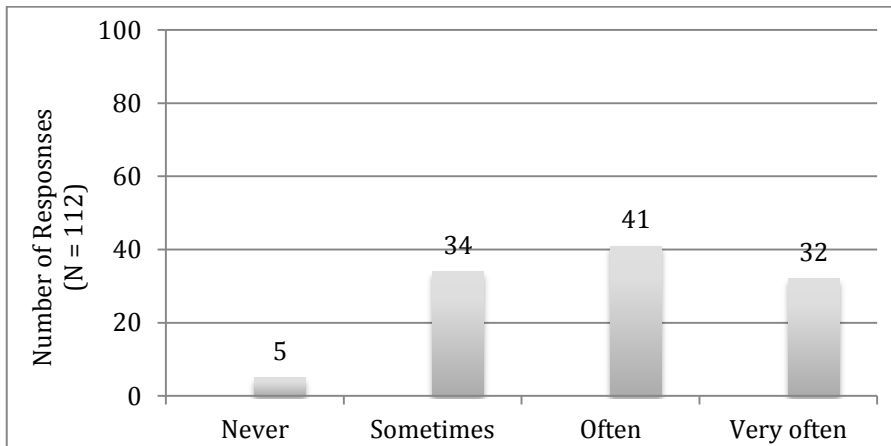
Of the 112 respondents 66, or 60%, indicated that they collaborate 75% or more of their research time and only one respondent indicated that s/he never collaborated at all. The relatively even spread of responses shows the wide variation in the amount of time researchers in Massey's College of Sciences spend in collaborative research. The time that researchers engage in collaborative research is further explored in the Discussion chapter.

Figure 4.2.2.2: Percentage of total collaborative research time spent in collaboration with researchers in own discipline



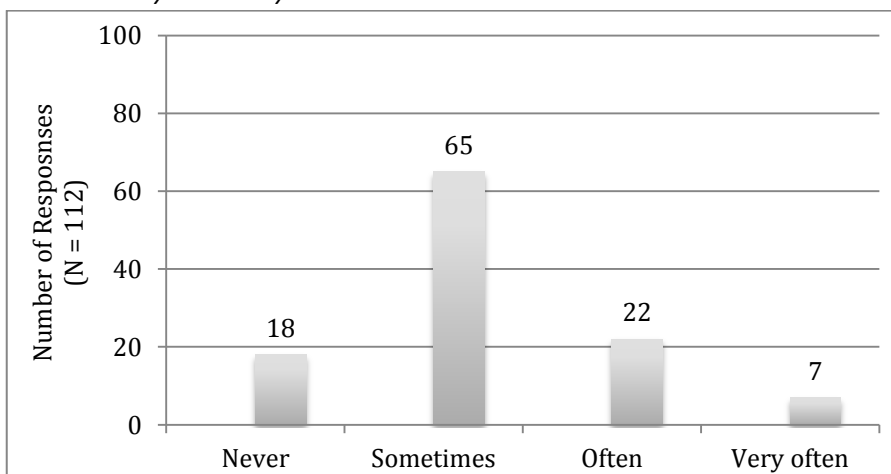
Most researchers tend to collaborate within their own discipline and only 18 respondents, or 16%, reported that they collaborated outside of their own discipline 75% or more of their research time. Collaborating outside of one's own discipline is considered in the Discussion Chapter.

Figure 4.2.2.3: Frequency of collaboration with researchers from within own academic unit



The previous question suggests that researchers tend to collaborate within their own discipline and the spread of responses for this question suggest that this collaboration may be within their own discipline and within Massey University. The tendency for researchers to collaborate within their own discipline and their own academic unit can be found in the Discussion chapter.

Figure 4.2.2.4: Frequency of collaboration with researchers from other academic units within Massey University



The infrequency of collaboration with other academic units within Massey University is noteworthy with most (58.0%) researchers indicating that they only sometimes collaborate with researchers in other academic units within Massey University and just over 16.0% indicating that they never do.

**Table 8: Comparison of collaboration of College of Sciences researchers with researchers from other academic units of Massey University**

	Never (%)	Sometimes (%)	Often (%)	Very Often (%)
College of Business (N = 109)	88.9	8.2	1.8	0.9
College of Education (N = 112)	88.3	10.7	0.8	0.0
College of Humanities and Social Sciences (N = 111)	81.0	17.1	0.9	0.9
College of Creative Arts (N = 111)	95.5	4.5	0.0	0.0

The extent of collaboration by researchers from the College of Sciences with researchers in other Colleges within Massey University is similar regarding all four other Colleges. Collaboration is limited and occurs most frequently with researchers in the College of Humanities and Social Sciences, and least frequently with researchers in the College of Creative Arts. These findings are considered in the Discussion chapter.

#### **4.2.3 Collaboration with researchers in other universities**

This section of the survey focuses on collaboration patterns of College of Science researchers with researchers in other universities. Information was sought on collaboration with researchers in other New Zealand universities, Australian universities, and other overseas universities.

**Table 9: Collaboration with researchers from other universities**

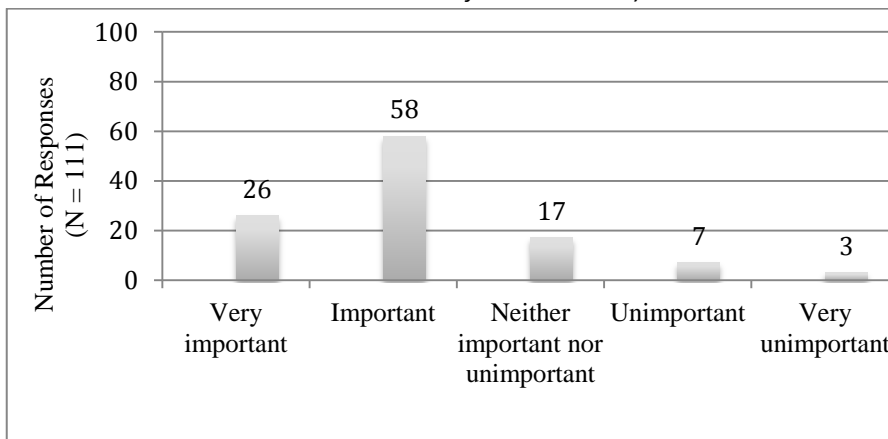
	Never (%)	Sometimes (%)	Often (%)	Very Often (%)
Other New Zealand universities (N = 111)	31.5	49.5	17.1	0.4
Australian universities (N = 112)	44.6	43.7	11.7	1.7
Other overseas universities (N = 111)	18.0	43.5	37.5	10.8

The low level of collaboration with colleagues in other New Zealand universities is quite striking as is the low level of collaboration with colleagues in Australian universities. The choice of collaborators is considered in the Discussion chapter.

**4.2.4 Reasons for collaborating**

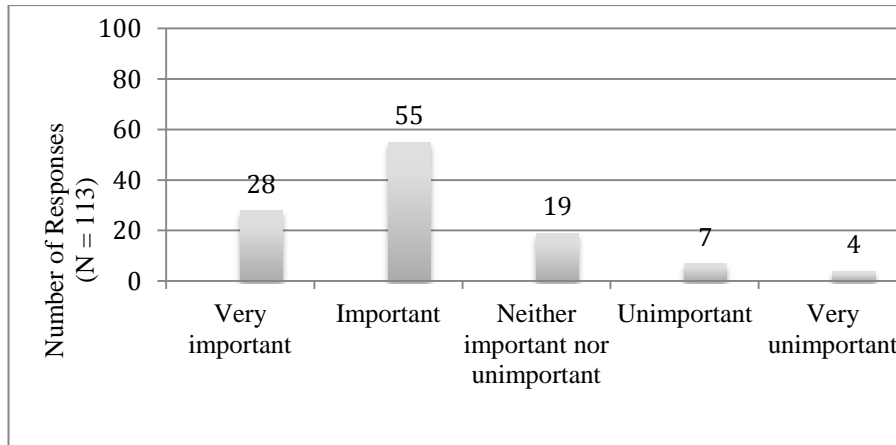
In this section respondents have indicated the importance they attach to a range of factors which influence a decision to collaborate. Table 12 provides a representative list of additional reasons for collaboration from respondents. The data in this section and the reasons why researchers collaborate are explored in the Discussion chapter.

*Figure 4.2.4.1: Importance of accessing expertise from other science disciplines (in the decision to collaborate with other scientific researchers)*



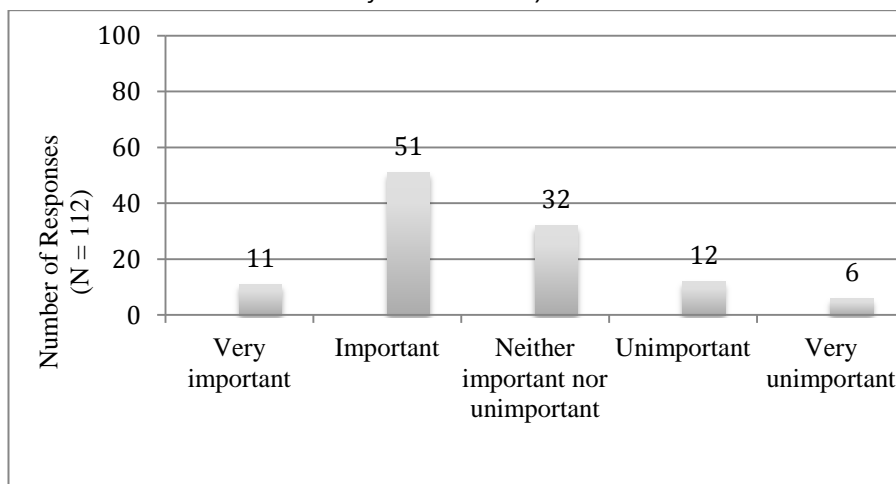
Being able to access expertise from other science disciplines is clearly an important factor in a researcher's decision to collaborate as demonstrated in these responses with 75.6% of respondents in agreeing that it is important or very important.

Figure 4.2.4.2: Importance of meeting funding agency expectations (in the decision to collaborate with other scientific researchers)



With a similar outcome to the previous question, meeting the expectations of the funding agency is important or very important in a researcher's decision to collaborate. This is discussed in section 5.4.

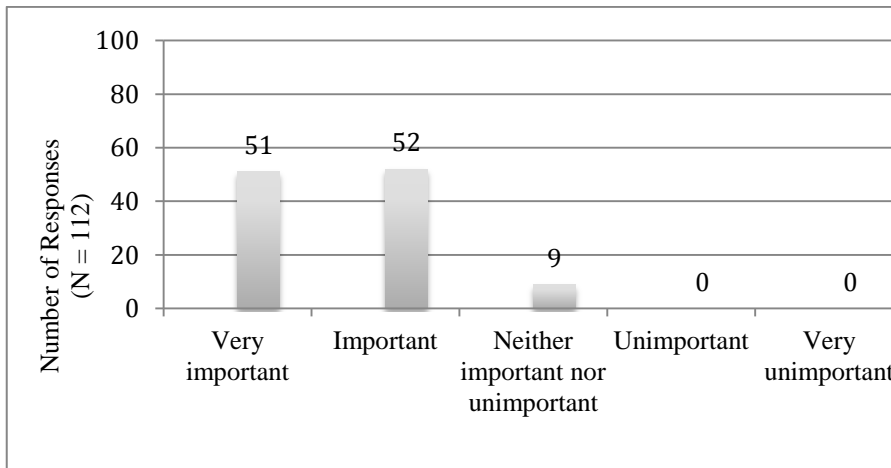
Figure 4.2.4.3: Importance of increasing efficiency in the use of resources (in the decision to collaborate with other scientific researchers)



Being able to increase efficiency in the use of resources is clearly important or very important to most researchers in their decision to collaborate although for

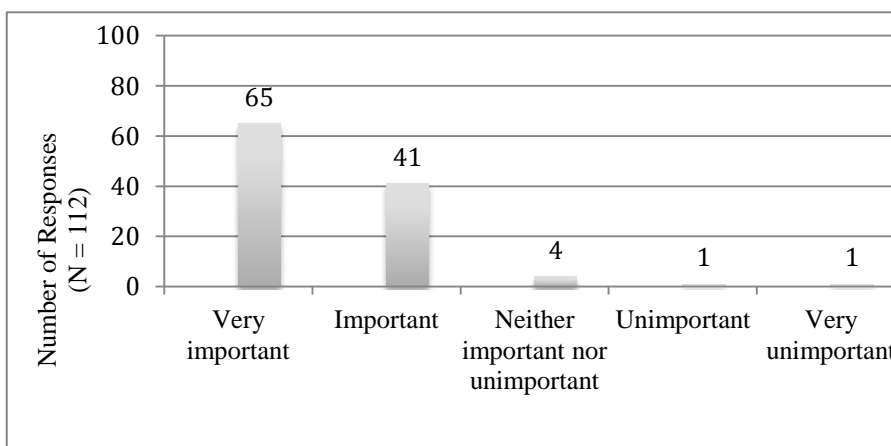
16% it is not an important factor. Collaborating to increase efficiency is further discussed in section 5.4.

Figure 4.2.4.4: Importance of increasing the chances of success (in the decision to collaborate with other scientific researchers)



An overwhelming 103 (92%) of respondents indicate that they see collaboration as being important or very important in increasing the chances of success. Only 9 (8%) have a neutral view on this, and no respondents indicated that it was unimportant. Success in collaboration is explored in the Discussion chapter.

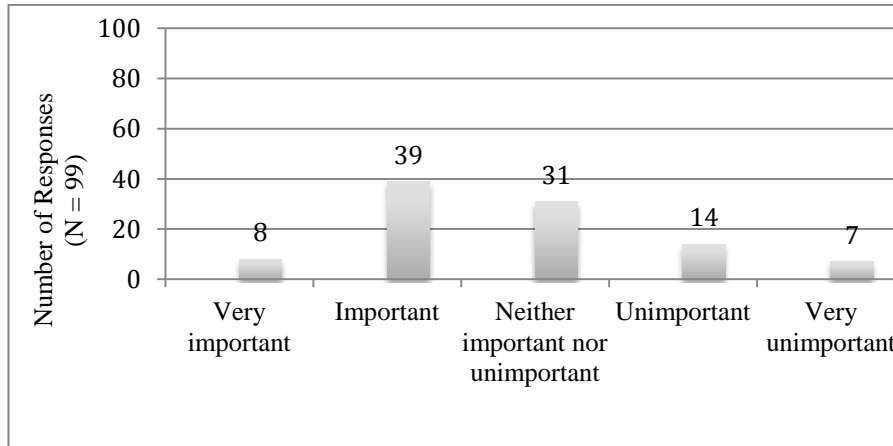
Figure 4.2.4.5: Importance of Better project outcomes (in the decision to collaborate with other scientific researchers)



This question produced an emphatic result with 95% of respondents claiming that they collaborate because it may bring about better project outcomes. This result is very similar to the results of the previous question where 92% or

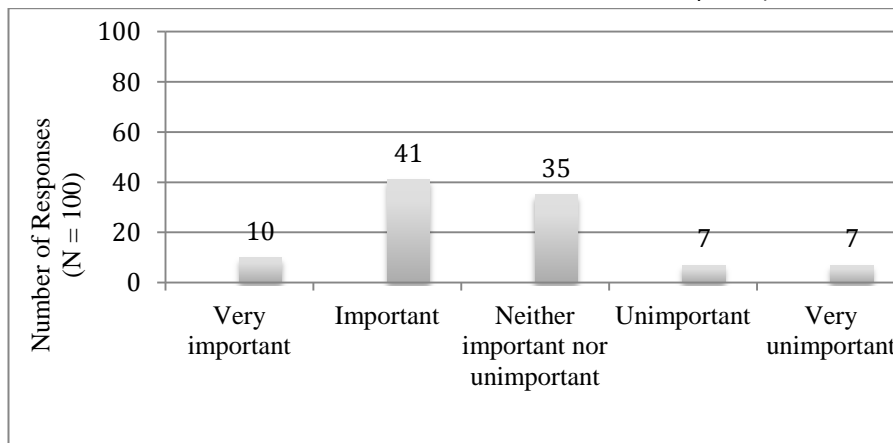
respondents collaborate to increase their chances of project success. In both cases a very small proportion of respondents see it as unimportant.

Figure 4.2.4.6: Importance of accessing different ways of thinking and different research methods (in the decision to collaborate with 'non science' researchers)



This question and the next (4.2.4.7) had the lowest number of respondents and this large number of non-responses to these questions is interesting. In the case of each question there is a relatively even spread of responses indicating lack of agreement. The views of respondents on collaborating with non-scientists is considered in the Discussion chapter.

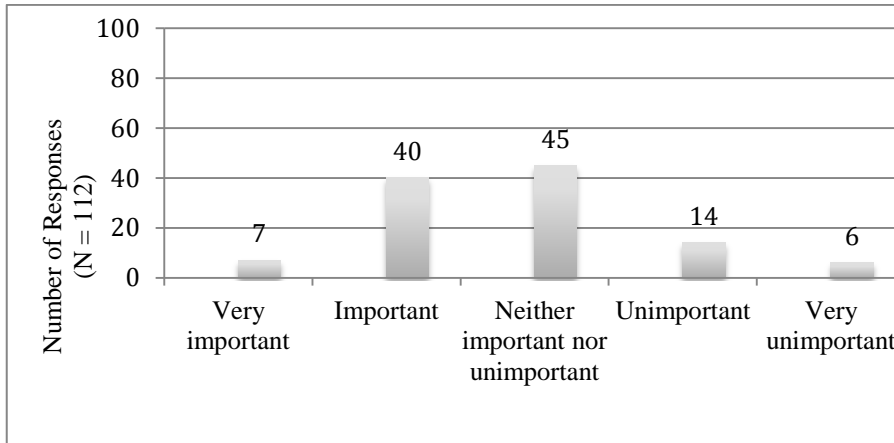
Figure 4.2.4.7: Importance of meeting the expectations of the funding agencies (in the decision to collaborate with researchers in 'non science' disciplines)



This question on the importance of meeting the expectations of the funding agencies in a decision to collaborate with non scientists drew a similar number and spread of responses as did the previous question on the importance of being able to access different ways of thinking and different research methods. The

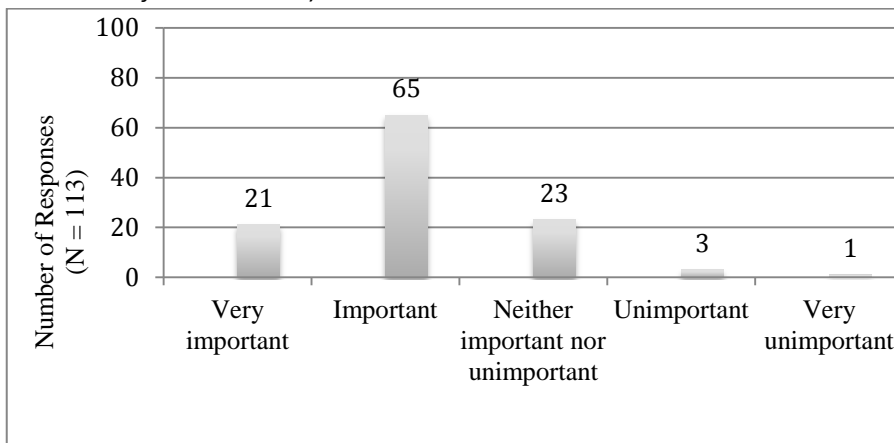
low number of responses and the relatively even spread indicating a wide range of views.

Figure 4.2.4.8: Importance of achieving prestige or visibility (in the decision to collaborate with other scientific researchers)



The achievement of prestige or visibility is important or very important for 38% of researchers in deciding to collaborate. For a similar proportion (40.2%) it is neither important nor unimportant, and for 17.8% it is unimportant or very unimportant. This result is considered in the Discussion chapter.

Figure 4.2.4.9: Importance of enhancing productivity (in the decision to collaborate with other scientific researchers)



In contrast to the previous two questions, 4.2.4.7 and 4.2.4.8, there is strong agreement that the enhancement of productivity is important in deciding to collaborate. Productivity and collaboration is considered in the Discussion chapter.

Table 10: Summary table of frequency of responses to questions concerning the importance of various factors influencing a decision to collaborate (Questions 4.4.1 – 4.4.9) in **five categories of importance**.

<i>Factors influencing decision to collaborate</i>	<i>Category</i>	a: Very Important %	b: Important %	c: Neither Important Nor Unimportant%	d: Unimportant %	e: Very Unimportant %
<b>Access expertise from other science disciplines</b>		23.4	52.2	15.3	6.3	2.6
<b>Meet the expectations of the funding agency</b>		24.7	48.6	16.8	6.1	3.5
<b>Increase efficiency in the use of resources</b>		9.8	45.5	28.5	10.7	5.3
<b>Increase the chances of success</b>		45.5	46.4	8.0	0	0
<b>Achieve better project outcomes</b>		58.0	36.6	3.57	0.89	0.89
<b>Access different ways of thinking and different research methods with non science collaborators</b>		8.0	39.9	31.3	14.1	7.0
<b>Meet the expectations of funding agencies with non science collaborators</b>		0.0	41.0	35.0	7.0	7.0
<b>Achieve prestige or visibility</b>		6.2	35.7	40.0	12.5	5.3
<b>Enhance productivity</b>		18.5	57.5	20.3	2.6	0.8

For 58% of respondents getting better project outcomes is an important or very important reason to collaborate. This is closely followed by 45.5% of respondents choosing increasing the chances of success as an important or very important reason to collaborate. The least important reason to collaborate is to meet the expectations of funding agencies when collaborating with non-science researchers. Enhancing productivity is considered to be important for 57.5% of respondents and accessing expertise from other science disciplines is important for 52.2%.

Table 11: Ranking by importance of factors influencing a decision to collaborate (**Questions 4.4.1 – 4.4.9**)

Note that categories 'a' and 'b' and categories 'd' and 'e' are collapsed to simplify. The rankings were averaged and the result displayed in the column headed 'Overall Ranking'. The Discussion chapter examines how these results compare with those from other studies.

<i>Reason for collaborating</i>	Categories a and b Important/Very Important <i>Ranking</i>	Category c Neither Important Nor Unimportant <i>Ranking</i>	Categories d and e Unimportant/ Very unimportant <i>Ranking</i>	<i>Average Ranking</i>	<i>Overall Ranking</i>
<b>Increase the chances of success</b>	2	8	9	6.3	1
<b>Better project outcomes</b>	1	9	8	6	2
<b>Access expertise from other science disciplines</b>	4	7	6	5.6	3
<b>Meet the expectations of the funding agency</b>	5	6	5	5.3	4
<b>Enhance productivity</b>	3	5	7	5	5=
<b>Meet the expectations of funding agencies with non science collaborators</b>	9	2	4	5	5=
<b>To increase efficiency in the use of resources</b>	6	4	3	4.3	7
<b>Access different ways of thinking and different research methods with non science collaborators</b>	7	3	1	3.6	8=
<b>Achieve prestige or visibility.</b>	8	1	2	3.6	8=

Note: In Table 10 responses to the set of questions relating to the importance respondents attach to the influence of various factors in deciding to collaborate were displayed in five Categories by importance. In Table 11 a clearer picture of which reasons for collaborating are most important to researchers is achieved by reducing the five Categories to three by combining Categories a and b and Categories, d and e, and then ranked.

**Table 12: Other reasons suggested by respondents for collaborating in their research.**

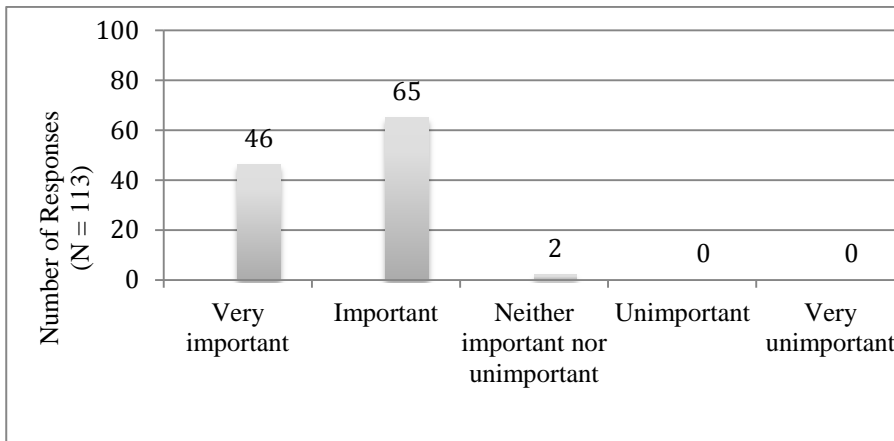
Emergent Theme	Number of responses	Representative comments from respondents on other reasons for collaborating
<b>Accessing Expertise</b>	22	<ul style="list-style-type: none"> <li>Access to specialised expertise and techniques</li> <li>Access to the knowledge and experience of others</li> <li>Skills mix and complementary skills and knowledge and mutual benefit</li> <li>Wider perspective and ability to look outside the square</li> </ul>
<b>Benefits and advantages</b>	20	<ul style="list-style-type: none"> <li>Collaborators are chosen on the basis of: <ul style="list-style-type: none"> <li>Location overseas because expertise not available in NZ</li> <li>Trust and integrity</li> <li>Personality, easy to get on with, enjoyable company and able to work together</li> <li>Reputation as a co worker and good productivity record (finishing and delivering)</li> <li>Ability to combine expertise and limited funding available</li> <li>Personal linkages</li> </ul> </li> </ul>
<b>Fun/satisfaction</b>	18	<ul style="list-style-type: none"> <li>Enjoying the interaction and exchange of ideas</li> <li>Working with others in a team motivating/satisfying/interesting, and enjoyable</li> <li>Collegiality of working with people of diverse and/or complementary skills</li> <li>Able to share with others of like minds with a common interest in project outcomes</li> <li>Moral/professional duty to assist</li> <li>Improvement of own knowledge</li> </ul>
<b>Tactical reasons for collaborating</b>	8	<ul style="list-style-type: none"> <li>Reputation building</li> <li>International networking</li> <li>Meeting funding agency preferences</li> <li>Seizing unplanned opportunities</li> <li>Links to otherwise inaccessible data sources</li> <li>Importance of a problem</li> <li>Producing a PBRF eligible research output</li> </ul>

**Note:** Responses underwent a thematic analysis. This process is discussed in Chapter 3, Methodology.

#### 4.2.5 Characteristics of successful collaboration

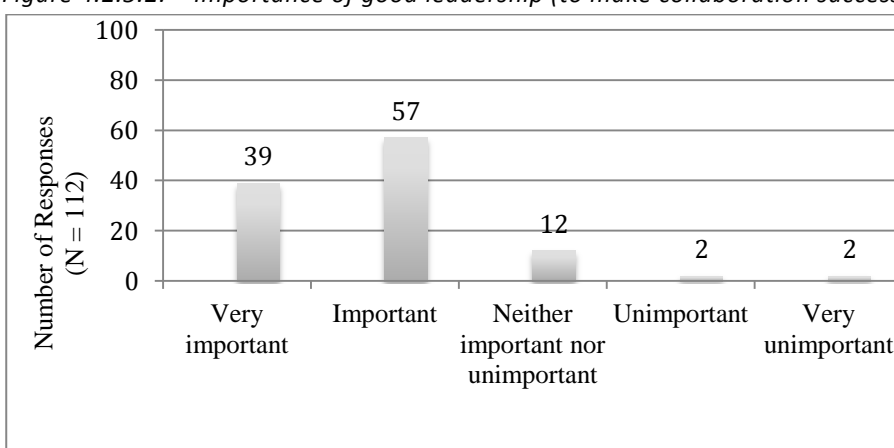
In this section respondents were asked to rate factors according to their importance in making collaboration successful.

Figure 4.2.5.1: Importance of frequent communication amongst members (to make collaboration successful)



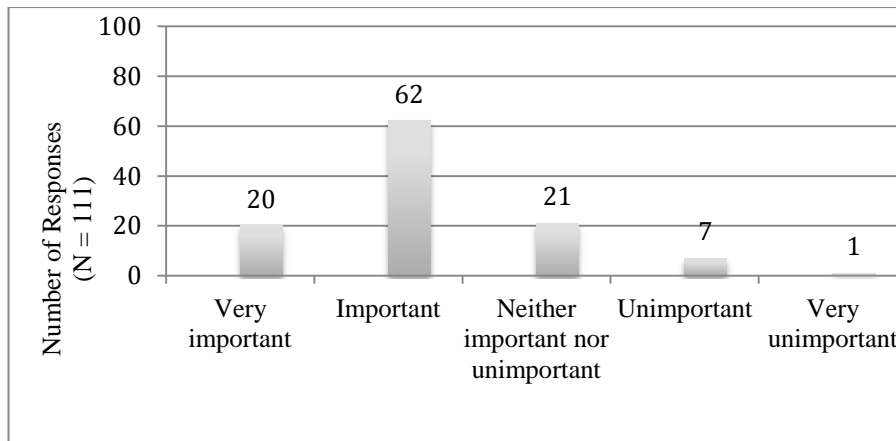
There is very strong agreement on the importance of frequent communication amongst team members with 98.2% of respondents indicating that it is either important or very important in making collaboration successful. Whilst there is a small group of 2 (1.76%) who are neutral, there were no respondents who indicated that it was unimportant. The importance of communication to successful collaboration is explored in the Discussion chapter.

Figure 4.2.5.2: Importance of good leadership (to make collaboration successful)



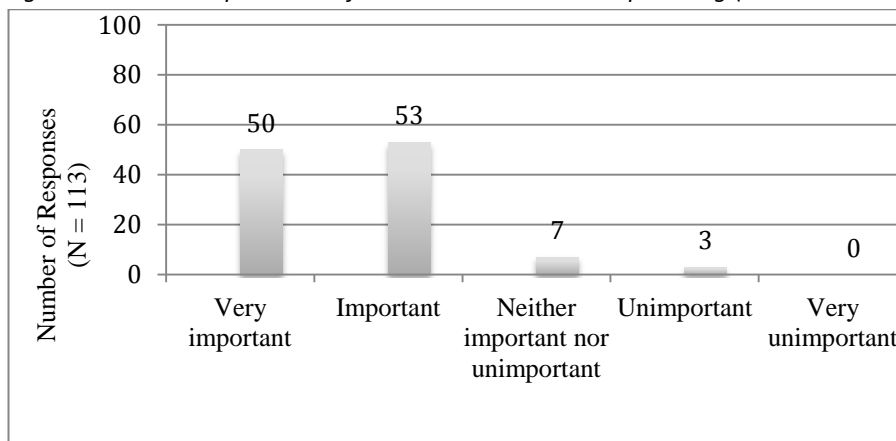
An emphatic result with most respondents (85.7%) agreeing that good leadership is important or very important in making collaboration successful. Leadership as a component of successful collaboration is considered in the Discussion chapter.

Figure 4.2.5.3: Importance of having an agreed method of sharing the recognition and reward (to make collaboration successful)



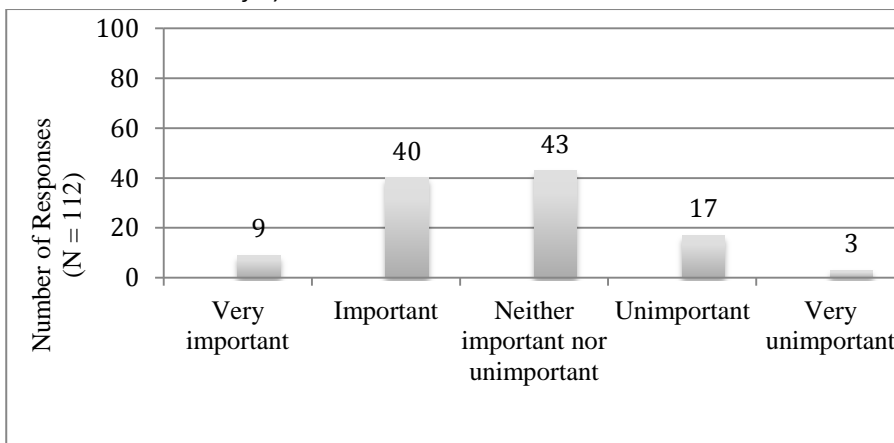
For most respondents (82 or 73.8%) having an agreed method of sharing the recognition and reward is important or very important in making collaboration successful. Agreement on sharing recognition and reward is considered in the Discussion chapter.

Figure 4.2.5.4: Importance of clear coordination and planning (to make collaboration successful)



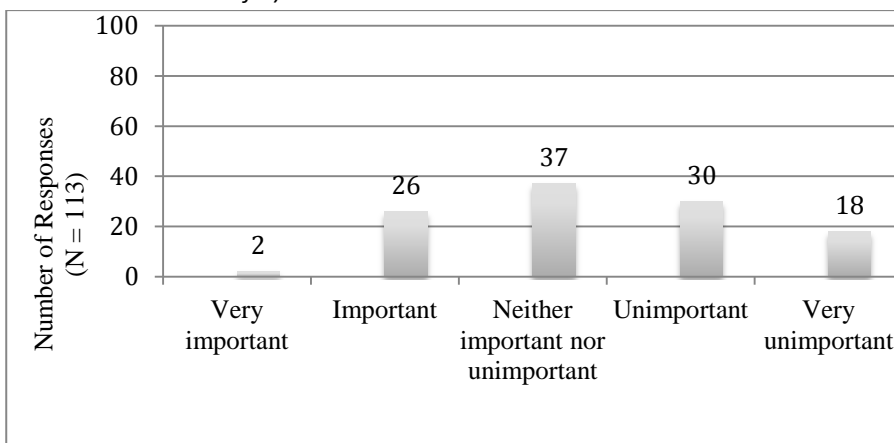
The very strong agreement (91%) that having clear coordination and planning important or very important in making collaboration successful is noteworthy. The importance of coordination and planning to collaborative research is taken up in the Discussion chapter.

Figure 4.2.5.5: Importance of team members having worked together previously (to make collaboration successful)



The spread of responses to the question of the importance of having team members working together prior to collaborating for successful collaboration indicates that the respondents have varying views. This issue is explored in the Discussion chapter.

Figure 4.2.5.6: Importance of team members being geographically close to each other (to make collaboration successful)



This question yielded the most even spread of responses in the survey, showing much less agreement than for other questions in this section. Proximity, and its importance, in collaborative research is considered in the Discussion chapter.

Table 13: Summary table of the frequencies of responses to questions concerning the importance of various factors in successful collaboration (**Questions 4.5.1 – 4.5.6**).

<b>Factors</b>	<b>Very unimportant %</b>	<b>Unimportant %</b>	<b>Neither important nor unimportant %</b>	<b>Important %</b>	<b>Very important %</b>
<b>Having frequent communication among team members</b>	0	0	1.7	57.5	40.7
<b>Having good leadership</b>	1.7	1.7	10.7	50.8	34.8
<b>Having an agreed method of sharing the recognition and reward</b>	0.9	6.3	18.9	55.8	18.0
<b>Having clear coordination and planning</b>	0	2.6	6.19	46.9	44.2
<b>Having had team members working together previously</b>	2.6	15.1	38.3	35.7	8.0
<b>Having team members geographically close to each other</b>	15.9	26.5	32.7	23.0	1.7

The three factors rated by the most respondents as being very important in making collaboration successful are clear coordination and planning (ranked as very important by 44.2% of respondents), frequent communication (ranked as very important by 40.7% of respondents), and good leadership (ranked as very important by 34.8% of respondents). The factor rated as most unimportant was having team members geographically close to each other at 15.9%. Furthermore, this factor and that of having team members working together previously, elicited the most markedly ambivalent response where many respondents saw them as neither important nor unimportant. In the following table these factors are ranked by importance.

**Table 14: Ranking of success factors by importance: Questions 4.5.1 - 4.5.6**

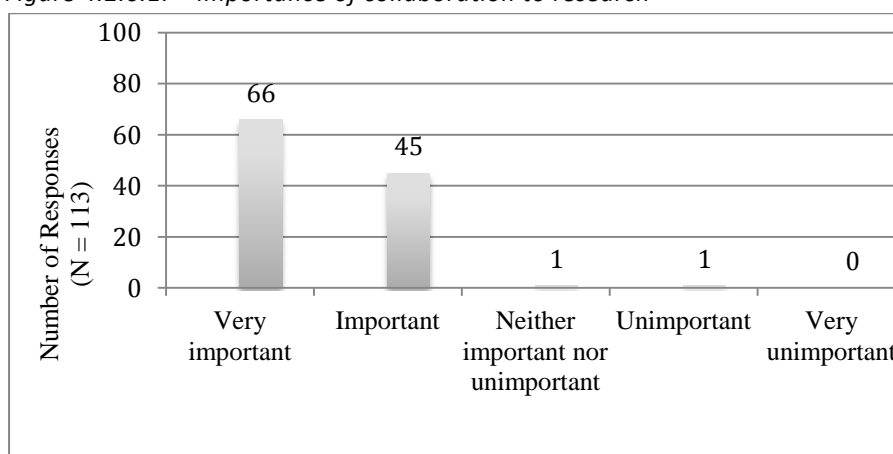
Factors perceived as important or very important in making collaboration successful	Percentage of Respondents	Rank
Having frequent communication among team members	98.2	1
Having clear coordination and planning	91.1	2
Having good leadership	85.6	3
Having an agreed method of sharing the recognition and reward	73.8	4
Having had team members working together previously	43.7	5
Having team members geographically close to each other	24.7	6

These results are explored in the Discussion chapter.

#### 4.2.6 Value of collaboration to respondent’s research

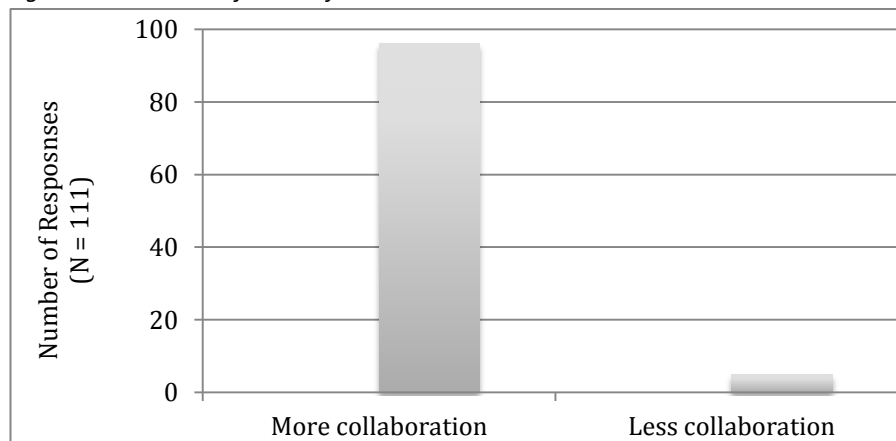
In this section respondents identified the level of value they ascribe to collaboration in their research and described, in their own words, why collaboration is of value to their research.

Figure 4.2.6.1: Importance of collaboration to research



An overwhelming 98.2 % of respondents regard collaboration as being valuable or very valuable to their research. The value that respondents ascribe to collaboration in their research is explored further in the Discussion chapter.

Figure 4.2.6.2: Preference for more or less collaboration



This question resulted in the respondents giving a clear indication that they would like to be involved in more collaborative work; these results support the results of the previous question.

#### 4.2.7 Reasons for Valuing Collaboration

Respondents were asked to contribute other reasons why they value collaboration in scientific research and from those ideas seven themes have been derived. Those themes, the numbers of responses for each theme and representative comments covering the different aspects of each theme are set out in table 15.

**Table 15: Reasons for valuing collaboration**

Theme	Number of responses	Representative comments on the different aspects of this theme
<b>Opportunities can arise from collaboration.</b>	21	<ul style="list-style-type: none"> <li>• International opportunities emerge</li> <li>• Collaborators provide new problems and materials</li> <li>• Idea generation is fostered</li> <li>• Complex data analysis opportunities possible</li> <li>• Difficult research projects are possible</li> <li>• Large projects are possible</li> <li>• Collaboration necessary for success in many fields of research today</li> <li>• Complex societal problems requiring the complementary approaches of both natural and social sciences are possible</li> <li>• Collaboration optimises funding access</li> <li>• Exposure to other funding bodies is fostered</li> </ul>
<b>There is value in working with others</b>	14	<ul style="list-style-type: none"> <li>• Collaboration is highly motivating &amp; stimulating</li> <li>• Work can be shared</li> <li>• The load can be spread</li> <li>• Collective enthusiasm and drive is generated</li> <li>• Isolation is reduced</li> <li>• Helping others is possible</li> <li>• Supporting the research of others is possible</li> <li>• Impromptu meetings are productive</li> <li>• Working with others is enjoyable</li> <li>• Network development is encouraged</li> <li>• Networks are enlarged</li> </ul>
<b>Collaboration can increase access to equipment and expertise</b>	14	<ul style="list-style-type: none"> <li>• Access to equipment is easier</li> <li>• Resources, ideas, peer review, manpower not available in New Zealand can be accessed</li> <li>• The available resources can be 'stretched'</li> <li>• Complementary expertise can be accessed</li> <li>• A new dimension is added to work</li> <li>• Large numbers of study subjects are accessible</li> </ul>
<b>Collaboration promotes learning and opportunities for mentoring</b>	14	<ul style="list-style-type: none"> <li>• New approaches are accessible</li> <li>• New skills and ideas are raised</li> <li>• There is a diversity of perspectives</li> <li>• Skills in managing projects are learned</li> <li>• New skills in writing and designing proposals are</li> </ul>

		<p>learned</p> <ul style="list-style-type: none"> <li>• New skills, methodologies and tools are accessed</li> <li>• Critical evaluation from different perspectives</li> <li>• New insights and learning from others</li> <li>• Scope of work is increased</li> <li>• Working with experts valuable</li> <li>• Mentoring from senior researchers is motivating</li> <li>• Funding more secure because of reputations of supervisors</li> <li>• Working with younger researchers is satisfying</li> </ul>
<b>Collaboration can enhance project outcomes</b>	9	<ul style="list-style-type: none"> <li>• Research outputs are increased</li> <li>• Efficiency is improved</li> <li>• Highest cited publications and largest grants are derived from collaborative projects</li> <li>• Success comes from team work</li> <li>• Best work is collaborative</li> </ul>
<b>Collaboration can be of different types</b>		<ul style="list-style-type: none"> <li>• Theoretical research is possible</li> <li>• Research is global</li> <li>• Wider geographic spread of types of activities</li> <li>• Research relevant to industry is fostered</li> <li>• Applied research and product development</li> <li>• Collaboration is more important in some areas than others</li> <li>• Breadth in research is encouraged</li> </ul>
<b>Difficulties and barriers can arise in collaborative research</b>	4	<ul style="list-style-type: none"> <li>• Control is shared</li> <li>• Time to communicate must be built in</li> <li>• Planning and setting expectations is required</li> <li>• Some researchers can be marginalized</li> <li>• Networks are not available to all researchers</li> </ul>

### 4.3 Phase 2: Qualitative Phase: Interviews

The interviews were undertaken with researchers, a senior officer of each of four main funding agencies, and a senior manager of Massey University. Material from the interviews has undergone thematic analysis. This process is detailed in Chapter Three, Methodology, but in brief it can be described as a process of sorting and resorting data on the basis of similar meanings or connotations, into categories or themes. In analysing the material from the interviews, King's (2004) template

approach (discussed in Chapter 3, Methodology) was used. This template was structured on the basis of the key ideas in the research objectives and the material was sorted accordingly. The data was then converted into narrative form under each theme heading. The Findings are presented here and in the following chapter, Discussion chapter, each theme is explored in relation to earlier studies.

#### **4.3.1 Perspective of the researchers**

Three leaders of collaborative research teams and the five members of research teams were interviewed and from the thematic analysis of the interviews the following five themes emerged:

1. General views on collaboration [relates to objective 1]
2. Drivers/reasons to collaborate [relates to objective 2]
3. Skills and competencies required: [relates to objective 3]
  - leadership skills
  - managerial skills
  - member skills
4. Forming a team for collaborative work [relates to objective 3]
5. Successful collaboration characteristics [relates to objective 4]

##### **4.3.1.1 Theme 1: General views on collaboration**

Many interviewees commented on the fact that the science sector in New Zealand is small and all subdisciplines in science may not be represented in the country. The limitation on resources was also frequently commented on and given as part of the reason that increasingly researchers are looking overseas for collaborators.

A number of researchers stated that institutions have a role in terms of the policies and infrastructure to support collaborative research and the strategic direction that should be taken. *"I think it's essential they [institutions] facilitate collaboration... They can put some tools and mechanisms in place that fan or facilitate the collaboration to make it easier"* (Interviewee 7, personal communication, 2011). One researcher favourably described the regular 'brainstorming' meetings that are held in some sections of the College of Sciences at Massey University aimed at sparking ideas. Researchers in allied fields are invited

to these meetings and they were described by one researcher as being *“like scientific speed dating”* (Interviewee 5, personal communication 2011). This same researcher went on to query the degree to which this activity should be formalised and how it can be done with researchers outside Massey University.

The process of collaborative research was raised by several researchers who described the process as a story, the starting point for collaborative research being the initiation of ideas where expertise and common ground already exists and then there is a process of building ideas and integrating perspectives. The story has an over-arching idea which will probably change over time, and a number of different components which may form markers, chapters, or milestones in the story. In the words of one researcher, *“you’ve got these bits of work that you put together to a single story line”* (Interviewee 2, personal communication, 2011). Several researchers commented that a collaborative research project is more than just a number of disciplines being brought together, and is a group of people from different disciplines with a shared goal working towards a mutually shared outcome. As one interviewee stated, *“we’re all sort of working towards the same goal. Buy-in, time and effort are required”* (Interviewee 5, personal communication, 2011). Timing was raised by one interviewee as an important factor in collaboration. The interviewee went on to describe how even in the very early stage of a project before funding can be sought, all researchers must contribute time and effort to the development of an idea.

#### **4.3.1.2 Theme 2: Drivers/reasons to collaborate**

Many interviewees pointed out that collaborative research is intellectually stimulating, satisfying and fun. It can also augment the quality of the outputs and knowledge transfer is more rapid. Other drivers suggested by interviewees fall into two main groups: a. tactical drivers and b. access to expertise.

##### *a. Tactical drivers*

Researchers talked of the widely held perception that funding agencies require applicants for research grants to collaborate if they wish to be successful. Several interviewees pointed out that many project applications are collaborative even

where the work does not really require collaboration. Several other interviewees discussed the merits of collaborating for efficiency reasons. One big project of \$2 million rather than twenty contracts for \$100,000 is administratively less costly, and it was suggested such a project probably had a better chance of getting funding than many small projects. As one interviewee said, *"I can see collaborations being encouraged by government bodies because it makes it administratively cheaper"* (Interviewee 5, personal communication 2011). It was pointed out that sometimes in large projects it can be difficult to spend that budget.

Another interviewee pointed out that when research ideas are novel or when there are limitations to the resources, collaboration can be the only way research in some areas is possible. Novelty on its own can be risky in terms of getting funding and thus it is not always prudent to pursue novel ideas, however, through collaborating with researchers in allied areas it is sometimes possible to include the more tangential or novel aspects of problems in a project. In other cases because equipment and facilities are not available on campus researchers choose to collaborate in order to gain access to it.

A key driver in academic research is the publication of research papers and collaboration with other researchers can enhance publication possibilities. Assessment of performance of academic researchers in New Zealand is through the Performance Based Research Fund (PBRF) mechanism and it was claimed that some researchers collaborate in order to get a better PBRF score.

#### *b. Accessing expertise*

Several researchers claimed that bigger projects can be undertaken by collaborating and by tapping into other expertise of other researchers, and some claim that *"the only way to get some of that money is to be part of a larger project"* (Interviewee 2, personal communication, 2011). A number of researchers in the fundamental sciences pointed out that when looking for collaborators, typically they look for researchers in the applied sciences who have problems to solve. This view was confirmed by one of the applied scientists who commented that *"as an applied scientist I can see how we help focus the ideas of some of the more fundamental scientists about what is practical and what is realistic"* (Interviewee 2, personal

communication, 2011). The fundamental researcher may not have a good understanding of the problem or how to solve it but can contribute knowledge to developing that solution and contribute to the development of technologies which also helps with the solving of the problem.

One of the very positive spin offs from collaboration, according to researchers in this study, is how the breadth of contacts particularly with international collaborations can be extended and how other avenues of opportunity can arise in further collaborations and funding sources.

#### **4.3.1.3 Theme 3: Skills and competencies needed**

Skills and competencies as identified by researchers as needed for collaborative research have been grouped into a. Leadership skills and competencies; b. Managerial skills and competencies; and c. Member skills and competencies.

##### *a. Leadership skills and competencies*

It was claimed by one interviewee that leadership of a project goes to the researcher who initiates the project and gets the money regardless of their level of leadership competency and skills. Most interviewees were of the view that there are a number of competencies and skills that leaders must have if they are to be successful.

According to interviewees, leaders have a dual role as leader and as a team member. A leader must have a vision and be able to articulate that vision but must also be able to map that vision to the individual visions of all members of the team. The leader is also a team member and must have the competencies and skills required of a team member. To undertake this dual role a team leader requires well developed conceptual skills, well developed observational skills, and well developed interpersonal skills including being able to see things from another person's perspective and being willing and able to listen to other people's ideas. The converse is that leaders must be able to accept criticism as a great deal of time is spent discussing the leader's ideas and plans. As one interviewee said, "*no one person always has the best ideas*" (Interviewee 5, personal communication, 2011).

*b. Managerial skills and competencies*

One mid-career researcher claimed that the management around scientists is not strong enough and the generally hands-off approach led to some inefficiencies and ineffectiveness and at times an energy-sapping focus on irrational topics such as office size. The different stages of a project and the levels of experience of team members will require different levels and kinds of management. As one senior researcher pointed out in the early stages team members need to be managed more than in later stages, giving the example of younger team members when collaborating with external parties can easily antagonise others because of actual or perceived arrogance, a patronising attitude, or choice of language.

Most interviewees were in agreement that managers did need certain skills and the following were suggested by interviewees as the most fundamental skills required:

- Listening skills;
- Planning, budgeting and coordinating skills;
- People skills;
- Skills in handling the expectations of team members, the funding agencies, and external parties;
- Skills of being able to integrate the knowledge, skills and ideas of all team members; and
- Skills in handling the expectations and demands of academia and commerce.

*c. Member skills and competencies*

Researchers described how different people bring different skills and competencies to a team and a project. In addition to the expected high level of professional competency including discipline knowledge and research capability, team members need a set of interpersonal skills. One interviewee claimed that *“it’s the personal skills which are the most important ones”* (Interviewee 2, personal communication,

2011). The following were identified by interviewees as being fundamental interpersonal skills:

- Maintenance of respect for everyone involved;
- Taking responsibility for components;
- Sharing views and appreciating the views of others;
- Ability to both give and receive criticism;
- Open-mindedness; and
- Acceptance that collaboration will take more time than working alone:

#### **4.3.1.4 Theme 4: Forming a team for collaborative work.**

Research can be quite isolating but leading and working in teams does also have its challenges. As noted earlier a leader has a dual role as both leader of the team and manager of the project. For credibility the leader must be a leader in some aspect of science and have the skills of a project manager. As one interviewee stated, for a project to work you need the 'right' people with the 'right' science expertise and the 'right' interpersonal skills. All interviewees accepted that different people bring different skills and abilities to a team and the concept of complementarity in skills, expertise, and experience was raised by one interviewee who said *"it [our collaborative research] works really well, because our skills are complementary"* (Interviewee 5, personal communication, 2011). The need for 'buy-in' (meaning agreement and commitment to support) from all members of the team was identified by several interviewees as being vital. The degree of buy-in was seen as being determined, at least to some extent, by the distribution of the work. It was suggested that all members should have their own area of responsibility and *"we need to be actually (sic) quite explicit about what we're thinking because otherwise the project can go in different directions that might not be how we expected the project to go. So we do actually have to be clear about what's happening at any particular time"* (Interviewee 5, personal communication 2011). Peer pressure was noted by the interviewee as being the force that can ensure that members keep to deadlines and stay with their responsibilities.

It was pointed out that in many research teams there tends to be a nucleus of researchers who work closely and form a tight group and then there are other researchers in a more peripheral role.

Many interviewees raised trust as being one of the most fundamental attributes of a team member. As one interviewee stated “*you work with people you trust*” (Interviewee 3, personal communication, 2011) and another pointed out that trust is very important and all team members must work on developing trust “*especially when a project is just starting up*” (Interviewee 1, personal communication, 2011). Building a team takes time and researchers must be prepared to invest the time into that building.

#### **4.3.1.5 Theme 5: Successful collaboration.**

Success in collaboration comes in a variety of forms. For some researchers success is having funding; for others it is high productivity, the completion of the research and publishing of the outputs in respectable journals; and for others it is attracting students and especially overseas students.

All interviewees were able to suggest various ways to ensure a collaborative research project would be a success. For one the key was for members to look at the project as a “project to be managed” not just as “science to be done”; having a common goal; maintaining a focus on the research question; and having all stakeholders feeding into the dialogue. Process was considered important by a number of interviewees. Communication, trust and transparency were identified as vital to success. One interviewee suggested that developing a model of the collaborative process would be useful as it would permit all players to see the big picture and see how their component fitted into that picture.

The responses can be grouped under three headings of (a) protocols on authorship; (b) relationships; and (c) training.

##### *a. Protocols on authorship*

The existence of authorship protocols and conventions, just like their absence, can be a source of conflict amongst team members. One of the tasks for leaders of projects is to ensure that there is a protocol in place, that all participants are aware

of it, and that the protocol is clear. This point was clearly articulated by one interviewee who said, *“it [the protocol] should be quite clear and the leader of the project should make [sic] the protocol in place and inform the participants ... it should be flexible and open enough to give the credit to everyone who is doing the work”* (Interviewee 7, personal communication, 2011). Upfront discussion by the scientific team about the form of an authorship protocol is recommended by interviewees. Two aspects that were emphasised by interviewees were that a protocol needs to be flexible and able to be shaped for individual projects, and that credit for work should be attributed to all involved. This discussion did, however, raise two further issues relating to how far attribution of credit extends beyond the research scientists involved, and the difficulties of identifying the specific work completed by specific team members.

b. Relationships

Interviewees suggested that collaboration depends strongly on the interpersonal relationships amongst team members and in the words of one interviewee, *“you don’t want to become friends with everybody, but all members must work very strongly to ensure that good relationships are established and maintained”* (Interviewee 1, personal communication, 2011). Other interviewees suggested that being friends does help to ensure that there are good relationships and as stated above, building trust is very important. Frequent face to face meetings are important and are considered to work better as channels of communication than do solely electronic means, such as email and telephone, of communicating. Openness, free flowing information, willingness and openness to receiving criticism, and feeling free to ask questions is very important. One interviewee described this as feeling free to show a *“kind of vulnerability”*.

One interviewee suggested that relationship difficulties can be magnified in a small community and because the New Zealand science community is quite small it can be difficult to extract oneself from a project as it not easy to find a replacement.

### c. *Training*

Career development and career management was discussed by most researchers and the need for a *“better model for career movement”* (Interviewee 8, personal communication, 2011) was raised. The concept of less experienced team members being mentored by more senior team members was raised by several interviewees all of whom were at varying stages of their careers. Mentoring was seen as important aspect of researcher training as was the need for mentors to have training in that role.

Most interviewees agreed that managers needed to have managerial skills and that training was required. As one senior interviewee noted, *“I have never had any training but should have had it early in my career before having to manage teams - not when in the role – it’s too late then”* (Interviewee 6, personal communication, 2011). Added to that comment was the point that university thinking has changed and now researchers are getting more opportunity to get that training earlier. Another interviewee pointed out that formal courses in leadership and management are becoming more common but seem to be rather ad hoc in the University.

Several interviewees suggested that teams could be more productive if team members had formal training in team skills as well as the leaders and the managers in the teams having training in leadership and management. In addition to the formal learning that can take place in courses, team members learn from each other and from collaborating with external parties such as end users.

#### **4.3.2 Perspective of funding agencies**

Comment was sought from the four key research funding agencies on collaboration in scientific research. Interviews (in one case this took the form of written comment to the questions) were undertaken with senior officers from each agency. All four agencies were willing to be involved and all shared their understandings and experiences willingly. The three face-to-face interviews were held in the office of the officer being interviewed.

Discussion of the methodology of interviews can be located in Chapter Three, Methodology, and the interview guides used in the interviews with the four

research funding agencies are in Appendices Q, 1 – 4. The transcripts from these interviews underwent a process of thematic analysis which is described in Chapter Three, Methodology.

The agencies consulted were: The Ministry of Science and Innovation (MSI); The Tertiary Education Commission (TEC); The Health Research Council (HRC); and The Marsden Fund.

#### **4.3.2.1 Ministry of Science and Innovation (MSI) (<http://www.msi.govt.nz/>)**

An interview was undertaken with the senior staff member acting in the role of Policy Manager. At the time of consultation The Ministry of Science and Innovation (MSI) had only been in existence for six months having been established February 1 2011 by the merger of two other agencies: the Foundation for Research, Science and Technology, formerly the main funding agency of government funded scientific research; and the Ministry of Research, Science and Technology, formerly the main government policy agency for research, science and technology. The new ministry is the lead agency charged with driving the science and innovation sector in New Zealand and is responsible for the policy and investment functions of both former agencies. At the time of consultation policy development in the new ministry was still in its early stages and discussion in the interview largely reflected the policies of the former agencies.

#### **4.3.2.2 The Tertiary Education Commission (TEC) (<http://www.tec.govt.nz/>)**

An interview was undertaken with the senior officer in charge of tertiary education research funding. The TEC does not directly fund research but is responsible for the PBRF policy and allocation of funds to tertiary institutions according to the PBRF framework.

#### **4.3.2.3 The Health Research Council (HRC) (<http://www.hrc.govt.nz/>)**

A written response was received from the senior officer on behalf of the Chief Executive. The HRC supports research that has the potential to improve health outcomes and delivery of healthcare. The majority of funding is through an annual funding round to independent research projects that are researcher initiated.

#### **4.3.2.4 The Marsden Fund (administered by the Royal Society on behalf of MSI) (<http://www.royalsociety.org.nz/programmes/funds/marsden/about>)**

An interview was undertaken with the senior officer in charge of the Marsden programme. The Marsden Fund is a contestable fund which is investigator initiated and is not subject to government socio-economic priorities. The Fund supports research excellence in science, engineering and mathematics, social sciences and the humanities. Marsden is regarded as the hallmark of excellence for research in New Zealand and competition for grants is intense.

#### **4.3.2.5 Summary of interviews with funding agencies**

All four agencies had similar views on the meaning of the term collaboration and that it incorporated the notion of bringing together researchers, or sets of researchers, with different knowledge, expertise or resources, to share ideas, resources and data, to work in a synergistic way on a particular project. The three strategically focused agencies, MSI, TEC, and HRC, take a broad view of collaboration and inferences can be drawn that they see it as being embedded in the institutional research structures and processes. *"We're wanting to do internationally recognised science...you can't do that in isolation....you need to talk to other people; that's the way that ideas get developed"* (Interviewee 9, personal communication, 2011). These agencies accept that collaboration can take many forms and include vertical arrangements of post-graduate students and supervisors; horizontal arrangements between equal status colleagues; arrangements within or between groups; disciplines or institutions; virtual or actual, domestic or international; ranging from simple co-operation to complex, fully integrated collaborations, which may include end-users, decision-makers, or policy-makers. The Ministry is quite overt about looking for collaboration and the rationale for that position is that *"We need to collaborate to really get that best world class kind of science going and from the Ministry's point of view we're very keen to see collaboration in the science projects that we invest with"* (Interviewee 9, personal communication). Unlike the other three agencies, the Marsden Fund (which supports curiosity driven basic research that has no strategic or applied focus) views collaboration as limited to knowledge transfer and sharing expertise.

*“We [Marsden Fund] don’t have any socio or economic outcome that we have to obtain. So we’re just looking for pure knowledge basically. That’s what we’re trying to gain is fundamental knowledge”* (Interviewee 10, personal communication, 2011).

The development of research capability and competency was regarded by all agencies as a desired outcome of the funding process. At the heart of the competencies and skills which, in part, constitute capability, there must be a willingness to communicate with colleagues and a willingness to share ideas early in a project. This extends to researchers being prepared to put ideas out into the marketplace where they can be tested. One agency suggested that researchers should regard failure of a project as a learning experience and *“that it’s okay to have an idea tested and to have it rebuffed”* (Interviewee 9, personal communication, 2011).

The four agencies also agreed that collaboration should be encouraged as a way of augmenting the size of the small science sector in New Zealand and reducing the geographic and disciplinary isolation of researchers. It is viewed as a means of raising standards, quality, and research capability, enables access to resources and skills, and the achievement of critical mass. MSI does look for collaboration: *“Not collaboration for collaboration’s sake, but collaboration because you need to deliver on the outcome of the research that you’re trying to achieve”* (Interviewee 9, personal communication). Even though there is no requirement for collaboration in Marsden Grants, there is an incentive to do so as international collaborators are required to bring their own money to a project.

The agencies also see that *“collaboration amongst researchers can strengthen a research proposal and lead to innovative projects and original research findings”* (Interviewee 12, personal communication) and it can expedite knowledge transfer and research uptake with end-users. It was pointed out that adding a ‘name’ to a proposal in order to augment credibility is not a good technique as the reviewing panels are fully aware of workloads and commitments!

The ultimate goal of any research assessment exercise would be the measurement of the outcomes, identification of the benefits of research and being able to attribute and measure the impact of a research project on the economy. It

was pointed out that *“measuring research outcomes is very difficult and agencies are always looking for better ways of measuring success”* (Interviewee 9, personal communication). Various kinds of indicators are used, such as the number of papers produced, who the collaboration linkages are with, the extent of the linkages, the appropriateness of the linkages, and the continued relevance of a project.

The four agencies all have formal feedback and assessment processes written into contracts and these generally include a funding schedule, annual plan, key performance indicators (KPIs), annual reporting, and regular reporting throughout the term of the contract. Often funding continuation is dependent on favourable reviews from on-going monitoring and evaluations. This may include identification of the benefits derived from the research and if collaborations have continued, and in what form, after the funding has ceased.

One of the desired outcomes of the collaboration initiatives is to make a research career in New Zealand sufficiently attractive that high calibre overseas researchers would want to come and join the New Zealand research sector. From the TEC’s perspective, collaboration can be a means for keeping promising young PhDs in New Zealand (Interviewee 11, personal communication, 2011).

The key difference is in how the agencies put their collaboration requirements into practice. The MSI and the HRC do so through their contestable funding programmes, and the TEC, whilst not funding research directly, does so indirectly through the Centers of Research Excellence (CoRE) programme which is based on a collaborative approach, and provides guidelines (inspirational rather than mandatory) for the allocation of funds from the Performance Based Research Fund (PBRF). As noted applicants to the Marsden Fund are not required to incorporate collaborative activity in proposals, although it is quite acceptable for applicants to include it if it is an essential aspect of the project.

#### **4.3.3 Summary**

Most of the scientific researchers in The College of Sciences, Massey University engage in collaboration. In the main it is in-house, generally in their own discipline, in their own academic unit, and infrequently with researchers in other Colleges of the University. At the national level (with other universities), there is limited

collaboration and the international collaboration is mainly with researchers in the United States and rarely with Australian universities. The most common type of collaboration output is the production of a journal article.

Many of the reasons given by researchers for collaborating are tactical reasons to increase chances of being funded, but for most researchers the most important reasons for collaborating are in order to do better research, to increase the chances of a successful project, and to get better outcomes.

The agencies which fund scientific research in New Zealand take a broad view of collaboration and accept that it can come in many forms from simple co-operation to complex, fully integrated collaborations, and may include end-users and other interested parties. Of the four funding agencies, three are strategically focused and the Marsden Fund supports curiosity-driven basic research which has no strategic or applied focus.

Collaboration is not mandatory in the applications from researchers for funding; however, the three strategic agencies encourage it as a way of augmenting the size of the small science sector in New Zealand and reducing the geographic and disciplinary isolation of researchers. They also see it as a means of raising standards, quality, and research capability, enabling access to resources and skills, and the achievement of critical mass. The issue of measuring research outcomes is a constant concern for funding agencies and they are always looking for better ways of measuring success.

In the following chapter these findings are discussed in relation to earlier studies on collaboration, and their implications reviewed.



## CHAPTER FIVE: DISCUSSION

Collaboration lets me be part of big projects I couldn't do on my own, and lets me tap into expertise I need but don't have. It would be ideal if I, as a non-senior, non-professor type, had more opportunity to collaborate with people who have extensive track records and prominent standing as international experts, as such people have a greater success rate of getting their proposals funded and their papers accepted, and can act as mentors to researchers like me.

(Survey Respondent, February, 2011)

### 5.1 Introduction

In this chapter the findings of this study are discussed with reference to the literature on collaboration in scientific research.

There were two phases to the data collection. The first phase was a survey of academic staff of the College of Sciences at Massey University to establish the extent of their collaborative research activity, and their views on collaboration. The second phase was a set of interviews with researchers and funding agencies to explore areas such as motives, process, competencies, and success in collaboration. Discussion of the findings has been informed by reference to one further interview with the Assistant Vice-Chancellor – Research & Enterprise and to the key strategy document of the University, *Road to 2020* (2011, pp., 10).

The survey and the interviews, like all qualitative research, have produced a great deal of data. The survey data which provided contextual information was subjected to basic (univariate) analysis. All the basic contextual data is included but the volume of data of the interview material meant that some choice had to be made on what to include and what to omit. The two criteria used to determine if a topic should be included are: meaningfulness, and congruency with the literature. A formal definition of the term 'meaningfulness' is difficult to find and the term is being used here in the sense of judging the topic or item on the basis of (a) relevance to the objectives of this study, and (b) importance and value of the topic

to the objectives of the study. The second criterion is congruency between the data and the literature.

The interview transcripts, or my notes in the case of two interviewees who did not wish to be recorded, and the written answers to the questions from another interviewee who could not be personally interviewed and recorded, were subjected to a thematic analysis based on the template approach described by King (1994, 2004) and discussed in Chapter Three, section 3.5. The codes or themes were based on the research objectives which can be found in Chapter One, the introductory chapter.

A theme is defined as a recurring comment that “captures something important about the data in relation to the research question, and represents some level of *patterned* response or meaning within the data set” (V Braun & Clarke, 2006, pp., 10). This chapter is structured around those themes. In a few cases where comments from respondents fall outside the categories but are particularly interesting they are noted.

As in other chapters of this thesis, those researchers who completed the survey are referred to as “survey respondents” and all those who were interviewed are referred to as “interviewees”. All direct quotes are in italics with double quotation marks.

In the College of Sciences (<http://science.massey.ac.nz/structure.asp>), there are 423 academics of which 120 completed the questionnaire giving a completion rate of 28 %. Careful consideration was given to the timing of distribution of the questionnaire, there were three follow-ups, and anticipating that the subject would be salient to the population targeted, the completion rate was disappointing. Nevertheless, I am indebted to the 28 % who contributed to the survey and to those who gave their time and expertise in the interviews. The proportion of female survey respondents, and interviewees, at 29 %, is similar to the gender ratio in the College of Sciences. In both the survey and interviews there was a spread in experience, disciplines, and representation of the applied and the fundamental sciences.

## 5.2 Extent of collaboration

The overall pattern emerging from both the survey and interview data is that most of the scientific researchers in The College of Sciences, Massey University, engage in collaboration, mainly in-house, and infrequently with researchers in other Colleges of the University. There is limited collaboration at the national level (with other universities), and the international collaboration is mainly with researchers in the United States.

As reported in Chapter Four, Findings chapter, most researchers in this study collaborate for at least 25% of their total research time, and for 25 % of respondents all of their research activity is collaborative. Most collaborative research is in-house, in the researcher's own discipline and within their own academic unit. This is similar to the collaborative activity of scientists at Victoria University of Wellington reported in a 2003 study (Morrison, et al., 2003). The output of the collaborative activity is mainly the publication of journal articles, preparation and presentation of conference papers, applications for funds, and undertaking the research itself.

Little collaborative research is undertaken with researchers in other Colleges of the University and findings of this study show that it is seen as unimportant. This view is consistent with Summer's (2010) results of a survey of scientists across the entire science sector in New Zealand in 2008, which showed that 60 % of scientists had never been involved in, or even witnessed, collaboration between social scientists and physical scientists. This is also consistent with the assertion of Baines et al. (2006) that there are few social scientists (if any) working in physical or biological research programmes on an ongoing basis. The sentiment of many survey respondents is expressed in the words of one interviewee who said *"why would I collaborate with non-scientists? I don't need to, and there are too many opportunities for me here"* (Interviewee 1, personal communication, 2011).

Bozeman and Boardman (2003) assert that often researchers collaborate because funding agencies require it rather than because it is based on a sound theory of collaboration or demonstrated need to do so. However, as the Assistant Vice-Chancellor – Research & Enterprise (AVC, R&E) pointed out, there does have to be a reason to collaborate (personal communication, 2011) and from the funding

agency perspective one interviewee stated *“Not collaboration for collaboration’s sake, but collaboration because you need to deliver on the outcome of the research”* (Interviewee 9, personal communication).

Within the College of Sciences, there are, however, a few examples of projects where social scientists are members of scientific research teams and their role, at least in part, is to ensure that the interface between scientific researchers and external parties is smooth and untroubled. As discussed in Section 2.7.1, research does show that there are personality and behavioural differences between scientists and non-scientists and studies by C Cohen and S Cohen (2005) and Jaffe et al. (2010) show that sociologists, as a group, are often able to bridge the personality differences between natural scientists and members of the business community. One of the interviewees described how when young scientists work with industry for the first time, they need to be carefully managed to ensure that they do not antagonise external collaborators by using language appropriate only to scientific discourse, or do not patronise. *“It is easy for a scientist to come across as being quite arrogant”* (Interviewee 8, personal communication, 2011).

Half of the researchers in the College of Sciences collaborate sometimes with academics at other New Zealand universities, but over one third never do. This low level of collaboration with other New Zealand universities may be related to the observation that as the number of domestic institutions involved in co-authorship increases, the expected average citation rates per article reduces significantly (Leimu & Koricheva, 2005; Ordonez-Matamoros, et al., 2010; Persson, Glanzel, & Danell, 2004). An earlier study by Goldfinch, Dale and DeRouen (2003) shows low levels of national collaboration in New Zealand, and the results of a study by He et al. (2009) of New Zealand biochemists demonstrates the ambivalence the biochemists feel about the importance and contribution of collaboration at the national level. The same study, however, shows that international collaboration, and within-university collaboration, are significantly related to the quality of an individual paper and thus the citation potential (He, et al., 2009).

Over half of the survey respondents indicated that they collaborated with overseas researchers. These collaborators are more likely to be scientists from

universities in the United States than from Australian universities. This result is consistent with the MORST funding data for 2010 (MORST, 2010).

Networks are a very important aspect of collaboration and the relationships between collaboration, networks, citation, and the impact of papers from local, national and international collaborations are discussed in Section 2.8.2.

### **5.3 Views of collaboration**

Like the terms science, scientific method, and models of science as discussed in Chapter Two, the term collaboration, discussed in section 2.3, is used and defined in many ways both in the literature on collaboration, and in general usage. As a concept it is difficult to define and Smith and Katz (2000) suggest that this is partly because researchers have a general understanding of the term and there is little consensus on where informal linkages end and collaboration begins. The funding agencies and associated organisations complicate this further, as discussed in the section 2.3, by rarely spelling out in their documentation what is meant by the term collaboration. In a recently published evaluation report of a major global collaborative project, the authors acknowledge that collaboration was not defined before the project started, at the beginning of the evaluation study, or by any participants (Penman, Pearce, & Morton, 2011).

Whilst funding agencies all see collaboration a little differently, they were able to articulate more precisely what collaboration means to them than were the researchers. For the Marsden Fund, where collaboration is not a mandatory feature of the research proposals considered for funding, it is viewed as simply a transfer of knowledge and sharing of expertise between individuals or groups in different teams and organisations. Such sharing between members of a single team is regarded as normal team interaction rather than as collaboration (Interviewee 10, Personal communication, 2011). The three strategic agencies, MSI, HRC, and TEC, take a broad view of collaboration and see it as a process of bringing together people with different knowledge, expertise or resources to work in a synergistic way on a particular project. They see it as a way of strengthening research and research proposals (a view supported by Siemens, 2010), and as a way of nurturing creativity, thus they encourage and support collaboration. *“The HRC recognises that*

*collaboration amongst researchers can strengthen a research proposal and lead to innovative projects and original research findings”* (Interviewee 12, personal communication, 2011); *“We [MSI] want them [the researchers] to work with the best in the world so we can be assured we get the best teams for doing the research and the best outcomes for New Zealand”* (Interviewee 9, personal communication, 2011); and *“the TEC recognises that groups increase quality and we encourage collaboration across disciplines”* (Interviewee 11, personal communication, 2011).

All agencies accept that collaboration can take on a wide variety of forms and structures and the inclusion of end users is encouraged where appropriate. *“Collaboration is not just between scientists but is also between scientists and people who are going to use the research”* (Interviewee 9, personal communication, 2011). It is interesting to note that in the transdisciplinary approach to research and regarded as the most extreme form of collaboration, integration of the disciplines is required, and the teams always include end users (Klein, 2004). Post-normal science which is non-linear, complex, dynamic, and regarded as the broad and encompassing approach necessary for addressing global problems in areas such as health and environment, also includes end users in its teams (Funtowicz & Ravetz, 1994).

In the survey, respondents were not able to articulate their views on what collaboration is quite as clearly as the funding agencies were able to do, and tended to describe it as a sharing of knowledge from different parties coming from different fields. They were, however, positive towards the general concept, for even though 25% of respondents indicated that they collaborate for less than 25% of their research time, 95% said that they would like to do more collaboration, and 98% of them stated that they saw collaboration as being valuable to their research.

At a strategic level, Massey University encourages collaboration. The AVC, R&E, points out that collaboration is a type of engagement which can take many forms; it can be an informal or a formally structured arrangement; and it can operate at many levels and between individuals or between groups (personal communication, 2011). The document *The Road to 2020* acknowledges that increasingly, the sustainability of world-class research will depend on the

development of “functional collaborations and tactical partnerships both domestically and internationally” (MU, 2011).

#### **5.4 Drivers of collaboration**

Survey respondents were asked to provide the reasons why they choose to collaborate. The reasons they gave fall into three main groups which roughly coincide with the collaboration ‘drivers’ identified in section 2.4 of the Literature Review. The first is a group of reasons relating to researchers “wanting to do better science”. They include collaborating to ensure better project outcomes, to increase chances of success, and to enhance productivity. In contrast, the second group comprises the ‘least important’ reasons which include collaborating in order to increase prestige, to access different ways of thinking and different research methods, and to collaborate with non-scientists in order to meet the expectations of funding agencies. The third group comprising a set of reasons which are neither important nor unimportant relate to accessing expertise from other disciplines, increasing efficiency in the use of resources, and meeting the expectations of the funding agency. As noted in section 1.2.3.2, increasing efficiency is important from the institutional perspective.

That respondents regard meeting the expectations of the funding agency, as being a relatively unimportant reason to collaborate, requires comment. Many writers have noted that funding agencies see collaboration as a ‘laudable goal’ because it adds value to a project, and others have recorded that various governments around the world make collaboration a prerequisite to any research investment (Perianes-Rodriguez, Chinchilla-Rodriguez, Vargas-Quesada, Olmeda-Gomez, & Moya-Anegon, 2009; Sonnenwald, 2006).

In New Zealand, the HRC in some of its funding streams (for example, the Rangahau Hauora Māori investment stream, and the New Zealand Health Delivery investment stream), requires collaboration with end users in the research that it funds (HRC, 2011). Documentation from other funding agencies suggests, explicitly or implicitly, that collaboration is a worthwhile goal (Adams, et al., 2010; Jordan, 2010; MORST, 2010). A number of writers have suggested that the relationship between research collaboration and research output is more assumed than

investigated (Abramo, et al., 2010; S Lee & Bozeman, 2005) and He et al. (2009), in one of the few studies of collaboration in New Zealand, asserts that many of the initiatives that have been launched to encourage collaboration have been based on the simple assumption that collaboration is a “good thing”.

The strategic agencies interviewed in this study: MSI, HRC, and TEC, are also the agencies from which the researchers in this study source their funds. They are all government bodies and thus their funding regimes are all influenced, to a greater or lesser degree, by government priorities. The Marsden Fund, established by the government in 1994 to fund excellent fundamental research and administered by the Royal Society (a body corporate governed by the Royal Society Act 1997), is government funded and whilst not subject to government socio-economic priorities it operates under Terms of Reference issued by the Minister of Science and Innovation. Scattered throughout the documentation of these agencies are references to “collaboration”. It is found in documentation of FRST and MORST, the agencies which preceded the Ministry of Science and Innovation, as a measure of performance (FRST, 2008, pp., 23, 2009); and as a measure of organisational success (MORST, 2009, pp., 27); and the term is used by both the Health Research Council and the Tertiary Education Commission as a criterion in the assessment of research proposals (AAAS, 2011; HRC, 2009, pp., 42; TEC, 2007, pp., 5). Despite collaboration being overtly important in the allocation of research funds, featuring in the documentation of three of the four main funding agencies, and being referred to by the Minister for Research, Science and Technology in a major policy speech in 2009 on government priorities in research, science and technology, in which the “encouragement of collaboration” is referred to as one of those priorities (Mapp, 2009), the term remains undefined.

In the Massey University Strategic document, entitled *Road to 2020* (MU, 2011), the intent to establish collaborations features quite prominently. These collaborations are suggested for a number of purposes including the teaching programmes being “informed by research and enriched by case studies developed by partners and collaborators” (MU, 2011, pp., 3). How these collaborations and partnerships are to be achieved and implemented is not stated.

It is not surprising then, that even though researchers may consider that meeting the expectations of the funding agencies to be relatively unimportant as a reason to collaborate, they do so because of the widespread perception that it is tactically sound to include in any proposal for funding even though it may not be a requirement, or even necessary. A number of interviewees talked of inserting collaborations in applications where they were really not needed. This practice is exacerbated by the requirement for project budgets to be greater than \$30,000.00 *“before the agency will even look at it”* (Interviewee 2, personal communication, 2011).

D Smith and Katz (2000) report that these “forced” collaborations can lead to the assembling of “artificial” collaborative teams and they do not always produce good research. It has also been recorded, in at least one study, that researchers do not like these artificial top-down teams and in consequence have a negative attitude towards collaborative research (Laberge, et al., 2009).

Encouraging researchers to bring many smaller projects together to frame as a single large project, where this makes sense, is administratively sensible. This notion is not lost on the researchers and illustrates one of the ten key behavioural characteristics identified by Devine in his game theory analysis of how researchers adapt their behaviour in a competitively funded science system (in this case the New Zealand science system) to enhance the outcomes they desire (Devine & Webb, 2004). Games-playing by researchers to increase chances of receiving funding was identified in the Roberts Report to the UK funding bodies on assessment of research as one of the reasons for reviewing the Research Assessment Exercise (RAE) (G.Roberts, 2003). On a more positive note in this study, one interviewee noted that sometimes good ideas arise when *“you’re sort of pushed together by other forces, but this can cause conflict”* (Interviewee 3, personal communication, 2011) and other scholars support the view that having to “work” to get projects to fit under one umbrella can stimulate divergent thinking and creativity (see Heinze & Kuhlmann, 2008; Heinze, Shapira, Rogers, & Senker, 2009; Levine & Moreland, 2004).

## 5.5 The value of collaboration

When survey respondents were asked to state why they saw collaboration as being valuable to them, the most commonly given reason related to the opportunities that can come from collaborative research. Collaborative research means being part of a team, and being part of a team working on big, international, and multi-disciplinary projects, described by Thune (2010) as the “grand challenges,” does bring benefits. These benefits which are discussed in section 2.4.4 can be in the form of enlarged professional networks which, it is claimed, can provide access to a variety of resources and opportunities, including leads on funding, conferences and collaborative projects not otherwise accessible (Ynalvez & Shrum, 2009).

Survey respondents also noted that collaboration fosters idea generation. Studies by Levine and Moreland (2004) and Beaver (2001) support the view that collaboration increases creativity, particularly when it involves some degree of diversity, as this may stimulate divergent thinking. As noted earlier in section 5.3 one of the key reasons given by the Ministry of Innovation and Science for encouraging collaboration is because it stimulates the generation of ideas.

The remaining reasons given by participants in this study for valuing collaboration fall into three key thematic groupings:

The first thematic grouping is a collection of reasons focusing on the personal value that is derived from working with others. Many survey respondents and interviewees stated that they find collaboration enjoyable and fun and in most of those responses collaboration was described as stimulating, highly motivating, and as generating collective enthusiasm. The view that researchers are intrinsically motivated to collaborate because they enjoy social interactions and that they actively seek to share ideas and jointly conduct research as a way of minimising the isolation and to increase productivity is supported by many scholars (see Bozeman & Corley, 2004; De Langhe & Greiff, 2010; D L Hull, 1997; Melin, 2000; Rafols & Meyer, 2007). Running through the comments from researchers in this thematic grouping was a strong thread of comment related to supporting, helping others, and sharing the load. The concept of “sharing”, discussed in detail by D'Amour Ferrada-Videla, San Martin Rodriguez, and Beaulieu (2005), is one of four key

concepts frequently associated with collaboration. The other three are partnership, interdependency and power.

The second group of reasons focused on how collaboration permits researchers to access expertise and equipment. In the main, the views in this group relate to process and how resources can be 'stretched through collaboration'. Many survey respondents and interviewees commented on how collaboration enables them to access expertise, knowledge and equipment that is not available in the small New Zealand research sector with limited resources. *"My philosophy is you go where people have got the equipment"* (Interviewee 3, personal communication); *"one of the drivers for me to collaborate is because I can't be an expert in each and every part of the system"* (Interviewee 3, personal communication); *"I use collaboration as a marketing vehicle to funding agencies or investors, and to attract postgraduate students"* (Interviewee 6, personal communication).

The small size of the New Zealand science sector, with its attendant critical mass issues, limitations to the breadth of disciplines, and limited resources, was raised by researchers, funders and the AVC, R&E. Interviewees claimed that these limitations are a major reason why increasingly individual researchers are looking overseas for collaborators. The funding agencies regard collaborative research as one way of augmenting the size of the science sector in New Zealand and thereby reducing the geographic and disciplinary isolation of researchers (MSI, 2011; HRC, 2011; RSNZ, 2011, personal communications). Size limitations are being addressed by Massey University through actively engaging with research collaborators and partners, domestically and internationally as a means of enhancing the research capacity and capability of the institution (MU, 2011). As the Assistant Vice-Chancellor stated, *"New Zealand is trying to operate as a large country but it needs to join forces with others to get the critical mass"* (AVC, R&E, personal communication, 2011).

This group of responses from survey respondents and interviewees can be described as incentives to collaborate and explained in management theory terms as appropriation of strategic resources to best fit capacities and opportunities (Hemphill & Vonortas, 2002; van Rijnsoever, Hessels, & Vandeberg, 2008). Added value comes from the augmenting of the researchers peer review capacity and

capability and thus collaboration contributes to the quality monitoring processes as has already been noted in the Literature Review, Section 2.1.5.

The third thematic grouping of reasons to collaborate relate to learning and mentoring and include a range of comments on how collaboration creates opportunities for less experienced researchers to work with more senior and experienced researchers. A few senior researchers noted that collaboration provides the opportunity to work with younger researchers as a stimulant to productivity, as reported in a study by Carayol & Matt (2004). The literature reflects the view that diversity of seniority and experience in a team is an important factor in team composition and collaboration success (Harvey, et al., 2002).

Despite there being little collaboration with researchers from other Colleges in Massey University, 40 % of survey respondents indicated that being able to access different ways of thinking and different research methods was important and most interviewees said that “Learning from each other” and exposure to new skills, methodologies, and tools was valuable. This view is supported by a number of scholars who point out that members all bring different perspectives and views to a problem and are able to provide critical evaluation of a problem from the different perspective (Bozeman & Corley, 2004; Melin, 2000; Poole, et al., 2009).

Mentoring from senior researchers in a collaborative project was identified by respondents as being highly motivational and valuable. Interviewee 1 described how in the early stages of their career working with a highly reputable senior researcher can give a feeling of security, particularly in relation to securing funding. The literature supports the view that being part of an established, reputable research team can enhance opportunities to be part of collaborative research projects, and the productivity of more junior researchers can increase when working with senior or experienced researchers (Rey-Rocha, Garzon-Garcia, & Martin-Sempere, 2006).

Whilst there was some negative comment about researchers no longer having control of a whole project in a collaborative venture, most respondents saw this as a trade-off for the benefits that can arise from collaboration. The importance of mentoring is further discussed later in this chapter in section 5.6.3.5.

## **5.6 Elements of collaboration**

Collaboration in scientific research is a complex and dynamic social activity that occurs within the context of science, organisational, academic, national and international science policies and norms. The key elements of the process of collaboration are discussed in the sections which follow.

### **5.6.1 Teams and their composition**

By definition, collaboration involves more than one person and teams have become the norm in many scientific disciplines. Forming a team is a complicated process and many of the issues relating to teams are discussed in Section 2.6. One interviewee pointed out that the individualistic approach of universities means that academics are not necessarily good team players. The issue of personality has already been touched on in Section 2.7.1, and the inclusion of social scientists in some research groups to ensure a smooth interface with external parties is discussed in Section 5.2. Teamwork is becoming increasingly important as scientific research becomes more complex, interactive, and social, and Cohen points out that relationships between researchers will determine how well they share their skills, expertise, and knowledge with others in a team (2005). In section 4.3.1.5 the importance of good interpersonal relationships to the success of a collaborative research project was highlighted.

Respondents agree with the literature that *“to make an academic team work well, you have to have the ‘right’ people with the ‘right’ science expertise and the right interpersonal relationships”* (Interviewee 1, personal communication, 2001). Other interviewees agreed with the view that the mix of individuals, or group composition, of a team is critical and in Cummings’ and Keisler’s view having a mix of experience and perspective is important in relation to performance, and to the work satisfaction of members of a team (Cummings & Kiesler, 2005).

Teams are formed because there is a need to bring together individuals with different ideas, skills, and resources (Guimera, et al., 2005) but very little research has been done on how to select individuals to form a team (Morgeson, Reider, & Campion, 2005). Traditionally, teams in the research workplace have been established on the basis of personal relationships, discipline expertise, experience,

diversity in experience and seniority (Partington & Harris, 1999). Individual personality types and behaviours in the team process have not normally been considered as a framework for establishing a team. Attention is, however, now turning to these features as a way of putting together a balanced team (see Salas, Cooke, & Rosen, 2008; Shi-Jie & Li, 2004). Team role theory, as this is known and originally used only at the level of senior management teams, is now viewed as equally applicable to non manager teams (Fisher, Hunter, & Macrosson, 2002). Team role theory is discussed in Section 2.6.

### **5.6.2 Groups to teams**

Several interviewees commented on how a group, defined as two or more people with some interdependence, evolves into a team with a common goal, and how long this can take to happen (see Paulus, 2000). The literature supports the view that the evolution of a group into a team takes time and must be factored into planning. The transition from group to high performance team has been documented by Gersick (1988) as a series of steps, starting with agreement on a framework for viewing the problem to be researched. This complex first step has been documented by Massey et al. (2006). As a group moves through a series of stages it evolves into a real team with a common goal and members start to see themselves as being mutually accountable for achievement of that goal (Katzenbach & Smith, 1993). As the team meets obstacles, and as the needs change, it will continue to evolve (Gersick, 1988). Flexibility throughout that process is very important because *“if everything is cast in stone negotiation to rearrange the project is a nightmare and can cause conflict and be counterproductive”* (Interviewee 2, personal communication, 2011).

Understanding the steps through which teams traverse is particularly important at the team design and establishment phases. Many of the interviewees commented on how it *“takes time”* for relationships to evolve, for *“trust to build”*, for the *“creation of a culture of success and a common goal”* and that *“It is important to work on trust especially when you’re starting up, and when things are going well ... because invariably the wheels will fall off somewhere - something happens - someone doesn’t come through and if you already have a good*

*relationship with that person, you can pick up the phone, and they'll do almost anything for you"* (Interviewee 1, personal communication, 2011).

In this survey, prior experience was seen as important or very important for collaboration for only 49% of respondents, and as noted in Table 14 (section 4.2.1) ranks behind frequent communication, coordination and planning, and good leadership in importance.

It has been established that prior experience of working together can shorten the time a group takes to evolve into a team (Hinds, 2000). Where there is a history of positive collaboration the probability of producing a positive payoff in future is raised, thus there is an expectation that people who have worked together will choose to work together in subsequent groups (Hinds, Carley, & Krackhardt, 2000). Because individuals who have previously worked together share more common ground at the outset they may not have to spend as much time in overcoming any distance, disciplinary or institutional barriers, and establishing and sustaining relationships. This is termed collaboration readiness and is an important consideration in the selection of members of a team (K L Hall, Stokols, et al., 2008; Hinds, et al., 2000; Stokols, Hall, et al., 2008). Unfortunately we do not know just how much prior experience is required thus care must be taken to ensure that newcomers are not excluded from involvement in projects.

### **5.6.3 Challenges for teams**

Researchers who engage in collaborative scientific research will be faced with a number of challenges. In the following sections, 5.6.3.1 to 5.6.3.7, seven of the major challenges identified in the study are discussed.

#### **5.6.3.1 Mixed objectives"**

Managing organisational contradiction, for example between external market forces and internal inertia, or efficiency and effectiveness, is a function of top management teams in all kinds of organisations and firms, including scientific research organisations (Raisch & Birkinshaw, 2008; W. K. Smith & Tushman, 2005). Agencies which allocate research funds may require efficiency and economic and social benefits in research outputs while the scientists want autonomy, and stable

and high levels of funding (Gulbrandsen, 2005). Funding agencies such as FRST use competition and contestability as the basis for allocating research funds and simultaneously encourage collaboration between individuals and groups of scientists (Edmeades, 2004). Individual researchers are confronted with the potentially conflicting requirement to “play for the team” and simultaneously work to distinguish themselves as individual high achieving researchers. Although teamwork is about sharing and collaboration the reward system in science is very individualistic (C Cohen & S Cohen, 2005) for most interviewees in this study balancing the demands of teamwork and the need for individual recognition was not a problem. Whilst most agreed that there was some tension the general sentiment was that individual attitude would determine whether emerging opportunities for recognition were taken up by researchers. For managers of scientific research teams one of the most important challenges is ensuring that team members receive individual recognition for their contributions to the work of the team (McAuley, Duberley, & Cohen, 2000). Katzenbach et al. (1993, pp., 14) take this a step further and suggest that this is also a function of the whole team and “Real teams always find ways for each individual to contribute and thereby gain distinction”.

Another example of the complexity that researchers have to navigate is between the intuitively contradictory propositions of individual research performance assessment of the PBRF (Performance Based Research Fund) and collaborative research activity.

The rationale for using individual assessment and reporting as the basis for the PBRF, as argued by Professor Jonathan Boston the principal architect of the PBRF methodology, was because of its congruence with research practice, the strong incentives built into the system, and the transparency of the process (Curtis, 2008). Boston (2007) later pointed out that he was not entirely convinced that individual ratings did provide these benefits.

Since inception the PBRF has undergone some fierce criticism. For example R. Smith (2008) claimed that the PBRF has corrupted the whole academic institution; Middleton (2004) has criticised it on the grounds of its focus being on research rather than on research and teaching; Bridgeman’s (2007) criticism is

because of its negative impact on the role of the academic as the critic and conscience of society; and C Hall, Morris Mathews, and Sawicka (2004) have criticised it on the grounds of excessive compliance costs for academics and institutions.

The documented criticism, however, does seem to be on contextual professional issues rather than on actual work practices of academics and not all academics are critics of the PBRF. Professor Chris Shore of Auckland University reports (on the basis of individual interviews) that *“On balance most staff appeared to support PBRF ... primarily ... because it recognises research as a major element of what universities do”* (Shore, cited in R. Smith, 2008, pp., 6).

In this study of researchers in The College of Sciences, Massey University, most of the researchers interviewed indicated that the PBRF and collaborative scientific research did not pose problems for them. As one interviewee said *“I don’t see a conflict, but am I missing something?”* (Interviewee 1, personal communication). The only negative comments about the PBRF, and these related to process rather than to the PBRF per se, was in the difficulty of attributing credit for work done (this of course is not peculiar to research undertaken within the PBRF framework) and then continued with the comment that the difficulties in attribution are one of the reasons why protocols are so vital. One interviewee did suggest that some researchers might choose to work independently because they think that a higher PBRF score would result. S/he commented that *“probably the only negative that I see out of PBRF is that it is in opposition to this whole let’s work together more collaborative approach”* (Interviewee 5, personal communication, 2011).

In three interviews, and alluded to in several others, the vulnerability of teams was raised and the need for management strategies to deal with rapid change, or situations where key team members or collaborators “fall over”. There is limited literature in the area of risk management in research. In some fields and disciplines where there might be actual, or perceived, public health and safety issues in the outputs as in some environmental research, some medical research and some cutting edge technological disciplines such nanotechnology, and synthetic biology, there is an increasing focus on risk management. In some

disciplines and technological areas the management of risk is very well developed and in private sector research one is likely to find risk being managed (see Calvert & Martin, 2009; Illes, et al., 2008; Maynard, 2006; Renn, 2006; Wright, 2011). Collaborative research does carry considerable risk in terms of information leakage, relational, institutional, or financial risk (Hoecht, 2004) and the management of that risk is, according to Couchman and Fulop (2004), a developing area. The traditional risk management principles such as acceptable risk, cost–benefit analysis, and feasibility are not easily applied to scientific research, however, Marchant, Sylvester and Abbott (2008) maintain that we cannot just wait for the uncertainties to be resolved before undertaking risk management efforts.

The second area of concern that was raised relates to the difficulties that can arise for a researcher undertaking collaborative commercial research in an academic environment. The specific difficulty discussed was the termination of a research project. The differences between an academic environment and a private sector laboratory have been well documented by C Cohen and S Cohen (2005) who points out for a researcher termination of any project is difficult and if the reasons for doing so seem to have no bearing on the progress of the work it can be quite disillusioning. The possibility of instant termination of a commercial project can preclude the inclusion of post graduate students in research teams undertaking commercial work. *“When a project has gone beyond its useful life in the commercial world it would stop immediately but in a university setting with students paying for their studies termination is not possible”* (Interviewee 8, personal communication, 2011). The inclusion of students in scientific research teams undertaking commercial projects calls for clear and unambiguous contractual arrangements with the external third party and with the student members of the team.

### **5.6.3.2 Leadership**

For 85% of survey respondents, good leadership was either important, or very important to collaboration. A number of interviewees commented that they perceive there to be no clear differentiation between management and leadership. *“It’s challenging to see the difference...I’m not sure there really is a difference between management and leadership, we’re just teasing that out within our*

*leadership training group at the moment*" (Interviewee 1, personal communication, 2011). A statement such as this is quite congruent with general practice despite there being a specialist literature on the discipline of 'leadership' which clearly distinguishes between the two terms (Avolio, Sosik, Jung, & Berson, 2003; Grint, 2007; Kets de Vries, 1984; Mumford, Zaccaro, Harding, Jacobs, & Fleishman, 2000). According to Kouzes and Posner (1995), leadership is about relationships and helping people to achieve a vision, whereas management is about maintaining order, planning, organisation, and coordinating resources. Leadership is discussed in section 2.7.

When describing the competencies and attributes that a leader must have, interviewees most frequently stated that a leader must have a vision and most importantly, be able to articulate that vision. This is consistent with the literature on leadership (see Bass, 1990; Bolden & Gosling, 2006; Jennings, et al., 2007). One interviewee added that a leader not only had to have a vision, and be able to communicate that vision, but also had to be able to map that vision to the multiple visions of team members to ensure a congruency of direction, motivation and commitment. Inherent in this comment is that leaders need to be able to see things from another person's perspective – a point made by a number of interviewees and discussed in Chapter Two, section 2.7.

Interviewees identified two roles that a team leader should carry out as leader of research teams. The first is as leader or expert in some aspect of science. In this role they have been described as "intellectual leaders" (Cohen, et al., 1982), or as "thought leaders" (Klavans & Boyack, 2008) and are committed to working at the leading edge of science and willing to shift emphasis from older ideas to newer ideas. This role is also known as a "captain's role" as it includes directing the scientific work of other researchers (Farris & Cordero, 2002). The second role is as managerial/administrative leader of a team (Chompalov, et al., 2002). Functionally a "catalyst role" the main focus is on the provision of the appropriate environment for high performance (Farris & Cordero, 2002). Both roles were identified by most interviewees and survey respondents but the terms "science leader", and "team leader" were used. Two interviewees described how a team leader is able to foster relationships between team members that go beyond friendship into a special kind

of professional relationship. This last point may relate to the concept of shared mental models (discussed in Section 2.6), a mechanism that allows teams to adapt quickly to circumstances as individuals draw on their own knowledge of other team members and their likely behaviour, and thus are able to predict what their team members are going to do (see Marks, et al., 2001; Mathieu, et al., 2000).

Most of the younger interviewees raised the topic of mentoring and the role that a leader plays in promoting the enhancement of capabilities of team members through training and mentoring of less experienced team members. *“I am new to academia and I lead that project but am new to supervising so I’m looking for a bit of support. I am being mentored by my leader. I just check in or call on for different things”* (Interviewee 1, personal communication). Mentoring, which was discussed in Section 5.6.3.5 is regarded by C Cohen and S Cohen as one of the most important tasks for a leader (2005).

One aspect of leading a team and a research project that was frequently commented on as being a challenge was the apportionment of a leader’s time into research time and into leadership time. As has been pointed out in the Literature Review, Section 2.7.3, in general, as the number of team members increases, the time available for individual research decreases. One interviewee claimed that *“as leader I spend 5-10% of my time in research and 85% of it in strategic leadership”* (Interviewee 8, personal communication, 2011). Balancing the scientific effort and the leadership and managerial responsibilities is claimed to be one of the most difficult problems for new leaders (Hurd, 2009; Sapienza, 2004; 2005).

There exists considerable literature on the allocation of time between research and teaching for academics and the factors which influence the allocation (see Carayol & Matt, 2004; Kim & Cummings, 2011; Milem, Berger, & Dey, 2000), but research on the allocation of time between leadership and managerial functions of academics and research time is very difficult to find. Two reasons have been proposed by C Cohen and S Cohen (2005) to explain why researchers spend so much time on the managerial component of their work. The first is that the people who are being managed are focused on their research at the expense of the interpersonal and social aspects of their roles and it often falls to the leader of the team to be the negotiator and mediator between team members. Mulec (2004)

suggests that this heavy focus on managerial functions is because of the potentially conflicting situation of researchers with a high degree of expertise and autonomy working within a framework of organisational control structure and processes. The second reason is that often appointment to managerial and leadership roles is on the basis of technical competency rather than any assessed managerial competency (Hysong, 2008) and a great deal of learning about leading and managing is "on the fly". Often portrayed in negative terms, 'learning on the fly' is regarded by Lombardo and Eichinger as one of the critical competencies for all leaders (2000).

A related and important and concerning issue raised by the more senior researchers was the effects on research competency when a high proportion of a leader's time is devoted to managerial or other functions. As more and more time is taken up in leading, managing, and administering there is a danger of a researcher's highly honed skills being dulled, and because time for reading becomes more limited, staying up with the literature becomes a problem. *"Reading time is limited so [I] has to rely on students to keep up with the literature"* (Interviewee 8, personal communication, 2011). The loss or diminution of any of the defining traits of professionalism is termed 'deprofessionalisation' (C Clark, 2005), a phenomenon which has been reported in many areas of professional activity recent over years (Demailly & Broise, 2011; Haug, 1976). Examples are the use of practice guidelines as part of evidence-based medicine Filc (2006), in law the regulatory changes, specialisation, and changes to autonomy (Anleu, 1992; Brooks, 2011), and in academia financial stringency, targeting of funds, accountability for budgets, reduced autonomy, declining collegiality and commitment to the institution, and managerialism (Bryson, 2004; R. Hull, 2006).

One of the senior interviewees commented on the amount of time that had to be devoted to winning and managing external research contracts, particularly the time consuming aspects of liaising and coordinating activities when contracts included both internal and external participants. The lack of administrative support staff exacerbates this problem. *"The more successful you are the less research assistance you get because you're expected to earn that money externally"* (Interviewee 6, personal communication).

Career structure and managing a scientific research career was seen as a challenge by the less experienced interviewees. It was asserted that to be regarded as a senior researcher, one must lead research projects (Interviewee 4, personal communication), and as already noted in section 2.7 and supported by Interviewee 8, (section 4.3.1.5) promotion means getting out of research into administration, leading and managing. Promotion out of one's expertise is, of course, not peculiar to science and would be true of most academic disciplines. As one interviewee said "*you start off, do your own science, you manage your own and students' science, and then you may become a leader of your own group and no longer get to do science all the time*" (Interviewee 1, personal communication, 2011).

Discussions on moving from being a bench scientist to leader and manager raised a number of problematic issues around career pathways, choices and mentoring. In research many leaders and managers are also active researchers and for scientific researchers it is suggested that their driving force is most often the creation of knowledge and expertise in the field, rather than on their eagerness to lead others. The underlying assumption is that individuals who excel in research in their discipline will also excel in supervising and managing others (Hysong, 2008). The issue is twofold: does technical skill add value to managerial competence, or is technical competence necessary solely to give credibility in the eyes of those being managed? In academic settings, to be regarded as trustworthy, managers and leaders must be experts in a professional field (Adler, Elmquist, & Norrgren, 2009), and in other professional settings legitimacy and acceptance by a workgroup increases if managers have an understanding of professional practices, and expertise (Murphy, Blyth, & Fiedler, 1992).

The difficulties of combining leadership roles with specialist research roles, the transition from specialist researcher to manager, and the management of organisational contradiction have been addressed by many scholars. These issues are discussed in section 5.6.3.1. The traditional track for an academic researcher is to progress from individual researcher, to team member, supervisor of a group/team, manager of the team, and leader of a team. Training for each of these new roles is generally haphazard and Adler et al. ask that "if effective research management and leadership capabilities are seen as important for productive

research institutions ... a complementary university career track might be necessary" (Adler, et al., 2009, pp., 1144). Such an approach would mean the use of different or additional criteria for attainment of full professor positions rather than use of the traditional criteria. The changing nature of career paths is discussed by Baruch (2004) who points out that careers are becoming multidirectional, dynamic and fluid rather than linear, static and rigid as has been practice in the past. Whilst the academic career model was criticised by some interviewees it is noted that some of the aspects of the academic career model, such as the lateral and downwards movements which are possible without losing status, are being considered by other organisations as they look for different career models.

Interviewees described how the leadership role changes as a collaborative project moves through its stages (Corley, et al., 2006; Sapienza, 2004). These phases have been described by Sargent (2004) as: 1. Initiation of the project; 2. Clarification of the nature and type of research; 3. Project implementation, emphasising the specific roles individuals play; and 4. Project completion, including the evaluation of outcomes. In discussion with interviewees all stages were clearly identified, with the exception of the roles aspect of stage 3. It was observed by the leader of a number of large projects that as projects move through these stages often the structure will change from being very hierarchical at the beginning, to a flatter structure as participants' confidence builds and the project is established and progresses. It was noted by one interviewee that in team situations where the objective is to lead one another toward the achievement of collective goals and relationships are well established, the leadership may be simply nominal or shared. This position is supported by Pearce, Manz and Sims (2009), but it was also noted that that the hierarchical structure remains for contract or temporary staff (Interviewee 6, personal communication, 2011).

### **5.6.3.3 Management**

The literature on the management of research is very limited and what there is, as Adler, Elmquist and Norrgren (2009) point out, is mainly studies of exceptional individuals like Thomas Alva Edison. As noted in section 2.1.5, scientific inquiry and research is a complex, iterative, and sometimes messy process, and managing

research teams can be challenging. There are many models of collaborative scientific research (see Timothy Hinkin, Holtom, & Klag, 2007; J. Kraut, et al., 1988; Mintzberg, Jorgensen, Dougherty, & Westley, 1996; Sonnenwald, Bergquist, Maglaughlin, Kupstas-Soo, & Whitton, 2001) and in the main they describe collaboration in terms of stages and tasks (similar to the steps through which groups of researchers move in the process of evolving into teams as discussed section 5.6.2) but put little emphasis on the complex, iterative, and sometimes messy process as research has been described by Mitroff (1974).

Noted earlier in this chapter, and discussed in Section 2.7, discussion with interviewees about the nature of managing a research team was generally intermixed with discussion about leading a research team. This mixing of the terms is often true of much of the literature as well (Sapienza, 2004; 2005). For the most part, in interviews, managing a research team was usually described in terms of functions such as budgeting, monitoring, planning, organising, coordinating, handling the expectations of team members and funding agencies, and liaising with other external parties. The key difference between managing and leading, as has been noted in section 2.7, is that managers act to limit choices, or as one interviewee stated *“to define and confine”* (Interviewee 1, personal communication, 2011), and leaders develop fresh approaches to old problems. It was acknowledged that the way team members are managed varies according to the stage of the project. In the early stages of a project researchers need to be managed more than in later stages and, as pointed out in section 5.2 less experienced team members need to be managed more than experienced team members.

Most interviewees commented on the importance of “people skills” for a manager. These skills included listening skills, managing the expectations of the team and its members, and being able to handle conflict. A great deal of discussion with interviewees centred around the importance of general social processes of collaborative research to success – a position which is supported by the literature on teams (Paulus, 2000). The social processes of collaboration include the whole range of interpersonal skills that managers need but most importantly include self awareness, emotional intelligence, and negotiation skills (C Cohen & S Cohen,

2005). In a study of 200 scientists and engineers in which they were asked to describe the most effective science leader, Sapienza found that being caring and compassionate was most frequently named and was followed by those who have managerial skills, and technically skilled was a distant third (Sapienza, 2007).

As success is dependent on the performance of every team member, the creation of an environment in which an individual can function effectively is critical. Creating such an environment is considered by Hurd and Juri (2005), who have coached many scientists, to be one of the most critical tasks of a manager. "Leading science effectively, including how closely to manage and when (and what) to communicate, ultimately rests on a foundation of sensible caring for individuals, for their ideas, for their career development, and for their feelings" (Sapienza & Lombardino, 2005, pp., 103).

#### **5.6.3.4 Team membership**

Most interviewees commented on the need for thoughtful technical composition of a team and that different people bring different skills, competencies, and attributes, including seniority and experience, motivation, and the appropriate institutional and external networks, to a project. The components of this "competence mix" (Simonin, 1997), identified by interviewees most frequently as critical team membership competencies, are high research capability and a package of personal skills.

Many interviewees spoke of trust between team members as being vital for successful collaboration and representative comments include "*You have to work on trust*"; "*you work with people you trust*"; and "*you need to trust and respect other team members as individuals, and as scientific researchers ...that's what makes it work well*" (Interviewee 3, personal communications, 2011). The issue of trust which is discussed in the Literature Review Section 2.6, is considered by many writers a key component of well functioning teams (Davenport, et al., 1998; Wray, 2006), while others suggest that trust is important but not mandatory (Shrum, et al., 2001). Professional autonomy is critically important for a researcher and on becoming a team member some autonomy is relinquished (C Cohen & S Cohen, 2005), interviewees, however, did not regard this as a problem. Whilst trust is

clearly regarded by interviewees and survey respondents as an important feature of teams and collaborative research practice, particular behaviours that contribute to trust were not specified.

High research capability, as noted above, is regarded by interviewees as a fundamental prerequisite for team membership. When probed for meaning of high research capability, in most cases the answer was a description of exemplary discipline knowledge and the ability “to do” research. When prompted for an opinion on research competencies responses from interviewees were limited to researchers having the necessary laboratory and field skills and being able to manage resources in a fashion acceptable to peers and to those who contribute the resources (institution and agencies). There was little comment on the knowledge, behaviours, skills, and attributes of effective and highly skilled researchers at various stages of careers as described in various taxonomies or classifications of research competencies by scholars such as Bromley, Boran, and Myddelton (2007); Huang (2007); Newbury (2002), and the UK Research Council (CRAC, 2011); however, interest was expressed in the concept of research competencies frameworks.

#### **5.6.3.5 Mentoring**

Throughout the interviews, early stage researchers and female researchers discussed how valuable it is to be mentored by senior researchers. The value is seen in terms of learning new skills and knowledge and particularly for the female researchers, in being able to penetrate the networks of the senior researchers. A number of more senior researchers talked of how valuable it is for them to mentor their more junior colleagues. No researcher reported having ever had any training in how to go about mentoring. Mentoring by a more experienced colleague is seen as an important, even a core, aspect of any research training programme and is increasingly being recognised as an essential catalyst for providing emerging researchers with the norms, standards, values and attitudes, and knowledge, skills, and behaviours to develop into successful independent researchers (Chew, Watanabe, Buchwald, & Lessler, 2003; Keyser, et al., 2008; Ynalvez & Shrum, 2009). Mentoring today is far removed from the casual, informal arrangement of the past,

and is now generally a formal, contractual agreement with goals being set that relate to strengthening academic competency, technical skills, and the responsible conduct of research; supporting personal and professional development; and providing emotional support and encouragement (L Haynes, Adams, & Boss, 2008). Given that the productivity of a team is directly related to the productivity of members, it seems clearly in the interests of the senior researchers to be skilful mentors to more junior team members (C S Cohen, 2005). Massey University has taken up this challenge and has stated its intent to provide mentoring and career development advice to early career researchers in the first of its six big goals in its strategic document *Road to 2020* (MU, 2011).

#### **5.6.3.6 Training**

Many interviewees noted that their career paths start in a laboratory, move to administration, in some form either as a functional or a formal position, and thence to managerial and leadership positions. For most scientists, their training equips them for the early stages of their career as a researcher but it is unlikely to have encompassed training as a collaborative researcher. Very few researchers have had formal training in collaborative research methods (Poole, et al., 2009), or, as many interviewees pointed out, training to manage or lead scientists, or to mentor early career researchers. As researchers progress along career pathways into management and leadership roles, for most, the skills and competencies required are learned 'on the fly' (Kreeger, 1997; Sapienza, 2004; 2005). In the words of a senior academic "*.... once you become a leader, they give you some management training, some appraisal of staff, but that's a bit bottom of the cliff stuff, isn't it, once you're already there? We should have had it years ago as young researchers*" (Interviewee 6, personal communication, 2011).

The research on training scientific researchers in management and leadership is limited, and as Adler, Elmquist and Norrgren (2009) claim it is an unprioritized area. The research that does exist suggests that because for the scientist, scientific research is a calling and is at the heart of their very identity, when they move into management and leadership positions they face unique challenges (Hurd & Juri, 2005; A. Zuckerman & Brajkovich, 2003). Sapienza (2005) suggests that if

researchers are to take on managerial and leadership roles then they must be provided with sophisticated education and training in those areas. “The bottom-line cost to organisations that fail to develop effective scientific leaders, simply put, is that people do not have the opportunity to contribute their best thinking” (Hurd, 2009). Furthermore C Cohen and S Cohen ask “If scientists are willing to invest time and effort into learning a new skill, why not do the same for management and interpersonal skills? And why, when they do decide to do so, do they wait until the need is acute?” (2005, p., 9).

In the three areas of training discussed: 1. Training in collaboration skills; 2. Training in leading and managing researchers; and 3. Training in mentoring, the UK Research Council has been very active in developing policy, programmes, and resources for researchers and managers of researchers. Under the auspices of Vitae, an organisation supported by the UK Research Councils, and managed by CRAC: The Career Development Organisation which works through the UK GRAD Programme (2003 – 2007), promotion of the personal, professional and career development of doctoral researchers and research staff in higher education institutions and research institutes in the United Kingdom takes place. Amongst its many resources is a framework for research competencies, including competencies for collaborative research (RCUK, 2010), and in 2008 it launched The Concordat, a statement which sets out the expectations and responsibilities of research funders and institutions in relation to the management of researchers. It also includes the responsibilities of research group leaders and managers for the support of researchers in their career management and training (RCUK, 2008) and mentoring. The UKHERD programme was initiated in 2005 as a network of professionals working with research staff in UK institutions working on developing training and resources for career development of researchers. In New Zealand no similar programme has been developed at the national level, however, an online training programme initiated by Auckland University but later dropped because of funding problems was discussed in the interview with the AVC, R&E. It was suggested that government investment was necessary to kick start a national programme that could be tailored to suit individual institutions (AVC, R&E, personal communication, 2011).

### 5.6.3.7 Authorship protocols

As discussed in Section 2.8.2, having an agreed method of sharing recognition and reward is an important factor in collaboration success. The literature indicates that allocation of authorship is very important but a growing concern for researchers because of the difficulties of identifying the nature and extent of individual contributions to a multiple authored article (Biagioli, 2003). In the hyperauthor situation described by Cronin (2001a) attribution is particularly difficult and using the traditional author listing protocols could mean “that any given individual is likely to appear as an author on hundreds or even thousands of publications” (Birnholtz, 2006).

As the author list is the formal means of according credit and the foundation upon which reputation and promotion are founded, having a credit attribution mechanism that makes collaborative work attractive to scientists is very important for researchers. Attribution of credit to all participants involved in a research project has not always been the norm as has been noted in section 2.2.2. In the “Collective research” practised in 17<sup>th</sup> and 18<sup>th</sup> century described by Shapin (1989) even though a project may have been the efforts of many people credit was only attributed to one person. The complexity of research projects today in terms of size, resources and numbers of researchers, technicians and engineers has led Galison (2003) to suggest that there needs to be some rethinking about scientific authorship and to whom credit should be accorded.

At Massey University all research practice is based on the principles in the Code of Responsible Conduct of Research (MU, 2010a), and the authorship and acknowledgments must proceed according to the conventions of disciplines and the College. Discussions with interviewees concerning co-authorship protocols suggested that the policy varied across the College of Sciences and ranged from total absence of a protocol, meaning arrangements are designed each time one was required; to a standard, formal protocol which is tailored to suit each time it is used; and almost every variation in between. One interviewee suggested that protocols were often driven by the journals determining what constitutes a co-author. The most common difficulties raised were about “free riders” and unfair practices, which generally referred to the practice of senior, but non-contributing

researchers, expecting prime placing in the sequence (Interviewee 1, personal communication, 2011). A further difficulty related to ensuring that protocols were clarified at the start of a project, and modified later if necessary, and how it is not always easy to raise this issue at the beginning of a project, particularly with more senior researchers.

The issue of attribution of credit and the desirability of overt protocols has taken on a new importance with the introduction of PBRF, with its individual assessment and reporting methodology (discussed in section 5.6.3.1).

## **5.7 Successful collaboration**

The survey respondents, almost universally, saw collaboration as an important or very important way of increasing the chances of making a project successful. Success was seen by survey respondents in two dimensions: project success, that is the achievement of the objectives of the project, or the academic outcomes; and project management success, judged on the performance of the researchers against cost, time and quality (see Cooke-Davies, 2002). As has been noted in the Literature Review in Section 2.9, determining the success of research collaboration is an exercise in both measurement and judgement. Hinings and Greenwood (1996) discuss collaboration success in three dimensions: 1. Objective outcomes, measured (i.e. counted) in the form of publications, reports and presentations; 2. Subjective outcomes, judged (i.e. evaluated by opinion) on the basis of satisfaction with the collaborative learning experience; and 3. How much learning a researcher was able to gain from other collaborators.

Researchers had three further criteria which they used in judging the success of a scientific research project. The first criterion was a judgement of how unobtrusive the fundamental processes and operations were throughout the project and how suitable they were to the objectives of the project; the second criterion related to the interpersonal relationships being positive throughout and at the conclusion of the project, and willingness of team members to share and be open to feedback; and the third criterion which was shared by all stakeholders, not just researchers, was that the objectives of the project were achieved within time and on budget.

It has already been noted in the Literature Review, section 2.8, for the funding agencies measuring success of collaboration is an important and ongoing activity and there is ongoing international research on developing new ways of measuring outcomes, identifying the benefits of research, and ways of attributing the impact of a research project on the economy.

Survey respondents were asked to rate six factors which contribute to collaboration success.

Table 16 shows the responses ranked in order of importance of factors. The three most important contributors to collaboration success, according to the survey findings, are:

1. Having frequent communication among team members
2. Having clear coordination and planning
3. Having good leadership

**Table 16: Ranking of factors contributing to collaboration success**

<b>Factor</b>	<b>Respondents Agreeing</b>	<b>Rank by importance</b>
<b>Having frequent communication among team members</b>	98.2%	1
<b>Having clear coordination and planning</b>	91.1%	2
<b>Having good leadership</b>	85.7%	3
<b>Having an agreed method of sharing the recognition and reward</b>	73.8	4
<b>Having had team members working together previously</b>	43.7	5
<b>Having team members geographically close to each other</b>	24.7	6

### 5.7.1 Frequent communication

For 98% of survey respondents frequent communication is a key element in making collaboration successful. This is consistent with the literature which supports the view that frequent communication is important from a managerial perspective and from a quality perspective (Hall et al., 2008; Kenna & Berche, 2010a; Leydesdorff & Wagner, 2008; Pinto, et al., 1993).

One interviewee describing ideal communication from the perspective of a team member advocated frequent and face to face meetings rather than relying on electronic media, and with all stakeholders. S/he added that team members needed *“to be open-minded, willing to listen, able to appreciate and accept the different views of others and then...willing to share their views”* (Interviewee 7, 2011). Another Interviewee emphasized the need for a free flow of information all the time, transparency, and that team members needed to feel comfortable in asking questions, and receiving feedback (Interviewee 1, 2011).

All of these views are quite congruent with the literature. Kraut and Egidio (1988) assert that frequent contact between potential collaborators is the most fundamental requirement for the development of collaborative relationship, and face-to-face discussion also is an important tool in the development and maintenance of group culture, authority, and the tacit norms of a group or team (B. B Levitt & March, 1988). The literature also shows that frequent discussion is used as a coordinating mechanism within highly interdependent groups such as a jury, aircraft crew, coaching staff, or in research teams where the way forward is uncertain and researchers have to decide on what is to be done, who will do the work, and how and the work is to be done (Kiesler & Cumming, 2002).

Awareness of another's work, frequent spontaneous, informal communication, and strong social ties are seen as important in the evolution of joint activities (Hara, et al., 2003; Kiesler & Cumming, 2002). This point is illustrated in the words of one interviewee who said that *“the collaborator that I've probably had most success with is my colleague next door: we have very close contact and we are very explicit about what we're thinking”* (Interviewee 5, personal communication, 2011).

### **5.7.2 Clear coordination and planning**

Second only to frequent communication in perceived importance to success in collaborative research is clear coordination and planning. Often underlying discussions on academic collaboration is the assumption that researchers know how to collaborate. The diversity in how researchers view collaboration and the variety of structures and processes that can be used in collaborating have already been noted in section 2.3 and our theoretical knowledge about the processes and mechanisms which facilitate successful research collaborations is limited (Defazio, et al., 2009; Morrison, et al., 2003). It is, however, generally accepted that having clear coordination and planning in order to link or integrate the different pieces of a project to accomplish a collective task is critical to success (Cummings & Kiesler, 2005; Garrett-Jones, Turpin, & Diment, 2006; Malone & Crowston, 1994; Ven, et al., 1976), and particularly so for geographically dispersed collaborations (Stokols, Misra, et al., 2008). As research projects increase in complexity the coordinating activities also become more complex.

In this survey, just over 90% of respondents, and most interviewees, agreed that coordination and planning are important for collaborative success. It is interesting to speculate why 10% of respondents do not see coordination as important. This was not, however, explored in this study. Perhaps it is because “good coordination is nearly invisible, and we sometimes notice coordination most clearly when it is lacking” (Duque, et al., 2005; Malone & Crowston, 1994, p., 90).

Co-ordination may mean different things to different researchers but it has been defined by Malone (1988), who coined the term “coordination theory”, as “managing dependencies between activities” (Malone & Cranston, 2001, p., 10). As for discipline a coherent body of theory must be built and although theories and concepts from many different fields are contributing to “coordination theory”, the discipline is still being developed. Coordination is about goal setting, task division, processes for communication, interpersonal processes, feedback and monitoring processes (Malone & Crowston, 1994), lines of authority and division of labour (Wray, 2000). Tools that have been developed in project management are used to assist in the processes of coordination and include schedules, roles, critical path

(CPM), PERT and GANTT charts; "who will do what by when" action lists; and Systems thinking analytical tools (Pollard, 2005).

### **5.7.3 Good leadership**

The third factor rated by survey respondents as being important in success of collaborative research is having good leadership. Leadership has been covered in Section 5.6.3.2.

### **5.7.4 Propensity to collaborate**

The concept of 'collaboration propensity' is well established in scientific research and has been defined as "the likelihood of an individual researcher engaging in collaboration" (Birnholtz, 2007, pp., 2227) but it extends to institutions, and to countries. There are many factors which foster the propensity to collaborate. For example, discipline specialisation and division of labour lead to greater propensity to collaborate (R. Ponds, 2009); increases in team size may mean greater specialisation and therefore lead to more collaboration (Adams, et al., 2005); the drive to build reputation and career (Whiteley, 2000, cited in Birnholtz, 2007); and access to expertise or resources (Melin, 2000), are considered to increase the propensity to collaborate; disciplines vary in their propensity to collaborate. Whereas in mathematics there is little collaboration, in the physical sciences and life sciences collaboration is common (B Clark, 2010; Hoekman, Frenken, & Tijssen, 2010).

A major influence over researchers' propensity to collaborate and co-author is geographic proximity. Hennemann, Rybski, and Liefner report that a researcher is up to 100 times more likely to have a national co-author than an international one although they do not indicate if these are in-house collaborators or at other institutions (2010). Authors are also more likely to cite papers generated by authors at close-by institutions (Borner, Maru, & Goldstone, 2004) and, for reasons that remain unexplained, the shorter the geographical distance between first and last authors on a paper, the more highly cited were their research papers (K Lee, Brownstein, Mills, & Kohane, 2010). The rule of thumb is that co-workers should be no more than 30 m apart, beyond which collaboration effectiveness declines precipitously (Allen, 1977, cited in Cummings & Kiesler, 2007). It has been pointed

out in section 5.7.2 that in geographically dispersed collaborations coordination is critical to success (Stokols, Misra, et al., 2008).

In this survey only 28% of survey respondents said that geographic proximity was important and for almost 50% it was either unimportant or very unimportant: as shown in Table 16 it was ranked last of six factors. Many studies show that collaboration whether near or distant demands greater costs (Beaver, 2001; Carayol & Matt, 2003; Cummings & Kiesler, 2005; 2007; Wray, 2006 ), although Morrison (2003) suggests proximity, whether geographic, cultural, intellectual, or physical, increases the incentives to collaborate. "Closeness can reduce those costs and closeness can increase quality" (Morrison, et al., 2003, p 290). It was thought by many that the introduction of the Internet and related technologies would make proximity less important, but it seems to have had little effect on the patterns of collaboration (Lorigo & Pellacini, 2007).

There is no evidence that the importance of physical distance as a propensity to collaborate has been declining although in Europe the territorial borders are declining in importance and there is a gradual converging toward a more integrated and interconnected European science system (Hoekman, et al., 2010). The changes in national, regional and global collaboration in scientific research are the subject of considerable international research activity (Hennemann, et al., 2010; Ponds, 2009; Ponds, et al., 2007). The researchers in this study indicated a preference to collaborate with researchers from the United States rather than Australia or nationally. This result is in line with that of Palmer and Laurenson whose data show that New Zealand scientific researchers collaborate more with researchers from the United States than from Australia (approximately 2:1) (Palmer & Laurenson, 2010).

Adams, et al. (2010) have foreshadowed the shift of the focus of New Zealand science researchers to one that is more regional and Government policy has already taken steps in this direction and is shifting its country-oriented approach to a regional one (MORST, Undated). This may help to minimise the "periphery effect" where scientists working "on the periphery" tend to collaborate with international individuals and institutions as a way of increasing the impact of their work, even when there are relevant domestic collaborators (see Goldfinch, et al., 2003, for a discussion of the 'periphery' effect in Crown Research Institutes in New Zealand).

The same periphery effect can be seen in Europe where, as Hoekman describes, “researchers in countries in Europe’s periphery tend to be the long-distance collaborators, whereas researchers in countries closer to Europe’s core are less so” (Mitroff, 1974, p. 677). Peripheral countries are naturally inclined to collaborate over longer distance and even more so if relevant proximate partners are lacking.

## **5.8 Summary**

The survey of scientific researchers in The College of Sciences, Massey University generated a wealth of data. Whilst the survey sample was not as large as I would have liked, it is accepted that the findings, whilst not representative of the whole population of researchers, may still make a contribution to the literature. As noted in Chapter Four, Findings, the timing of the distribution of the questionnaire was carefully considered, three follow-up reminders were sent out, and it was hoped that salience, or the importance of the topic to researchers as discussed in section 3.4.1.5, would play a role in engaging individuals in the target population. The low response rate could be interpreted as salience playing no part in whether researchers responded or did not respond, or despite the careful consideration of the timing of the survey, other factors, such as work load could have influenced decisions on involvement rather than lack of salience.

The interviews provided a rich set of data and those who were interviewed were generous in the time they contributed, and their considered views and thoughts on the topic of collaboration in scientific research.

Analysis of the survey data showed the extent of collaboration in scientific research undertaken by researchers in the College of Sciences showing a pattern similar to that at Victoria University of Wellington in 2003. Analysis also confirmed some aspects of the process of collaboration in scientific research that have already been noted in the literature, for example why researchers collaborate, but also identified other areas, for example, new ways of constructing teams, processes of coordination, and risk management in research, that have received little attention in the literature. Other issues identified in the analysis were areas that the researchers themselves suggested would assist them in undertaking collaborative scientific research. For example, training in competencies for collaborative

research, training in mentoring, and protocols for attribution of credit were identified in the analysis. Being able to measure the success of a collaborative project is important issue for both researchers and funders.

The set of recommendations which form part of the final chapter of this study are based on the themes and issues emerging from this study and the relevant literature.



## **CHAPTER SIX: CONCLUSION**

### **6.1 Introduction**

This research focused on the extent of collaborative scientific research in The College of Sciences, Massey University, and the views on collaboration of the researchers who undertook that research and of the agencies which funded the research. In Pinsonneault and Kraemer's terms, this study is exploratory in the sense of the researcher becoming familiar with the topic and establishing what the concepts are, and descriptive in the sense of the researcher identifying what is happening and what are the attitudes and opinions of the researchers and funders being studied (1993). The findings on the extent of collaborative research activity and the views of the researchers are informed by the university's policy position on collaboration, and by the policies and practices of the main research funding agencies.

A "mixed methods" approach was used in this study to gather the data: researchers in the College of Sciences were surveyed, and subsequently a series of interviews were undertaken with researchers and funders and the senior manager at Massey University in charge of research activity. A grounded theory approach was used to analyse the data.

This research is significant because New Zealand is part of a global movement towards efficiency and effectiveness in scientific research, and collaboration is an important aspect of that efficiency. Highlighted in the New Zealand component of a global review of science and research (Adams, et al., 2010), is a general increase in research activity, an increase in co-authored publications with international colleagues, and a shift in geographic focus. As has been pointed out in section 5.7.4, collaboration, particularly regional collaboration, is going to become increasingly important for New Zealand (Adams, et al., 2010). At the New Zealand Government level this move to regionalisation is already being implemented in order to participate in the changing economic, and science and research landscape rather than be an onlooker. Existing international science partnerships are being reprioritised and reoriented towards the regions of Asia-Pacific, Americas (North

and South), and Australia, and strategic partnerships for growth and capability building are developed (MORST, Undated).

Collaboration is not a new element in the science scene in New Zealand, but it is featuring more prominently in Government science policy (how science supports innovation in industry and commerce) as a key element in the economic intentions of government. Much of the government investment into science is premised on the understanding that economic growth rests ultimately on science and innovation (MSI, 2011a) and as the Minister for Science and Innovation, 20 October, 2010 stated, “Research and development is a key driver of economic growth” (Mapp, 2010).

At the international level, New Zealand maintains a number of bilateral (New Zealand to one country) and multilateral (New Zealand to many countries) science and technology relationships with other countries and organisations. These occur at both the government and scientist level. Examples are with China (since 2003), Korea (since 1997), Japan (since 2005), and the United Kingdom (formalised in 2009), the OECD Global Science Forum, NESTI (National Experts in Science and Technology Indicators) and CSTP (The Council for Science and Technology Policy), the Science & Technology Committee of FEALAC (The Forum for East Asia and Latin America Cooperation) (MORST, Undated).

In policy for science (the infrastructure and funding for science), collaboration in scientific research features prominently in the Statement of Corporate Intent of the newly established Ministry of Science and Innovation (MSI, 2011b). It also features prominently in the strategic plan of Massey University, *Road to 2020* (MU, 2011). Both of these documents will have a profound effect on the direction and structure of research activity of researchers in The College of Sciences, Massey University.

Achievement of the goals of both the Ministry of Science and Innovation and of Massey University itself will be facilitated through knowledge of current practices and preferences. Knowing the extent of collaborative research practices within the College of Sciences, understanding how researchers view and value collaboration, and knowing their preferences and practices are important foundations upon which the institutions can build their policies and practices.

## **6.2 Limitations of the study**

In Chapter One this study was described as a case study – an approach to research that some critics (e.g., Lukka & Kasanen, 1995; Simonton, 1977) assert is inadequate on the grounds that it is not possible to generalize on the basis of a single case, or that case studies are arbitrary and subjective. Flyvbjerg (2006) refutes this position and claims that as a method the case study holds up well when compared to others in the gamut of social science research methodology. As noted in the Introduction, Section 1.3, Kuhn (1987, cited in Flyvbjerg, 2006), promotes the importance of case studies as exemplars and the building blocks of the body of knowledge which forms a discipline. Theory can be built from case studies and Eisenhardt (1989), in describing the process of building theory, points out that one strength of theory building from cases is the likelihood of generating novel theory from juxtaposing contradictory or paradoxical evidence. Reconciling these positions can generate creativity. Thus the case study approach to social science research should be seen as a robust method and not as a limitation.

Like most surveys, the one used in this study was preceded by a pilot study and the feedback from the scientists who completed that pilot study was used to improve the final questionnaire. Sampson (2004) posits that pilot studies have the potential to be of much greater value to researchers than is generally the case and they should be designed to ensure that the outcomes will provide substantive information that can be used to improve a survey rather than just simply ‘tweaking’ research instruments. As a way of extracting greater value from a pilot study in the design of future questionnaires, the ‘piloting’ process could consist of two phases with the first focusing on the content and the information to be sought, and the second on the overall structure of the questionnaire, including the number, type, and structure of the questions. Approaching a survey in this manner would add time and cost to a survey but would improve the end result. The structure of the questionnaire would be tested, the coverage of the objectives would be tested, and the researcher would have time to reflect on the data from the pilot and make any modifications. The additional time and cost would have to be built into the design.

The pilot for this study (discussed in section 3.4.1.4) consisted of only the traditional single phase and the feedback focused on the structure of the

questionnaire and the structure of each question. Reflecting on the outcomes of the pilot this writer comes to the conclusion that had a two phase approach been used and the questionnaire content been discussed with those who completed the pilot, a more in-depth coverage of the process of collaboration would have been included. As feedback was focused mainly on structural issues, this shortcoming was not noticed.

A further limitation was the time constraints of the interviews. It was planned that the phase two interviews would only be 30 minutes long. The reasons were two-fold. The first reason was out of consideration to the researchers who were interviewed, and the second was to ensure that the interview stayed on track rather than meander. Interviewees were happy to be interviewed and all interviews were kept to the 30 minutes even though a number of interviewees stated that they were happy to go beyond that. The effect of the 30 minute time frame was that all interviewees were treated the same, the interviews did stay on track and the subsequent analysis was quite speedy. On the negative side, the 30 minute framework did mean that some of 'the flavour' of the stories being told by the researchers may have been lost, and possibly some ideas may not have had time to emerge in the discussion. Determining the time to be allocated to ensure a balance between imposing on interviewees and quality of response is an art to be honed.

### **6.3 Summary of findings**

This thesis has established that there has been limited study of collaborative scientific research in New Zealand. The overall intent of this study has been to make a contribution to what we do know about collaboration in scientific research in New Zealand. This concluding chapter is framed around the objectives to this study, as stated in Chapter One, Introduction.

#### **6.3.1 Objective 1**

To ascertain the extent of collaborative scientific research in The College of Sciences, Massey University, and how the stakeholders (funding agencies and researchers) in the scientific research process view collaboration.

As noted in the Discussion chapter, most of the scientific researchers engage in collaboration, mainly in-house, and infrequently with researchers in other Colleges of the University. Whilst collaboration between the Colleges may be encouraged, and researchers have indicated that accessing new ways of thinking and new ways of doing things is valuable, unless there is a clearly identified reason for collaborating with non-science researchers, scientific researchers are reluctant to engage in collaboration with researchers in other Colleges in the University (see section 5.5). The view that collaborating should be on the basis of need rather than simply because it is a 'good thing' to do is supported by the AVC, R&E (section 5.2) and by the MSI.

There is limited collaboration at the national level (with other universities in New Zealand), and international collaboration is mainly with researchers in the United States. Such a pattern of collaboration is in keeping with international patterns of collaboration and may reflect an implicit or explicit understanding that reputation can be enhanced more through either collaborating within one's own institution or through international collaborations rather than national collaborations. The researchers' predilection for collaboration with colleagues in the United States does not align well with a regional focus which, as discussed in section 5.7.4., is predicted to become important to New Zealand.

The data suggest that collaboration is defined and interpreted in a multitude of ways by researchers and funders. A wide variety of collaborative arrangements is being used in the College of Sciences, ranging from highly successful, proximal, two-person collaborations to large teams with many disciplines including social scientists, although the inclusion of social scientists is not the norm (see section 5.2). This variety reflects, and is part of, the larger, complex investigations involving end users now being used to approach large scale problems. It can be described as "post normal science" as researchers see a problem in the bigger picture and through a different lens, not just that of their own area of expertise. Just as collaboration requires researchers to develop additional skills, post normal science also requires additional skills (see Recommendation 6.4.1).

The study revealed that researchers willingly accept the freedom the strategic funding agencies permit them in deciding how their collaborative research

arrangements will be framed, but the lack of clarity in the definitions and criteria used by third parties as an indicator of performance, or as a way of judging the quality of work, as noted in section 2.3, can cause confusion. In any technical writing having conventional understanding of terms, in this case collaboration, is helpful just as is reference to authoritative works when writing on subjects outside of one's expertise.

### **6.3.2 Objective 2**

To identify the promoters, drivers, and barriers in collaboration; the reasons why collaboration is encouraged, and how scientific researchers overcome the barriers inherent in collaborative research.

Discussion in Chapter Five focuses on the reasons why researchers collaborate and emerging from the survey and the interviews is the view that they do so because they find it useful, enjoyable, and stimulating. The over-riding reason for collaborating, however, is because scientific researchers “want to do better science” and whilst there is very limited collaboration with researchers in non-science disciplines, as noted in section 5.2, where this does occur, it is to assure better outcomes. Despite this intrinsic motivation for researchers to collaborate there is a strong thread of pragmatism running through the reasons why researchers collaborate. Collaboration makes possible access to opportunities and resources that would not otherwise be available to researchers. This has the effect of opening up the horizons for individual researchers, and of strengthening the entire scientific research sector within New Zealand.

From the point of view of the four national research funding agencies in New Zealand, three require collaboration in research proposals and they do so because they see collaboration is a good thing that will help to deliver agreed outcomes, raise standards, and provide opportunities for researchers to work alongside the best in the world. All agencies agree that collaboration can raise the quality of proposals for funding, and see it as a way of augmenting the capacity and capability of the research sector in New Zealand. Whilst the Marsden Fund does not

require collaboration it is acceptable if appropriate to the project, and should a Marsden recipient choose to collaborate with an overseas researcher, the component of the project for which the overseas researcher is responsible must be self funded. The result is better networks, more resources, and greater capacity.

The study revealed a number of obstacles to collaboration, some of which are very practical relating to process, the extra time required for collaboration, extra costs, authorship protocols which can be quite complex, and for female researchers and younger researchers gaining access to the networks of established researchers can be problematic. Less tangible obstacles are the loss of ownership and control some researchers feel when engaged in collaborative research, and, as some claim, innovative thinking is reduced because novelty can be a barrier to funding. As discussed in section 4.3.1.2, novelty, on its own can be risky in terms of getting funding and thus it is not always prudent to pursue novel ideas; however, through collaborating it is possible to embed the more tangential or novel aspects of problems in much larger projects.

Many researchers spoke of the lack, or perceived lack, of institutional support for collaboration. In Chapter One of this study it was pointed out that in Massey University's strategic document *Road to 2020* (MU, 2011) a range of practical mechanisms aimed at supporting collaborative research are listed and many have already been instituted within the University. At the institutional level, a more integrated approach to the dissemination of information on support structures and programmes would help in dispelling doubts about the available support.

### **6.3.3 Objective 3**

To describe the processes of cooperation and coordination used by scientists in collaborative projects, and to identify the personal, professional and management skills and competencies researchers consider important for successful engagement in collaborative research.

Teams are at the heart of collaborative scientific research and the processes of cooperation and coordination, as discussed in section 5.7.2, which are used to manage a research project, are regarded by most stakeholders as key to successful collaborative research. The view that a collaborative research project needs to be managed and not simply regarded as 'science to be done' was shared by funders and researchers and both shared the view that the coordination function was the primary role of the principal investigator. Good coordination is complex as evidenced by the emergence of the discipline of Coordination Theory (discussed in section 5.7.2) built around the management of the dependencies between activities and tasks comprising functions such as goal setting, task division, processes for communication, interpersonal processes, feedback and monitoring processes. Few researchers claimed to be expert or to have ever had any training in this area.

Collaborative research is a team activity and just as there is recognition that a research project has to be managed, there is also recognition that criteria other than just technical competence can be used in assembling a research team. Other ways of assembling a research team are discussed in section 5.6.1. Researchers constantly drew discussion to the role of the leader and the skills needed to manage a team of scientific researchers, and throughout discussions on teams researchers voiced the need, and desire, to engage in professional development in the skills and competencies of collaborative research, leadership, management and mentoring, appropriate to all stages of a research scientist's career. The clearly expressed call by researchers for professional development discussed in section 4.3.1.5 has an added potency when researchers referred to the training opportunities afforded their colleagues in the Crown Research Institutes.

In section 5.6.3.2 the strong views expressed by researchers on academic career pathways is described. Their views focus on the need for a more active management of careers and for the researchers to be able to access trained mentors and career consultants. Serendipity is no longer being seen as the best, or even the desired, way of managing one's career. Some scholars suggest that as academic careers in science have changed over recent decades and there is now increasing emphasis on research centres, relationships with industry, sourcing funding for research from organisations other than established government funding

agencies, changes in publishing patterns arising from these structural changes and from collaboration practices, it would be timely to consider alternative career pathways for research scientists. The issue of alternative career structures is discussed in section 5.6.3.2.

#### **6.3.4 Objective 4**

To ascertain how stakeholders (funding agencies and researchers) evaluate the effectiveness/success of collaboration.

Stakeholders in scientific research do not all share the same criteria for judging the success of a research project and the question of how the effectiveness and success of collaborative research might be evaluated raised many more questions than it answered. An important point raised and discussed in section 5.1 was that the funding agencies are continually looking for better measures of “meaningfulness” and ways of valuing research, particularly mechanisms that would enable them to attribute the contribution that scientific research makes to economic growth.

Having reliable mechanisms for attributing value is important to researchers because authorship credit is the key to their professional and academic success. As discussed in section 6.1, science and technology are regarded as key elements in economic development and judgements on its contribution to that growth will have an impact on the direction and magnitude of research funding.

In section 5.7 it was noted that from the point of view of the researchers, a collaborative project was judged to be successful in two dimensions: project success or the achievement of the objectives of the project; and project management success, judged on the performance of the researchers against cost, time and quality. In addition researchers had three further criteria: The first was the unobtrusiveness of the fundamental processes and operations used in carrying out the research project and the suitability of those processes to the objectives of the project; the second was that the interpersonal relationships were positive throughout and remained so at the conclusion of the project, and team members were willing to share and open to feedback; and the third criterion which was

shared by all stakeholders, not just researchers, was that the objectives of the project were achieved within time and on budget.

There are three factors which researchers identified as being the most important contributors to collaboration success: frequent communication among team members; clear coordination and planning; and good leadership. Each of these factors is discussed in sections 5.7.1-5.7.3.

In section 5.6.3.1 the issue of 'risk management' is discussed. Risk management is an area which has received little attention in the literature but is becoming increasingly important in the management and governance of scientific research as collaboration between university research scientists and researchers in other institutions and industry increases. Collaboration increases risk and prudent management would ensure that risk would be identified, evaluated and steps to manage the risks be taken.

### **6.3.5 Objective 5**

To review how funding agencies utilise knowledge of the collaboration process when designing their funding architecture, and how scientific researchers utilise their knowledge of collaboration in designing their applications for funds and their research projects.

Funders take note of feedback from all stakeholders and strive to improve their policies and operations to ensure that the requirements of the shareholders (government ministers), and the needs of the providers (the researchers) are met. In 2010 the legislative foundation for the New Zealand government investment in science and technology research was changed in order to improve efficiency in allocating research funds, to reduce complexity and transaction costs and to become more responsive to sector needs.

All funding agencies undertake analysis of the data collected in relation to their funding activities. The MSI has a range of indicators it uses to gather information on all aspects of their funding activities, the research resulting from that funding, and the uptake of the research by industry. Information from this analysis is used to streamline funding processes and this has meant continuous and

sometimes destabilising change for all participants. In contrast when the processes used by the Marsden Fund were designed, simplicity was one of the key factors used and this has meant that there has been little change to these processes since establishment of the fund. One of the benefits of this stability is the accumulation of data permitting statistical analysis.

As has been noted in section 4.3.2.5, the funding agencies, with the exception of the Marsden Fund, all encourage, and in some cases actually require collaboration in the scientific research projects they fund (see section 5.4). These expectations influence the way that researchers frame and structure their proposals to funding agencies. For example; (a) sometimes researchers will add components which may not be necessary to the success of the project but are added as they are seen as tactically useful; (b) a number of small projects, each of which is too small to be considered for funding, may be coalesced into one large project in order to reach the minimum level for funding; (3) non-scientist collaborators may be included; and (4) to maximize chances for funding and to reduce the risk of rejection proposals may be less innovative and creative than they might otherwise be (novelty and risk in proposals is discussed in section 4.3.1.2). All stakeholders recognise that 'game-playing' (described in section 5.4) is a feature of the interaction between funders and researchers. The objectives of the Marsden Fund would make such game-playing less likely to occur as proposals to that fund are judged by peers solely on research excellence and researcher competency, and other factors such as utility and alignment with government priorities do not have to be considered.

The complexity of the process of collaborative research was noted by researchers and the development of a model of successful scientific research collaboration was raised as one way of getting a better understanding of the process. The concept of modelling collaborative research, raised in section 4.3.1.5 and later discussed in section 5.6.3.3, would comprise identification of the elements in the process of collaborating and showing how these elements integrate with the social dynamics throughout a research project.

## **6.4 Recommendations:**

The final objective in this study was to provide researchers with a set of recommendations on collaboration. The following recommendations which have emerged from this study focus on the six main areas of need identified in this study.

### **6.4.1 Training and development**

The researchers who participated in this study clearly identified training and development in collaborative research practice as being very important and expressed interest in undertaking training. A comprehensive professional development package should be developed for scientific researchers at various career stages. The package would comprise four areas of training and development:

#### **6.4.1.1 Leadership, supervision, and management**

Leaders and managers have different roles: a leader influences the opinions and attitudes of others to accomplish a shared goal and a manager ensures that people and processes are in place to be able to achieve the goal. Some competencies, described as clusters of knowledge, skills, attitudes, abilities, behaviours, and other characteristics, are shared by leaders and managers but other competencies are specific to the different roles.

There are many lists of competencies required by leaders and managers of scientific research teams such as the following by Jennings, Scalzi, Rodgers, and Keane (2007) which outline the competencies shared by leaders and managers, and identify those peculiar to either leaders or managers.

1. Shared competencies and attributes: Personal qualities; Interpersonal skills; Thinking skills; Communication skills; Change skills; Management skills (e.g., planning, organizing; Business skills (e.g., finance, marketing)
2. Leaders specific competencies: Vision setting; People development; and
3. Manager specific competencies: Human resources management.

Having a set of competencies is not sufficient to make either a good manager or a good leader and the way the skills, attributes, behaviours and competencies are put together and used, will determine how effective a manager or leader will be. Writers who have contributed substantially to discussions of effectiveness of

leaders and managers are Sapienza (2005) who describes the attributes of effective leaders, and discusses the three important competencies of delegating, resolving conflict, and motivating; Lorange, Roos and Brønn (1992) discuss the "competence mix" required of the management team running collaborative research; Hurd (2009) focuses on the difficulties scientists have in becoming effective managers; and C Cohen and S Cohen (2005) focus on management skills for scientists.

These materials would provide a sound foundation for the development of a professional development programme for scientific researchers on leadership, supervision, and management.

#### **6.4.1.2 Mentoring and coaching**

Mentoring today is a formal, contractual arrangement between professionals and formal training programmes for mentors in scientific research institutions have been established. For example the National Institutes of Health (NIH) Mentor Development Programme aimed at training senior staff as mentors established in 2006 at 12 academic institutions (Feldman, et al., 2009), and at the CSIRO a mentoring programme was run in one section of the CSIRO. The evaluation in 2000 judged it as highly successful, with every mentor and mentored person who took part reporting benefits and recommending that the programme be extended across the organisation (MacGregor, 2000).

The aim of most mentoring programmes is not to teach specific skills or improve work performance directly but rather to provide personal/professional support, guidance and an introduction to new contacts and networks. The literature on mentoring in science is limited although the following scholars make major contributions to the area. L Haynes, Adams and Boss (2008) and C Cohen and S Cohen (2005) discuss the role and importance of mentoring in the development of scientists, Benabou and Benabou (1999) focus on mentoring programmes and the differences between mentoring and coaching, and Kahn and Greenblatt (2009) consider the challenges for mentors and different strategies in mentoring. Designing a mentoring training programme based on the referenced work above, and implementing such a programme would fill a need voiced by the researchers interviewed in this study.

### **6.4.1.3 Collaborative research skills and networking**

There are many taxonomies of research skills and behaviours. In the main the skills deemed as vital for researchers are grouped into three areas: 1. a set of general research skills and transferable skills; 2. a framework for research methods training; and 3. subject and discipline guidelines. In 2001 the UK Research Councils published the Researcher Development Statement (RDS) which sets out the knowledge, behaviours and attributes of effective and highly skilled researchers (RCUK, 2010). The RDS comprises four domains within each is a set of sub-domains and descriptions of the different aspects of being a researcher. These domains are: 1. Knowledge, intellectual abilities; 2. Personal effectiveness; 3. Research governance and management; and 4. Engagement, influence and impact. The RDS is supported by the Researcher Development Framework (RDF) a tool for planning, promoting and supporting the personal, professional and career development of researchers.

Whilst reference to specific skills for collaborative research is limited, the RDF (CRAC, 2011) does have a subset of collaboration skills, the IGERT programme in the United States and the Canadian CIHR programme (see section 2.6.1) both have a focus on collaborative research skills, and the following scholars have made valuable contributions in this area; Fischer, Tobi and Ronteltap (2011) discuss the research process and related issues; Maglaughlin and Sonnennwald (2005) identify factors which impact collaboration. All of these writings could all be drawn upon in the development of a package of collaborative research and networking skills for New Zealand scientific researchers.

### **6.4.1.4 Teams and the processes and dynamics of collaborative research projects**

Scientific research is increasingly being undertaken by teams and creating effective teams means meeting the needs of individual team members as well as creating a vision for group performance. There is a considerable literature on team formation, team roles, team processes, and building and motivating high-performance teams.

The following contribute to material on teams and their functioning. Fisher, Hunter and Macrossan (2002), team roles and effective teams; Hara et al. (2003), has a framework of various types of collaboration among scientists and identifies

factors that influence collaboration; Cummings and Kiesler (2005), discuss collaborating across boundaries and coordination; Stokols et al. (2008); overview of teams and team functioning; and K L Hall et al. (2008) on team functioning; and Marks, Mathieu and Zaccaro (2001) on team processes. All of these studies would provide material on teams, their configuration and functioning as the basis for developing materials to assist researchers in assembling research teams.

#### **6.4.2 Career management**

A career management programme should be developed which includes examination of trends in academic career structure, alternative career models, career pathway options which incorporate research and management, training and resources for career development, and access to career advisors and coaches. The creation of such a programme was clearly identified by researchers as an area of need, and is becoming a focus of research as evidenced by studies by Baruch and Hall (2004) comparing academic and corporate careers; Duberley, Cohen and Mallon (2006) who focus on how scientific careers are structured within institutional contexts; and Sargent and Waters (2004) discussion of influences on academic careers and collaborations.

#### **6.4.3 Awareness of institutional support**

Greater promotion throughout the University of existing programmes of support for collaboration should take place to raise awareness of researchers of the institutional supports that are available. Consideration by researchers of the best ways an institution can support research collaboration in terms of the infrastructure, processes, and support for activities at the interface of academia and industry may identify new ways of encouragement and support. Studies by Kraut and Egidio (1988), Y.Lee (2000), Cummings and Kiesler (2005), focus on institutional support for collaboration.

#### **6.4.4 Regionalisation**

The trend toward global regionalisation of scientific effort through collaborative research activity has the potential to create opportunities for New Zealand scientific researches. This trend is discussed at the global level by Georghiou (1998)

and in relation to New Zealand by Baines (2006), and by Adams, King and Webster (2010). The New Zealand Government has indicated a desire to improve international linkages and to leverage New Zealand's investment in science and innovation through these bilateral and multilateral international relationships. New Zealand has strong research ties with Australia particularly in agriculture, biotechnology and environmental sciences, and in some large infrastructure projects. There are also formal, and strengthening, science and innovation agreements with China, Japan, Singapore and the Republic of Korea and it is recommended that consideration be given to how scientists can tap into the opportunities that will arise out of this framework.

#### **6.4.5 Authorship protocols**

The wide variation in authorship protocols across an institution can create difficulties particularly for early career scientists. A generic authorship protocol should be developed that can be used across the university and tailored to individual situations as required.

#### **6.4.6 Best practice**

A handbook of best practice for managing collaborative research projects should be developed. The focus of a handbook would be on the professional development package as discussed in Recommendation 6.4.1. Such a handbook would include, inter alia, sections on the process of collaborative scientific research, planning, coordination, teams and forming teams, co authorship, skills and competencies, leadership and management, support for collaborative projects.

### **6.5 Opportunities for future research**

The breadth of this study has identified a large number of possible areas of future research; however, the following five areas emerge most directly and urgently from this study.

#### **6.5.1 Regionalisation**

The international trends toward collaboration and regionalisation of scientific research have huge impacts and consequences for a small country such as New Zealand with its limited breadth and depth of research base. An in-depth

investigation is needed into how New Zealand can work within, and alongside, this emerging international framework and what policies, processes and infrastructure at the individual, institutional and national level are required to support, develop and grow collaborative scientific research.

### **6.5.2 Professional development**

A number of countries have recognised that in order to stay competitive, researchers like other professionals need to engage in continuous professional development. Examples are the United Kingdom 'Concordat' programme aimed at supporting the career development of researchers (RCUK, 2008); the United States IGERT programme focusing in interdisciplinary training and collaborative research (NSF, 2011). New Zealand has yet to establish an integrated and longitudinal professional development programme for scientific researchers and the need for such a programme has been acknowledged by the researchers in this study. Research into the professional development needs of scientific researchers is necessary and timely.

### **6.5.3 Academia and industry**

The linkages between academia and industry continue to grow and the traditionally clear boundary lines between the two are blurring as researchers simultaneously pursue academic and commercial activities. The interface between academia and industry is a potentially rich area for research as the different and potentially conflicting procedures and requirements of these two sectors can lead to complications and impediments in working across boundaries. There is opportunity for research into processes and mechanisms at this interface and evaluation of the newly created interface specialist role intended to facilitate interaction between academic scientific researchers and industry and technology transfer (an example being the inclusion of a sociologist in a research team working with industry).

### **6.5.4 Collaborative scientific research process**

To date, investigation into the process of collaborative scientific research and the dynamics of researcher practices is limited. Further investigation is warranted into the management of the dependencies between research activities and tasks (the

coordinating function), how disciplines can be integrated, how the perspectives of researchers and stakeholders can be incorporated into the managing of a research project, and how teams can be constituted, maintained and renewed.

#### **6.5.5 Return on investment**

Investment in scientific research and innovation is expensive and measuring the contribution or return on that investment is very complex, as it is the outcome of many commercial, social and environmental factors. Being able to demonstrate the contribution of their research to public welfare is important to researchers in terms of continuation of research funding, and important to funding agencies in terms of giving guidance as to how to direct investments in the future. As an area of research this is of particular interest to funding agencies.

#### **6.6 Concluding comment**

The findings suggest that the extent of collaboration is in line with the collaboration activity of the researchers who took part in the Victoria University of Wellington study in 2003 (Morrison, et al., 2003).

In the main, the researchers surveyed and interviewed enjoyed collaborating and found it rewarding in terms of increasing the likelihood of successful scientific outcomes to projects; enhancing opportunities to work with established and successful scientists, particularly internationally; adding to their sources of funding; and for purely social reasons. Many of them, however, did hold the view that the University provided little in the way of professional development for its researchers and gave little support to researchers who wished to collaborate. There are, however, a number of initiatives that the university has had in place to foster collaborative research which researchers can access; these are perhaps inadequately publicised.

New Zealand funding agencies, whilst they do not clearly define what is meant by collaboration, all regard it as being very valuable as it can augment the size and capability of the science sector in New Zealand. The funders all take a flexible view of the kinds of structural forms collaborations can take.

Finally, the scientific researchers who contributed to this study can overall be described as enthusiastic about their work, and generally enjoy collaborating with

their peers. This enthusiasm is summed up in the following words from one of the interviewees.

We all have quite complementary skills, and I bet you if we had a big idea, a big project, I think we could make a lot more progress than what we do when we just work on our own little ideas. With that sort of "cooperativity" (sic), I'd really like to see what we could do

(Interviewee 5, personal communication, 2011)



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**Appendix A: Examples of use of terms ‘collaboration’ and ‘cooperation’**

AGENCY	PUBLICATION	
MINISTRY OF RESEARCH, SCIENCE, AND TECHNOLOGY (MORST)	2008 2009 ANNUAL REPORT p. 6: OVERVIEW	“The stable funding environment (SFE) initiatives.... This change will enhance <b>collaboration</b> and build capability.”
	p. 25: SERVICE PERFORMANCE	“Enable our research sector to effectively <b>collaborate</b> internationally and respond to the changing international innovation environment.”
	p. 28: Enduring Business Objective	“Expand and consolidate <b>co-operative</b> relationships with North Asia and Europe.”
	MORST ANNUAL REPORT 2006   2007 p. 9 (3.1)	“In October 2006, MORST, in <b>collaboration</b> with Business New Zealand,.....”
	MORST ANNUAL REPORT 2001/2002 p. 38	“The scientific publications indicator shows that there is active international <b>collaboration</b> in environmental research in New Zealand....”
	Briefing to the Incoming Minister 2008: <a href="http://www.morst.govt.nz/Documents/publications/bim/MoRST-BIM-December-2008.PDF">http://www.morst.govt.nz/Documents/publications/bim/MoRST-BIM-December-2008.PDF</a> .	The word ‘ <b>collaboration</b> ’ appears frequently throughout the document.

AGENCY	PUBLICATION	
FOUNDATION FOR RESEARCH, SCIENCE AND TECHNOLOGY (FRST)	2009/10 Investment round. Your guide to the application process p. 2	“We expect to see <b>collaboration</b> , where necessary...”
	STATEMENT OF INTENT 2009-2012  2.5 Our stakeholders p. 7	“We work <b>collaboratively</b> with all major public and private sector research organisations...” “ Stakeholders with whom we <b>collaborate</b> in investing our funds...” “... to increase the potential for international research <b>collaborations</b> ...”
	ANNUAL REPORT 2008/2009 8.1.2 International Investment Opportunities Fund p. 25	“Supports research providers to participate in research <b>collaborations</b> that attract international co-funding and supports participation in international research programmes...”
	ANNUAL REPORT 2007/08 1. Chair’s review p. 2	“... we continue to play a leading role in the valuable trilateral <b>collaboration</b> between the Foundation, the Tertiary Education Commission and New Zealand Trade and Enterprise.”

AGENCY	PUBLICATION	
ROYAL SOCIETY OF NEW ZEALAND: <a href="http://www.royalsociety.org.nz/Site/funding/cdrp/default.aspx">http://www.royalsociety.org.nz/Site/funding/cdrp/default.aspx</a> Cross Departmental Research Pool (CDRP), 2010/11 Investment Round Request for Proposals and Guidelines for Applicants	3.5 Proposal Interviews p. 7	"... potential to create benefit and the degree of potential for inter-agency <b>collaboration</b> ."
	5. Criteria for the assessment of proposals p. 17	"The team has strong <b>collaborations</b> with appropriate agencies and researchers..."
THE HEALTH RESEARCH COUNCIL (HRC):	The Research Partnerships for New Zealand Health Delivery initiative: to support <b>collaborations</b> that position research within practice or service delivery p. 4	"... requires the health research community and the health delivery sector to work <b>collaboratively</b> to provide innovative and workable solutions..."
		"A key feature of this <b>collaborative</b> model for undertaking research is to encourage meaningful research collaborations with end-users..."
	Statement of Intent 2009/2010 p. 2	The 2009/10 Letter of Expectation from the Minister of Health, emphasised <b>collaboration</b> with MoH, MoRST, other research funders and DHBs

AGENCY	PUBLICATION	
TERTIARY EDUCATION COMMISSION	2003 Quality Evaluation, Evaluating Research Excellence: the 2003 Assessment. p. 1	“... and between universities and Crown research institutes to improve <b>collaboration.</b> ”
	Purpose	3 “Centres of Research Excellence are ... inter-institutional networks with researchers working <b>collaboratively</b> on .....
	Eligibility	4 “Will take responsibility for the management and <b>coordination</b> of the research plan...”
	ACE Networks – Information for Providers 12/2/04 p. 3	“Builds a co-operative approach where competition has ruled <ul style="list-style-type: none"> <li>• Promotes ownership of changes</li> <li>• <b>Collaboration</b> promotes efficiency and long term effectiveness...”</li> </ul>
	p. 3	“... coordination and <b>collaboration</b> activities linked with the Tertiary Education Strategy.”
	Evaluation of the E-Learning Collaborative Development Fund Findings p. 12	The eCDF projects have been a significant conduit for <b>collaboration</b> ”

**Appendix B: Typology of collaboration (O’ Sullivan, 2010)**

INSTITUTIONAL CONTEXT	ACADEMIC FIELD TYPE REPRESENTED	UNIDISCIPLINARY	[-----] MULTIDISCIPLINARY	CROSS DISCIPLINARY INTERDISCIPLINARY	-----] TRANSDISCIPLINARY
Lone researcher Individual	Individual	Non-collaborative			
Simple group (all from a single)	Homogeneous	Researchers from a single discipline work together to address a common problem			
	Heterogeneous		Researchers work in parallel or sequentially: discipline-specific bases to address a common problem	Researchers work jointly: still from discipline-specific bases to discipline-specific to address a common problem	Researchers work jointly: share conceptual framework drawing together discipline-specific theories, concepts and approaches to a common problem
Complex group (researchers from multiple administrative units)	Homogeneous	Researchers from a single discipline work together to address a common problem			
Multi-sector group (researchers from multiple units and multiple sectors (e.g. government, community, academic, business, etc	Homogeneous	Researchers from a single discipline work together to address a common research problem			
	Heterogeneous		Researchers work in parallel or sequentially from discipline-specific bases to address a common problem	Researchers work jointly but still from discipline-specific bases to address a common problem	Researchers work jointly using a shared conceptual framework drawing together discipline-specific theories, concepts and approaches to address a common problem

Collaborative research can be classified in three dimensions: the number of different administrative units represented in the research team (institutional context); the number of academic fields present on the research team (homogeneous or heterogeneous), and the manner in which the work is performed and knowledge is created (disciplinarity).

## Appendix C: Belbin team roles

<p><b>Shaper</b> Highly motivated with a lot of nervous energy and a great need for achievement.</p>	<ul style="list-style-type: none"> <li>• Like to challenge lead and push others to action, can be headstrong and emotional in response to disappointment or frustration.</li> <li>• Generally make good managers because they generate action and thrive on pressure</li> </ul>
<p><b>Plant</b> Innovators and inventors – can be highly creative.</p>	<ul style="list-style-type: none"> <li>• Often enjoy working on their own away from other members of the team.</li> <li>• Tend to be introvert and react strongly to criticism and praise.</li> <li>• Great for generating new proposals and to solve complex problems</li> </ul>
<p><b>Co-ordinator</b> Ability to pull a group together to work towards a shared goal.</p>	<ul style="list-style-type: none"> <li>• Mature, trusting, and confident they delegate readily. They stay calm under pressure.</li> <li>• Quick to spot an individual’s talents and use them to pursue group objectives.</li> <li>• Co-ordinators are useful to have in charge of a team with their diverse skills &amp; personal characteristics</li> </ul>
<p><b>Monitor Evaluator</b> Serious-minded, prudent individuals.</p>	<ul style="list-style-type: none"> <li>• Slow deciders who prefer to think things over – usually highly critical thinking ability.</li> <li>• Usually make shrewd judgements by taking into account all the factors.</li> <li>• Important when analysing problems and evaluating ideas and suggestions.</li> </ul>
<p><b>Resource investigator</b> Good communicators both with other members of the group and with external organisations.</p>	<ul style="list-style-type: none"> <li>• Natural negotiators, adept at exploring new opportunities.</li> <li>• Adept at finding out what resources are available and what can be done.</li> <li>• Relaxed personalities, strong inquisitive sense and a readiness to see the possibilities of anything new.</li> <li>• Very good for finding resources and heading negotiations.</li> </ul>
<p><b>Implementer</b> Well organised, enjoy routine and have a practical common-sense and self discipline</p>	<ul style="list-style-type: none"> <li>• Systematic approach to tackling problems</li> <li>• Reliable and hardworking.</li> <li>• Will do what needs to be done whether or not they will enjoy the task.</li> </ul>
<p><b>Team worker</b> Supportive members of the team.</p>	<ul style="list-style-type: none"> <li>• Flexible and adaptable to different situations and people.</li> <li>• Perceptive and diplomatic.</li> <li>• Good listeners</li> <li>• Avoid conflict</li> <li>• Good at allowing everyone in the group to contribute.</li> </ul>

<p><b>Completer-Finisher</b> Have a great capacity for follow-through and attention to detail, and seldom start what they cannot finish</p>	<ul style="list-style-type: none"> <li>• Dislike carelessness</li> <li>• Reluctant to delegate, they prefer to tackle tasks themselves.</li> <li>• Good at tasks that involve close concentration and a close degree of accuracy.</li> </ul>
<p><b>Specialist</b> Pride themselves on acquiring technical skills and specialist knowledge</p>	<ul style="list-style-type: none"> <li>• Priorities are to maintain professional standards and advance their own subject.</li> <li>• Very committed.</li> <li>• Provides technical expertise. Usually called upon to make decisions involving experience and expertise.</li> </ul>

R Meredith Belbin, *Management Teams: Why They Succeed or Fail* (Butterworth Heinemann, 2nd ed., 2004) ISBN: 0 7506 5910 6

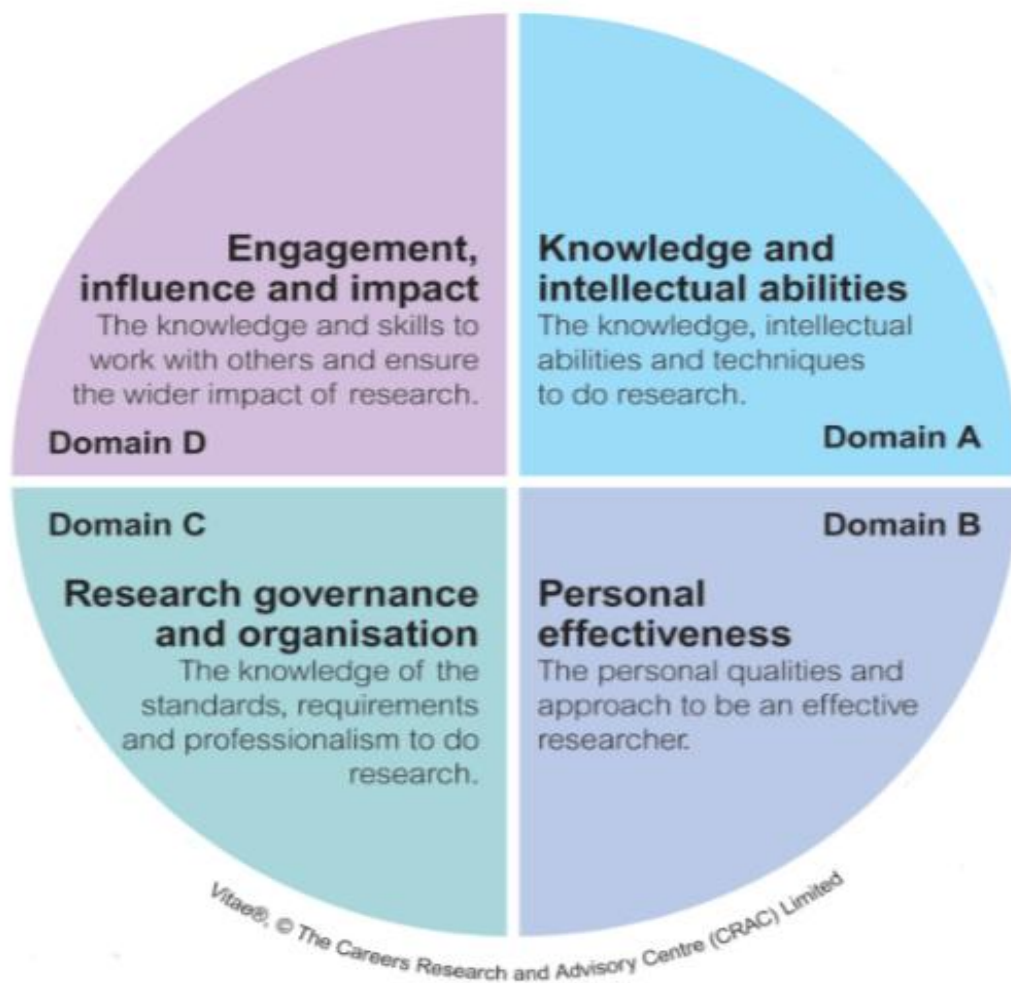


## Appendix D: Researcher Development Framework (RDF)

Developed for the UK Research Council the Researcher Development Statement and Researcher Development Framework cover the knowledge, behaviours and attitudes of effective and highly skilled researchers throughout their career. The Researcher Development Statement has replaced the Research Councils' Joint Skills Statement (2001) as the professional development framework for researchers at all levels. A Professional Development Planner has been developed to assist researchers in designing their professional development programme.

(<http://www.vitae.ac.uk/researchers/291411/RDF-Professional-Development-Planner.html>)

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([www.vitae.ac.uk/rdfconditionsofuse](http://www.vitae.ac.uk/rdfconditionsofuse))



**Researcher Development Framework (RDF): The Framework comprises four domains as follows:**

<b>DOMAIN A:</b> Knowledge and intellectual abilities	<b>DOMAIN B:</b> Personal effectiveness	<b>DOMAIN C:</b> Research governance and organisation	<b>DOMAIN D:</b> Engagement and Influence and impact
<p><b>A1 Knowledge Base</b></p> <ol style="list-style-type: none"> <li>1. Subject knowledge</li> <li>2. Research methods - theoretical knowledge</li> <li>3. Research methods - practical knowledge</li> <li>4. Information seeking</li> <li>5. Information literacy and management</li> <li>6. Languages</li> <li>7. Academic literacy and numeracy</li> </ol> <p><b>A2 Cognitive Abilities</b></p> <ol style="list-style-type: none"> <li>1. Analysing</li> <li>2. Synthesising</li> <li>3. Critical thinking</li> <li>4. Evaluating</li> <li>5. Problem solving</li> </ol> <p><b>A3 Creativity</b></p> <ol style="list-style-type: none"> <li>1. Enthusiasm</li> <li>2. Perseverance</li> <li>3. Integrity</li> <li>4. Self Confidence</li> <li>5. Self-reflection</li> <li>6. Responsibility</li> </ol>	<p><b>B1 Personal Qualities</b></p> <ol style="list-style-type: none"> <li>1. Enthusiasm</li> <li>2. Perseverance</li> <li>3. Integrity</li> <li>4. Self Confidence</li> <li>5. Self-reflection</li> <li>6. Responsibility</li> </ol> <p><b>B2 Self-management</b></p> <ol style="list-style-type: none"> <li>1. Preparation and priorities</li> <li>2. Commitment to research</li> <li>3. Time Management</li> <li>4. Responsiveness to change</li> <li>5. Work-life balance</li> </ol> <p><b>B3 Professional and career development</b></p> <ol style="list-style-type: none"> <li>1. Career management</li> <li>2. Continuing professional development</li> <li>3. Responsiveness to opportunities</li> <li>4. Networking</li> <li>5. Reputation and esteem</li> </ol>	<p><b>C1 Professional conduct</b></p> <ol style="list-style-type: none"> <li>1. Health and safety</li> <li>2. Ethic, principles and sustainability</li> <li>3. Legal requirements</li> <li>4. IPR and copyright</li> <li>5. Respect and confidentiality</li> <li>6. Attribution and co-authorship</li> <li>7. Appropriate practice</li> </ol> <p><b>C2 Research management</b></p> <ol style="list-style-type: none"> <li>1. Research strategy</li> <li>2. Project planning and delivery</li> <li>3. Risk management</li> </ol> <p><b>C3 Finance, funding and resources</b></p> <ol style="list-style-type: none"> <li>1. Income and funding generation</li> <li>2. Financial management</li> <li>3. Infrastructure and resources</li> </ol>	<p><b>D1 Working with others</b></p> <ol style="list-style-type: none"> <li>1. Collegiality</li> <li>2. Team working</li> <li>3. People Management</li> <li>4. Supervision</li> <li>5. Mentoring</li> <li>6. Influence and leadership</li> <li>7. Collaboration</li> <li>8. Equality and diversity</li> </ol> <p><b>D2 Communication and dissemination</b></p> <ol style="list-style-type: none"> <li>1. Communication methods</li> <li>2. Communication media</li> <li>3. Publication</li> </ol> <p><b>D3 Engagement and impact</b></p> <ol style="list-style-type: none"> <li>1. Teaching</li> <li>2. Public engagement</li> <li>3. Enterprise</li> <li>4. Policy</li> <li>5. Society and culture</li> <li>6. Global citizenship</li> </ol>

## Appendix E: Factors that lead to success in collaborative research

<p><b>1. The Nature of the Work</b></p>	<p>Participants can work somewhat <b>independently</b> from one another The work is <b>unambiguous</b></p>
<p><b>2. Common Ground</b></p>	<p><b>Previous collaboration</b> with these people was successful Participants share a <b>common vocabulary</b> Participants share a <b>common management</b> or working style</p>
<p><b>3. Collaboration Readiness</b></p>	<p>The culture is naturally <b>collaborative</b> The goals are <b>aligned</b> Participants have a <b>motivation</b> to work together that includes mix of skills required, greater productivity, they like working together, there is something in it for everyone, NOT a mandate from the funder, the only way to get the money, asymmetries in value, etc. Participants <b>trust</b> each other to be reliable, produce with high quality and have their best interests at heart Participants have a sense of <b>collective efficacy</b> (able to complete tasks in spite of barriers)</p>
<p><b>4. Management, Planning and Decision Making</b></p>	<p>The principals have <b>time</b> to do this work There is critical <b>mass</b> at each location A <b>management plan</b> is in place The <b>project manager</b> is respected has real PM experience exhibits strong leadership qualities A <b>communication plan</b> is in place The plan has room for <b>reflection</b> and redirection No <b>legal</b> issues remain (e.g. IP) No <b>financial</b> issues remain (e.g. money is distributed to fit the work, not politics) A <b>knowledge management system</b> is in place Decisions are based on <b>fair and open criteria</b> &amp; free of <b>favouritism</b> Everyone has an opportunity to <b>influence</b> or challenge decisions Leadership sets culture, management plan and makes the collaboration visible.</p>

Adapted from AAAS (1989). Science for all Americans: A project 2061 Report of Literacy Goals in Science, Mathematics, and Technology. Washington, DC: American Association for the Advancement of Science.



## Appendix F: Ethics approval for this study



### MASSEY UNIVERSITY

15 July 2010

Margaret Emerre  
17 Armour Avenue  
Mount Victoria  
**WELLINGTON 6011**

Dear Margaret

**Re: What is the Role of Collaboration in Scientific Research in New Zealand?**

Thank you for your Low Risk Notification which was received on 14 July 2010.

Your project has been recorded on the Low Risk Database which is reported in the Annual Report of the Massey University Human Ethics Committees.

The low risk notification for this project is valid for a maximum of three years.

Please notify me if situations subsequently occur which cause you to reconsider your initial ethical analysis that it is safe to proceed without approval by one of the University's Human Ethics Committees.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

**A reminder to include the following statement on all public documents:**

*"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.*

*If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director (Research Ethics), telephone 06 350 5249, e-mail [humanethics@massey.ac.nz](mailto:humanethics@massey.ac.nz)."*

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to provide a full application to one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

John G O'Neill (Professor)  
**Chair, Human Ethics Chairs' Committee and  
Director (Research Ethics)**

cc Dr Elizabeth Gray  
School of Communication,  
Journalism and Marketing  
Wellington

Prof Frank Sligo, HoS  
School of Communication,  
Journalism and Marketing  
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Massey University Human Ethics Committee  
Accredited by the Health Research Council

Te Kunenga  
ki Pūrehuroa

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[www.massey.ac.nz](http://www.massey.ac.nz)



**Appendix G: Letter to PVC Anderson seeking approval to undertake this survey**

17 Armour Ave  
Mt Victoria, Wellington  
25 November, 2010

Pro Vice- Chancellor Robert Anderson  
College of Sciences  
Massey University

Dear Professor Anderson

Re: Request to survey staff in The College of Sciences, Massey University.

I am undertaking a DBA through Massey University, with the research topic 'The Role of Collaboration in Scientific Research', focusing on scientific research within universities. I have completed the course work and am now preparing to undertake the field work.

This letter is to request permission from you as Pro Vice-Chancellor, College of Sciences, Massey University, for me to survey academic staff in the College of Sciences.

The survey has been piloted with 6 members of the Science Faculty at Victoria University of Wellington and the feedback used for improvement. It is quite a short survey, containing 38 short-answer questions, and should take less than 10 minutes to complete.

1. **OUTLINE OF MY RESEARCH:** I am studying collaboration in scientific research, an area of increasing interest to both researchers and those charged with allocating public research moneys. Collaboration has increased dramatically over recent years and the motives for researchers to collaborate vary, from increasing access to equipment and other resources, to matters of prestige and promotion. Other stakeholders have their own motives for preferring researchers to collaborate.

The field work will comprise:

- a. Electronic ally surveying a set of scientific researchers to establish the extent of collaboration, the reasons why researchers choose to collaborate, and relevant demographic data; this will be followed by
  - b. Undertaking interviews with: researchers from various universities in New Zealand who have either led collaborative teams or been a member of a team; a group of key officers in publicly funded research funding agencies; and a number of senior staff in universities who have roles in managing the organisation's research portfolio.
2. CONFIDENTIALITY: As the data from the survey and the interviews will be reported at aggregate level with no individuals identified, anonymity and confidentiality can be assured.
  3. FEEDBACK: On completion of the thesis, in addition to the formal university requirements, I plan to provide feedback to participants on the outcomes of the research through a short summary report. I also plan to develop some materials on collaboration, based on recommendations arising from the research, which I hope can be of assistance to researchers in their collaborative activities.
  4. SUPERVISORS: My supervisors are:
    - Dr Elizabeth Gray, Senior Lecturer,  
School of Communication, Journalism, and Marketing  
Massey University; and
    - Professor Frank Sligo  
School of Communication, Journalism, and Marketing  
Massey University
  5. I have discussed this request with Ms Pauline Penketh who suggested that, should you agree to my request to survey academic faculty of the College of Sciences, I could work through her and the survey distribution (electronic) be expedited through the Assistants in each School .
  6. TIMEFRAMES: I would like send out the survey towards the end of January 2011, and the interviews will be undertaken over the first three months of 2011.

7. ETHICS: a Low Risk Notification for this project was lodged with the Massey University Human Ethics Committee on 14 July 2010 and the letter, of 15 July 2010, noting that this project has been recorded on the Low Risk Database is attached.

I come to doctoral study after many years of involvement in science and research in a variety of roles including work with the Foundation for Research, Science and Technology; and serving as Manager of Research Planning and Policy, Ministry of Forestry; Manager of Research, Forest Industries Council; Board member of Scion; and General Manager, Queensland Science and Technology Council. I am a member of the Royal Society of New Zealand and the Association of Scientists.

I am very keen that at the conclusion of this study, outcomes that will be of value to active researchers will be made readily available.

I look forward to your response.

Yours sincerely

Margaret Emerre

B.Sc. (Biological Sciences), University of Idaho, USA.

M.Sc. (Funding of Basic Research), Griffith University, Australia.

Student number: 08369607

Attachments:

1. Copy of survey
2. Scanned letter from the Ethics Committee
3. Copy of letter to researchers



## **Appendix H: Approvals to survey and interview**

Approval to survey and interview academic staff of The College of Sciences, Massey University

RE: Request to PVC Anderson to survey staff                      5/11/2010 4:36 pm

Hello Margaret

I can advise that Robert is comfortable with your proposal. The Human Ethics Committee requirements have been met and your application was very complete.

Wonderful to meet you – go forth and research.

Look forward to future contact perhaps

Cheers

Pauline

**Pauline Penketh** | Manager - Administration

College of Sciences | **Massey University** | Private Bag 11-222 | Palmerston North  
4474 | New Zealand

E-mail: [p.m.penketh@massey.ac.nz](mailto:p.m.penketh@massey.ac.nz) | phone: +64 6 350 5381 Internal ext: 5381





## **Appendix I: Letter to academic staff, College of Sciences seeking participation**

28 February 2012

Dear College of Sciences faculty member:

Thank you for taking the time to respond to this questionnaire.

I am studying for a Doctorate of Business and Administration at Massey University with the thesis topic, 'The role of collaboration in scientific research'. I am about to undertake the field work, the first stage of which will comprise a survey of scientific researchers at Massey University.

Collaboration in scientific research has increased dramatically over recent years and my aims in this research are to establish the extent of collaboration at Massey University and the reasons why researchers choose to collaborate; and to follow this with interviews with researchers who have either led collaborative teams or been a member of a team. The focus will be on the research process and I hope that the feedback to researchers will be of value to them in planning, managing and conducting their collaborative projects.

The survey has been piloted with researchers at Victoria University of Wellington and Pro Vice-Chancellor Robert Anderson had agreed that I can undertake the survey of staff in the College of Sciences. A Low Risk Notification has been lodged with the Massey University Human Ethics Committee (14 July 2010).

The survey, which is anonymous and the results will be in aggregate form, is quite short and should take less than 10 minutes to complete. I appreciate your assistance in this endeavour, and at the conclusion of the research I will provide to the College of Sciences a report of the research findings, which I hope will demonstrate the value of collaboration in scientific research, and may be valuable to you and your colleagues.

Should you wish to contact me please feel free to do so.

Yours sincerely

Margaret Emerre

Margaret.emerre@paradise.net.nz

The survey can be accessed through copying and pasting the URL below into your internet browser:

[https://masseybusiness.qualtrics.com/WRQualtricsSurveyEngine/?SID=SV\\_6hAXcayFBtNJfs8&SVID=&Preview=Block&ID=BL\\_bHFkwHhwOLs50PO](https://masseybusiness.qualtrics.com/WRQualtricsSurveyEngine/?SID=SV_6hAXcayFBtNJfs8&SVID=&Preview=Block&ID=BL_bHFkwHhwOLs50PO)

## **Appendix J: Letter to thank survey respondents**

6 April 2011

17 Armour Ave

Mt Victoria

Wellington

To all those who contributed to the success of my recent survey of members of The College of Sciences, Massey University.

Dear Everyone

I am delighted at the response to my recent survey on collaboration and want to thank everyone who contributed through either completing the survey or through distributing and promoting to individuals. I now have some very interesting and useful data which I am now mulling over. In due course I will return the favour, and will forward a summary of the outcomes.

Thank you to everyone

Margaret Emerre



## Appendix K: Information sheet for participants



### INFORMATION SHEET

### REVIEW OF COLLABORATION IN SCIENTIFIC RESEARCH IN THE COLLEGE OF SCIENCES, MASSEY UNIVERSITY

Interviewee:

Interviewer: Margaret Emerre  
17 Armour Ave  
Mt Victoria, Wellington  
04 382 8657 027 412 4997

This interview is a follow up to a recent survey of academic staff of The College of Sciences, Massey University on collaboration in research. The survey looked at the extent and types of collaboration and the interview is to gather in-depth views, and information on the processes used by researchers in collaborative research, and to ascertain how success is measured.

#### **Ethics clearance:**

*"This project has been evaluated by peer review and judged to be of low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.*

*If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director (Research Ethics), telephone 06 350 5249, email [humanethics@massey.ac.nz](mailto:humanethics@massey.ac.nz)".*

### **Project Procedures**

- The information derived from this interview will be analysed as part of the data for inclusion in DBA thesis.
- The audio recording will be transcribed and then wiped clear
- Anonymity of the interviewee will be maintained. Names and identifying details will not be recorded or included in any documentation.

### **Participant involvement**

An interview lasting 30-40 minutes.

### **Participant's Rights**

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the study;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used;
- be given access to a summary of the interview write up when it is concluded; and
- the audio recorder can be turned off at any time during the interview at your request.

**Appendix L: Participant consent form**



**REVIEW OF COLLABORATION IN SCIENTIFIC RESEARCH IN THE COLLEGE OF SCIENCES, MASSEY UNIVERSITY.**

**Interviewer: Margaret Emerre**

**Date:**

**PARTICIPANT CONSENT FORM**

**This consent form will be held for a period of five (5) years**

The details of the study explained to me and my questions have been answered to my satisfaction.

I understand that I may ask further questions at any time.

I agree/do not agree to the interview being recorded.

I wish/do not wish to have data placed in an official archive.

I agree to participate in this study under the conditions as discussed.

**Signature:**

**Date:**

.....

**Full Name - printed**

.....



**Appendix M: Relationship between objectives and data required**

<b>WHAT I WANT TO KNOW</b>	<b>QUESTIONS</b>	<b>OBJECTIVES</b>
1. Are Massey scientific researchers collaborating?	Q. 1. What percentage of your research time is in collaboration with other scientific researchers?	1. View of collaboration
2. With whom do they collaborate?	Q.2 What percentage of your collaboration time is with researchers from: various options given)	
	Q.3. How often do you collaborate with researchers in Social Sciences and Humanities?	
	Q. 8 In which of the following types of collaboration have you been involved? (various options given)	
	Q.11. Do you believe that collaboration is of value to your research?	
3. Why do researchers collaborate?	Q.4. How important is each of the following in your decision to collaborate with other researchers?	2. Promoters/Barriers
	Q.5. How important is each of the following in your decision to collaborate with researchers in 'non science' disciplines?	
	Q.12. Would you like to collaborate more?	

4. What competencies are required a. Personal/ Professional/ Managerial	Q. 12. Indicate the importance of the following competencies in making a collaboration successful. (list of factors)	3. Competencies
5. What makes a collaboration successful?	Q.7. A successful collaboration is one which: (Various options given)	4. Success
5. What makes a collaboration successful?	Q.7. A successful collaboration is one which: (Various options given)	
6. Demographic data	Q.9. What is your discipline or subdiscipline?	
	Q.10. How many years have you been in research?	
	Q.13. What is your gender?	
	Q. 14. What is your position in Massey University?	

## Appendix N: Development of questions for survey questionnaire

The objectives are listed in column 1 and Objective 2 has been split into two for clarity: line 2a focuses on the promoters of and reasons for encouraging collaboration, and line 2b focuses on the barriers to and difficulties in collaborating.

Objectives	What I Want to Know	Questions	Method
1. To ascertain how the stakeholders (funding agencies and researchers) in the scientific research process view collaboration;	1.1 Are Massey scientific researchers collaborating?  1.2 With whom do they collaborate?	<ul style="list-style-type: none"> <li>• What percentage of your research time is in collaboration with other scientific researchers?</li> <li>• What percentage of your collaboration time is with researchers from: <ul style="list-style-type: none"> <li>○ Other MU Colleges</li> <li>○ Other NZ universities</li> <li>○ Australian universities</li> <li>○ Other overseas universities</li> </ul> </li> <li>• In which of the following types of collaboration have you been involved? (various options given)</li> <li>• Do you believe that collaboration is of value to your research?</li> </ul>	Survey
	What are the University policies? How are they implemented?	<ul style="list-style-type: none"> <li>• Is collaboration encouraged? How?</li> </ul>	Interview
	1.3 What are the policies in the Funding Agencies ? 1.4 How are they implemented?	<ul style="list-style-type: none"> <li>• How is 'collaboration' defined?</li> <li>• Is collaboration encouraged?</li> </ul>	Interview

<p>2a. To identify the <b>promoters, drivers,</b> and barriers in collaboration; the <b>reasons why collaboration is encouraged,</b> and how scientific researchers overcome the barriers inherent in collaborative research;</p>	<p>2.1 Why do researchers collaborate? 2.2 What are the rewards for collaborating? 1.5 Why is it encouraged?</p>	<ul style="list-style-type: none"> <li>• What is the importance of the following in your decision to collaborate with other researchers: <ul style="list-style-type: none"> <li>○ meeting expectations of the funding agency</li> <li>○ achieving better project outcomes</li> <li>○ accessing equipment &amp; other resources</li> <li>○ increasing efficiency</li> <li>○ increasing chances of success</li> <li>○ achieving prestige or visibility</li> <li>○ enhancing productivity</li> <li>○ What is the importance of each of the following in your decision to collaborate with researchers in 'non science' disciplines <ul style="list-style-type: none"> <li>○ accessing different ways of thinking?</li> <li>○ meeting the expectations of funding agencies?</li> </ul> </li> </ul> </li> <li>• Would you like to collaborate more?</li> <li>• Are there any other reasons why you would like to collaborate?</li> </ul>	<p>Survey and Interview</p>
<p>2b. To identify the promoters, drivers, and <b>barriers in collaboration;</b> the reasons why collaboration is encouraged, and <b>how scientific researchers overcome the barriers inherent in collaborative research;</b></p>	<p>2.3 What are the difficulties &amp; how are they addressed?</p>	<ul style="list-style-type: none"> <li>• What are the challenging aspects of collaborating?</li> </ul>	<p>Interview</p>

<p>3. To describe the processes of cooperation and coordination used by scientists in collaborative projects, and to identify the personal, professional and management skills and competencies researchers consider important for successful engagement in collaborative research;</p>	<p>3.1 What competencies are required by a researcher;  a. Personal competences;  b. Professional competencies;  c. Managerial competencies.</p>	<ul style="list-style-type: none"> <li>• How important are the following factors in the success of collaboration: <ul style="list-style-type: none"> <li>○ leadership;</li> <li>○ coordination and planning;</li> <li>○ communication;</li> <li>○ location.</li> </ul> </li> </ul>	<p>Survey and Interview</p>
<p>1. 4. To ascertain how stakeholders (funding agencies and researchers) evaluate the effectiveness/success of collaboration;</p>	<p>4.1 What makes collaboration successful?  4.2 Is this knowledge used?</p>	<ul style="list-style-type: none"> <li>• What are the characteristics of a successful collaboration?</li> <li>• How is this knowledge used?</li> </ul>	<p>Interview</p>
<p>2. 5. To ascertain how funding agencies utilise knowledge of the collaboration process when designing their funding architecture, and how scientific researchers utilise their knowledge of collaboration in designing their applications for funds and their research projects;</p>			

Sub objectives			
1. To identify the characteristics of the respondent population?	Demographic data of researchers	<ul style="list-style-type: none"> <li>• What is your discipline or subdiscipline?</li> <li>• How many years have you been in research?</li> <li>• What is your gender?</li> <li>• What is your position in Massey University?</li> </ul>	
2. To record the seniority of the interviewee	Demographic data of the funding agency interviewees	What is your role in the agency?	Interview

## Appendix O: Development of interview guides

The table that follows sets out the study objectives, the information required and the questions. Note that Objective 2 is split into two sections. The first, 2a covers the promoters and drivers of collaboration, and the second, 2b, covers the barriers to collaboration and how researchers can overcome them. NB Areas shaded in grey are not included in any of the interview guides

Questions to:	Researchers	Funding Agencies	AVC,R&E MU
<b>Objectives</b>			
<b>Objective 1: Views on collaboration</b>	Definition of collaboration?	Definition of collaboration?	Definition of collaboration?
<b>Objective 2b:</b> To identify the promoters, drivers, and <b>barriers in collaboration</b> ; the reasons why collaboration is encouraged, and <b>how scientific researchers overcome the barriers inherent in collaborative research</b> ;	What are the difficulties & how are they addressed?		
<b>Objective 3:</b> To describe the processes of cooperation and coordination used by scientists in collaborative projects, and to identify the personal, professional and management skills and competencies researchers consider important for successful engagement in collaborative research;	What competencies are required for successful collaboration? a. Personal b. Professional c. Managerial		What competencies are required for successful collaboration? a. Personal b. Professional c. Managerial
<b>Objective 4:</b> To ascertain how stakeholders (funding agencies and researchers) evaluate the success of collaborations	What makes collaboration successful?	What makes collaboration successful? How is this knowledge used?	What makes collaboration successful? How is this knowledge used?
<b>Objective 5:</b>			

To review how funding agencies utilise knowledge of the collaboration process when designing their funding architecture, and how scientific researchers utilise their knowledge of collaboration in designing their applications for funds and their research projects			
<b>Demographic data</b>			

## Appendix P: Questionnaire

### SURVEY OF COLLABORATION IN SCIENTIFIC RESEARCH COLLEGE OF SCIENCES MASSEY UNIVERSITY 2011

Q.1 What is your position in Massey University?

- Assistant Lecturer
- Lecturer
- Senior Lecturer
- Associate Professor
- Professor
- Junior Research Officer
- Research Officer
- Senior Research officer
- Tutor
- Senior Tutor
- Practising Veterinarian
- Senior Practising Veterinarian
- Professional Clinician
- Senior Professional Clinician
- Post doctoral Fellow

Q.2 What is your gender?

- Female
- Male

Q.3 How many years have you been an active researcher following your terminal qualification?

- 0-5
- 6-10
- 11-20
- 21-30
- 30+

Q.4 In which academic discipline or sub-discipline do you work?

- 

Q.5 In which of the following types of collaboration have you been involved?

- Jointly publishing a book or part of a book
- Jointly publishing a journal article
- Jointly preparing and presenting a paper at a conference
- Jointly supervising a graduate student
- Jointly preparing and submitting a research proposal
- Jointly receiving a research grant
- Jointly carrying out a research project
- Other

Q.6 What percentage of your research time is in collaboration with other scientific researchers?

**0%                      25%                      50%                      75%                      100%**

**Time percentage**                                                                                            

Q.7    Of the time you spend in research collaboration, what percentage of that time is with Researchers in your own discipline?

**0%                      25%                      50%                      75%                      100%**

**Time percentage**                                                                                            

Q.8    How often do you collaborate with researchers from within your own academic unit?

**Never                      SometimesOften                      Very often**

**Frequency**                                                                              

Q.9    How often do you collaborate with researchers from other academic units of Massey University

**Never                      SometimesOften                      Very often**

**Frequency**                                                                              

Q.10   How often do you collaborate with researchers from other New Zealand Universities?

**Never                      SometimesOften                      Very often**

**Frequency**                                                                              

Q.11   How often do you collaborate with researchers from Australian universities?

**Never                      SometimesOften                      Very often**

**Frequency**      **Never**      **Sometimes****Often**      **Very often**  
                 

Q.12 How often do you collaborate with researchers from other overseas universities?

**Frequency**      **Never**      **Sometimes****Often**      **Very often**  
                 

Q.13 How often do you collaborate with researchers from business/industry?

**Frequency**      **Never**      **Sometimes****Often**      **Very often**  
                 

Q.14 How often do you collaborate with researchers in the College of Business, Massey University?

**Frequency**      **Never**      **Sometimes****Often**      **Very often**  
                 

Q.15 How often do you collaborate with researchers in the College of Education, Massey University?

**Frequency**      **Never**      **Sometimes****Often**      **Very often**  
                 

Q.16 How often do you collaborate with researchers in the College of Humanities and Social Sciences, Massey University?

	<b>Never</b>	<b>Sometimes</b>	<b>Often</b>	<b>Very often</b>
<b>Frequency</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.17 How often do you collaborate with researchers in the College of Creative Arts, Massey University?

	<b>Never</b>	<b>Sometimes</b>	<b>Often</b>	<b>Very often</b>
<b>Frequency</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.18 In deciding to collaborate with other scientific researchers, how important is being able to access expertise from other science disciplines?

	<b>Very Unimportant</b>	<b>Unimportant</b>	<b>Neither important nor Unimportant</b>	<b>Important</b>	<b>Very important</b>
<b>Importance</b>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.19 In deciding to collaborate with other scientific researchers, how important is being able to meet the expectations of the funding agency?

	<b>Very unimportant</b>	<b>Unimportant</b>	<b>Neither important nor unimportant</b>	<b>Important</b>	<b>Very important</b>
<b>Importance</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.20 In deciding to collaborate with other scientific researchers, how important is the possibility of achieving better project outcomes?

**Very unimportant**      **Unimportant**      **Neither important nor unimportant**      **Important**      **Very important**

**Importance**                             

Q.21 In deciding to collaborate with other scientific researchers, is being able to access equipment and other resources important?

**Very Unimportant**      **Unimportant**      **Neither important nor unimportant**      **Important**      **Very important**

**Importance**                             

Q.22 In deciding to collaborate with other scientific researchers, how important is being able to increase efficiency in the use of resources?

**Very Unimportant**      **Unimportant**      **Neither important nor unimportant**      **Important**      **Very important**

**Importance**                             

Q.23 In deciding to collaborate with other scientific researchers, how important is being able to increase the chances of success?

**Very Unimportant**      **Unimportant**      **Neither important nor unimportant**      **Important**      **Very important**

**Importance**                             

Q.24 In deciding to collaborate with other scientific researchers, how important is being able to spread risk of failure?

**Very Unimportant**      **Unimportant**      **Neither important nor unimportant**      **Important**      **Very important**

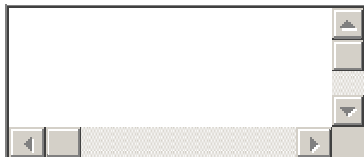
Q.25 In deciding to collaborate with other scientific researchers, how important is the achievement of prestige or visibility?

	<b>Very Unimportant</b>	<b>Unimportant</b>	<b>Neither important nor unimportant</b>	<b>Important</b>	<b>very important</b>
<b>Importance</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.26 In deciding to collaborate with other scientific researchers, how important is the enhancement of productivity?

	<b>Very Unimportant</b>	<b>Unimportant</b>	<b>Neither important nor unimportant</b>	<b>Important</b>	<b>Very Important</b>
<b>Importance</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.27 Is there anything else that is important in your decision to collaborate with other scientific researchers?



Q.28 In deciding to collaborate with researchers in 'non science' disciplines, how important is it to access different ways of thinking and different research methods?

	<b>Very Unimportant</b>	<b>Unimportant</b>	<b>Neither important nor unimportant</b>	<b>Important</b>	<b>Very important</b>
<b>Importance</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.29 In deciding to collaborate with researchers in 'non science' disciplines, how important is it to meet the expectations of funding agencies?

	<b>Very Unimportant</b>	<b>Unimportant</b>	<b>Neither important nor unimportant</b>	<b>Important</b>	<b>Very important</b>
<b>Importance</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.30 To make a collaboration successful how important is having an agreed method of sharing the recognition and reward?

	<b>Very Unimportant</b>	<b>Unimportant</b>	<b>Neither important nor unimportant</b>	<b>Important</b>	<b>Very important</b>
<b>Importance</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.31 To make a collaboration successful how important is having clear coordination and planning?

	<b>Very Unimportant</b>	<b>Unimportant</b>	<b>Neither important nor unimportant</b>	<b>Important</b>	<b>Very important</b>
<b>Importance</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.32 To make a collaboration successful how important is having good leadership?

	<b>Very Unimportant</b>	<b>Unimportant</b>	<b>Neither important nor unimportant</b>	<b>Important</b>	<b>Very important</b>
<b>Importance</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.33 To make a collaboration successful how important is having had team members working together previously?

	<b>Very Unimportant</b>	<b>Unimportant</b>	<b>Neither important nor unimportant</b>	<b>Important</b>	<b>Very important</b>
<b>Importance</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.34 To make a collaboration successful how important is frequent communication among team members?

	<b>Very Unimportant</b>	<b>Unimportant</b>	<b>Neither important nor unimportant</b>	<b>Important</b>	<b>Very important</b>
<b>Importance</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

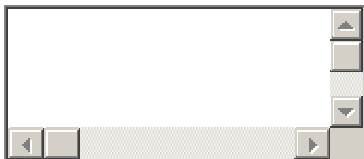
Q.35 To make a collaboration successful how important is it to have team members geographically near to each other?

	<b>Very Unimportant</b>	<b>Unimportant</b>	<b>Neither important nor unimportant</b>	<b>Important</b>	<b>Very important</b>
<b>Importance</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.36 How valuable is collaboration to your research?

	<b>Of no value</b>	<b>Of value</b>	<b>Neither littlevaluable nor invaluable</b>	<b>Valuable</b>	<b>Very valuable</b>
<b>Value</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q.37 Would you please elaborate on your answer to the previous question on the value of collaboration to you research?



Q.38 Concerning your level of collaboration would you prefer:

- More collaboration
- Less collaboration

## **Appendix Q, 1: Interview questions: Member of research team**

These are 'stimulus questions' with the focus is on the experience and views of the individual

---

As a member of a scientific research team can you

1. Describe a successful collaborative project (Obj. 6)
  - a. What made it successful?
  - b. Any unsuccessful? What were the barriers?
  - c. Describe the process used
  - d. How did you get involved
  - e. What was your involvement in the management, coordination, design of the project
  - f. Why were you invited to be a team member?
  - g. Training/competencies (Obj. 5)
2. Can you describe the relationships
  - a. Between team members and the leader of a project?
  - b. Between team members (Obj. 4)
3. Overall view of collaboration and collaborating (Obj. 1)
  - a. Risks and frustrations of collaborating (Obj. 3)
  - b. Promoters and drivers of collaboration (Obj. 2)



## **Appendix Q, 2: Interview questions: Leader**

These are 'stimulus questions' with the focus is on the research process, the experience and views of the individual

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As a leader of research teams in science can you tell me about

1. Describe a collaborative project that you would describe as successful
  - a. What made it a success? (Obj .4, 6)
  - b. Any unsuccessful?
  
2. The process you use
  - a. Idea & initiating project (Obj. 5)
  - b. How do you pick your team? Skills, competencies, roles required.
  - c. Any structural form preferred?
  - d. Managing, coordinating, monitoring (Obj. 4)
  
3. Leadership of scientific researchers
  - a. Is leading scientific researchers different to other forms of leadership?
  - b. Do you get any training ?
  - c. Skills and competencies required. (Obj. 3)
  
4. What are the 'tough' aspects of collaboration: the risks and frustrations
  
5. Does the university promote collaboration? (Obj. 2)
  - a. If so how does it do this?
  - b. What could be done to make it easier?
  
6. What is your overall view of collaboration and collaborating/why you do it/what value is it (Obj. 1)



**Appendix Q, 3: Interview questions: Funding agencies**

The objective is to ascertain how funding agencies in the scientific research process view collaboration.

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1. How does the agency interpret the word 'collaboration'?
2. Does the agency support, and ask for, collaboration in scientific research it funds?
3. Does the agency actively facilitate collaboration? How?
4. How does the agency determine if the collaboration is successful?
5. Are there any penalties or rewards for collaborating?

#### **Appendix Q, 4: Interview questions: Assistance Vice-Chancellor**

These are 'stimulus questions' with the focus is on the experience and views of the individual

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1. How does the institution interpret the word 'collaboration'? (Obj.1)
  
2. Does your institution encourage and support collaboration in scientific research?
  - a. Within institution/domestic/Australia/other OS (Obj. 2)
  - b. Why?
  - c. What form does the encouragement and support take?
  
3. Is there a University policy framework in relation to:
  - a. Authorship – are all named on any publication?
  - b. IP ownership
  
4. For internal allocation of funds what are the criteria – collaboration? (Obj.3)
  
5. How does the institution deal with the contradictory situation of encouraging collaborative research and individuality in career development and promotion? (Obj. 4)

## GLOSSARY

AVC, R&E	Assistant Vice-Chancellor, Research & Enterprise
AAAS	American Association for the Advancement of Science
CoP	Community of Practice
CoS	College of Sciences, Massey University
CERN	Convention for the Establishment of a European Organization for Nuclear Research
CSIRO	Commonwealth Science and Technology Organisation
CoRE	Center for Research Excellence
CUDOS	Acronym for the Mertonian Norms of science
CRI	Crown Research Institute
CRAC	Career Development Organisation
ESA	European Space Agency (ESA)
HRC	Health Research Council
FRST	Foundation for Research, Science and Technology
FTE	Full time equivalent
MoRST	Ministry of Research, Science and Technology
MSI	Ministry of Science and Innovation
MU	Massey University
NETSCC	NHR National Evaluation, Trials, and Studies Coordinating Centre
NUSAP	Acronym for <b>N</b> umerical <b>U</b> nit <b>S</b> pread <b>A</b> ssessment <b>P</b> edigree (a notational system to better manage and communicate uncertainty in science for policy).
NSF	National Science Foundation
NZAS	New Zealand Association of Scientists
OECD	Organisation for Economic Co-operation and Development
OED	Oxford English Dictionary
PBRF	Performance Based Research Fund
UK	United Kingdom
RA	Research Association
R&D	Research and Development

RSNZ	Royal Society of New Zealand
RCUK	Research Council United Kingdom
TEC	Tertiary Education Council
TEO	Tertiary Education Organisation