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Changing Research Practices in the Digital Information and Communication Environment

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Executive summary

In the context of the emerging knowledge-based economy, innovation and the capacity of the national innovation system to create and disseminate scientific and scholarly information are increasingly fundamental determinants of national prosperity. In their foundational work on National Innovation Systems, the OECD observed that prosperity in a knowledge economy depends as much, if not more, on the knowledge distribution power of the system than it does on its knowledge production power (OECD 1997, p43). This makes the infrastructure supporting research communication and collaboration, information search and access, and dissemination and publication a key element of the national innovation system. It is essential, therefore, to provide cost-effective access to, and dissemination of scientific and scholarly information in support of research and its economic, social and environmental applications.

This study examines evolving research practices, focusing on how practices are changing and what the implications of those changes are for scholarly communication and the future development of the research infrastructure. It outlines a coherent agenda for the evolutionary development of a sustainable research information and scholarly communication infrastructure.

Approach

Wide-ranging statistical and literature reviews provide a framework for analysis. Interviews were conducted with a structured sample of senior researchers in a range of research fields and institutional settings. Findings were confirmed and extended in a series of workshops. Both interviews and workshops targeted the leading edge of research in order to shed light on the direction of development and future needs. They focused on *why* researchers do what they do, rather than simply on *what* they do, because it is only by understanding the evolving needs of leading researchers that we can effectively resource research activities in the future.

Analysis focuses on three key areas of research activity: communication and collaboration, information search and access, and dissemination and publication. The key questions posed are:

- How do researchers conduct their research, and how is that changing?
- What are their major information sources, and how are those sources changing?
- How do researchers access, use and manage information, and how is that changing?
- How do researchers use their sources in the creation of new content, and how that is changing?

- How do researchers communicate with colleagues and publish their findings, and how are scholarly communication activities changing?
- How do researchers use technology, especially Information and Communication Technologies (ICTs), and how is it changing their activities?
- What are the implications of evolving research practices for those tasked with resourcing research and providing the necessary research information resources and communication infrastructures?

Key findings

We find that there is a new mode of knowledge production emerging, changing research practices and bringing new information access and dissemination needs. Adjustments will be required to the existing research information and scholarly communication system to accommodate these changes, but new opportunities are emerging for more cost-effective and sustainable information access and dissemination. To fully realise these opportunities, however, it will be necessary to take a more holistic approach to the development of the research information infrastructure and scholarly communication system.

A new mode of knowledge production is emerging

A new mode of knowledge production has emerged over recent years, characterised by Gibbons et al. (1994) as Mode 2. With the emergence of Mode 2 research there is: increasing diversity in the location of research activities; an increasing focus on interdisciplinary, multidisciplinary and transdisciplinary research; an increasing focus on problems, rather than techniques; greater emphasis on collaborative work and communication; and greater emphasis on more diverse and informal modes of communication.

The existing research information infrastructure has evolved over many years, during which traditional disciplinary Mode 1 research has been the dominant mode of knowledge production. Consequently, the existing infrastructure is better suited to the traditional than the new mode of knowledge production. The key to developing research infrastructure for the future is to think through the implications of the changes in research practices implied by the emergence of Mode 2 research and the development of e-science.

There are new information access and dissemination needs

The emergence of a new mode of knowledge production is bringing with it new information access and dissemination needs. There is increasing demand for access to a wider range of more diverse sources; for access mechanisms that cut across disciplinary silos; and for access to, and management of non-traditional, non-text digital objects. Research databases, related software and other analytical objects are now core tools, as the very nature of discourse shifts from hypothesis testing towards collecting, processing and analysing primary data.

As the U.S. National Research Council noted:

> *The rapidly expanding availability of primary sources of data in digital form may be shifting the balance of research away from working with secondary sources such as scholarly publications. Researchers today struggle to extract meaning from these masses of data, because our techniques of searching, analyzing, interpreting, and certifying information remain primitive. New automated systems, and perhaps new intermediary institutions for searching and authenticating information, will develop to provide these services, much as libraries and scholarly publications served these roles in the past.* (National Research Council 2001, p5).

New digital object access management systems will be required, and there will be increasing demand for collaborative research support applications and research support systems that enable researchers to bring together the increasingly disparate digital objects used in research in such a way as to facilitate enhanced integrated analysis.

The system for the creation, production and distribution of scientific and scholarly knowledge must be viewed holistically

Many factors have influenced the development of the present research infrastructure and scholarly communication system. Its elements have evolved and are often considered separately. As a result, developments have been somewhat piecemeal and there are sometimes conflicting forces at work.

It will be essential to take an holistic approach to 're-engineering' the system, which treats the creation, production and distribution of scientific and scholarly information, the management of information rights and access, systems of evaluation and the underlying infrastructure as parts of a single research information infrastructure and scholarly communication system.

Research practices are directly shaped by systems of evaluation, changing funding patterns and priorities. Existing evaluation and reward structures tend to lead to conflicting incentives in relation to scientific and scholarly communication. Establishing a coherent structure of incentives that operates system-wide is an essential step towards providing more cost-effective access and dissemination in support of both research and its economic, social and environmental applications.

Emerging dissemination and publication pathways offer new opportunities

Scientific and scholarly publishing is now evolving along two distinct paths – one in which large multinational commercial publishers are increasing their dominance in such areas as 'branded' journal titles and access to scientific publication, and the other in which there are a variety of open access initiatives.

Open access digital repositories, operating in parallel with existing commercial publishing mechanisms, may provide a major opportunity to develop a sustainable information infrastructure for both traditional and emerging modes of knowledge production. Together, they provide the foundation for more effective and efficient access to, and dissemination of scientific and scholarly information.

The challenge

The process of knowledge production is cumulative, with knowledge applied to knowledge, such that knowledge is both an output and an input. How researchers source that knowledge input, how they communicate with each other and how they communicate and disseminate findings are crucial, not only for the progress of knowledge but also for the capacity of the national innovation system to underpin prosperity in the global knowledge economy. As the traditional systems of knowledge production and dissemination are disrupted and alternative modes of knowledge production emerge the future development of research infrastructure and the provision of information resources becomes more challenging – perhaps even more challenging than many have yet realised.

There are many challenges to be met. There is a need to:

- Establish a mechanism for the identification of research information infrastructure priorities that is representative of all stakeholders and able to gain support for identified initiatives;
- Stimulate informed debate about research infrastructure and scholarly communication issues, collaborating internationally where appropriate;
- Stimulate innovation through reforms to incentive systems – including, *inter alia*, research evaluation, intellectual property rights, grant allocation and peer review mechanisms;
- Encourage institutional leadership to facilitate access to, and management of digital repositories; and
- Support ongoing research into evolving research practices, research infrastructure and scholarly communication needs.

The way ahead

To meet these challenges and develop a sustainable research information infrastructure and scholarly communication system it will be necessary to take an holistic approach and pursue a coherent agenda. That agenda should focus on:

- Creating a coherent structure of incentives based on an holistic approach to the system for the creation, production and distribution of research information;
- Providing the infrastructure and tools to support collaborative research activities in both traditional and new modes of knowledge production;
- Enabling access to necessary information access mechanisms and resources, and equipping users with appropriate information skills to enable their use; and
- Encouraging the development a system of scholarly communication and research dissemination built on the principle of open access.

Mechanisms and processes

There is a need to put in place mechanisms and processes that engage all stakeholders and enable consensual outcomes based on an holistic approach to research information infrastructure development. We call on stakeholders to:

- Support the development of an holistic approach to research infrastructure and scholarly communication issues;
- Establish a mechanism for the identification of systemic priorities, which represents all stakeholders and is able to gain support for identified initiatives;
- Pursue initiatives that seek to reduce the bureaucratisation of research activities – such as, for example, the development and implementation of best practice standards, standard contracts and the development of common compliance and reporting systems across funding sources; and
- Support an advocacy program to inform and engage, which focuses on:
    - researchers' awareness of, and access to collaborative support systems and the development of collaborative project management skills;
    - raising awareness and equipping researchers with the skills necessary to maximise the benefits of emerging information access and dissemination possibilities; and
    - encouraging researchers to license publishers rather than giving away copyright.

The incentive structure

There is a need to stimulate innovation through reforms to incentive systems – including, *inter alia*, research evaluation, intellectual property rights, grant allocation and peer review mechanisms.

Research evaluation

In respect to research evaluation there is a need to:

- Adjust performance measurement and research evaluation systems to take account of both traditional and emerging modes of knowledge production by, for example, giving greater recognition to:
    - a wider range of activities and outputs;
    - team-based work and collaborative activities;
    - scientific, social, economic and environmental outcomes; and
    - wider and more diverse communication and dissemination, linking to performance and practice as well as further research; and
- Explore the possibility of basing research evaluation on quality, quantity and 'relevance' factors, and extend the evaluation period to move away

from a 'procurement model' towards a system that is based on investment in people.

Incentives

In respect to incentives there is a need to:

- Examine whether current intellectual property rights practices provide sufficient incentives for the application and commercialisation of research outcomes – focusing on practices relating to the distribution of both property rights and licensing revenues between research institutions, centres/departments and individuals;
- Encourage the use of non-exclusive, but royalty bearing licensing, so as to minimise potential tensions between publication and commercialisation;
- Expand the focus of intellectual property rights management to include copyright, as well as patents and licensing; and
- Provide greater support to researchers in contract negotiation and through the promulgation of standard contracts and conditions.

Peer review

In respect to peer review of both grant applications and publications there is a need to:

- Explore ways to encourage reforms to peer review, which seek to introduce greater care and transparency while retaining the benefits of the system – such as, for example, open review (where the reviewers are named), published review (where reviews are published with the paper), increased payment for reviews, and increased recognition of review activities in performance assessment and evaluation; and
- Examine the need for further reforms to research council proposal review and assessment processes – such as, for example, expanding international reviewer possibilities through reciprocal arrangements at the national level.

Research infrastructure

It is necessary to provide the infrastructure and tools to support collaborative research activities in both traditional disciplinary and new modes of knowledge production, and to enhance access to necessary information resources. We call on stakeholders to:

- Support the development of high bandwidth research networks and grid applications (eg. through AREN and GrangeNet) with encouragements for researchers to push application development across all disciplines and fields of research;
- Encourage the development of collaborative research support applications – such as, for example, electronic records management, desktop videoconferencing, etc.;

- Investigate the possibility of developing and implementing research support systems that enable researchers to bring together the increasingly disparate digital objects used in research in such a way as to facilitate enhanced integrated analysis;
- Pay greater attention to non-disciplinary modes of search and access – such as generic front-end searching, and problem oriented rather than disciplinary portals and gateways; and
- Facilitate access to research databases, related software and analytical objects, with identified priorities feeding into action as soon as a research needs assessment has been completed.

Open access

We must encourage the development of a system of scholarly communication and research dissemination built on the principle of open access. To that end there is a need to:

- Establish an integrated open access digital repositories initiative based on Australia's higher education and research institutions, which recognises and accommodates the needs of both traditional and emerging modes of knowledge production, and is built on clear strategies for digital rights management, metadata management and access management;
- Encourage the population of repositories through initiatives that seek to:
    - promote awareness of their purpose and potential;
    - encourage retention of copyright and standardised licensing to publishers;
    - provide the necessary support to enable use; and
    - provide incentives that reward researchers for adopting the systems; and
- Explore the development of new metrics, which exploit the ability of digital repositories to provide a range of new metrics for research evaluation that are better suited to the 'measurement' of the outputs and impacts of both traditional and new modes of knowledge production.

1. Introduction

There are a number of inter-related factors driving changes in the ways in which researchers create, access and communicate information. Among the more significant of these are increasing demands for the commercialisation of research outcomes and for measurable research performance, and the impact of information and communication technologies (ICTs). It is only by understanding both the evolving needs of researchers and the emerging mechanisms for meeting them that we can effectively resource their activities at the individual, institutional and national levels.

This project examines evolving research practices, focusing on how practices are changing and what the implications of those changes are for scholarly communication and the future development of the research information infrastructure. It was supported by the Australian Commonwealth Department of Education, Science and Training's Research Evaluation Programme, and is intended to provide an input into the Government's thinking on the future development of Australia's research infrastructure.

1.1 Overview of the study

A review of the international literature and Australian research activities provides a framework for analysis. It explores various conceptualisations of emerging modes of knowledge production, long-term trends in R&D in Australia and a range of international studies of research practices in the digital information and communication environment. The major part of the study is a survey of evolving research practices. Data were collected at two levels, in-depth interviews and workshops. Interviews were conducted with a small structured sample of senior researchers in a range of research fields and organizational settings. Findings were validated and extended using workshops, in order to ensure that they did indeed reflected typical practices and how researchers themselves see evolving research infrastructure and resourcing issues.

The key questions posed in this study are:

- How do researchers conduct their research, and how is that changing?
- What are their major information sources, and how are those sources changing?
- How do researchers access, use and manage information, and how is that changing?
- How do researchers use their sources in the creation of new content, and how that is changing?

- How do researchers communicate with colleagues and publish their findings, and how are scholarly communication activities changing?
- How do researchers use technology, especially Information and Communication Technologies (ICTs), and how is it changing their activities?
- What are the implications of evolving research practices for those tasked with resourcing research and providing the necessary information and communication infrastructures?

1.2 Outline of the report

Drawing on an international literature review and an analysis of R&D activities in Australia, *Chapter 2* examines evolving modes of knowledge production and the changing nature of research. It begins with a brief review of the most widely used conceptual models of the evolution of knowledge production that have informed debate on science and technology policy in recent years. Using this review as a basis for analysis, it then examines long-term trends in research in Australia – looking at changes in the patterns of funding, R&D activity, collaboration, publishing and patenting.

Drawing on an international literature review, *Chapter 3* explores the impacts of information and communication technology (ICT) and the digital information and communication environment on researchers and research practices. Beginning with a brief review of the 'big picture' impacts of ICTs on research activities, it then focuses on the three key areas of communication and collaboration, information search and access, and dissemination and publication. This sets the scene for our analysis of research activities in Australia.

Based on a series of in-depth interviews and workshops, *Chapter 4* presents a picture of changing research practices in Australia. Interviews and workshops were wide-ranging and exploratory. They focused on *why* researchers do what they do, rather than simply on *what* they do, because it is only by understanding the evolving needs of researchers that we can effectively resource their activities in the future.

Chapter 5 presents a brief summary of the key themes and examines major issues arising from the study. It concludes by outlining of a coherent agenda for the development of a sustainable research information infrastructure.

2. The production of knowledge

This chapter draws on an international literature review and Australian examples to examine evolving modes of knowledge production and the changing nature of research. It begins with a brief review of the most widely used conceptual models informing debate on science and technology policy in recent years. Using this review as a basis for analysis, it examines long-term trends in research in Australia – looking at changing patterns of funding, R&D activity, collaboration, publication and patenting. It seeks to reveal the extent to which the changes described in conceptual analyses of knowledge production are reflected in research practices in Australia.

2.1 Models of knowledge production

There are various models which seek to explore the nature and context of knowledge production. Perhaps most prominent among recent models are:

- The *Systems of Innovation* approach, which encompasses a wide range of work focusing on the system(s) within which knowledge is produced, communicated and applied;
- The *New Production of Knowledge*, which is based on comparing and contrasting 'ideal type' conceptualisations of traditional disciplinary research (Mode 1) with an emerging transdisciplinary, problem oriented mode of knowledge production (Mode 2);
- The *Triple Helix*, which seeks to describe the emerging inter-relationship between universities, industry and the state; and
- *Post-academic science*, which seeks to describe the emerging era of science and contrast it with traditional 'academic science'.

A useful starting point is to briefly explore each of these models, focusing on what they tell us about how the practice of research is evolving and how changes impact on the ways in which researchers source, communicate and disseminate information and produce knowledge.

2.1.1 Systems of Innovation

The Systems of Innovation (SI) approach has become well established over the last 10 years and is widely discussed (Edquist 1997; 2001). Its focus is in the name. It is about *innovation*, not the impacts of innovation (which is dealt with by, for example, New Growth Theory). Nor is it, primarily, about the production of knowledge (which is seen as just one element of the innovation system). It is also a *systems* perspective, drawing heavily of evolutionary systems thinking. The importance of the SI approach is its influence on S&T policy, and thereby on the organizational and institutional structures within which research takes place. The SI approach defines organizations and institutions as the main components of the system, and explores both market and non-market relations between them. Its focus is on the functions of the system (ie. to create, diffuse and use innovations).

Various authors have put forward lists of the major functions of an innovation system. That of Liu and White (2001) is indicative of the kinds of functions mentioned. They include:

- Research (basic, development, engineering);
- Implementation (manufacturing);
- End-use (bringing together complementary knowledge); and
- Education.

Such lists invariably include research and education, and commonly also include skills supply and competencies. They make clear the importance of research in the higher education sector, where research training forms such an important part of research practices.

In the SI approach "there is no one-to-one relationship between functions and organizations. For example, research or the creation of new knowledge can be carried out by research institutes, universities or research oriented firms." (Edquist 2001, p12). Comparative studies have shown significant variation in mixes of organizations and functions and of organizations and institutions within different systems of innovation – most notably between different national systems, but also between different regional and sectoral systems.

The SI approach has a particular perspective on the nature of knowledge production. Edquist (2001) noted that in the SI approach innovations are normally seen as based on learning that is '*interactive*' – innovations do not happen in isolation. Hence knowledge is often of two sorts:

- 'scientific' knowledge generated through 'pure' research, which is often seen as an input to the innovation process; and
- knowledge generated through 'learning', which is often seen as an outcome of interaction in a problem oriented context.

The SI approach sees the sources of knowledge or learning as: R&D, learning-by-doing, learning-by-using, and learning-by-interacting. Hence, knowledge is not simply an input derived from basic research. It is also generated throughout the innovation process, and throughout the innovation system, as learning. The ways in which different forms of knowledge are produced, communicated and diffused vary significantly.

2.1.2 New Knowledge Production

Following Gibbons et al. (1994) a number of analysts have noted that a new mode of knowledge production has emerged, which is distinct from traditional notions of 'science'.[1] It is referred to as Mode 2, and contrasted with the traditional Mode 1 knowledge production. As Gibbons (2001) put it:

> *Mode 1 refers to a form of knowledge production – a complex of ideas, methods, values, norms – that has grown up to control the diffusion of the Newtonian model to more and more fields of enquiry and ensure its compliance with what is considered sound scientific practice. Mode 1 is meant to summarise in a single phrase the cognitive and social norms which must be followed in the production, legitimation and diffusion of knowledge of this kind. For many, Mode 1 is identical with what is meant by science. Its cognitive and social norms determine what shall count as significant problems, who shall be allowed to practice science and what constitutes good science. Forms of practice which adhere to these rules are by definition 'scientific' while those that violate them are not.*
>
> *…in Mode 1 problems are set and solved in a context governed by the, largely academic, interests of a specific community. By contrast, Mode 2 knowledge [production] is carried out in a context of application. Mode 1 is disciplinary while Mode 2 is transdisciplinary. Mode 1 is characterised by homogeneity, Mode 2 by heterogeneity. Organisationally, Mode 1 is hierarchical and tends to preserve its form, while Mode 2 is more heterarchical and transient. Each employs a different type of quality control. In comparison with Mode 1, Mode 2 is more socially accountable and reflexive. It includes a wider, more temporary and heterogeneous set of practitioners, collaborating on a problem defined in a specific and localized context* (Gibbons 2001).

Among the many characteristics of this New Mode of Knowledge Production (Mode 2) are:

- Increasing diversity in the location of research activities – with a greater range of organizations involved in research (eg. universities, research institutes, hospitals, firms, industry associations, etc.);
- Increasing focus on interdisciplinary and, more particularly, transdisciplinary research – with teams of researchers coming together to work on common problems that cannot be tackled adequately within a single disciplinary framework (eg. environmental or health problems);
- Increasing focus on problems, rather than techniques – with solutions being sought from a range of disciplinary 'toolboxes' and valued for their contribution to the solution, rather than to the toolbox;
- Increasing blurring of organizational borders and greater emphasis on collaborative work and communication – with a more flexible team approach in which teams form around problems, and then break up and move on to form different teams around different problems; and
- Changes in the modes of communication – including some increase in commercial guarding of intellectual property, less emphasis on publication in refereed journals and more on informal communication through networks of researchers.

[1] It should be noted that the reference here is not to 'science' as conventionally understood – rather, it refers to disciplined and reflexive inquiry more generally, and hence pertains as much to work in the Humanities and Social Sciences as to Science and Technology (McWilliam et al. 2002, p41).

Again there are differences between modes in terms of the way in which knowledge is created, communicated and diffused.

Table 2.1 Characteristics of Mode 1 and Mode 2 knowledge production

	Mode 1	*Mode 2*
Context	Research is undertaken in terms of the norms of academic practice and pure research. It is driven by the interests of the discipline community.	Research is use-driven but constrained by resources (especially time). Knowledge is produced in diverse teams, and reflects both interests and intended outcomes.
Discipline base flow	Knowledge development is framed and authorised by disciplinary norms and communities. Theory and application are distinguished.	Knowledge is transdiciplinary integrative and consensual. There is a dynamic between theory, application and the context.
Social organization	Knowledge production is deeply institutionalised, with limited multi-agency collaboration.	The site of knowledge production tends to draw on both academic and 'industrial' resources and values. Teams are transitory and diverse, with composition changing as projects evolve.
Accountability	Researchers are accountable to, and judged by their peers.	Social and economic accountability permeates the knowledge production process, and includes the interests of diverse stakeholders.
Quality control	The scientist is seen as the expert. Quality control is based on the notions of disciplinary norms and excellence. A key criteria is the contribution to the discipline.	Quality is judged on a broad range of criteria, including intellectual merit, cost-effectiveness and economic and social relevance. Quality control is context and use dependent, adapting to local contexts and emerging circumstances.

Source: McWilliam, E. et al. (2002) *Research Training in Doctoral Programs: What can be learned from professional doctorates?* DEST, Canberra, p41.

2.1.3 Triple Helix

Etzkowitz (2002) suggested that in the United States:

> *A new institutional configuration to promote innovation, a "triple helix" of university, industry and government is emerging… The dynamic of society has changed from one of strong boundaries between separate institutional spheres and organizations to a more flexible overlapping system, with each taking the role of the other. The university is a firm founder through incubator facilities; industry is an educator through company universities and government is a venture capitalist through the Small Business Innovation Research (SBIR) and other programs… Government has also encouraged collaborative R&D among firms, universities and national laboratories to address issues of national competitiveness* (Etzkowitz 2002).

It has been noted that the triple helix model has identified four processes related to major changes in the production, exchange and use of knowledge (Min-Wei Lin 2001):

- There is an internal transformation in each of the helices (eg. companies are developing ties through strategic alliances, while universities are becoming more 'entrepreneurial');
- The institutional spheres increasingly bring about transformation in another sphere (eg. government revising rules of intellectual properties rights);
- A new overlay of trilateral linkages, networks, and organizations among the three helices has been created to institutionalise the interfaces and stimulate organizational creativity and regional cohesiveness (eg. Cooperative Research Centres encouraging interaction among members in the three spheres); and
- The inter-institutional networks have a recursive effect on the originating spheres as well as the larger society (eg. universities are being transformed from a closed universe of scholars talking to scholars, to increasingly permeable organizations operating interactively with industrial and social communities) (Steven 2002).

Again there are new communication and information patterns implied by this permeability, and in the support of deepening linkages between spheres.

2.1.4 Post-academic science

In *Real Science*, Ziman (2000) characterised modern science as 'post-academic', suggesting that:

> *Post-academic research is marked by an increasing degree of collectivization as a response to the growing complexity of research problems, [and] the increasing costs of scientific equipment, but also the growing potential for research collaboration that is offered by information technology. Another important explanation of the collectivization process is that research areas today normally consist of amalgamations of areas and specialties, while older disciplinary demarcations are becoming obsolete. Scientific problems are defined by large groups and constellations of researchers and other actors within and beyond the academic system rather than by single researchers. Thus, research is no longer a self-governing isolate. Contemporary research in medicine, technology and the sciences (but also in other areas) is centered around the research group. The groups consist of a mixture of students, assistants, graduate students and professors, where colleagues, funding agencies, companies, and scientific networks influence the organization and direction of research* (Nilsson 2001).

Nilsson (2001) also noted that these developments are accompanied by a painful transformation of the power relations within the academic system, where groups of researchers who used to be very influential are marginalized in both intellectual and political terms. At the same time, new groups have emerged as the spearheads of scientific progress, often with good connections with the political system. The research system is changing both in terms of its social organization and models and modes of knowledge production. Some established disciplines are declining, while new research areas are emerging.

2.1.5 Knowledge production and research practice

There are many facets to these recent models of knowledge production and how the practice of research is changing, other models that deserve mention, and numerous critiques of all of them. Nevertheless, they have important and obvious elements in common that point to some key dimensions of change in the ways in which research is conducted and knowledge produced.

There are cultural and institutional changes. Foray (1997, pp73-74) noted that there is a shift from the traditional Baconian system of 'open science' to more restricted access regimes, as the commercialisation of research findings and blurring of organisational boundaries occurs. This tension is played out most noticeably in universities, where there is a clash between traditional, disciplinary, 'pure' research oriented to undirected inquiry and free publication in refereed journals; and increasing interactions between universities, industry and government, increasing access restrictions (eg. patenting), publication restrictions and commercial influence in the choice of topic and direction of research. There is, in essence, a clash between Mode 1 and Mode 2 research.

There is increasing awareness that the organisational forms chosen for the funding and conduct of research effect how knowledge is produced and how researchers interact internally and with their environment (Vaughan 1999; Wilts 2000). Nilsson (2001) suggested that to understand the future development of research, we need to look into the organizational setting of research. Collaboration between disciplines and organizational settings plays an increasingly important role in the structuring of research work, and is a central part in the reconfiguration of knowledge production toward more permeable forms. This is not merely a policy trend, but also an increasingly important aspect of how knowledge is produced.

In *The Enterprise University,* Marginson and Considine (2000) discussed changes in the structure and governance of Australian universities in the latter part of the 1990s, and the impact these changes have had on the management structures, institutional systems and frameworks within which research is managed. They noted a trend towards the commercialisation of research and the increasingly competitive nature of funding, and identified the results of these as being: a tendency to reduce risk, the manipulation of publication in order to maximise funding impact, an emphasis on quantity rather than quality; and a focus on the short-term.

There are clearly fundamental changes to the incentive structures faced by many researchers, be they within universities or in other research organizations. For example, the issue of behaviour modification in response to the measuring of research output is discussed by Talib (2001) who reported on studies conducted over a number of years in the context of the United Kingdom's Research Assessment Exercise (RAE). His 1998 survey findings showed that the RAE time scale and the perceived preferences of the RAE panel members were increasingly influencing the choice of research topic, and creating a rush to publish prematurely and to recycle papers. A tendency for 'gaming' was also noted in a recent review of the RAE (Roberts 2003).

The mix of traditional and new modes of knowledge production varies between both fields of research and between loci of research. Gibbons (2001) noted that:

> *Research carried out in the context of application might be said to characterise a number of disciplines in the applied sciences and engineering – eg. chemical engineering, aeronautical engineering or… computer science. Historically these sciences became established in universities but, strictly speaking, they cannot be called applied sciences, because it was precisely the lack of the relevant science that called them into being. They were genuinely new forms of knowledge though not necessarily of knowledge production because, they too, soon became the sites of disciplinary-based knowledge production in the style of Mode 1. These applied disciplines share with Mode 2 some aspects of the attribute of knowledge produced in the context of application. But, in Mode 2 the context is more complex. It is shaped by a more diverse set of intellectual and social demands than was the case in many applied sciences… While it may give rise to genuine basic research… it is increasingly in computer, materials, bio-medical and environmental sciences that theories are developed in the context of application and… these continue to fertilise lines of intellectual advance that lie outside disciplinary frameworks* (Gibbons 2001).

Others have noted the relative mixes of Mode 1 and Mode 2 research in various fields, and how some have pursued 'scientisation' (eg. economics) while others have pursued mixed modes (eg. management) (Van Aken 2001).

The OECD recently noted that industry-science relationships are undergoing fundamental changes, prompted by globalisation and other factors, as part of an overall trend towards accelerated development of a market for knowledge. The most visible transformations are the emergence of broad alliances between universities and firms, and growing activity in the realm of commercialisation of results through licensing of intellectual property and spin-off companies (OECD 2002, p7). This echoes and reinforces the points made by Etzkowitz and Leydesforff (1997) in relation to the emergence of a triple helix, suggesting that it is an OECD-wide, if not worldwide phenomenon.

Different loci of research also vary as to their share of modes. Universities are often portrayed as the last bastion of disciplinary research, and some have foreseen the marginalisation and decline of universities as loci of research. Godin and Gingras (2000) suggested instead that universities will in fact remain the centre of the knowledge production system, and that other sectors, such as hospitals, private industry and government laboratories will remain closely linked. The pre-eminence of the university system is reiterated in the work of Guena (1999) who is one of the many writers to examine the move to commercialisation and its impact on research. He provided a detailed analysis of funding models for knowledge production in universities in the European Union, including the United Kingdom, and concluded that increasing competition for research funding has led to the polarisation of universities into two groups: a small group of research-focused universities and a larger group with a lesser focus. The roles of different sorts of universities in pursuit of predominantly Mode 1 versus Mode 2 research has also been noted in Australia (Ronayne 1997). There are also wide differences between the mixes and modes of research in government research institutes in various countries (Meyer-Krahmer 1997).

Importantly for this project, there are fundamental information and communication differences between the traditional and emerging modes of knowledge production. Mode 1 research has formalised systems for scholarly communication, peer review and quality control, and for education, training and accreditation. Mode 2, on the other hand, tends to rely more on informal modes of communication and dissemination. Hicks et al. (1997) noted that the pattern of publications in the natural sciences shows a move by researchers towards publishing in interdisciplinary or transdisciplinary journals. Gibbons (2001) noted that, because of the interdisciplinary, interactive and dispersed nature of Mode 2 research, Mode 2 is critically dependent on emerging computer and communication technologies. Gibbons also noted that communication among scientists is influenced by two factors: one is their mobility, while the second relates to how they set priorities and select problems. He suggested that interdisciplinarity has been facilitated through the availability of improved means of communication (Meyer-Krahmer 1997, p309). Turpin et al. (1996) noted that, in Australia, there is strong evidence to suggest that [knowledge] transfers between academic research and industry are led by the movement of people and the establishment of broad-ranging personal networks. Again emphasising the importance of informal mechanisms of communication and dissemination.

It is important to note that most analysts see Mode 1 and Mode 2 research operating in parallel, with the new mode of knowledge production supplementing rather than replacing traditional 'science'. Indeed, as ideal types, Modes 1 and 2 present in mixes. Foray (1997, p81), a proponent of the Systems of Innovation approach, noted a "splitting behaviour and the survival of knowledge openness through a complentarity relationship." Similarly, Gibbons (2001) suggested that:

> *Although Mode 1 and Mode 2 are distinct modes of production, they interact with one another. Specialists trained in the disciplinary sciences do enter Mode 2 knowledge production. While some may return to their original disciplinary base others will choose to follow a trail of complex solving [of] problems that are set by a sequence of application contexts. Conversely, some outputs of transdisciplinary knowledge production, particularly new instruments may enter into and fertilise any number of disciplinary science* (Gibbons 2001).

Mode 2 knowledge will not supplant the traditional disciplinary structure of Mode 1 knowledge, but supplement it and interact with it (Ang 1999). As McWilliams et al. (2002) noted, they are complementary and contemporary rather than competing and exclusive modes of knowledge production. There are, then, many inter-dependencies, which suggest that both Mode 1 and Mode 2 research will continue to exist in parallel, and enough fundamental difference to suggest that the absorption of either one by the other will be difficult.

There have been a number of studies exploring the ways in which such changes are affecting universities in Australia, and they suggest that many of the trends identified internationally are also observable in Australia (Coaldrake and Stedman 1998; Slaughter and Leslie 1999; Martin 1999; Marginson and Considine 2000; Anderson et al. 2002). Cooper et al. (2002) suggested that the transformation of universities follows the emergence of the global knowledge economy and related social changes, with increased attention to knowledge in use undermining the traditional role of the university and creating divergent and conflicting demands. Clearly, there is a tension between traditional disciplinary (Mode 1) research and open access, on the one hand, and emerging new forms of knowledge production (Mode 2) and application, on the other.

When the traditional system of research scholarly communication is disrupted and alternative parallel systems emerge, *and* there is a need for communication between the parallel modes and for cross-fertilization, the development of research information infrastructure and provision of information resources becomes much more challenging – perhaps even more challenging than many have yet realised.

2.2 Changing nature of research

The remainder of this chapter presents a brief review of quantitative indicators of change in research activities in Australia. It reveals that many of the changes noted in the literature on the changing nature of knowledge production can be observed in the long-term trends in research in Australia. Readers willing to take our word on that may wish to skip to chapter 3.

2.2.1 Level of expenditure and source of funds

As in other countries, there is increasing recognition of the value of R&D activities and their contribution to economic and social development. This is driven, in part, by increased awareness of the emerging global knowledge-based economy and the realisation that future prosperity is likely to be increasingly tied to the production and application of knowledge. In Australia, annual national expenditure on R&D increased from AUD 364 million in 1968-69 to AUD 10 251 million in 2000-01, or by 11% per annum over the last 32 years.[2]

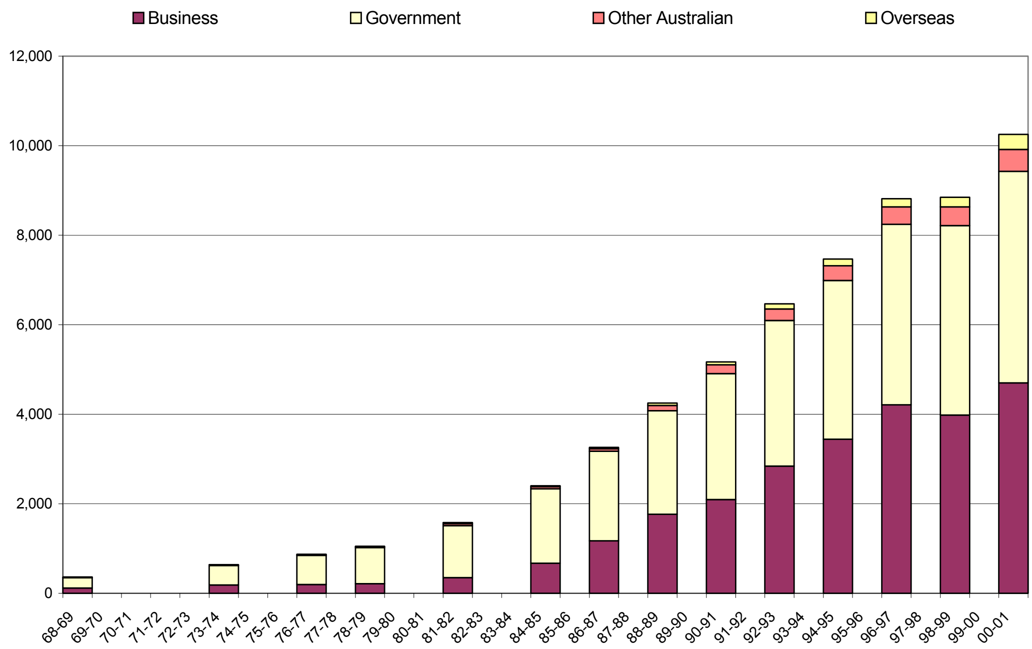
Within that overall increase there have been some significant changes in the sources of funding. The business sector has increased its proportional contribution, while governments have reduced theirs. From AUD 118 million in 1968-69, the business sector's annual funding of R&D increased to AUD 4 702 million in 2000-01 – by 12% per annum. Commonwealth government funding of R&D increased by 10% per annum, from AUD 169 million in 1968-69 to AUD 3 923 million. Over the same period, state government funding of R&D increased by 8.5% per annum, from AUD 60 million to AUD 804 million. As a result, the business sector increased its share of total R&D funding from 32% to 46%, while government's share declined from 63% to 46%.

Reflecting the globalisation of research activities, overseas sources increased their funding of R&D in Australia by almost 12% per annum, from AUD 9 million in 1968-69 to AUD 336 million in 2000-01. This, while still relatively small, suggests that Australian research is increasingly linked into international R&D activity. These data on the sources of research funding suggest that there are increasing linkages between business and research, with quite substantial shifts in funding from sector to sector.[3]

2 All expenditure data are presented in current values.

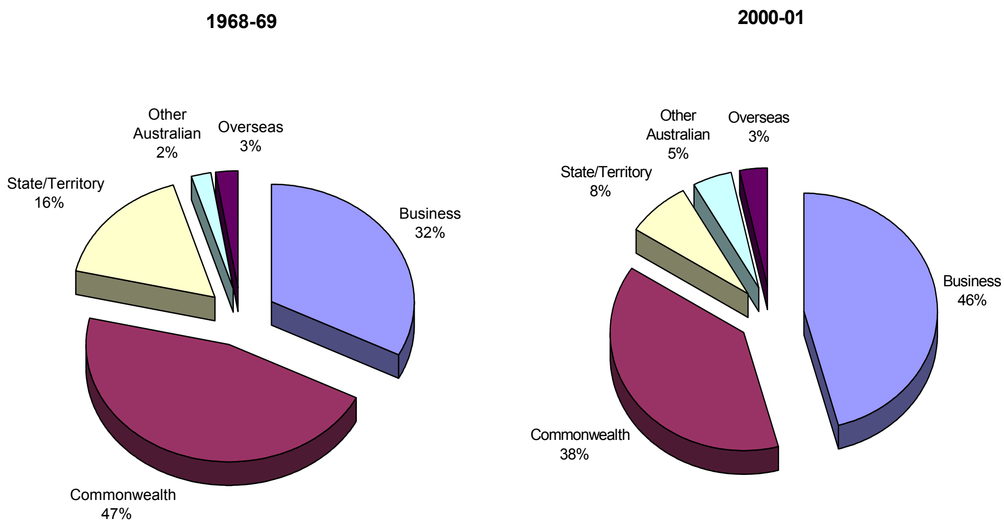
3 Funding is a less than perfect indicator of linkages between research and business for a variety of reasons. For example: there may be many valuable interactions that do not involve cash flows; and direct funding arrangements (eg. agricultural research levies) are not captured.

Figure 2.1 R&D expenditure by source of funding, 1968–69 to 2000–01 (AUD m)



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Figure 2.2 R&D expenditure by source of funding, 1968–69 and 2000–02 (%)

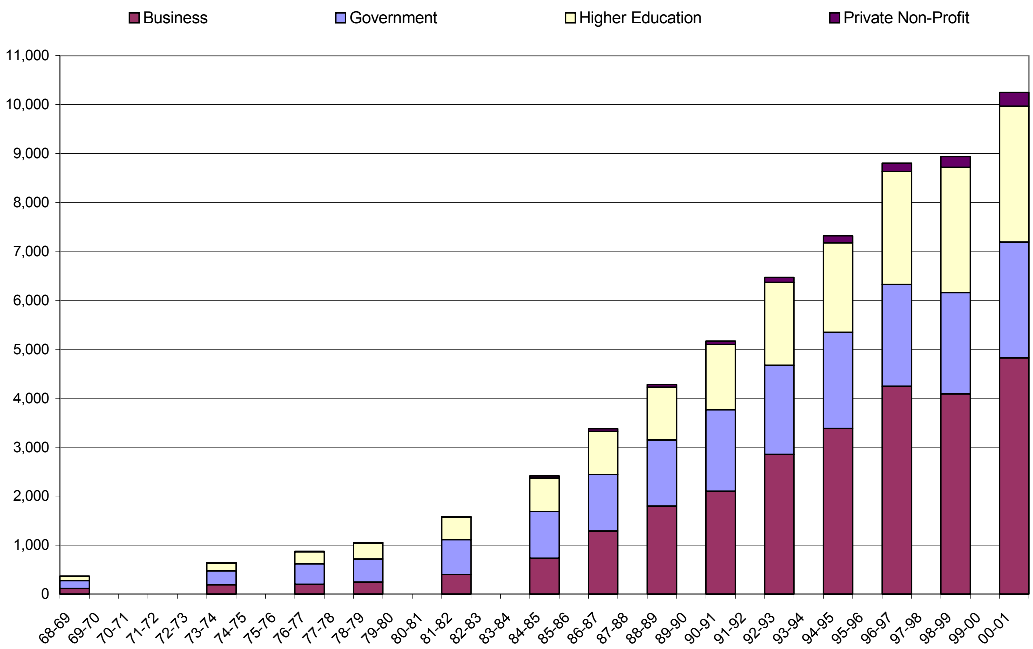


Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

2.2.2 Location of research activity (expenditure)

Over the last 32 years, expenditure on R&D by private non-profit organizations has increased most rapidly, but at just 2.8% of total expenditure it remains very small. Annual business sector expenditure on R&D has increased from AUD 119 million in 1968-69 to AUD 4 825 million in 2000-01 (by 12% per annum) and higher education expenditure has increased from AUD 86 million to AUD 2 775 million (by 11% per annum). Government expenditure has grown more slowly. Commonwealth government expenditure on R&D increased from AUD 117 million in 1968-69 to AUD 1 425 million in 2000-01 (by 8% per annum), while state, territory and local government expenditure increased from AUD 40 million to AUD 944 million (by 10% per annum).

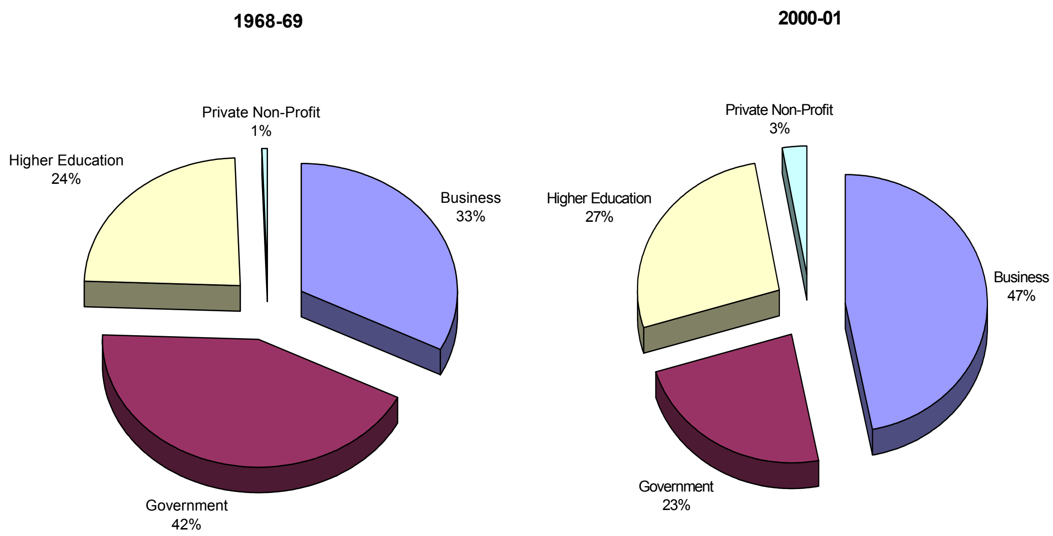
Figure 2.3 R&D expenditure by sector of performance, 1968–69 to 2000–01 (AUD m)



Source ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

As a result, the business and higher education sectors have increased their share of R&D expenditure in Australia, while government's share has fallen. The business sector increased its share of total R&D expenditure from 33% in 1968-69 to 47% in 2000-01, the higher education sector increased its share from 24% to 27% and the private non-profit sector increased its share from 0.7% to 2.8%. Over the same period, the share R&D expenditure within Commonwealth Government declined from 32% of total to just 14%, while state governments' share fell from 11% to 9%. Thus the increase in the influence of the business sector both as a source of funding *and* as a location for the performance of research is clearly evident.

Figure 2.4 R&D expenditure by sector of performance, 1968-69 and 2000-01 (%)



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

It is notable that the higher education sector plays a more significant role in R&D activity in Australia than is often the case elsewhere. For example, 'academic' R&D is reported to have accounted for around 12% of R&D expenditure in the United States during 1999, 18% in France, 17% in Germany, 15% in Japan and 20% in the United Kingdom – compared with 29% in Australia (National Science Board 2002, p5-10).

2.2.3 Source of funding by sector of expenditure

Looking at the source of funding by sector of expenditure reveals something of the extent and pattern of linkages and interactions between the various organizations and sectors involved in funding and performing research. It reveals a number of interesting points.

Looking at column shares of R&D funding during 2000-01 (Table 2.2 below):

- 94% of business sector R&D funding goes to the business sector, and 3% goes to higher education – suggesting still somewhat limited private sector support for higher education research;
- 81% of state government R&D funding goes to state institutions and 11% to higher education – suggesting limited engagement between state governments and the business sector (although it should be noted that these data do not fully reflect significant expenditures by state governments on economically and socially oriented consultancies);

- 62% of overseas funding goes to the business sector, 18% to higher education and 10% to Commonwealth Government organizations – probably reflecting the mix of organizations from which it is sourced, more than their cross-funding support for each other; and
- 61% of Commonwealth Government funding goes to higher education, 31% to Commonwealth organizations and just 4.4% to the business sector (although it should be noted that this understates government support for industry R&D through the R&D tax concession and a variety of sectoral research levies).

Table 2.2 R&D expenditure by source of funds and sector of expenditure, 2000–01 (%)

Source of funds / *Sector of expenditure*	*Comm'*	*State*	*Business*	*Other*	*Overseas*	*Total*
Business	4.4	1.0	93.9	4.7	61.7	47.1
Commonwealth	30.9	3.4	1.6	15.0	10.2	13.9
State/Territory	1.8	80.9	1.2	32.9	2.3	9.2
Higher Education	61.1	10.9	2.9	19.4	18.0	27.1
Private - Non-Profit	1.8	3.7	0.4	28.0	7.8	2.8
Total	100.0	100.0	100.0	100.0	100.0	100.0
Business	3.5	0.2	91.5	0.5	4.3	100.0
Commonwealth	85.1	1.9	5.4	5.1	2.4	100.0
State/Territory	7.6	68.9	5.8	16.9	0.8	100.0
Higher Education	86.3	3.2	4.9	3.4	2.2	100.0
Private - Non-Profit	25.6	10.5	6.5	48.1	9.3	100.0
Total	38.3	7.8	45.9	4.7	3.3	100.0

Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Looking at row shares of R&D funding during 2000-01:

- 92% of business spending on R&D is funded by the business sector, 4.3% is funded from overseas (reflecting the activities of multinational corporations in Australia) and 3.5% is funded by the Commonwealth Government (again, this number is somewhat understated);
- 86% of higher education R&D spending is funded by the Commonwealth Government and 5% is funded by business – suggesting increasing, but still somewhat limited private sector support for university research;
- 85% of Commonwealth spending is funded by the Commonwealth Government; and
- almost 70% of state and territory government R&D spending is funded by state and territory governments.

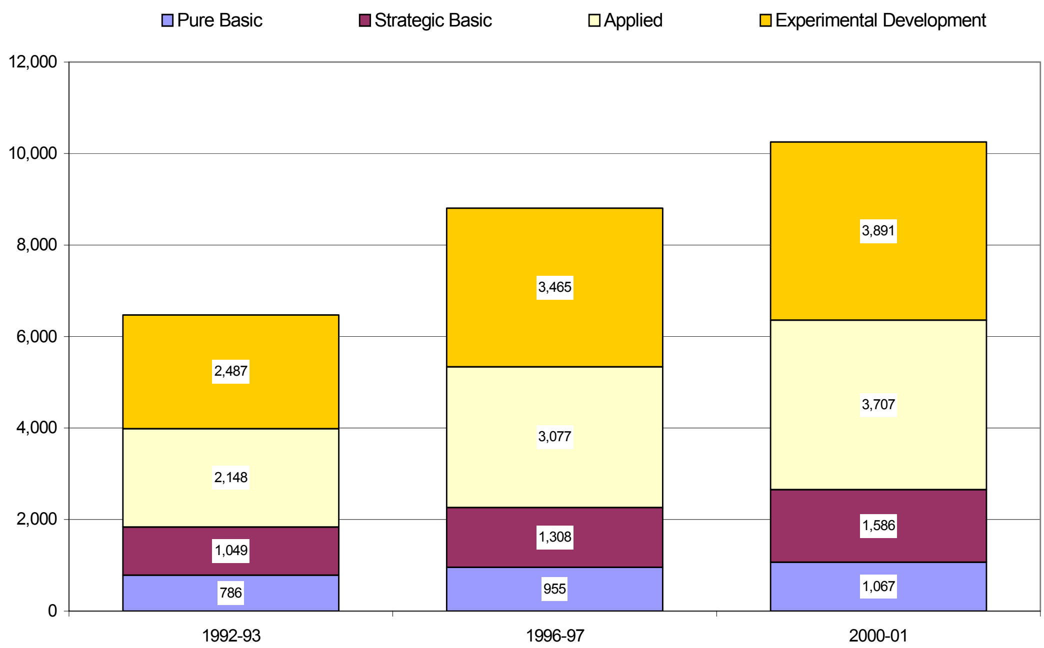
In so far as funding indicates interaction, these data suggest a limited level of interaction between private and public sector research activities and funding.

However, as noted later, the level of scientific collaboration, and of patent citation of public science would suggest that cross-fertilisation and commercialisation are much more significant than these direct funding linkages reveal.

2.2.4 Type of research activity (basic or applied)

There is increasing emphasis on applied research, which increased from AUD 2.1 billion to AUD 3.7 billion over the period, or by 7.1% per annum. Expenditure on experimental development increased by 5.8% per annum, from AUD 2.5 billion to AUD 3.5 billion, while expenditure on basic research has grown more slowly – strategic basic research by 5.3% per annum and pure basic research by 3.9% per annum.[4]

Figure 2.5 R&D expenditure by type of activity, 1992-93 to 2000-01 (AUD m)



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

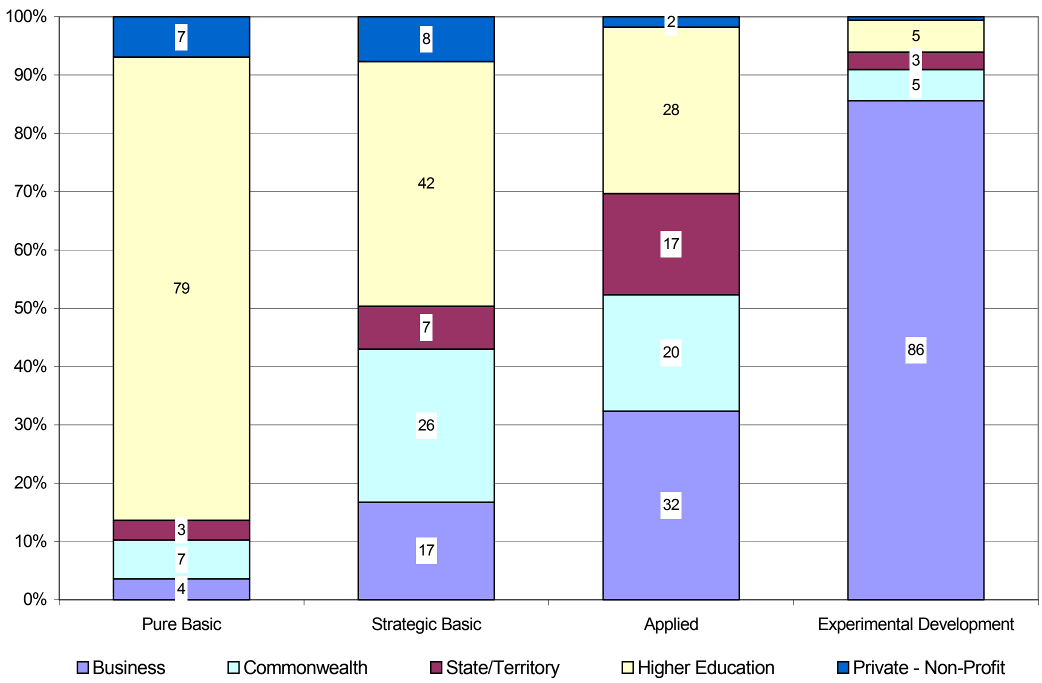
In 1992-93, experimental development accounted for 38% of R&D expenditure in Australia, applied research for 33%, strategic basic research for 16% and pure basic research for 12%. By 2000-01, applied research had increased its share of total R&D expenditure to 36%, while experimental development accounted for a steady

4 While it is widely recognised that the traditional distinction between pure and applied research is breaking down, as 'pure' research increasingly leads quite directly to commercial outcomes and applied research increasingly feeds back into discovery, it remains a useful framework within which to explore long-term trends of funding and focus.

38%. Both pure basic research, down to 10%, and strategic basic, down to 15.5%, lost share. So there has been a shift in emphasis away from pure research towards applied and developmental activities, which likely reflects the increased influence of the business sector and, perhaps, a shift in the mix of research activity from traditional disciplinary science to more applied, interdisciplinary activities (eg. environmental sciences, biotechnology, etc.).

In 2000-01, 79% of pure basic research was conducted within higher education. Conversely, no less than 86% of expenditure on experimental development took place in the business sector. The majority of commonwealth and state government activity is in the strategic basic to applied areas – with commonwealth activity favouring strategic basic research and state activity favouring applied research. These patterns are as one would expect. However, looking more closely at growth rates in various types of R&D expenditure reveals some interesting developments.

Figure 2.6 Type of R&D activity by sector of performance, 2000-01 (%)



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Discounting the private non-profit sector, which is very small and growing rapidly from a low base, the fastest growth in experimental development and applied research expenditures occurred in higher education – at 9.5% and 9.3% per annum over the period 1992-93 to 2000-01, respectively. The higher education sector recorded the slowest growth of all sectors in pure basic research expenditure, at 2.9% per annum. Conversely, strategic basic and pure basic research expenditure in the business sector increased by 8.3% and 7% per annum, respectively; while applied research and experimental development expenditure increased more slowly

– by 6.8% and 6.6% per annum, respectively. Commonwealth Government organizations, such as the CSIRO, increased their pure basic research expenditure by 9.1% per annum over the period 1992-93 to 2000-01, while experiencing a decline in experimental development expenditure of 3.2% per annum.

Table 2.3 Annual change in R&D expenditure by sector and activity, 1992-93 to 2000-01 (%)

	Pure Basic	*Strategic Basic*	*Applied*	*Experimental Development*	*Total*
Business	7.0	8.3	6.8	6.6	6.8
Government	7.3	2.0	5.1	-2.2	3.4
- Commonwealth	9.1	2.3	4.9	-3.2	2.7
- State/Territory	4.3	1.0	5.5	0.0	4.4
Higher Education	2.9	6.5	9.3	9.5	5.6
Private Non-Profit	13.8	10.9	19.0	19.5	13.7
Total	3.9	5.3	7.1	5.8	5.9

Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

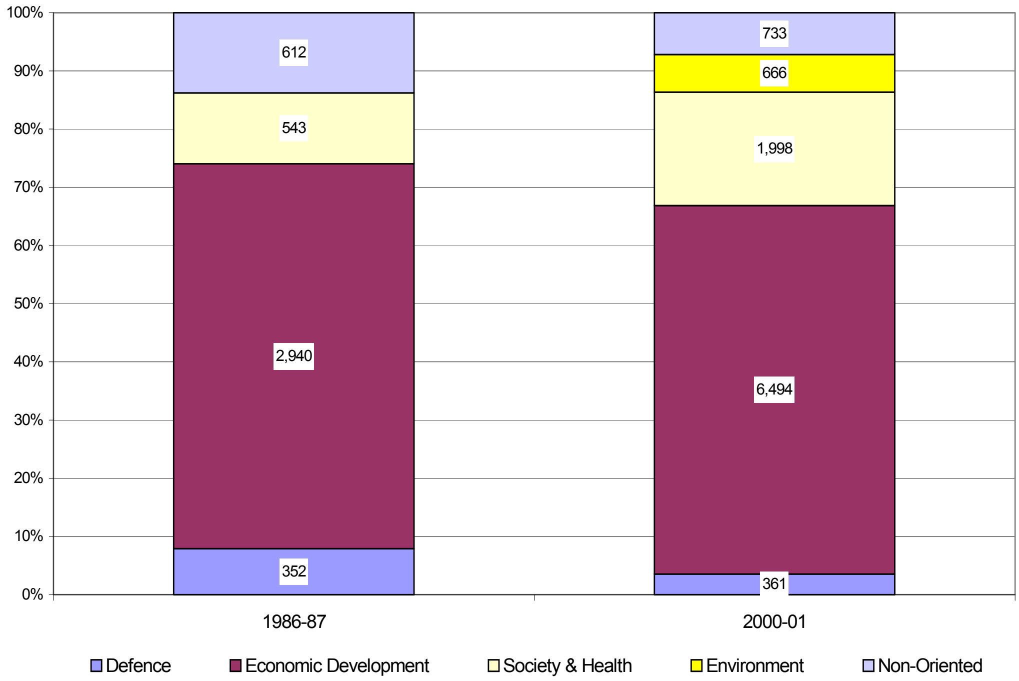
It is still overwhelmingly the case that higher education R&D activity is focused on pure/basic research, while business sector R&D activity is focused on experimental development. However, these growth trends reflect a restructuring of research activities, and some diversification of the locus of research. Both the business sector and government appear to be increasing their involvement in basic research, while there is an increasing emphasis in higher education institutions on applied research and experimental development. While still small, these shifts could have a significant impact on researcher perceptions and on their research practices (National Science Board 2002, p5-36). These trends reflect the kinds of changes, convergences and cross-overs widely noted in the literature on changing modes of knowledge production, and reveal the dynamics and modalities of change with Australian research.

2.2.5 Objectives of research activity

Looking at R&D activities according to their socio-economic objective gives another perspective on the changing emphases of research activities, particularly in regard to shifts towards problem oriented (Mode 2) research. Over the period 1986-87 to 2000-01, expenditure on R&D by socio-economic objective (SEO) increased by 6% per annum. Society and health (10% per annum) and economic development (6% per annum) were the fastest growing areas, while expenditure on non-oriented research (broadly speaking, pure/basic research) increased by just 1.3% per annum.

Increases in expenditure on economic development as an SEO were experienced across the sectors – increasing by 9.8% per annum in higher education, 9% per annum in the business sector and 4.8% per annum in government. Expenditure on non-oriented research increased 4.2% per annum in the higher education sector, but declined in other sectors – eg. by 8% per annum in government, driven by a 9.5% per annum decline in commonwealth government institutes.

Figure 2.7 Trends in R&D expenditure by socio-economic objective, 1986-87 to 2000-01



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

These trends, which see declines in non-oriented research expenditure, reflect a shift towards research activities that are less disciplinary and more problem oriented (eg. environment, society and health) – a shift from Mode 1 towards Mode 2 research.

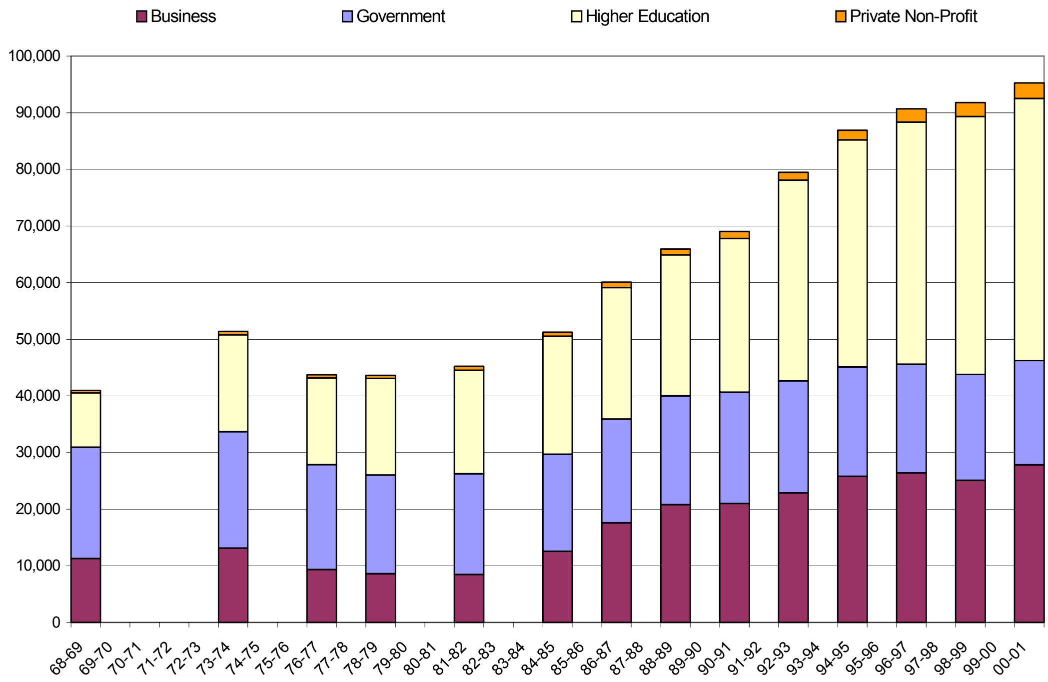
2.2.6 Human resources devoted to research

The number of people engaged in research has also grown, but not as fast as has expenditure on research. In 1968-69, there were 41 000 people employed in research (ie. person years devoted to R&D). By 2000-01, this had increased to more than 95 250. Hence, research employment has grown 2.7% per annum over the last 32 years, compared with an 11% per annum increase in expenditure. Discounting inflation, these trends are consistent with both increased capital intensity of research and increased labour productivity in research.

In 2000-01, 46 287 or approximately 50% of all Australian research workers were employed in the higher education sector, making it the largest employer of researchers. Some 27 839 or 30% were employed in the business sector, and a further 2 721 or less than 3% were employed by private non-profit organizations.

The remaining 18 408 (20%) were employed in government organizations – 9 711 (10%) by commonwealth government and 8 697 (9%) by state, territory and local governments.

Figure 2.8 Human resources devoted to R&D by sector, 1968-69 to 2000-01 (number)

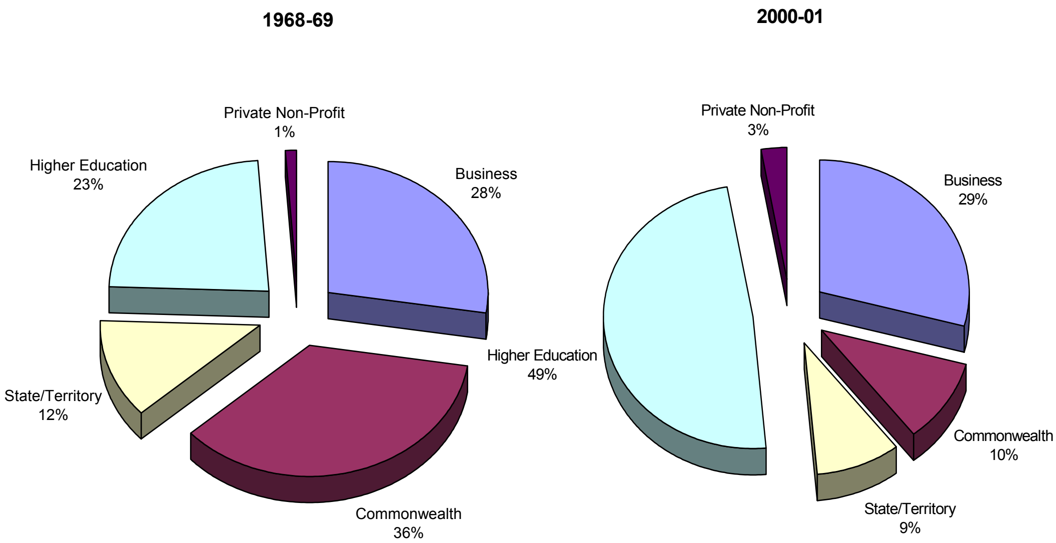


Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Higher education, and private non-profit organizations, have experienced higher rates of increase in research employment over the last 32 years than other sectors. Private non-profit institutions increased their research employment from 438 in 1968-69 to 2 721 in 2000-01, or by almost 6% per annum. Higher education, the largest sector, increased research employment from 9 580 to 46 287, or by just over 5% per annum. Research employment in the business sector increased by less than 3% per annum over the period. Government research employment has declined over the last 32 years – from 19 648 in 1968-69 to 18 408 in 2000-01, or by 0.2% per annum. The loss has been in commonwealth government organizations, down from 14 671 to just 9 711 (by 1.3% per annum). State and territory governments' research employment has increased over the period, by 1.8% per annum.

In percentage terms, higher education has been the sector with the largest gain in research employment over the last 32 years – accounting for 23% of total national research employment in 1968-69, compared with 49% in 2000-01. Conversely, the Commonwealth Government has experienced the biggest declines – accounting for 36% in 1968-69, compared with just 10% in 2000-01. Other sectors, including the business sector and state and territory governments account for much the same share of research employment now as they did 30 years ago.

Figure 2.9 Human resources devoted to R&D by sector, 1968-69 and 2000-01 (%)



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

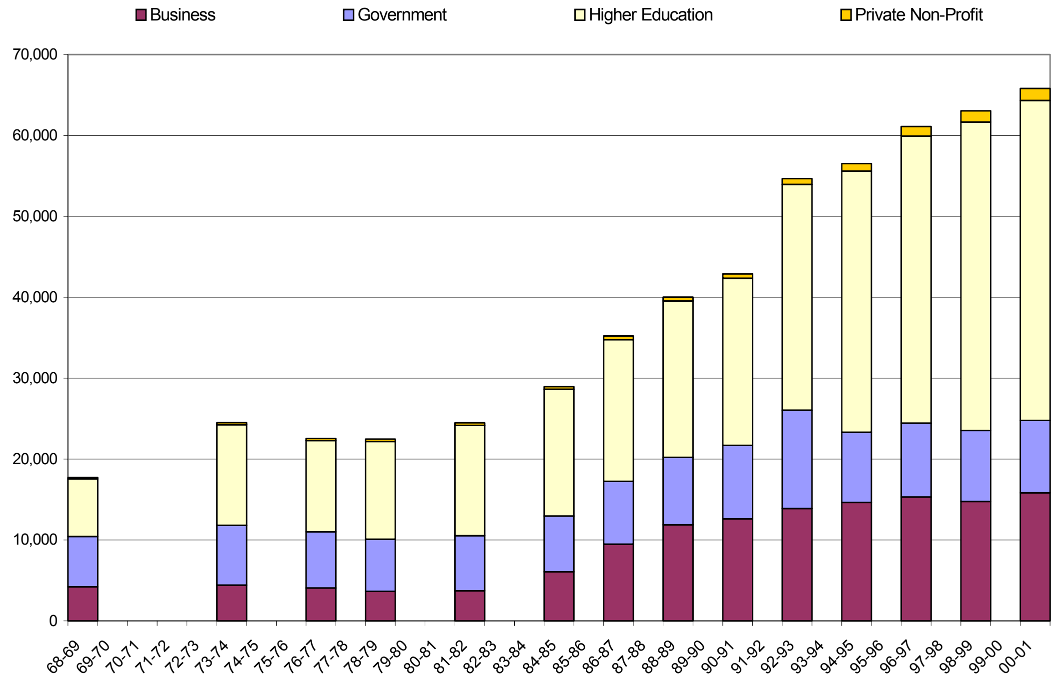
Scientists and engineers

Not all of those employed in research are scientists and engineers (ie. *researchers*). R&D surveys also count research management and administration personnel. In 2000-01, 19 485 or 69% of the person years employed on research in Australia were classified as researchers, with the remainder being classified as technical and support staff.

The number of *researchers* employed in Australia increased from 17 734 in 1968-69 to 65 805 in 2000-01. Higher education is the largest employer of researchers, with 39 507 or 60% of the total in 2000-01. The business sector employed a further 15 830 (24%), and governments a further 8 972 (14%) – 4 524 in Commonwealth Government organizations and 4 448 in state and territory government institutions.

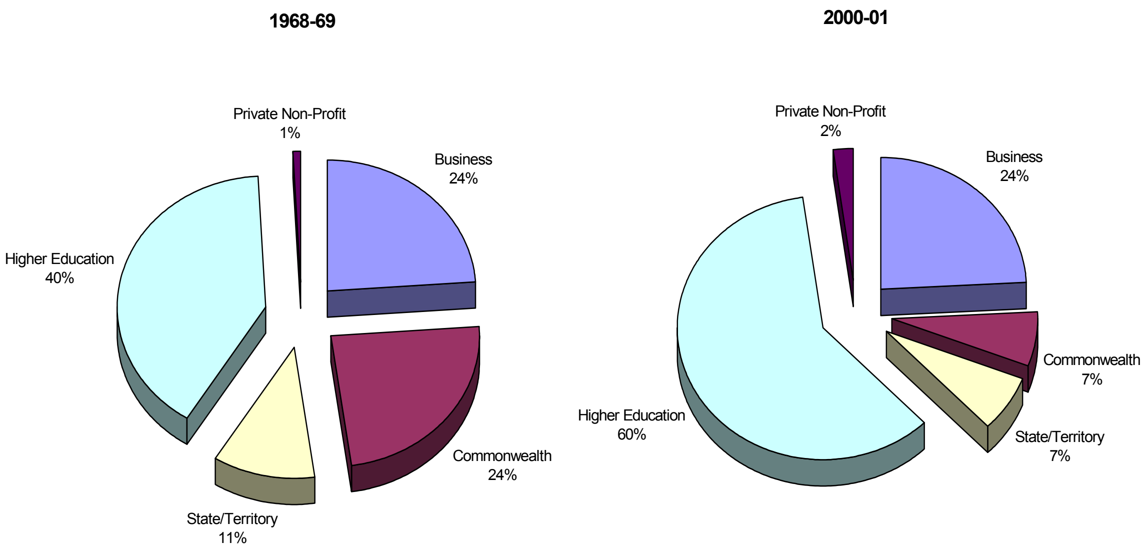
The higher education sector experienced the largest growth in research employment – from 7 132 in 1968-69 to 39 507 in 2000-01 and increasing 5.5% per annum. Private non-profit organization also experienced a relatively high rate of growth in research employment, but numbers remain low (less than 1 500 people in 2000-01). The employment of researchers in the business sector increased by 4.2% per annum, from 4 222 in 1968-69 to 15 830. Employment of researchers by government has grown much more slowly (1.2% per annum). In 1968-69, the Commonwealth Government employed 4 215 researchers, rising to 4 524 in 2000-01 – an increase of just 0.2% per annum. Over the same period, state and territory governments increased their employment of researchers from 1 957 to 4 448 – an increase of 2.6% per annum.

Figure 2.10 Researchers devoted to R&D by sector, 1968-69 to 2000-01 (Number)



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Figure 2.11 Share of researchers (RSE) devoted to R&D by sector, 1968-69 and 2000-01

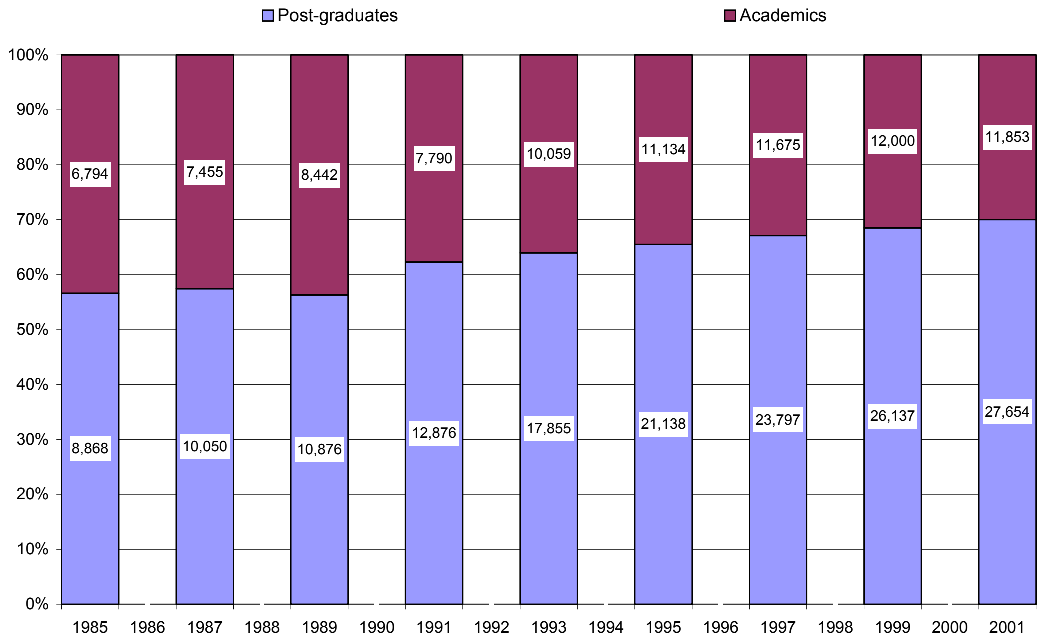


Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Over the period 1968-69 to 2000-01, the higher education sector increased its share of researcher employment from 40% to 60%. The largest proportional decline was in Commonwealth Government, which accounted for 24% of researcher employment in 1968-69 compared with just 7% in 2000-01. Other sectors have maintained relatively stable shares of overall researcher employment over the last 30 years.

Over the last 30 years there has also been a significant increase in the share of employment in research accounted for by researchers, and a fall in the level of technical and support staff. In 1968-69, researchers accounted for 43% of total R&D employment in Australia. By 2000-01, their share had increased to 69%. The relative share of researchers is highest in higher education, where researchers accounted for 74% of R&D employment in 1968-69 rising to 85% in 2000-01. Researchers accounted for: 37% of R&D employment in the business sector in 1968-69, rising to 57% in 2000-01; 39% of R&D employment in the private non-profit sector in 1968-69, rising to 55%; 39% of R&D employment in state and territory government in 1968-69, rising to 51%; and 29% of R&D employment in Commonwealth Government in 1968-69, rising to 47%. These data suggest an increase in the administrative load on researchers, most especially in the higher education sector, and a decline in research support.

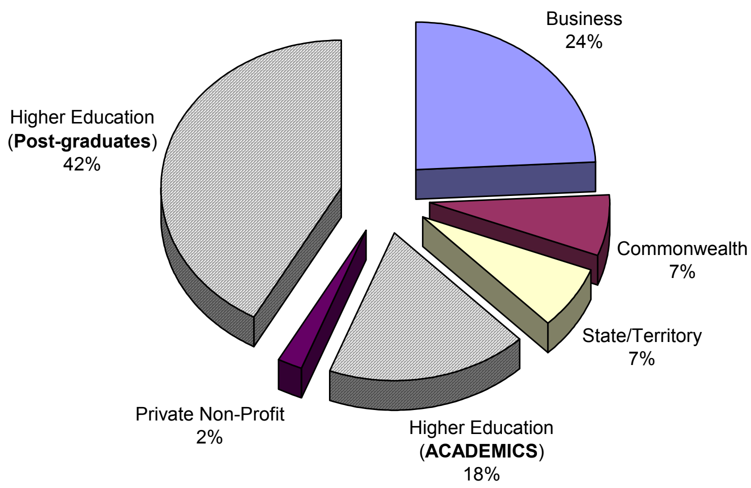
Figure 2.12 Post-graduate and academic researchers in higher education, 1985 to 2001 (per cent)



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

One factor that must be borne in mind when interpreting researcher employment in the higher education sector is that the definition includes both academics and post-graduate students enrolled in research degrees. The number of postgraduates has been increasing faster than the number of academic researchers. In 1984-85, postgraduates accounted for 57% of total researchers employed in higher education – ie. 8 868 out of a total 15 662. By 2000-01, the proportion of postgraduates had increased to 70% – ie. 27 654 out of a total 39 507. These trends suggest an significant increase in the research teaching load of academic researchers.

Figure 2.13 Researchers by sector, 2000-01 (%)



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Excluding postgraduates, there were around 38 000 researchers in Australia in 2000-01. Showing post-graduates separately makes a significant difference to the perception of sector shares, with academic researchers accounting for around 20% of total research employment in Australia in 2000-01 and postgraduates for 40%. If postgraduate research training is considered education rather than research, the sectoral distribution of research activity in Australia looks very different.

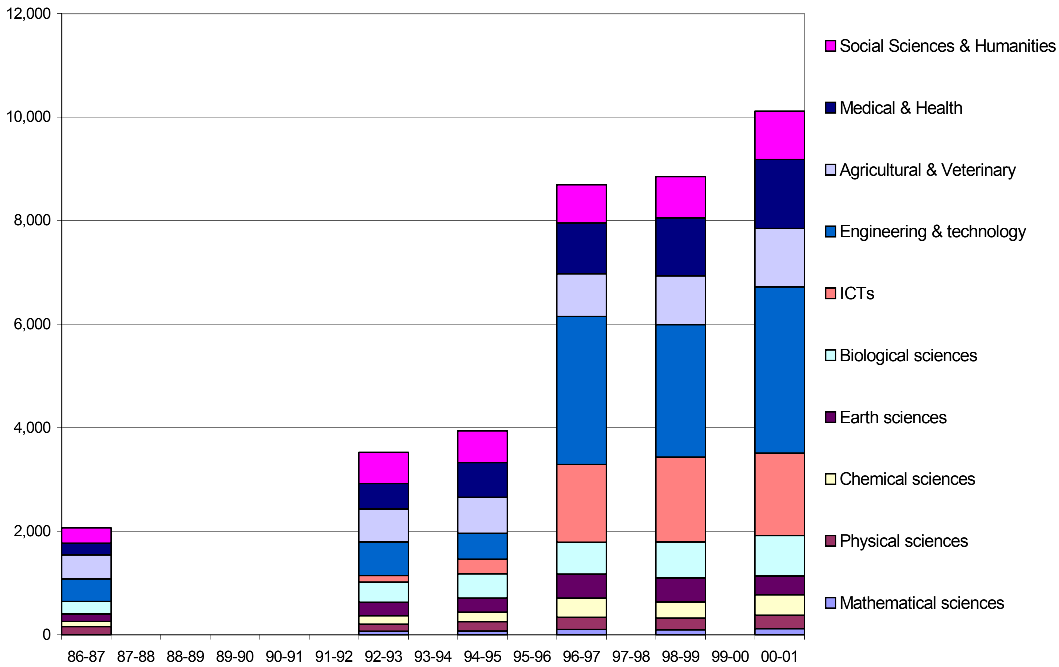
2.2.7 Fields of research

Detailed data relating to fields of research are limited. Nevertheless, it is possible to gain some insights into the changing focus of research and changes in the relative mix of research fields and disciplines.

At an estimated AUD 3 210 million in 2000-01, engineering and technology are the largest field(s) of research by expenditure. Information and communication technology (ICT) related expenditure reached AUD 1 592 million in 2000-02, medical and health science related expenditure AUD 1 331 million, agricultural, veterinary and environmental sciences expenditure AUD 1 132 million, social sciences and humanities AUD 932 million, and biological science AUD 783 million.

No other field of research received more than AUD 400 million during 2000-01. Clearly, the applied and interdisciplinary fields of research are bigger than are the traditional disciplines.

Figure 2.14 R&D expenditure by field of research, all sectors 1986-87 to 2000-01 (AUD m)

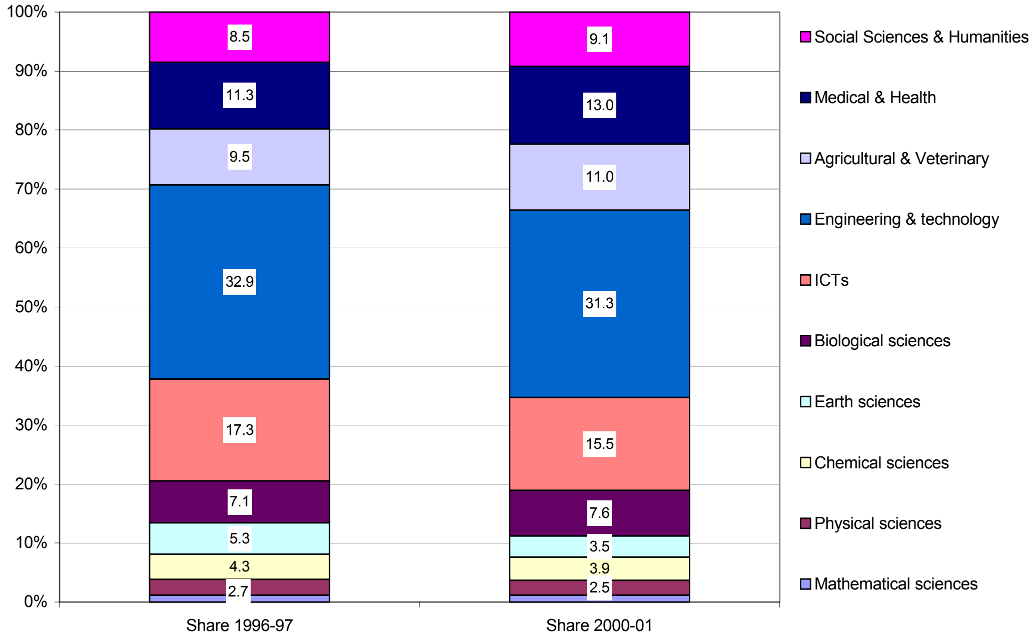


Note: Business sector not included until 1996-97.
Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Limited comparable time series data are available, because business sector R&D was not classified by field of research until 1996-97. Consequently, it is possible to explore all sectors over the period 1996-97 to 2000-01, and public sector R&D over the longer period 1986-87 to 2000-01.

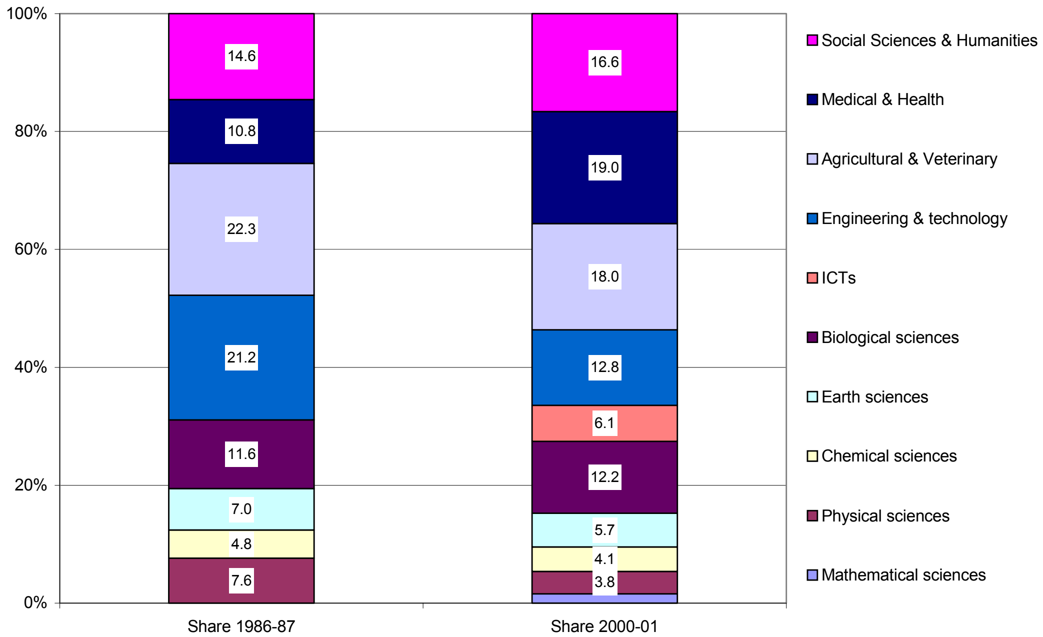
Doing so reveals that between 1996-97 and 2000-01, annual expenditure on R&D by field of research increased from AUD 8 693 million to AUD 10 251 million, or by 4.2% per annum. Faster growth was experienced in agriculture, veterinary and environmental sciences (8.2% per annum), medical and health sciences (7.9% per annum), biological sciences (6.2% per annum) and social sciences and the humanities (6.0% per annum). The only field to decline over the period was earth sciences, by 6.1% per annum from AUD 464 million in 1996-97 to AUD 360 million in 2000-01. These trends suggest that the applied sciences and interdisciplinary areas of what might be called Mode 2 research have enjoyed more rapid growth over recent years than have traditional disciplinary areas.

Figure 2.15 R&D expenditure by field of research, all sectors 1996-97 and 2000-01 (%)



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Figure 2.16 Public sector R&D expenditure by field of research, 1986-87 and 2000-01 (%)



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

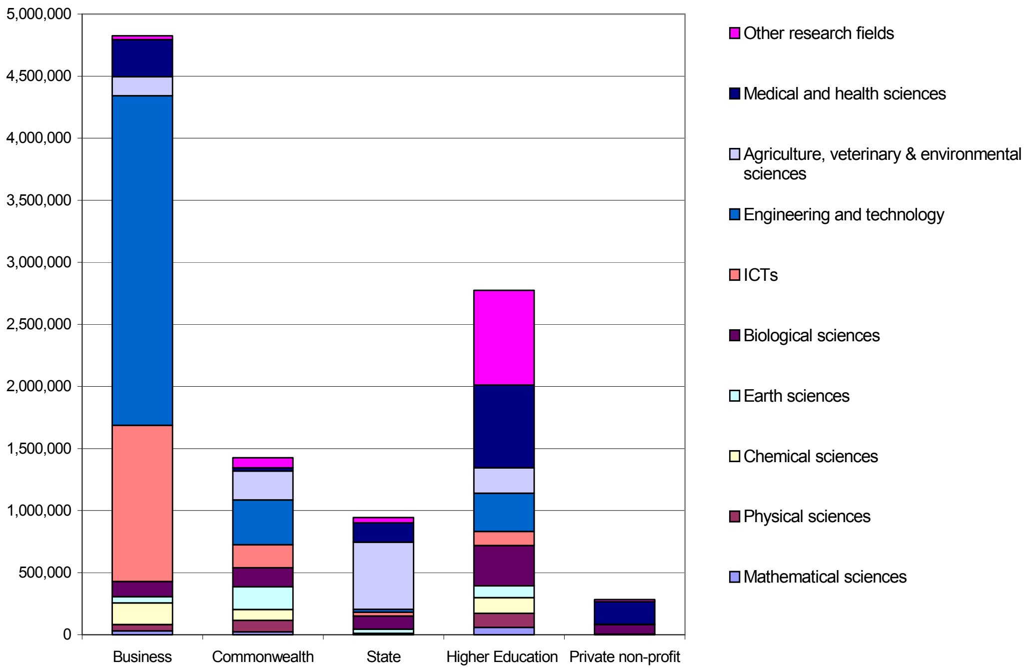
Looking at *public sector* R&D by field of research over the longer period 1986-87 to 2000-01, we find that annual expenditure increased from AUD 2 067 million to AUD 5 426 million, or by 7.1% per annum. Data are incomplete for mathematical sciences and ICT, but it is clear that there has been rapid growth in expenditure in the latter field over that period. That aside, faster than average growth was experienced in medical and health sciences (11.5% per annum), social sciences and humanities (8.1% per annum) and biological sciences (7.5% per annum).

2.2.8 Research fields by sector of performance

Looking at the location of research by research field sheds light on what types of research activity is located where, and what types of research inputs and resources various research locations might require. There are notable difference between sectors in the levels of activity in various research fields and disciplines.

In 2000-01, the business sector accounted for 79% of all R&D expenditure in Australia in the fields of ICTs and engineering and technology. The commonwealth accounted for around 11% of expenditure in these fields and higher education for a further 8% to 10%. In no other field does the business sector perform above its overall R&D spending average, making the focus of the business sector on applied and/or interdisciplinary fields clear.

Figure 2.17 R&D expenditure by field of research and by sector of performance, 2000-01 (AUD '000)



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

The Commonwealth Government was active in the earth sciences, in which it accounted for more than 50% of total national expenditure, physical sciences (36%), chemical sciences (22%) and agriculture, veterinary and environmental sciences, mathematical sciences and biological sciences, in all of which the commonwealth accounted for around 20% of total expenditure. This reflects continued focus in commonwealth institutes, such as the CSIRO, on pure research in the traditional disciplines, as well as more applied and interdisciplinary activities. State and territory governments accounted for 47% of total expenditure on agriculture, veterinary and environmental sciences, 13% of all expenditure on biological sciences and 12% of all expenditure on medical and health sciences (mainly though teaching and research hospitals).

The higher education sector accounted for 82% of total national expenditure on research in the social sciences and humanities, 50% of spending on mathematical sciences and medical and health sciences, 44% of spending on physical sciences, 41% of spending on biological sciences and 32% of national spending on chemical sciences. Much of the spending in the private non-profit sector is on medical and health sciences, through private hospitals and clinics.

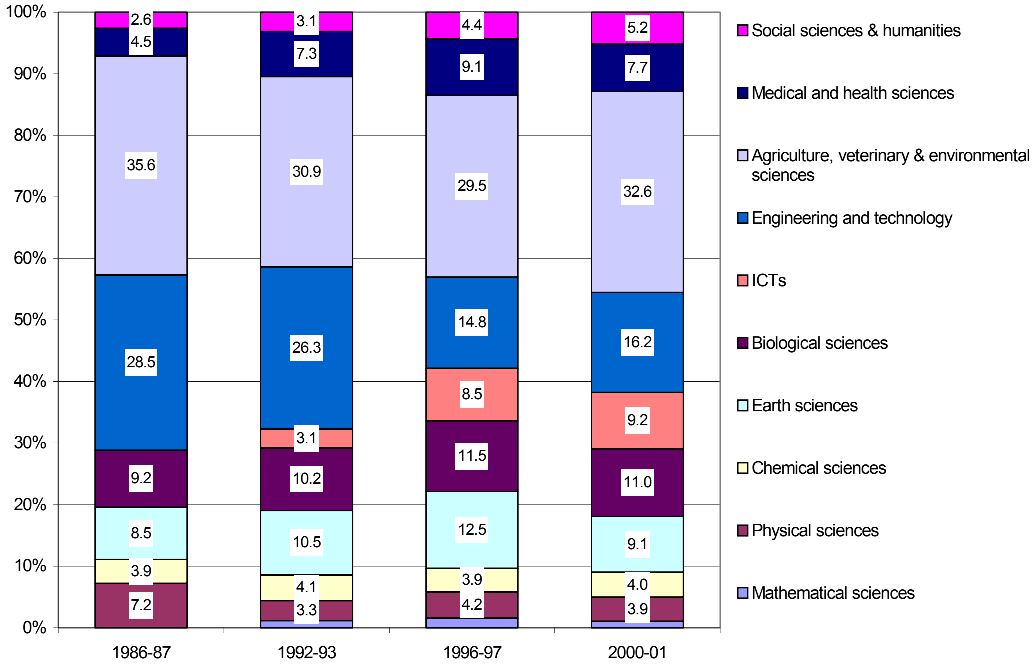
Historical data by sector and field of research are limited, with the business sector first included in field of research classification in 1996-97. Even over that limited period, however, some notable changes have occurred. The business sector has increased research in the mathematical sciences by 27% per annum, from 12% of total expenditure in that field in 1996-97 to more than 26% in 2000-01. The business sector has also increased its share of research in biological sciences from 9.5% to 16%, agriculture, veterinary and environmental sciences from 10% to 14% and medical and health sciences from 18% to 23%. No other sector has made major expenditure increases in activities by field of research. The major fall in share of activity by field of research is the Commonwealth Government's decline in mathematical sciences, from 31% of total expenditure in that field in 1996-97 to less than 20% in 2000-01. Again, the increasing activities of the private sector are evident, with an implied diversification of loci of research in those fields in which business sector activity has seen most growth.

Research in the government sector

In the government sector, annual expenditure by field of research increased from AUD 1 136 million in 1986-87 to AUD 2 368 million in 2000-01, or by 5.4% per annum. Data are incomplete, but it is clear that the most rapid increase in expenditure occurred in ICTs. Social sciences and humanities (10.6% per annum) and medical and health sciences (9.6% per annum) were the other fields experiencing strong growth over the period.

Throughout the period, however, the major foci of research activity in the government sector have been agricultural, veterinary and environmental sciences, which accounted for almost 33% of all government R&D expenditure in 2000-01, and engineering and technology, which although receiving a declining share still accounted for more than 16% of government R&D expenditure.

Figure 2.18 R&D expenditure shares by field of research in the government sector, 1986-87 to 2000-01 (%)



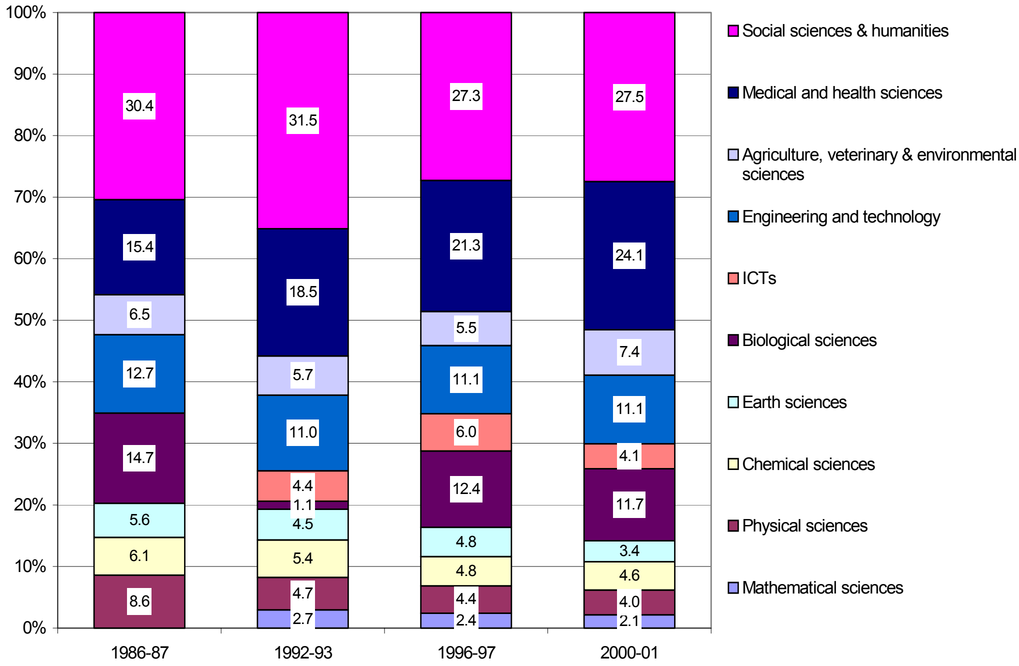
Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Research in the higher education sector

In the higher education sector, annual expenditure by field of research increased from AUD 882 million in 1986-87 to AUD 2 775 million in 2000-01, or by 8.5% per annum. Data are incomplete, but it is clear that there has been a rapid increase in expenditure on ICTs. That aside, medical and health sciences have grown most rapidly, from AUD 136 million in 1986-87 to AUD 668 million in 2000-01, or by 12% per annum. Agricultural, veterinary and environmental sciences were the only other field to experience above average growth for the sector – rising 9.5% per annum from AUD 57 to AUD 205 million.

In 2000-01, social sciences and humanities received the largest share of R&D funding in higher education, accounting for 28% of total expenditure – down from more than 30% in 1986-87. Medical and health sciences were the other major focus of activity in the sector, accounting for 24% of total funding in 2000-01 – up from 15% in 1986-87.

Figure 2.19 R&D expenditure shares by field of research in the higher education sector, 1986-87 to 2000-01 (%)



Source: ABS: compiled from various sources. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Research staffing in higher education

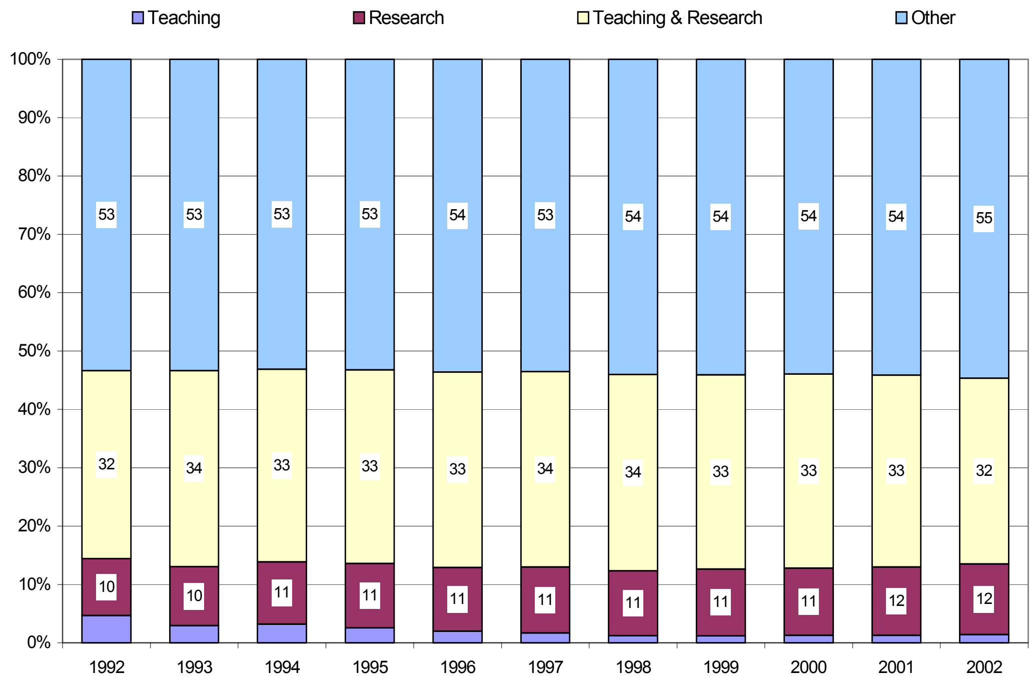
Between 1992 and 2002, higher education staff numbers increased from 73 995 to 81 145 or by 5.7%. Those classified as specialist teaching staff declined dramatically, by more than 70% from 3 472 in 1992 to 1 154 in 2002. Those classified as specialist researchers increased rapidly over the period, from 7 186 to 9 822 or by 27%.[5] Nevertheless, specialist researchers still accounted for less than 13% of total higher education staff in 2002, with a further 34% classified as both teaching and research. As these figures reveal, there are relatively few specialist researchers in the higher education sector. The majority of employees in higher education (almost 55% in 2002) neither teach nor do research.

University staff, including researchers, have felt the impacts of change in many ways. One characteristic of recent funding trends has been a decline in the share of funding received from government. The overall revenue of Australian universities increased by AUD 3.8 billion or 70% between 1991 and 2000, driven largely by a diversification of sources, with revenue raised from source other than the Commonwealth Government increasing from 27% in 1991 to 37% in 2000 (Nelson

[5] These data report full time equivalent jobs, rather than person years. Hence they differ slightly from higher education research employment numbers cited above.

2002, p31). This suggests a more diverse range of influences on the conduct of research within the higher education sector than was formerly the case.

Figure 2.20 Higher education staff by function, 1992 to 2002 (%)



Note: Includes full-time and fractional full-time staff.
Source: DEST. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

At the same time, there has been increasing insecurity of tenure within Australian universities. Between 1991 and 2000, the number of fulltime staff increased just 3%, while the number of fractional staff increased by 33%; and the number of tenured staff increased by 7%, while the number of limited term appointments increased by 19%. Despite this, the student-staff ratio increased from 15 to 19 (27%) over the same period (Nelson 2002, p61). Department of Education, Science and Training data show that research income per FTE staff increased 8.3% per annum between 1995 and 1999, from AUD 19 717 to AUD 27 085. So, there appear to have been significant productivity improvements in both teaching and research.

Higher education funding

As noted above, recent years have seen underlying shifts in the composition of government and other funding to higher education, effecting both teaching and research functions. The OECD (1999) noted that: in several national systems, the relative importance of base funding has been diminishing. There have also been significant compositional changes within government funding.

> *In many countries, a considerable share of government support is now provided on a contract, mission-oriented basis, conditional on demonstrable or measurable short-term performance. There is a clear tendency in these countries to reduce base funding for university research ("first money flow" as it is sometimes called) as compared with conditional, mission-oriented, "second-flow" funding. This policy may be consistent with the knowledge-transfer functions of universities in contexts where second-flow funding has traditionally been low (10% or less of total government support). It becomes more problematic when less reliable conditional funding represents a large share of government support. Creative research is frequently a long-term process which requires some reasonable assurance of stable, long-term funding. In contrast, over reliance on conditional or contract support can lead universities to prefer short-term research projects when they are not sure that contract support for specific projects will continue to be forthcoming.*
>
> *Another source of stability – or instability as the case may be – has to do with the ways in which governments allocate base research funds. In many cases, total funds are allotted to universities on the basis of the number of students they enrol or graduate, with research funds a specific portion of total funds. Holding research support hostage to student enrolments could have serious negative consequences in the long-term if, as some analysts predict, the total number of students declines as a result of demographic trends. In the shorter-term, it can lead to instabilities tied to year-by-year variations in enrolments* (OECD 1999, p72).

The overall effect of these funding changes, with increased emphasis on competitive research grants allocated on a project basis, is to increase the dependency of higher education research on short-term funding, with shorter time horizons and demands for more immediate outcomes, and to create greater instability of tenure and career path for researchers within the system.

2.2.9 Publication and citation

Citation data are widely used to monitor research performance. Recent studies have tried to test some of the trends suggested in the literature by using bibliometric data on the growth of non-university research, and have confirmed the (non-controversial) thesis of the diversification of the loci of scientific production, a trend also visible in the diversification of R&D investments. For example, in OECD countries, the share of GERD funded by government decreased from 40.9% to 34.5% between 1986 and 1995, with industry taking the place left by government (Godin and Gingras 1999). At the same time it seems that more knowledge production is taking place outside higher education (Katz and Hicks 1998). Australian citation data appear to reveal: increasing output; increasing collaboration (co-authorship), both domestic and international; and increasing internationalisation and globalisation of the research.

Table 2.4 Australia's share of publications and citations in the Science Citation Index: fractionated publication counts, 1981–1999

Year	*World*		*Australian*		*Australia's share*	
	Publications	*Citations*	*Publications*	*Citations*	*Publications*	*Citations*
1981	400,310	6,830,418	8,623	150,507	2.15	2.20
1982	417,882	6,883,232	8,567	145,283	2.05	2.11
1983	425,394	7,041,279	8,579	154,975	2.02	2.20
1984	426,215	7,017,630	8,760	146,942	2.06	2.09
1985	455,111	7,346,116	9,328	156,199	2.05	2.13
1986	464,150	7,358,014	9,707	157,390	2.09	2.14
1987	460,649	7,403,578	9,565	147,303	2.08	1.99
1988	478,817	7,446,983	9,483	154,733	1.98	2.08
1989	497,848	7,448,997	10,129	145,278	2.03	1.95
1990	510,284	7,449,955	10,171	136,225	1.99	1.83
1991	518,396	7,201,416	10,371	133,826	2.00	1.86
1992	547,239	7,035,636	11,057	127,458	2.02	1.81
1993	537,521	6,557,195	11,346	122,700	2.11	1.87
1994	569,942	5,865,424	12,119	113,678	2.13	1.94
1995	584,293	4,988,981	12,547	98,935	2.15	1.98
1996	589,670	3,746,163	12,974	74,247	2.20	1.98
1997	586,275	2,548,098	12,863	49,713	2.19	1.95
1998	606,074	1,235,786	13,388	25,225	2.21	2.04
1999	600,073	209,283	13,357	4,625	2.23	2.21
CAGR	*2.3*		*2.5*			

Source: Butler, L. (2001) *Monitoring Australia's Scientific Research*, Australian Academy of Science, Canberra. (Available www.science.org.au/butler).

Between 1981 and 1999, worldwide scientific journal publication increased 2.3% per annum (functional counts). Over that same period, Australian publications increased by 2.5% per annum. The push for increased output, and the use of publication output as both a performance indicator and as a criteria for the distribution of funding, have no doubt contributed to the generation of more publications. However, citations have fallen, both worldwide and for Australian publications.[6] There are a number of possible explanations. These include:

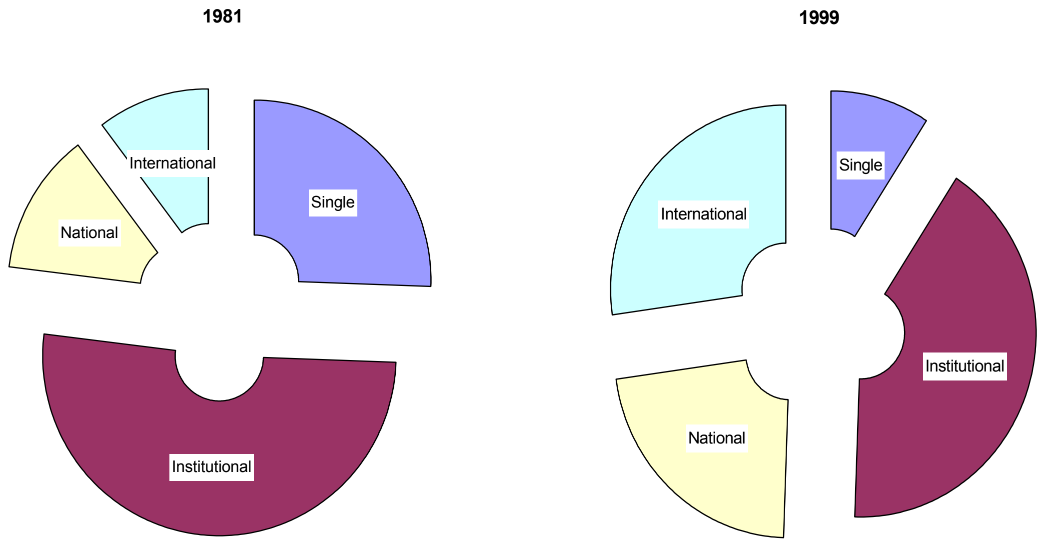
- the sheer volume of publication making it difficult for researchers to keep up with all publications in their field, and leading to lower citation levels;
- the quality and relevance of the publications being compromised by increasing institutional and economic incentives to publish more (ie. a focus on quantity rather than quality); and
- increasing journal prices forcing a rationalisation of academic library collections, which leaves them looking increasingly alike as they focus on

6 Personal communication with Dr. Linda Butler of the Australian National University's Research School for Social Sciences suggests that these broad trends continue in more recent unpublished data.

'core collections' of the most important journals, and reducing the visibility of many publications in the more peripheral literature (Perrault 1995).

Importantly, however, there have been significant shifts in the patterns of collaboration (as indicated by co-authorship) (Katz and Martin 1997). Between 1981 and 1999, the number of Australian publications increased 3.3% per annum. Over that same period, the number of publications with a single author decreased by 1.5% per annum. Between 1981 and 1999, papers with institutional collaboration increased 3.0% per annum, papers with national collaboration increased 7.6% per annum, and papers with international collaboration increased 9.9% per annum. In short, there is increasing national and international collaboration (co-authorship).

Figure 2.21 Levels of collaboration in Australian publication in the Science Citation Index, 1981 and 1999



Source: Butler, L. (2001) *Monitoring Australia's Scientific Research*, Australian Academy of Science, Canberra. (Available www.science.org.au/butler). Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

In 1981, 28% of Australian publications in the Science Citation Index (SCI) were produced by a single author, and a further 57% were collaborations between authors working at the same institution. Only 14% involved collaborations between authors working at different institutions within Australia, and 11% were international collaborations. By 1999 things were very different. Just 12% of Australian publications in SCI were produced by a single author, and a further 53% were produced by authors working at the same institution. Extra-institutional national collaborations accounted for 29% of publications, and international collaboration accounted for 35% of all publications.

Table 2.5 Levels of collaboration in Australian publications in the Science Citation Index, 1981–99

Year	*Total*	*Single*	*%*	*Institute*	*%*	*National*	*%*	*International*	*%*
1981	9,168	2,560	27.9	5,192	56.6	1,264	13.8	1,047	11.4
1982	9,155	2,371	25.9	5,278	57.7	1,340	14.6	1,124	12.3
1983	9,234	2,330	25.2	5,314	57.5	1,448	15.7	1,249	13.5
1984	9,443	2,264	24.0	5,527	58.5	1,457	15.4	1,300	13.8
1985	10,076	2,399	23.8	5,825	57.8	1,529	15.2	1,423	14.1
1986	10,530	2,410	22.9	6,107	58.0	1,756	16.7	1,568	14.9
1987	10,384	2,258	21.7	6,145	59.2	1,877	18.1	1,553	15.0
1988	10,460	2,105	20.1	6,145	58.7	1,998	19.1	1,858	17.8
1989	11,152	2,124	19.0	6,667	59.8	2,121	19.0	1,946	17.5
1990	11,316	2,086	18.4	6,671	59.0	2,234	19.7	2,175	19.2
1991	11,865	2,260	19.0	6,375	53.7	2,571	21.7	2,818	23.8
1992	12,774	2,150	16.8	7,015	54.9	3,019	23.6	3,212	25.1
1993	13,246	2,140	16.2	7,140	53.9	3,271	24.7	3,552	26.8
1994	14,265	2,223	15.6	7,750	54.3	3,447	24.2	4,012	28.1
1995	14,936	2,138	14.3	8,115	54.3	3,793	25.4	4,439	29.7
1996	15,555	2,149	13.8	8,342	53.6	4,245	27.3	4,758	30.6
1997	15,714	2,064	13.1	8,353	53.2	4,278	27.2	5,224	33.2
1998	16,508	1,992	12.1	8,840	53.5	4,652	28.2	5,700	34.5
1999	16,519	1,962	11.9	8,813	53.4	4,745	28.7	5,768	34.9
CAGR	*3.3*	*-1.5*		*3.0*		*7.6*		*9.9*	

Source: Butler, L. (2001) *Monitoring Australia's Scientific Research*, Australian Academy of Science, Canberra. (Available www.science.org.au/butler).

These data clearly indicated an increasing tendency for collaborative research and an internationalisation of collaborative activity. While high, the increase in collaboration seen in Australia, both nationally and internationally, mirrors worldwide trends (BIE 1996, p21). For example, the U.S. National Science Board (NSB) has suggested that more than half of all articles published worldwide in 1999 were co-authored, compared with 37% in 1986. As a collaborator in U.S. publications, Australia ranked 7th in 1999, behind Germany, the United Kingdom, Canada, Japan, France and Italy. And Australia ranked 8th in terms of breadth of international collaboration, with more than 113 countries involved in collaborative publication – up from 64 countries in 1986. Clearly, both the extent and breadth of collaborative research is increasing (National Science Board 2002, p5-43 to 5-47).

The NSB also noted that levels of collaboration vary considerably between disciplines and fields of research, with rates of international co-authorship highest for physics, earth science, space sciences and mathematics (32% to 35% of all U.S. published articles), and much lower in the social and behavioural sciences (around 10%). Interestingly, the NSB (2002) went on to suggest that:

> *Advances in IT have helped to reduce the geographical and cost barriers to domestic and international collaboration. E-mail greatly facilitates collaboration by allowing rapid exchange of information and eliminating the need for costly face-to-face meetings. The increasing use of high-capacity networks allows researchers to exchange huge data files, and improvements in software permit researchers to share research findings or conduct*

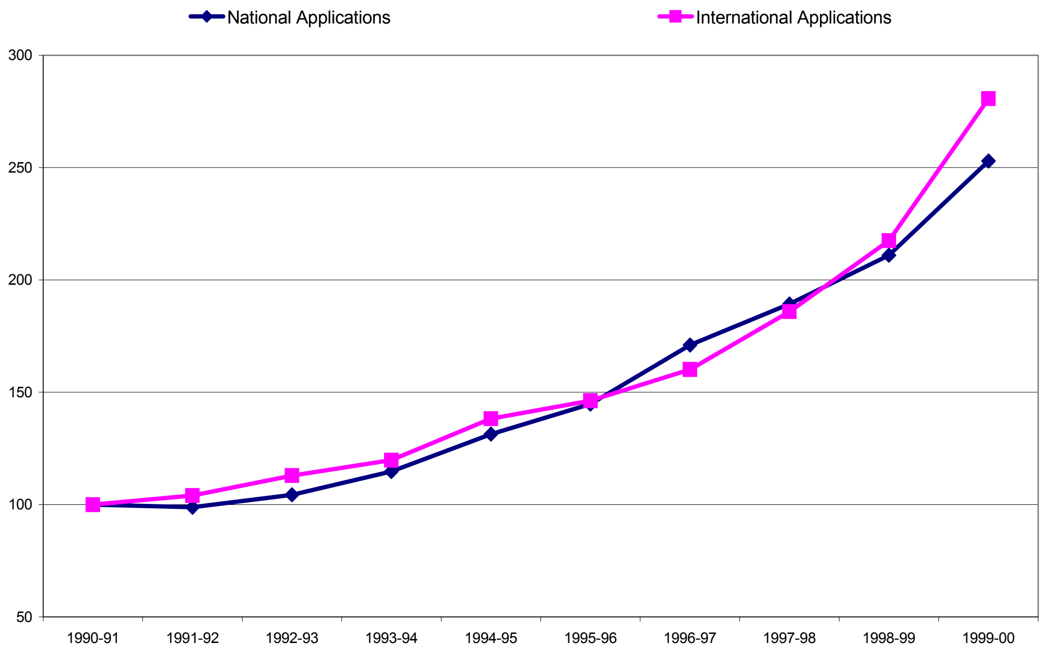
> *research on-line without requiring a centralized laboratory* (National Science Board 2002, p5-44).

These data suggest that, although there are differences between disciplines, both the traditional disciplines of Mode 1 research and the transdisciplinary fields of Mode 2 research are experiencing increasing collaboration.

2.2.10 Patenting

Patenting activity is often seen as one of the outputs of research and as an indicator of both the productivity of research and its commercial orientation. From the perspective of this study, patenting can be seen as an indicator of increasing interaction between organizations within the system of innovation and increasing problem and commercial orientation (ie. the trends associated with the emergence of a new mode of knowledge production). Moreover, analysis of patenting can be seen as a perspective on research outcomes which complements bibliometric analyses based on ISI citations – which tend to be biased towards reflecting traditional, disciplinary, Mode 1 research activities because of the focus on established refereed journals.

Figure 2.22 Patent applications received by IPAustralia, 1990-91 to 1999-2000 (indexed)

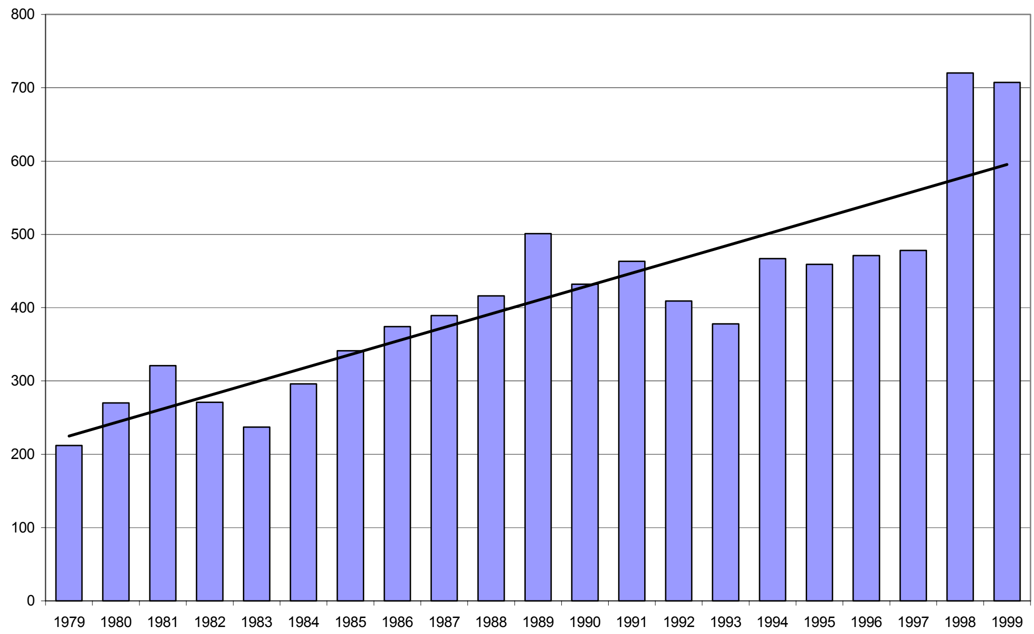


Source: IPAustralia. Analysis conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

IPAustralia receives patent applications for registration in Australia and, through international patent cooperation treaties, for registration overseas. During 1990-91, IPAustralia received a total of 27 529 patent applications. By 1999-2000, the annual number of applications had increased to 69 645, with applications increasing by almost 11% per annum. Over the same period, international applications received by the patent office increased from 612 to 1 718, or by more than 12% per annum.

Similarly, U.S. non-resident patent grants to Australian residents increased from around 200 per year in the late 1970s to more than 700 per year in the late 1990s. Despite cyclical variation year-to-year, the trend is clear. Between 1979 and 1999, U.S. patent grants to Australian residents increased by 6.2% per annum (National Science Board 2002). These data demonstrate a significant increase in patenting activity, together with an increasing internationalisation of that activity.

Figure 2.23 U.S. non-resident patent grants to Australian residents, 1979-1999 (annual count)

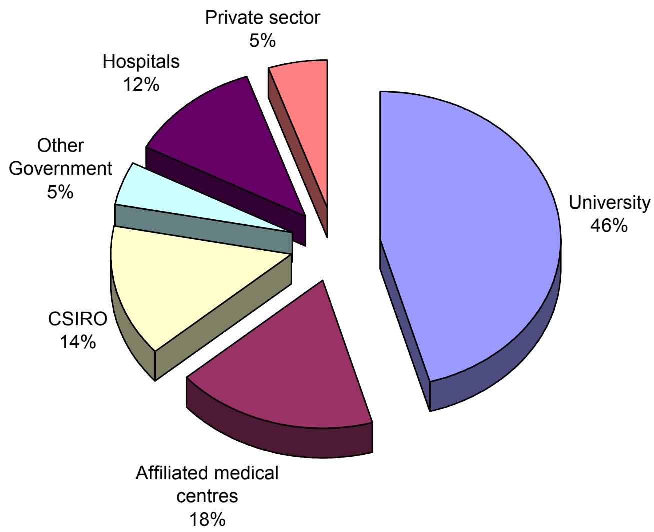


Sources: Complied from various sources, including: BIE (1996) *Australian science: Performance from published papers*, Bureau of Industry Economics Report 96/3, Canberra: AGPS, p201-202; Narin, F., Albert, M., Kroll, P. & Hicks, D. (2000) *Inventing our future: The links between Australian patenting and basic science*, Canberra: ARC & CSIRO, p25; and National Science Board (2002) *Science and Engineering Indicators 2002,* Arlington, VA: National Science Foundation, 2002 (NSB-02-1), pA6-56.

Looking at patenting activity by sector, CHI Research found that almost 60% of the U.S. non-resident patents granted to Australian residents were to private companies, with 5% granted to Australian universities, 4% to the CSIRO and around 3% to other government organizations. This suggests that commercialisation of patentable research findings occurs predominantly in the business sector (Narin et al. 2000).

Nevertheless, all sectors are actively patenting and there is a strong link between public sector science and patenting. Looking at the patterns of citation from U.S. patent grants to scientific papers (ie. citations to '*prior art*'), CHI Research found that not only is the number of references to scientific papers increasing rapidly, more than tripling over the six years 1987-88 to 1993-94, but also, overall, 73% of the papers cited by industry patents were produced in public sector and public funded institutions. Over the period 1988 to 1997, around 95% of all the citations to Australian science were to public sector science – including 63% to universities and related medical centres, and 14% to the CSIRO (Narin et al. 2000, p54). Thus, although it is often private companies that patent most they draw on public sector science as 'prior art'. Similar findings have been reported in other countries (Godin and Gingras 1999).

Figure 2.24 Sector of Australian papers cited in U.S. patents, 1988–97



Source: Narin, F., Albert, M., Kroll, P. & Hicks, D. (2000) *Inventing our future: The links between Australian patenting and basic science*, Canberra: ARC & CSIRO, p54.

The fact that there is increasing citation to scientific papers in U.S. patent applications, suggests increasing links between basic science and commercial or commercialisable innovations, between different loci of research (eg. between public and private sector research) and between fields of research. The National Science Board (2002) noted that:

> *The percentage of U.S. patents that cited at least one such article increased from 11% in 1985 to 24% in 1997, before falling to 21% in 2000. This development attests to both the growing closeness of some research areas, for example, life sciences, to practical applications, and the increasing willingness of the U.S. Patent and Trademark Office (PTO) to award 'upstream' patents, that is, research-driven products and processes that have less immediate commercial application, such as genetic sequencing. Thus, citations of scientific and technical articles provide an indicator of the growing link between research and innovative application, as judged by the patent applicant and recognized by PTO* (National Science Board 2002, p5-52)

The National Science Board also noted that the rapid growth of article citations in patents has centered on increases in the life sciences fields of biomedical research and clinical medicine. In 2000, citations to these two fields accounted for about 70% of all citations – although citations in other fields also increased. This suggests that these fields may be at the forefront of changes in the nature of research, driven by convergence and the opening of active new fields in the interstices between traditional disciplines.

Reports from Canada, suggest that collaborations (co-authorship) reveal similar sectoral and disciplinary patterns. For example, Godin and Gingras (1999) found that the:

> *Scientific collaborations of universities with industries, hospitals and government laboratories have increased by 155% from 1980 to 1995. It went from 14.6% of papers with at least a university address in 1980 to 21% in 1995. In that latter year, almost half of the collaborators are hospitals, followed by federal laboratories (23.3%), industries (10.6%) and provincial laboratories (9.2%).*
>
> *Intersectorial collaborations of universities varies [sic], of course, according to disciplines. For the year 1995, 33.2% of university papers in the field of clinical medicine were written in collaboration. This field also accounts for more than 50% of all intersectorial collaborations of universities. It is followed by Biology (21.8%), Biomedical research (20.5%), Earth and Space (20.2%), Engineering & Technology (16.2%), Physics (9.8%), Chemistry (6.8%), mathematics (2.6%)* (Godin and Gingras 1999, p9).

Clearly suggesting commonality of patterns of linkages through collaborations and patent citations.

2.3 What do these data show?

One of the factors effecting research practice is that research is being conducted in an increasingly diverse range of settings, with significant changes in the sources of funding and loci of expenditure. There has been a marked increase in R&D activity in the business sector and a relative decline in the government sector. Other sectors have seen a modest increase in their share of R&D expenditure and activity.

There is a shift away from pure/basic research towards more applied and developmental activities, and a decline in the share of expenditure on 'non-oriented' research with strong increases in the more interdisciplinary, problem oriented fields characteristic of Mode 2 research. Moreover, it is the business and government sectors in which expenditure on pure/basic research is increasing, while expenditure increases on applied activities are higher in the higher education sector – albeit from low bases. This suggests some convergence and cross-over of the traditional division of labour in research vis-à-vis the private and public sectors.

There has been a rapid increase in collaboration within and between research organizations, and between individuals both nationally and internationally. There has been a significant increase in publication output. Patenting too has increased rapidly, with international patent applications increasing even faster than domestic applications. Patent citation patterns suggest linkages between public sector science and commercialisation of intellectual property. All these trends indicate a wider range of research activities taking place in a wider range of settings, in both sectoral and geographic senses.

There is, in short, clear evidence of the emergence of a new mode of knowledge production in Australia, and of a new Triple Helix inter-relationship between universities and research organizations, industry and the state.

> *The nature of knowledge creation is changing, not only in Australia but internationally. While the inspiration and persistence of individuals will always remain the foundation stone of discovery, breakthroughs do not occur in a vacuum. Increasingly, the important questions for research are not based on disciplines but on issues or problems, demanding multi-disciplinary research solutions. As a consequence, there is now a growing emphasis on teamwork in research and complementarity of skills, with many networks of researchers pooling their diverse talents in a flexible way to pursue a common goal.*
>
> *At the same time, the traditional distinctions between 'pure' and 'applied' research are rapidly breaking down. While research unconnected to an ultimate use must continue to have a prominent place in our research institutions, there is no longer a simple one-way flow from 'basic' to applied research; rather there is a constant and increasingly rapid interaction between the two, with applied research efforts often generating questions which can only be answered at the 'basic' level.*
>
> *The locations of research activity are also changing, and knowledge generation is increasingly crossing the traditional boundaries between institutions and sectors. For example, in addition to their traditional task of generating knowledge, universities now receive and transform knowledge. At the same time, the primacy of the universities in basic research is being strongly challenged in a variety of fields such as the computer sciences, many applied sciences and engineering where the emphasis is on application of research. There is an increasing role for applications-driven approaches in many spheres of research, and a growing share of the national research effort is occurring in commercial settings. These trends are particularly pronounced in the fields of science and technology research, but are by no means confined to them; similar trends can also be observed across a range of the social sciences and humanities* (Kemp 1999, pp2-3).

There are many ways to look at these changes, but perhaps Gibbons et al. (1994) notion of the emergence of a new mode of knowledge production (Mode 2) provides the most useful shorthand summary. Mode 2 knowledge production supplements traditional disciplinary research, rather than replacing it – they are complementary and contemporary rather then competing and exclusive modes of knowledge production (McWilliams et al. 2002, p40).

The process of knowledge production is cumulative, with knowledge applied to knowledge, such that knowledge is both an output and an input. How researchers source that knowledge input, how they communicate with each other and how they communicate and disseminate findings are crucial, not only for the progress of knowledge but also for the capacity of the national innovation system to underpin prosperity in the era of the global knowledge economy. As the traditional system is disrupted and alternative modes of knowledge production emerge, and there is a need for communication and cross-fertilization between parallel modes, the future development of the research infrastructure and provision of information resources becomes more challenging – perhaps even more challenging than many have yet realised.

3. Changing research practices

This chapter presents a brief review of the literature on the impacts of the information technology revolution on research. It then presents a review of the extensive international literature on research practices in the three key areas of communication and collaboration, information search and access, and dissemination and publication. One of the notable features of the literature is its imbalance across these areas, with some (eg. the use of journals) covered extensively while others (eg. informal dissemination of material and research practices) rarely examined in any detail.

3.1 The impact of ICTs

The OECD (1998) noted that:

> *Science, particularly at the leading edge, requires funding, time, well-trained scientists and research assistants, access to data and information, access to sometimes expensive scientific instruments, ways to communicate and publish research results, and ways to join in collaborative structures. Recent developments in ICT, and the growth of the Internet in particular, affect many of these requirements, although their impact differs across disciplines* (OECD 1998, p69).

Similarly, the U.S. National Science Board (2002) noted that:

> *IT has provided new tools for the simulation and modelling of complex natural, social, and engineering systems. It has enabled new methods of data collection and has made possible the creation of massive, complex, and shared data sets. It has changed the way scientific knowledge is stored and communicated. IT has facilitated the sharing of computational resources and scientific instruments among scientists and engineers in different locations and has aided communication and collaboration among large groups of researchers* (National Science Board 2002, p8-24).

The U.S. National Research Council (2001) suggested a somewhat more revolutionary impact, noting that:

> *Digital computers and networks are revolutionizing the way we conduct research, just as they are recasting the way we do business and spend our leisure time. It grows easier every day to collect, manipulate, and disseminate information. Researchers everywhere are developing new ways to use these digital systems in every phase of their work. These new tools – both hardware and software – make possible more creative and productive research, including new forms of collaboration on a global scale* (National Research Council 2001, p1).

Information and communication technologies (ICTs) are enabling fundamental changes and affecting the practice of research. ICTs are:

- Enabling communication among scientists – encouraging collaboration, enlarging and improving teams. Collaboration is fundamental to interdisciplinary research and is thought to improve researcher productivity and quality;

- Enabling greater access to information of all kinds – published and unpublished, text and non-text. This is particularly important in relation to accessing large shared datasets (eg. the Human Genome Project);
- Providing access to high performance computing – fundamentally changing research in respect to modelling, simulation and visualisation, with new ways of 'seeing' hitherto hidden and inaccessible structures and processes now possible (eg. medical imaging and protein folding);
- Revolutionising scientific instruments – both by enhancing specific capabilities and making instruments more flexible in use;
- Enabling access to remote instruments – including large facilities and shared instruments, as well as remote sensing and data collection;
- Enabling easier handling and marshalling of information – thereby extending the capabilities of researchers to synthesise, process and create knowledge; and
- Enabling a greater variety of enhanced publication, dissemination and communication mechanisms.

As Sargent (2002, p12) noted, the growing use of information and communications technologies in research is having a fundamental impact on the way research is being conducted and is leading to the emerging concept of e-science.

The concept of the *grid* has also emerged as researchers harness high capacity networks, powerful computers, mass data storage systems, virtual and augmented reality and videoconferencing facilities, and large-scale instruments. Network technologies and services are now regarded as essential to support distributed research communities around the world. Examples of grid technologies include:

- Computing Grids – providing access to distributed computers to allow applications to be executed across multiple computing systems;
- Data Grids – allowing high-speed interactive access to large-scale distributed datasets (eg. in astronomy and bioinformatics);
- Instrument Grids – allowing access to large-scale instruments (eg. electron microscopes) so that experiments can be conducted remotely;
- Collaborative Working Environments (Collaboratories) – connecting sophisticated videoconferencing and shared systems facilities to allow group-to-group communication and interaction; and
- Cooperative Visualisation Environments – connecting visualisation and virtual reality facilities (visualisation grids) to allow researchers at different locations to simultaneously examine a computer-generated model of an engineered product (Sargent 2002, p12).

Atkins et al. (2003), reporting to the U.S. National Science Foundation, recently noted that:

> *Advances in computational technology continue to transform scientific and engineering research, practice, and allied education. Recently, multiple accelerating trends are converging and crossing thresholds in ways that show extraordinary promise for an even more profound and rapid transformation – indeed a further revolution – in how we create, disseminate, and preserve scientific and engineering knowledge* (Atkins et al. 2003, p4).

Atkins et al. (2003) noted that digital computation, data, information, and networks are now being used to replace and extend traditional efforts in science and engineering research, indeed to create new disciplines. The classic two approaches to scientific research, theoretical/analytical and experimental/observational, have been extended to *in silico* simulation to explore a larger number of possibilities at new levels of temporal and spatial fidelity. Advanced networking enables people, tools, and information to be linked in ways that reduce barriers of location, time, institution, and discipline. In many fields new distributed-knowledge environments are becoming essential, not optional, for moving to the next frontier of research (Atkins et al. 2003, p4).

From the perspective of this study, the key areas of ICT impacts on researchers' information practices are in: communication and collaboration, information search and access, and dissemination and publication. Each is discussed briefly below.

3.2 Communication and collaboration

ICTs, especially the use of e-mail, has enabled researchers to engage in broader networks of research than was previously possible. As the U.S. National Science Board noted: "computer networking was developed as a tool for scientists and engineers, and e-mail and file transfers have long supported collaboration among scientists and engineers. Shared databases, intranets, and extranets have helped geographically separated scientists and engineers work together." (National Science Board 2002).

Collaboration has been widely studied, with a number of authors suggesting reasons why it occurs and why there has been an apparent increase in collaborative research over recent years. It has also been pointed out that collaboration can take many forms, from simple participation in a small aspect of an experiment and the sharing of ideas and drafts, to fully fledge joint authorship and stewardship of the study. Citing a long list of previous studies, Katz and Martin (1997) noted that:

> *Previous authors have proposed a great many factors to account for the increase in multiple-author papers. These include…changing patterns or levels of funding; the desire of researchers to increase their scientific popularity, visibility and recognition; escalating demands for the rationalisation of scientific manpower; the requirements of ever more complex (and often large-scale) instrumentation; increasing specialisation in science; the advancement of scientific disciplines which means that a researcher requires more and more knowledge in order to make significant advances, a demand which often can only be met by pooling one's knowledge with others; the growing professionalisation of science, a factor which was probably more important in earlier years than now; the need to gain experience or to train apprentice researchers in the most effective way possible; the increasing desire to obtain cross-fertilisation across disciplines; and the need to work in*

> *close physical proximity with others in order to benefit from their skills and tacit knowledge* (Katz and Martin 1997).

Collaboration, especially international collaboration, is widely seen as beneficial. Walsh and Maloney (2001) found that computer network use is associated with more geographically dispersed collaborations as well as more productive collaborations. Katz and Hicks (1997) found that the citation of collaborative papers was higher than that of sole authored papers, and that the impact was higher for collaborative papers where those collaborations were international. These findings suggest that collaboration may produce increases in both productivity and quality (as measured by citation analysis).

Tighter links between geographically dispersed researchers creates denser international communities, with topics bringing together more complex workgroups in virtual research teams. Other things equal, such links should improve the match between the project needs and the skills marshalled, with the topic rather than geographical proximity determining the team's composition (OECD 1998). It has also been suggested that ICT-based communication has contributed to an overall increase in the amount of communication during collaborative projects, which may help promote greater commitment to the project and the research group and increase job satisfaction for the researchers (Walsh and Bayma 1996; OECD 1998). Cohen (1996) found a significant correlation between levels of e-mail use and co-authoring.

Some fields and disciplines seem to have more potential to benefit from the technology than others. Those fields where interdependence is high, with frequent interaction between collaborators, and those where collaborators are likely to be dispersed – such as mathematics, physics and aerospace – are most likely to benefit (Walsh and Bayma 1996; OECD 1998, p25; OECD 1999, p59). Computer-mediated communication among scholars in experimental biology, mathematics, physics and sociology has been investigated by Walsh et al. (2000). Practically all scholars were found to be using e-mail for professional purposes, such as participating on committees, submitting manuscripts and reviews or proposals to funding agencies, as well as communication with peers. The greatest benefits seem to be to facilitate scientific communication, providing the glue for the 'virtual college' (Walsh et al. 2000, p1304).

One early observation on collaboration was that theoretical work generally produced papers with fewer co-authors than experimental work (Smith 1958). Since then it has become widely accepted that experimentalists tend to collaborate more than theoreticians. Katz and Martin (1997) noted that:

> *Collaboration is particularly common in experimental research involving the use of large or complex instrumentation such as telescopes, particle accelerators or CT scanners… Collaboration may also depend on how basic or applied is the research. For example, Hagstrom (1965) has argued that applied research, like experimental research, tends to be more interdisciplinary, and research on a particular problem may therefore require a wider range of skills than any single individual, or even a single institution, is likely to possess. However, this is somewhat at odds with the findings of Frame and Carpenter (1979) who conclude that "the more basic the field, the greater the proportion of international co-authorships"* (Katz and Martin 1997).

This may not be at odds, but rather indicate differences between genuine collaboration and co-authorship as an imperfect indicator of it, and/or differences in the incentive structures and rewards systems, and thereby different motivations for publication.

The same authors also noted that one of the reasons for increasing collaboration was the growing importance of interdisciplinary fields.

> *It is becoming clear that some of the most significant scientific advances come about as a result of the integration or 'fusion' of previously separate fields. New or emerging fields like biosensors, optoelectronics or chematronics (the fusion of chemistry, life sciences and electronics) promise results likely to form the basis of major new technologies. Since few individuals possess the necessary range of skills, the only option is to bring together scientists from relevant disciplines and to forge a collaboration between them* (Katz and Martin 1997).

Thus making explicit the link between increased communication and collaboration and the emergence of a new mode of knowledge production (Mode 2).

Looking at levels of team work among researchers, Education for Change et al. (2002, p16) found that in a sample of more than 1 400 researchers drawn from the United Kingdom's 2001 Research Assessment Exercise Census, 41% reported working in teams – 71% of those in medical and biological sciences , 57% of those in other sciences, 36% of those in social sciences and 7% of those in humanities.

In terms of wider, less formal research networks, Brockman et al. (2001) suggested that wider collegial networks were important for humanities scholars in the United States, and implied that the level of collaboration in humanities is higher than had been thought.

> *Previous research in this area has underestimated the importance of collaboration by humanities scholars. Research projects in the social sciences and hard sciences are commonly funded and executed by a team and presented in articles co-authored by team members. By contrast, individuals write virtually all articles and books in the humanities. This has given rise to the impression that humanities scholars work alone. And in some senses, they do. Reading is a solitary activity, as is, generally, searching databases or browsing. Circulation of drafts, presentation of papers at conferences, and sharing of citations and ideas, however, are collaborative enterprises that give a social and collegial dimension to the solitary activity of writing. At times, the dependence of humanities scholars upon their colleagues can approach joint authorship of a publication* (Brockman et al. 2001).

They went on to note that the use of e-mail has facilitated an increase in the level of this sort of networking. Robertson and Young (2003) also noted extensive use of personal networks in their study of Australian research practices at Queensland University of Technology.

While there are notable difference between research fields and disciplines, it is clear that ICTs facilitate collaborative research, contribute to richer communication and wider collaboration, enable increases in research productivity and quality, and provide an essential foundation for the emerging new mode of knowledge production.

3.3 Information search and access

Prior studies of information access pay most attention to library mediated access to published materials – particularly refereed journals. There is much less attention paid to access to research databases, non-text and non-traditional materials. The following section provides a brief review of prior literature on information access by library and information 'users'. There follows a short review of prior literature on the use of research databases.

3.3.1 Library and information user studies

Education for Change et al. (2002) studied the ways in which researchers use information resources. A sample survey of 3 390 researchers was conducted, with findings supplemented with an extensive literature review and focus group interviews. The five major disciplinary groups included were medical and biological sciences, physical sciences and engineering, social sciences, area studies and languages, and arts and humanities. They found that, in general, academics were conservative in their approach to sources, but quick to seize new access opportunities.

Table 3.1 Percentage rating sources 'essential' (Sample from U.K. RAE Census 2001)

	Medical & Biological Sciences	Physical Sciences & Engineering	Social Sciences	Area Studies Language	Arts & Humanities	All
Printed refereed Journals	98%	96%	97%	98%	84%	95%
Books	60%	77%	92%	98%	93%	82%
Bibliographic tools, abstracting & indexing services	82%	75%	67%	74%	56%	71%
Electronic journals & other electronic publications	73%	62%	57%	26%	22%	53%
Electronic full text services	75%	57%	56%	27%	24%	52%
Other printed nonrefereed journals	19%	21%	38%	52%	46%	33%
Electronic pre-print archives	44%	45%	25%	12%	10%	30%
Computerised data sets	31%	28%	27%	12%	14%	25%
Photographs & still images	20%	16%	10%	23%	42%	20%
Newspapers	2%	2%	31%	34%	27%	18%
Rare books & MSS	3%	4%	9%	61%	49%	18%
Microfilm / microfiche	2%	3%	10%	51%	33%	14%
Moving images and / or sound recordings	9%	8%	5%	27%	22%	11%
Maps & charts	4%	7%	11%	10%	17%	10%
Artefacts	1%	4%	1%	6%	25%	6%

Source: Education for Change Ltd, SIRU University of Brighton and The Research Partnership (2002) *Researchers' Use of Libraries and other Information Sources: current patterns and future trends*, Research Support Libraries Group, p20. Available http://www.rslg.ac.uk/research/libuse/ accessed October 2002.

Education for Change et al. (2002) found that: printed refereed journals were regarded as 'essential' by 95% of U.K.-based researchers; books by 82%; bibliographic tools, abstracting and indexing services by 71%; electronic journals and other sources by 53%; full text services by 52%; electronic pre-print archives by 30%; and computerised datasets by 25% (Table 3.1). Some 45-50% of the researchers reported regular use of discussion lists, but few regarded them as 'essential'.

A disciplinary divide was apparent. Medical and biological sciences researchers focussed on journal literature and primary data, and three quarters of the group viewed electronic access to e-journals and electronic full-text services as essential. By contrast, less than a quarter of researchers in arts and humanities, area studies and languages perceived electronic access to journals as essential (Education for Change et al. 2002, p6). Nevertheless, all researchers saw the future as being strongly focused on the provision of electronic information and anticipate increased use of e-books, e-journals and the internet. All respondents said they used the library less than they did two years ago, and faculty members reported spending about 10% of their time in the library. Most of their information seeking was done from outside the library, and they noted that the amount of relevant information found on internet was growing in such a way that it will continue to reduce their use of library facilities. All disciplines recognized the benefit of electronic information being available at all times and from any location (Education for Change et al. 2002, p9).

The internet was seen as a significant research tool across all disciplines. Even in arts and humanities, where use of electronic journals and information sources was relatively low, researchers made use of generic search engines such as Google, electronic discussion lists and websites of important organizations on a regular basis. In contrast, less than a third of all researchers viewed mediated subject gateways, including institutional gateways and those provided as part of the Resource Discovery Network, as essential to their research (Education for Change 2001).

Heterick (2002) noted the increasing familiarity and ease in the use of electronic resources. Similarly, in a survey of the attitude of academics towards electronic resources, Guthrie (2001) indicated that the majority were comfortable using them, and they anticipated that they would in future become more dependent on them and less dependent on physical library collections. Again there were disciplinary differences, with those in the humanities valuing print archives more than those in the social sciences, and those in the humanities reporting a greater reliance on electronic catalogues than economists. Healy (2002) provided further information about disciplinary differences, suggesting that: 66% of those in law used electronic resources for research all or most of the time, compared with 56% of those in business, 48% of those in biological science and engineering, 46% of those in physical sciences, 37% of those in social sciences, and 25% of those in arts and humanities.

Reporting the same Digital Library Federation study, Friedlander (2002) found that researchers in the United States used multiple on- and offline sources to support their research and teaching, with more than 80% of the biological and physical sciences researchers in her sample reportedly using electronic journals, as did around 75% across the sample. Internationally, Key Perspectives (2002) reported that 32% of the researchers they surveyed suggested that pre-print archives were important in their area of research, and 62% said re-print (e-print) archives were important. Key Perspectives (2002, p39) also noted that 94% of respondents to their international survey reported that knowing that the material had been reviewed by experts was a very important feature for electronic journals.

In the United Kingdom, generic web search engines were rated 'very important' by 45% of researchers (Education for Change et al. 2002). Friedlander (2002) found that when searching for material to study, more than 80% of the faculty and students in her U.S.-based sample searched for information online. No more than 10-15% of U.K.-based researchers rated personal portals as 'very important', but institutional gateways and portals, online catalogues, and subject gateways and portals were somewhat more highly regarded. Brockman et al. (2001) noted that there was limited enthusiasm for discussion lists among their sample of U.S.-based humanities scholars.

Friedlander (2002) found that researchers in the United States valued their personal libraries and journal subscriptions, with 56% reporting that they were the most important way to stay current. Brockman et al. (2001) noted that in the United States, humanities:

> *Scholars build their own personal libraries to support not only particular projects but also general reading in their field. They buy or make photocopies of materials when possible so they can consult them frequently, mark passages, and write annotations on them* (Brockman et al. 2001, p8).

However, there is evidence that personal subscriptions are declining. Tenopir et al. (2003) found that the proportion of reading from personal subscriptions was declining, with the number of personal journal subscriptions among their sample of U.S.-based scientists falling from around 5.8 in the early 1990s to 2.8 subscriptions per scientist by 2001-02. They also found a high, but recently declining level of print among personal subscriptions.

The Stanford E-Just Surveys (E-Just 2002a) noted that table-of-contents alerts are the most used alerting service. Seventy per cent of the sample had used at least one of the three types of alerts (table of contents, citations of articles on topics of interest, and articles on keyword(s) of interest). Eighty per cent of the e-mail alert users said they had found table of contents (e-TOC) alerts to be useful. Similarly, Eason and Ashby (2002) revealed that many U.K.-based researchers use alerting services to keep up with current developments. Twenty per cent of researchers were active users, who were working towards a personal and integrated operation which would give them up-to-date information via a seamless, and wherever possible cost-free, route from search to full-text articles.

Sciences

Focusing on scholarly communication in the sciences, Tenopir and King have followed scholars and scholarly journals over an extensive period, looking at long-term trends and possible futures. Tenopir and King (2000) summarised data from surveys of scientists conducted between 1977 and 1998, studies of the characteristics of scholarly journals from 1960 to 1995 and an extensive review of the literature on publishing and scientists' information seeking and authorship practices. They suggested that reading and publishing patterns have changed substantially over time, and that the use of online sources was a major factor in recent changes.

The number of articles read per scientist increased from 100 per year in 1977 to 122 by the end of the 1990s. Those articles came from an increasing number of journal titles, an increasing number of electronic journals and increasingly included more e-prints. Browsing continues to be the single most important means of identifying relevant articles, with scientists purchasing fewer journals themselves and relying more heavily on those available through library subscriptions. Scientists were found to be reading more articles than engineers (Tenopir and King 2000).

In a follow up study, Tenopir and King (2002) confirmed the trends noted earlier and reported that the number of journal articles read per researcher had increased to 130 per year, although the average time spent reading has not increased. Disciplinary differences were again noted, with chemists reading an average of 276 articles per year, physicists 204, medical scientists 322 and engineers 72. Importantly, the later study also noted a move to reading electronic articles, which tended to be more current, and made up most of the observed shift towards the reading of more recent articles.

Journal articles were seen as more important than pre-prints, again with disciplinary differences. Physicists had a greater awareness of pre-print servers than did other groups. Among respondents from the Oak Ridge National Laboratory, pre-print reading constituted only 3.6% of all reading. "Of the 99 respondents [from the University of Tennessee], only eight were aware of the arXiv.org service, six were aware of the DOE PrePRINT network, and only four reported that they were aware of other pre-print services" (Tenopir and King 2002, p264). A third study of members of the American Astronomical Society demonstrated a higher use by astronomers of electronic resources, and particularly of pre-print servers, than was found among the previously studied groups (Tenopir 2002).

In a study conducted for the Ingenta Institute on how researchers in the United Kingdom accessed, used and paid for electronic articles from scientific journals, Worlock (2002) revealed that, on average, 65% of respondents ordered between one and five articles each week over and above materials available to them on subscription. Print was the preferred format for the reading of articles (75%), but there was less agreement about the preferred format for archiving articles. The author concluded:

> *the findings of this survey could be signalling that we are approaching a watershed in the migration from user behavior based on receiving and reviewing a periodical publication and using article ordering as a support service, towards a world where article ordering is the critical manifestation of the weekly process of reading and review in the research filed, leaving the printed journal merely as the back-up archival format. This does not mean that the death of the journal is imminent, but it could suggest that the release of articles online as soon as they are reviewed and accepted could be complemented by a much slower delivery of residual print and, in some cases, by the elimination of print entirely* (Worlock 2002, p226).

Detailed studies of electronic journal usage have carried out by the Institute for the Future for Stanford University Libraries and the Highwire Press using in-depth interviews, online surveys and web log analysis among users of biomedical literature (The Stanford E-Just Surveys). Their aim has been to look at the role of the electronic journal in scholarly scientific practice, its impact on the ways in which information seeking takes place and on the ways in which electronic journals add value to research. The study found that e-journals:

- Help researchers to get both depth in a narrow area *and* a broader view of the surrounding areas. It was suggested that "e-journals increase peripheral vision".
- Facilitate greater communication and information flow between researchers – by, for example, enabling them to clip and e-mail interesting papers, which they suggested "oils the network".
- Enable new ways of presenting results that aid communication (eg. visualization, multimedia, etc.); and
- Enable greater visibility (eg. researchers can attach data to a paper, or link it via the web, so others can experiment with the same data and findings. Importantly, they noted that this may reduce need for peer-review in journals, because "its out there for all to see") (Institute for the Future 2001; 2002).

In subsequent studies, E-Just (2002a; 2002b) suggested that e-journals had reached a mature stage among life scientists and clinicians, where almost everyone uses them regularly. Almost 80% of respondents had used e-journals during the week before responding to the survey, 8% had used e-journals more than a month ago, and 12% had used them during the last month. Only 2% were non-users. For most respondents, libraries were the main provider of their online access to e-journals (through institutional subscriptions). Forty-nine per cent of respondents said they visited libraries only when journals were not available online. Only 35% said they visited libraries to read/copy/browse printed editions of any journal on a regular basis. Sixteen per cent said they never visited libraries to access printed journal editions.

Smith (2003) focused on U.S.-based science and social science faculty use of electronic journals, and found that more science faculty members (77%) reported reading articles from electronic sources than did social scientists (69%). The most noticeable disciplinary difference was in personal electronic subscriptions – 35% of science faculty reported reading at least one article from a personal electronic subscription per week, as opposed to only 15% of social science faculty. In addition, slightly more science faculty reported weekly readings from both library print subscriptions and library electronic subscriptions than did their colleagues in the social sciences. While personal print and library print subscriptions were at the top of the 'frequently used' counts, library electronic subscriptions claimed the largest segment of total articles read per week (32%). When that figure was combined with the number of articles read in personal electronic subscriptions and other electronic sources, 44% of all articles faculty read in a week were from electronic sources.

Humanities and Social Sciences

User behavior and attitudes in the humanities and social sciences differ substantially from those in the sciences, reflecting the fundamental differences between different fields and modes of research. It is generally recognized that science researchers have been quicker to take up technology and have benefited more from the increasing availability of electronic journals, pre-print and e-print servers and developments in communications. Those in the humanities and social sciences, however, have not ignored the technology.

One study of the attitudes and practices of university-based humanists in 1998-99 indicated a familiarity with e-mail and word processing among all those interviewed, but marked differences in their access to high quality computing facilities (Massey-Burzio 1999). At that time, faculty complained that the threshold of knowledge required to use some library-based access technologies was too high, that interfaces to online services were often poor and that, on the whole, they preferred books, paper and the ability to browse the shelves physically.

More recently, Brockman et al. (2001) sought to discover how humanities scholars think about, organize and perform their research, how they use information resources and how electronic information resources affect work practices. They suggested that reading was the most important activity of the humanist.

> *Scholars spend a large percentage of their time reading. In fact, they perceive a real danger in not reading. Scholars reported that they do background reading (textbooks), comprehensive reading (everything possible), continual reading (simultaneous and associative), and that they "read around" a period or a person. They read books and related primary material closely – "for detail" and to become "immersed" in their area of inquiry. Scholars read in different media, but rarely read extended texts directly from a computer screen* (Brockman et al. 2001, p7).

Note taking was reported to be integral to reading, as was understanding the context of what is read. References were typically traced backwards, rather than forwards, making the use of citation databases of less value in humanities than in the sciences.

Brockman et al. (2001) also examined some of the intellectual and mechanical components of the research process. They found that technology was used extensively in the humanities for word processing, the organization of bibliographies, scanning/OCR and specialized applications, such as text and speech analysis and music. It was suggested that word processing served not only to preserve the text, but to permit extensive editing and experimentation with ideas. However, when it came to the publication of their work print was the preferred medium. Brockman et al. (2001) conclude that electronic texts have a strong potential to change research practices.

The research process of music scholars has been described by Brown (2002) and has been found to conform to other models of the humanities scholar: idea-generation, background work, analysis, writing and dissemination and current awareness. Music scholars were found to make consistent use of e-mail, discussion lists and other electronic technologies, as well as specific music software. Palmer and Sandler (2003) showed that, by an overwhelming margin, social science researchers preferred electronic access. Economics faculty were the most enthusiastic and anthropology faculty somewhat less so – but there was much less variance than expected. Overall, 75% of the faculty interviewed expressed a preference for electronic access either exclusively, or with some print backup. Of the remainder, 15% expressed a preference for access to both formats, while 6% preferred print only.

The *interdisciplinary* humanities scholar was discussed in detail by Palmer and Neumann (2002). The processes of interdisciplinary work were seen as extending the intellectual sphere by pushing boundaries beyond the scholars' primary expertise, the use of mechanisms which ensure that information is directed to them, maintenance of contacts in other disciplines and the playing of multiple professional roles. Interdisciplinary work was said to demand an understanding of new vocabularies and concepts and the ability to write for broader audiences. One difference noted between this group of scholars and disciplinary humanists was use of the internet for information seeking, with the interdisciplinary scholars making more use of the web "because materials that infused their work were easily found there" (Palmer and Neumann 2002).

The work of NINCH, the U.S. National Initiative for a Networked Cultural Heritage, is an example of a coalition of organizations in the arts, humanities and social sciences which seeks to provide leadership in the evolution of cultural discourse in the digital environment. Wulf (2002) has noted that the humanities offer a new opportunity to explore how information technology can be employed in fundamentally different ways that will provide fresh insights and enrich research in other applications through the demonstration, for example, of exemplary applications. It is clear that systems and services are now emerging that integrate/federate digitised collections, enable collaboration and facilitate new forms of analysis (Greenstein 2003; Henry 2003).

3.3.2 Information access and research practices

Nicholas et al. (2003) argued that we need to examine information search and access in the wider context of research. They concluded that the digital consumer has become 'promiscuous' with short attention spans, hostage to a variety of retrieval systems and an abundance of information sources. Increasingly researchers demand real time systems, with immediate access to information.

For some commentators the advantages of the, so called, Big Deal (where large publishers offer online access to their journal collections in integrated packages) are seen as increasing content for each dollar spent, maximising content delivery, providing a wider spectrum of material that could assist interdisciplinary studies and thus maximising use (Kohl 2002). Others, such as Frazier (2003), feel that these deals, usually spread over several years, lock libraries into arrangements that are not to the benefit of users or their institutions – who commit funds years in advance and typically face built-in price rises. In addition, the high cost of these 'must have' aggregated offerings has led to the capture of library acquisition budgets and the consequent squeezing out of the offerings of independent serial publishers and monograph purchasing.

The sciences have long been seen to be dependent on the scholarly journal. Many journals are now available in electronic form, either through paid subscriptions or because the journal is offered free of charge. Scholars have always made their research known through informal means as well, and have used technological developments to expedite this process (National Research Council 2002). With the emergence of Mode 2 research there is increasing evidence of new patterns of information search and access which both combine and transcend traditional patterns.

A recent review of Library and Information Services in the Commonwealth Scientific and Industrial Research Organization (CSIRO) reported that users required broader scientific information than in the past, reflecting that science has become more multidisciplinary, and with more intellectually mobile staff (through changing disciplines and projects) there is a growing need to search across a wider range of sources. The study also noted that researchers increasingly require access to commercial and business development information, as well as scientific information, as a result of more applied and commercial research activity.[7] In fact, there are many indicators of these emerging patterns of demand, including:

- the popularity of generic web search engines and the relatively lower use of subject gateways, except in areas where they tend to be problem oriented (eg. medical and health) or where the discipline remains strong (eg. mathematics);
- the popularity of databases of electronic journals and, as reflected in usage patterns, the scope they offer to cross disciplinary boundaries and access a much wider range of articles than before – crossing both titles and disciplinary boundaries; and
- the increasing use of research databases and the shift from hypothesis testing to 'suck-it-and-see science', which is leading some to use traditional source (eg. journals) less as they gain better access to primary sources (Institute for the Future 2001; 2002).

Online information search and access practices increasingly reflect the diverse needs of traditional disciplinary research *and* the needs of those engaged in an emerging new mode of knowledge production.

3.3.3 Use of research databases

Databases play an increasingly valuable role in research. The OECD (1998) noted that:

> *Scientists in many fields now produce data sets which are accessible via the Internet to colleagues around the globe. The Internet also provides new opportunities for scientists in different countries to combine local data sets into global ones. This is useful for research projects requiring data from around the world, notably in biological and Earth-related sciences, (eg. the Human Genome Project and the International Geosphere-Biosphere Programme). One notable… example was the immediate release of data collected by the Hubble Space Telescope (HST) to any astronomer wishing to study it* (OECD 1998, p28).

Important too in areas as diverse as astronomy, medicine and music is the increasing ability to store and manipulate images and sounds.

Analysis of this wealth of data increasingly involves complex software.

> *Technologies such as satellite imaging systems and particle accelerators collect huge amounts of data, the interpretation of which often requires specialised software. Computer*

7 Personal communication from Philip Kent, Executive Manager, Knowledge and Information Management, CSIRO, 2 May 2003.

networks can provide wider access to such software. For researchers, one of the most important changes wrought by the Internet, and particularly the WWW, has been the ability to readily upload specialised software code. Transfer and use of software via the Internet have become as essential to many researchers as e-mail. Given the increased sophistication of software and the considerable investment required to develop it, the incentive to share software is increasing. Programmes that earlier would have been written solely for personal use are now made available over the Internet, where libraries of free software for scientific purposes are growing (OECD 1998, p36).

Box 3.1 Examples of shared databases

Large shared databases have become important resources in many fields of science and social science. These databases allow researchers working on different pieces of large problems to contribute to and benefit from the work of other researchers and shared resources. Examples of such databases include the following:

GenBank (www.ncbi.nlm.nih.gov/Genbank/) is the National Institute of Health's annotated collection of publicly available DNA sequences. As of June 2001, GenBank contained approximately 12.9 billion base pairs from 12.2 million sequence records. The number of nucleotide base pairs in its database has doubled approximately every 14 months. As part of a global collaboration, GenBank exchanges data daily with European and Japanese gene banks.

The Protein Data Bank (www.rcsb.org/pdb/) is the worldwide repository for the processing and distribution of three-dimensional biological macromolecular structure data (Berman et al. 2000).

The European Space Agency (ESA) Microgravity Database (www.esa.int/cgi-bin/mgdb) gives scientists access to information regarding all microgravity experiments carried out on ESA and National Aeronautics and Space Administration missions by European scientists since the 1960s.

The Tsunami Database (www.ngdc.noaa.gov/seg/hazard/tsu.html) provides information on tsunami events from 49 B.C. to the present in the Mediterranean and Caribbean Seas and the Atlantic, Indian, and Pacific Oceans. It contains information on the source and effects of each tsunami.

The Earth Resources Observation Systems Data Center (edcwww.cr.usgs.gov/) houses the National Satellite Land Remote Sensing Data Archive, a comprehensive, permanent record of the planet's land surface derived from almost 40 years of satellite remote sensing. By 2005, the total holdings will come to some 2.4 million gigabytes of data.

Source: National Science Board (2002) *Science and Engineering Indicators 2002,* Arlington, VA: National Science Foundation, 2002 (NSB-02-1), p8-25.

Not only are ICTs important for storing and sharing scientific information, they are also increasingly important in automated data collection. In many areas data are now collected in digital form (eg. seismic data, remote imaging, mineral composition and oceanographic data, music and film) – ie. born digital. This makes data analysis faster and easier. Sinclair (1999) cited the example of automated gene sequencers, which use robotics to process samples and computers to manage, store, and retrieve data, and have made possible the rapid sequencing of the human genome, which in turn has resulted in unprecedented expansion of genomic databases (National Science Board 2002, p8-25).

Certainly in such areas as genetics, genomics and proteomics the cutting edge of scientific research and of information technology converge (eg. in bioinformatics) (Houghton 2002b). Databases allow researchers to analyse and manipulate protein structures and give access to huge volumes of genetic information. Discussing the genetic and genomic revolutions, Tollerman et al. (2001), suggested that:

> *The genomics wave is technology-driven, formed by the integration of new high throughput techniques with powerful new computing capabilities. It is active throughout R&D, most immediately at the drug discovery stage, and promises to enhance productivity greatly, without jeopardizing downstream success rates. The genetics wave is data-driven, exploiting the details of individuals' genetic variation that are emerging from the oceans of genomic data…*
>
> *We characterize genomics… as the confluence of two interdependent trends that are fundamentally changing the way R&D is conducted: industrialization (creating vastly higher throughputs, and hence a huge increase in data), and informatics (computerized techniques for managing and analyzing those data). The surge of data – generated by the former, and processed by the latter – is of a different order from the data yields of the pre-genomics era* (Tollerman et al. 2001, pp1-2).

In a study of U.K.-based academic researchers, Education for Change et al. (2002) found that 48% of the researchers they surveyed were using computerised datasets of primary data, and 34% thought that their use would increase in the future. They found that use was higher in the sciences, but still considerable in the arts and humanities. By research field:

- 31% of U.K.-based medical and biological sciences researchers considered datasets to be essential to their research, a further 24% used them and 44% believed that their use would increase;
- 28% of physical sciences and engineering researchers considered datasets to be essential to their research, a further 23% used them and 39% believed that their use would increase;
- 27% of social science researchers considered datasets to be essential to their research, a further 24% used them and 31% believed that their use would increase;
- 33% of areas studies and languages researchers considered datasets to be essential to their research, a further 12% used them and 23% believed that their use would increase; and
- 14% of arts and humanities researchers considered datasets to be essential to their research and a further 23% used them (Education for Change et al. 2002).

Similarly, in a survey of scientists and engineers in the United States, the National Science Foundation found that 34% reported using digital libraries and data repositories, and a further 23% expected to do so in the future (Atkins et al. 2003, pB5).

Lyman and Varian (2000) estimated that the world produced between 1 and 2 exabytes (ie. billion gigabytes) of unique information per year, roughly 250 megabytes for every man, woman and child on earth. Printed documents of all kinds comprise only 0.003% of the total. As Hey and Trefethen (2002) put it, "...it is evident that e-science data generated from sensors, satellites, high-performance computer simulations, high-throughput devices, scientific images and so on will soon dwarf all of the scientific data collected in the whole history of scientific exploration." Closer to home, it is notable that the fastest growing area of ICT related trade between Australia and the rest of the world since the early 1990s has been database and subscription services. Between 1993-94 and 2001-02, database services exports increased by 34% per annum and imports increased 33% per annum, compared with increases in overall ICT related services exports of 7.4% per annum and imports of 5.9% per annum (Houghton 2002a).

There is truly a revolution in the systems of scientific and scholarly information access, which has not yet entirely registered with most of those writing on scholarly communication. The U.S. National Research Council (2001) went so far as to suggest that:

> *The rapidly expanding availability of primary sources of data in digital form may be shifting the balance of research away from working with secondary sources such as scholarly publications. Researchers today struggle to extract meaning from these masses of data, because our techniques of searching, analyzing, interpreting, and certifying information remain primitive. New automated systems, and perhaps new intermediary institutions for searching and authenticating information, will develop to provide these services, much as libraries and scholarly publications served these roles in the past* (National Research Council 2001, p5).

The level of use of research databases and expectations regarding future use, and the potential therein for new modes of information access and dissemination, suggest a need to pay much more attention to the use of databases and non-traditional, non-text digital objects in the future.

3.4 Dissemination and publication

The main focus of attention in the literature on dissemination and publication has been on the publication of scientific journals and the potential for electronic publication to reduce the price of journals. There has been much less discussion of monographs, and very little discussion of non-text material or informal mechanisms of dissemination.

Scholarly publishing has been seen by many as being in crisis, because of rapidly increasing prices charged for publications (especially journals), the increasing quantity of information being published, the move from print to electronic publishing with its accompanying need for technological and network support, demands to maintain print collections, and the need to ensure that researchers can get access to the information they require. Early predictions of a rapid demise for print publishing are now being tempered. There has been a significant movement in the last three years, and there is little doubt that the future will be increasingly electronic, but it is unlikely that print will disappear entirely for some years as nearly all user studies indicate an substantial residual demand for print.

King and Tenopir (2003) noted that over the centuries scholarly journals have demonstrated remarkable stability. They identify two elements, however, which have evolved over the last thirty years that, they believe, have the potential to either destroy the scholarly journal system or substantially enhance its usefulness and value. These two factors are the development of ICTs and the ability to deliver material digitally to the desktop, and the underlying economics of the journal system.

Odlyzko (2002) suggested that ease of access and ease of use will dictate what comes to the fore, and that the traditional scholarly journal may not prove to be as important in the longer-term. He suggested that other forms of scholarly publishing might well emerge to take its place and that the key to their viability will be their visibility. "Whether they like it or not, scholars are engaged in a 'war for the eyeballs' just as much as commercial outfits, and ease of access will be seen as vital" (Odlyzko 2002, p18). JISC's Scholarly Communications Group (2002) suggested that multimedia and distributed computing grids are developments which extend the processes of scholarly communication, while at the same time presenting considerable management challenges. They pointed to the need for new pricing and publishing models, new applications of intellectual property law and new approaches to the preservation of digital repositories.

The increasing use of ICT allows for changing patterns of scientific and scholarly communication and discourse. Interactive collaboration enhances research productivity and innovation at the creation level, but traditional frameworks for publishing may constitute barriers. While online publishing has transformed access to material, there is increasingly a struggle between what Willinksy (2001) has called "corporate and civic forces". Publishing is now facing two distinct paths of evolution. One in which large multinational commercial publishers are increasing their dominance in such areas as 'branded' journal titles and access to scientific publications, and the other in which there are a variety of open access initiatives.

3.4.1 Scholarly publishing in transition

It was initially hoped that the introduction of electronic journals would reduce the cost of journals, but this has not been the case. Libraries often have to pay for both print and electronic versions, publishers' aggregations and electronic conversion charges as well as web portals. As a result, Harnad (2001) argued, the commercial publishers' price levels make most articles in the commercial literature inaccessible to most potential users.

Parks (2001) has identified a "Faustian grip in academic publishing" and suggested that while many solutions to the so called serials crisis have been offered, they all suffer the same Faustian Grip – "namely that the actors in the academic publishing game have little or no incentive to stop publishing in the current journals". Frankel (2002) argued that we now need to build a new publishing system, operating within existing copyright law that will embody the core values that shape scientific publishing. Frankel suggested that a shift in licensing arrangements will need to be achieved by developing consensus and not through local legislation or editorial coercion.

Copyright and licensing are one key to changing publishing patterns. This is a major issue as commercial publishers, particularly in the sciences, have significantly changed the commercial landscape of higher education and scholarly information access. There are now over 20 000 peer reviewed journals, most produced commercially, which operate as 'toll gates'. Bergstrom (2003) noted that research libraries now spend 91% of their serials budget on for-profit journals which account for only 38% of citations. In comparison, he noted that the 9% of U.S. research library serials budgets that go to not-for-profit journals accounts for 62% of citations.

McCabe (2002) identified the scientific journal publishing industry as a true market failure… suggesting that in the digital environment the only thing publishers need to provide is the infrastructure for providing the material online, a few account managers and advertising. But Morgan Stanley's analysis of the STM publishing industry, *Scientific Publishing: knowledge is power*, predicts that the nature of the industry will not change in the foreseeable future (Morgan Stanley 2002).

Six models of scholarly publishing were outlined by Kling et al. (2002). The five dominant models are:

- Pure electronic journals – an edited package of articles that is distributed to most of its readers in electronic form (eg. the *World Wide Web Journal of Biology* and the *Journal of the Association for Information Systems*);
- Hybrid paper-electronic (p-e) journals – package of peer-reviewed articles that is distributed primarily in paper form but is also available electronically (eg. *Science On-line, Cell, Nature,* and many others);
- Electronic print (e-print) servers – pre-print or re-print servers on which authors in specific fields post their articles (the original and most widely copied pre-print server is the Los Alamos physics server arxiv.org);
- Non-peer-reviewed publications on-line – including electronic newsletters, magazines, and working papers; and
- Personal Web pages – maintained by individuals or research groups. Many scholars post their own work on these sites, which may include re-prints of published material, pre-prints, working papers, talks and other unpublished material, bibliographies, datasets, course material, and other information of use to other scholars (See National Science Board 2002).

The sixth model suggested was that of working papers and technical reports, sponsored by the employing institution. This model, which Kling et al. (2002) called Guild Publishing, already exists, is widely used in such fields as economics and usually provides information free of charge or at low cost.

Harnad (2001) focused on researchers as the focal point for change because they are the producers of the content. Seeing the peer review service as an essential element of the publishing process, he argued that researchers should deposit/self-archive their peer reviewed papers in electronic open archives/institutional repositories. To achieve this he suggested six strategies: authors paying journal publishers for publisher-supplied online-offprints, boycotting journals that do not agree to give away their content online for free, library consortial support, delayed journal give-aways 6-to-12 months after publication, giving up established journals and peer review altogether in favour of self-archived pre-prints and post-hoc, ad-lib commentary and self-archiving all e-prints.

The issue of cost is an important one in terms of present debates. A model which has been receiving significant attention is one in which authors, institutions or libraries would pay the cost of peer review, thus enabling the free electronic dissemination of articles. This forms the basis of the publications in ninety journals by one major publishing firm, BioMed Central (www.biomedcentral.com). Another model is that of self-archived electronic pre-print, e-print and re-prints to be supported at the institutional level with shared metadata (ie. institutional repositories). The institutional repository is also important in that it enables the host institution to display its intellectual quality – a characteristic explored in depth in a recent position paper issued by SPARC, which also examines the relationship between the repository and the university press (Crow 2002a; 2002b).

Crow (2002a) suggested that institutional repositories centralise, preserve and make accessible an institution's intellectual capital *and* form part of a global system of decentralised, distributed repositories. This attribute is central to the role repositories can play in a disaggregated model of scholarly publishing. Lynch (2003) suggested that the development of institutional repositories was:

> *…a new strategy that allows universities to apply serious, systematic leverage to accelerate changes taking place in scholarship and scholarly communication, both moving beyond their historic relatively passive role of supporting established publishers in modernizing scholarly publishing through the licensing of digital content, and also scaling up beyond ad-hoc alliances, partnerships, and support arrangements with a few select faculty pioneers exploring more transformative new uses of the digital medium.*
>
> *Many technology trends and development efforts came together to make this strategy possible. Online storage costs have dropped significantly; repositories are now affordable. Standards like the open archives metadata harvesting protocol are now in place; [and] some progress has also been made on the standards for the underlying metadata itself. The thinking about digital preservation over the past five years has advanced to the point where the needs are widely recognized and well defined, the technical approaches at least superficially mapped out, and the need for action is now clear. The development of free, publicly accessible journal article collections in disciplines such as high-energy physics has demonstrated ways in which the network can change scholarly communication by altering dissemination and access patterns; separately, the development of a series of extraordinary digital works had at least suggested the potential of creative authorship specifically for the digital medium to transform the presentation and transmission of scholarship* (Lynch 2003).

Underpinning the institutional repository movement is the Open Archives Initiative (OAI). It aims to develop and promote interoperability standards that facilitate the efficient dissemination of content, while the OAI Metadata Harvesting Protocol allows the development of a global network of cross-searchable repositories (Needleman 2002). OAI compliant software which enables institutional archiving with appropriate harvesting is now freely available.

The Open Archive environment also offers opportunities for the digital monograph and e-presses. The Knight Higher Education Collaborative (2001) described scientific research as "deliberately cumulative and immediate in its impact", creating a "need for expediency [which has] helped make the scientific article the staple unit of expression…". By contrast, scholarly work in the social sciences and humanities is said to be "of a different kind and hence requires a different kind of communication" – namely, the scholarly monograph, which "has proven to be remarkably well suited" for the purpose (Knight Higher Education Collaborative 2001, p206).

While humanists are often seen to be embedded in the culture of the book, it should be noted that Brockman et al. (2001, p18) questioned the truism that humanities scholars prefer books to journals, suggesting that it is an oversimplification at best and may, in fact, be downright wrong. There is a growing awareness that the book can be improved in the networked environment, with the possibility for innovations which could benefit scholarship. The new electronic publishing initiatives appearing in 2002 and 2003 to some extent reflect the deconstruction of books into articles/chapters along the lines identified by Brockman et al.

The new digital environments have the potential, according to Wittenberg (2003), to transform the process of publication, particularly in the context of collaborative research output. Wittenberg noted that authors and editors will share an electronic space in terms of creation and editors will become part of the front line, seeing their authors "as active collaborators in creating new models rather than as lone toilers in specialized areas." Authors and editors will need to confront a number of questions, such as: will narratives necessarily be presented in a linear form; can meaning be changed by the form in which it is read; are there new ways to present an authorial voice; how does multimedia interact with text; and can one connect individual works of scholarship through electronic networks?

One proponent of change is Darnton (1999), who has put forward his vision as follows:

> *An "e-book," unlike a printed codex, can contain many layers, arranged in the shape of a pyramid. Readers can download the text and skim through the topmost layer, which would be written like an ordinary monograph. If it satisfies them, they can print it out, bind it (binding machines can now be attached to computers and printers), and study it at their convenience in the form of a custom-made paperback. If they come upon something that especially interests them, they can click down a layer to a supplementary essay or appendix. They can continue deeper through the book, through bodies of documents, bibliography, historiography, iconography, background music, everything I can provide to give the fullest possible understanding of my subject. In the end, readers will make the subject theirs, because they will find their own paths through it, reading horizontally, vertically, or diagonally, wherever the electronic links may lead* (Darnton 1999).

Another interpretation of the changing models of print and electronic text has been presented by Esposito (2003), who contrasted the printed book of history, the 'primal book', with the 'processed book'. Esposito said that this has at least five aspects: as a self-referencing text; as portal; as platform; as machine component and as network node. This allows for a flexibility in access and distribution which will call for different societal patterns of knowledge utilisation. The whole act of reading could be deconstructed from linear models, and publishing could become segmented.

Similarly, Cope and Kalantzis (2003) indicated that the printed book will see a significant change in what they call 'the mechanics of rendering'. In the world of print, text is marked up for a single rendering, but in the digital world text as published is marked up for structure and semantics, which allows for alternative renderings in formats such as print, web or audio. Lynch (2001) noted that two different and distinct things are happening to the book as it moves into the digital medium. It is being translated rather literally into a digital representation, and it is undergoing a transformative evolution into new genres of digitally-based discourse. Lynch recognized that the electronic book has still to establish "the balance points among publisher fears, consumer desires and technical capabilities" and that to date it had not found a sustainable economic model. However, a variety of models have emerged since 2001.

Lynch's 'new genres of digitally-based discourse' describe new forms of digital publication which are not as tightly bounded as the book, but which provide opportunities to link and interlink information, whether in text or in other formats. The trend towards this kind of publication is being assisted by the trend towards the provision of primary materials in digital form, including cultural heritage materials and other data equivalent to that being collected and assembled for scientific research. Lynch sees this kind of project as introducing the potential for data mining, or the humanities equivalent, and developed the idea of books which talk to each other through mark-up, "really good mark-up that exposes intellectual and semantic structure, that exposes content for linkage and data mining, and computation" (Lynch 2003).

A number of analysts have noted that appropriate systems for electronic dissemination and publishing differ among disciplines. It is equally clear that they differ according to mode of research (ie. between Mode 1 and Mode 2 knowledge production). At one extreme is the example of high-energy physics, with pre-prints typically made freely available at the time of submission to a journal.

> *This type of research evolves around a limited number of expensive instruments and involves large collaborative research groups, sometimes with over 400 scientists. Working practices for this type of science differ sharply from those of other disciplines. The collaborative structure of the work and the long time horizons involved mean that the research has been extensively reviewed before submission to a journal. A reviewer is unlikely to find major conceptual errors and is also unlikely to add much in terms of editing. Furthermore, there is little risk of plagiarism. The scientists involved are few and well-known, access to the equipment is extremely restricted, and the time to publication is very short.*
>
> *This is very different from a discipline like biology. Biological research is quite fragmented and involves many small research groups and individual researchers. Biological research is also easier to extend or copy, and research facilities are common and relatively cheap. Biology researchers are therefore more reluctant to share research prior to publication. Some areas of biology, such as cancer and AIDS research, are also closely linked to commercial applications, and researchers in these fields often work with the private sector. These researchers are often unwilling to share research methods, materials and results, as the work can be lucrative and is often highly competitive. Publication in biology is centred around peer-reviewed journals, and pre-prints are quite rare* (OECD 1998, p54).

Carim (2002) also pointed out that pre-prints are better suited to some disciplines that others.

> *In the physics arena, a culture of circulating hard copy drafts of articles to peers before submission for publication pre-dated the advent of digital technology. In* Scholarly Communication in the Third Millennium *(2 May 2000), John Houghton points out that universities and the public sector are less averse to sharing knowledge to push*

> *forward the boundaries of theoretical science, but that groundbreaking results achieved by the commercial sector in experimental science tend to be carefully guarded before patents are issued.* (Carim 2002, pp153-155).

Crucial factors determining research dissemination practices include: collaborative practices (team composition, sharing of data, commercial character of the research), the use of pre-journal publication formats (pre-prints, working papers or conferences), and the ways in which research journals are used (Kling and McKim 1997; OECD 1998; Kling and McKim 2000). To which might be added, the extent of commercial linkages and linkages to the context of application within the field of research and the balance within the field of Mode 1 and Mode 2 knowledge production.

All this suggests that we are just beginning on the road to much more flexible notions of publishing a wide range of linked digital objects, and that despite their resilience neither books nor journals are immune to change.

3.4.2 Publication motives and mechanisms

Although looking only at journal publication, Swan and Brown (1999) provided insights into the publication motivations of authors in the United Kingdom and elsewhere. They found that:

> *The main objective for publishing work remains communication with the author's peers. Enhancing career prospects is the second most common reason, followed by gaining personal prestige and funding for future work. Direct financial reward was only given as a reason by a tiny minority of respondents. Authors from the sciences and arts differ with respect to the importance of publishing their work on future funding. For scientists, this is an important reason for publishing, but is much less so for authors in the arts fields* (Swan and Brown 1999).

When choosing where to publish (ie. which journal) Swan and Brown (1999) found that authors consider a range of factors:

> *First among these is the reputation of the journal. Its impact factor, international reach and the coverage by abstracting and indexing services follow, very close together. The journal's circulation, subject coverage and publication speed were also cited by substantial numbers of respondents. There are… differences between authors working in various fields… Scientists are much more concerned about the availability of an electronic version of the journal than are workers in the arts. Publication speed is also significant to scientists, particularly chemists, whereas it is much less important to people working in social sciences or the humanities* (Swan and Brown 1999).

In a follow-up study, Key Perspectives (2002) noted that among their international sample, 91% saw traditional print and electronic journal publishing as important – twice as many as chose either all print or all electronic alternatives. Swan and Brown (1999) also noted that most researchers see the publication process, based around peer review, staying much the same, while being conscious that publishing is increasingly about building the author's C.V. and somewhat less about communication that was formerly the case. They observed that:

> *Looking forward to the future, more than two-thirds of authors wish to see scholarly publishing continue broadly in its present way, but the most popular expectation (and*

> *also hope) for the future was that electronic publishing with a rapid peer review system might develop further than at present. ...two-thirds of authors agree that the purpose of scholarly publishing does seem to be changing. It is seen as moving away from knowledge dissemination to the building of an author's C.V./resumé or reputation* (Swan and Brown 1999).

Using simple quantitative publications measures in research evaluation and the distribution of funding in Australia has recently been criticised by the Australian Academy of Social Sciences (Mann 2002), Academy of Science (Barber 2002) and the Academy of the Humanities, particularly in relation to publication patterns and the impact on early career researchers. It appears to be leading to increased publication in 'second tier' journals.

> *Last October the Academy [of science] published a report which showed that Australia's share of scientific publications had increased markedly over the 1990s, but the relative impact of Australia's publications, as measured by citations, had declined and continues to fall behind most other OECD countries. Even more disquieting are the findings reported by Linda Butler (of the Australian National University's Research School of Social Sciences) in her submission to this review, that this increase in university output has occurred disproportionably in journals of lower impact. Significantly, a similar effect is not seen in the output of other research agencies such as the CSIRO. Butler hypothesises that these results are consequences of a funding algorithm, introduced originally in the early 1990s and maintained in the post-White Paper reforms, that involves a volume-based publication measure that does not discriminate on any quality measures. In contrast to Australia the citation impact of U.K. science has increased over recent years, plausibly because excellence is the major factor that drives the allocation of block research grants to U.K. universities* (Barber 2002).

It seems that the structure of incentives faced by researchers influences both the type and quality of published output.

Quality control of published research through peer review continues to be an important issue, although there is some debate as to just how important it is, and whether there are alternatives. Looking at concerns in relation to publishing, Swan and Brown (1999) found that copyright, publication delays and peer review were the main areas of concern. Key Perspectives (2002, p27) found that among their international sample of researchers, 74% strongly agreed that peer review was preferred.

Jefferson et al. (2003) indicated that the use of peer review is usually assumed to raise the quality of the end product and to provide a mechanism for rational, fair and objective decision making. However, they noted that these assumptions have rarely been tested and that research has not clearly identified or assessed the impacts of peer review on importance, usefulness, relevance or quality of publications. In fact, the value of peer review is increasingly being questioned. Williamson (2003) noted the fact that while peer review has significant value for authors, reviewers and editors, the system is too slow, too expensive, too subjective and too biased.

Odlyzko (2002) took the view that the need for peer review is over-rated. Rowland (2002b) contradicted this, noting that researchers want to see peer review maintained, despite its shortcomings of subjectivity, bias, abuse, fraud and misconduct, and the costs it adds to the journal. In 2002, a special issue of the

Journal of the American Medical Association, devoted an entire issue to peer review. It concluded that the process is weak. A recent study for the Cochrane Collaboration produced further evidence on the ineffectiveness of the peer review system in improving the quality of published bio-medical research (Jefferson 2003). Cochrane Collaboration (2003) concluded that: at present, there is little empirical evidence to support the use of editorial peer review as a mechanism to ensure the quality of biomedical research. So widespread is concern that the British Royal Society has launched a review, charging a committee to determine best practice for peer review and to consider alternatives (Peek 2003).

McKiernan (2003) suggested a variety of models, such as moderator or tier based, which could be utilised in improving the process of peer review in the electronic era. Buckholtz et al. (2003) reported that the need for maintaining quality control in the system while working for change was an outcome from an international meeting at CERN in Geneva in March 2001. While the participants were unanimous in their belief that the certification and scholarly work remains a fundamental part of a scholarly communication system, it was also generally believed that the electronic environment allows for new and innovative approaches.

With the advent of new electronic communication possibilities and the emergence of a new mode of knowledge production, research communication and publishing have diverged. Increasingly over recent years, publishing has become a system for accreditation and reward, while communication and dissemination practices have become more diverse and less formal. Re-aligning the interests of researchers as authors with those of researchers as readers will require fundamental reforms to research evaluation, review and funding practices.

3.5 Common themes

There are a number of common themes in these studies of research practices around the world. These include:

- Major differences between disciplines, fields and modes of research in respect to communication and collaboration, information search and access, and dissemination and publication;
- Rapid increases in the use of electronic/digital tools and content in all disciplines, fields and modes – although some are further advanced as adopters than others (generally, sciences use ICTs more than the arts, but that may be due to lack of appropriate tools);
- Internet is seen as a very important tool, with widespread use made of generic search engines and somewhat less use of specialist portals and subject gateways;
- Interdisciplinary researchers make more use of the internet (and other electronic media);
- Rapid increases in the use of data, databases and datasets as primary sources, and a shift away from secondary sources (eg. publications) – both as an input to research and output from it;

- Collaboration and wider collegial networks are increasingly important – including in the humanities, where low co-authorship may disguise significant levels of collaboration;
- Social practices or the 'culture' within disciplines, fields and modes of research, and individual researcher habits are a significant influence on research practices;
- Widespread expectation of the persistence of print and of peer review, despite perceived problems and the increasing availability of alternatives; and
- Performance measures and funding demands are key drivers of researcher behaviour – researchers respond rationally to the incentive structure.

The next chapter explores changing research practices in Australia.

4. Research practices in Australia

This chapter reports findings from the original research conducted for this study – namely, a series of in-depth interviews with senior researches in Australia and four research practices workshops convened at universities in Australia's south-eastern states. The chapter begins by examining the characteristics of the researchers interviewed and the context of their research activities. It then explores research practices relating to the three key areas of communication and collaboration, information search and access, and dissemination and publication.

4.1 Characteristics and context

In-depth interviews were conducted during March and April 2003 with a small structured sample of active, senior researchers in Australia. Interviews were wide-ranging and exploratory. The aim was to go beyond *what* researchers do, to find out *why*. It is important to note that interviews targeted active, senior researchers able to talk authoritatively about their field of research, as well as their own work. This led to the selection of a sample that was more senior, in terms of both position and age, than would have been the case with a random sample. The sample was structured so as to target 'the leading edge' of research, and shed light on the direction of developments and future needs.

Issues and ideas arising from the interviews were further explored in workshops convened at four universities in Australia's south-eastern states during May 2003. Participants were encouraged to raise issues of concern to them, but discussions focused around major trends in research, and changing practices in relation to communication and collaboration, information search and access, and dissemination and publication. The workshops were used to gather information from researchers in a context that encouraged them to compare and contrast their experiences with researchers in other fields and disciplines, and to test some of the impressions and conclusions emerging from interviews.

Both interviews and workshops focused on research, rather than administration activities or teaching. A number of respondents made comments to suggest that their use of sources (both print and electronic) was broader in total than it was for their research. Questions like "Do you use online news services?" often drew such responses as "Yes, but not for research".

On some occasions it was not possible to ask all the detailed questions – see the interview guide at Appendix 4. In such cases, data collected from institutional or personal websites, reports and publications were used to fill in the gaps wherever possible (eg. for publication counts, work experience, funding grants gained, etc.). Nevertheless, occasional 'non-responses' remain, and in those cases reported percentages are of responses rather than respondents.

Interview and workshop findings build on a substantial corpus of knowledge (as outlined in chapters 2 and 3). Nevertheless, given the structure of the sample, the small sample size and the exploratory nature of the interviews, reported percentages can be taken as no more than a guide to *what* is happening. However, comments derived from the interviews and workshops shed considerable light on *why* it is happening, and that is the main purpose of this study. Hence, researchers' comments from both interviews and workshops are included to shed light on their thinking on particular issues and to provide a window onto their reasons for doing what they do. They either directly quote or paraphrase what was said, based on interview and workshop notes.

Box 4.1 The interview and workshop samples

Interviewees were selected because they were:

- Active researchers – as evidenced by a significant publication and/or patenting record;
- Senior researchers – able to talk authoritatively about their field of research, as well as their own work;
- From a range of fields and disciplines – covering a wide range of research fields and activities;
- From a range of institutional settings – including universities (faculty, university, special and key centres), public sector research institutions and cooperative research centres; and
- Selected so as to cover a range of basic criteria (eg. gender, location, etc.).

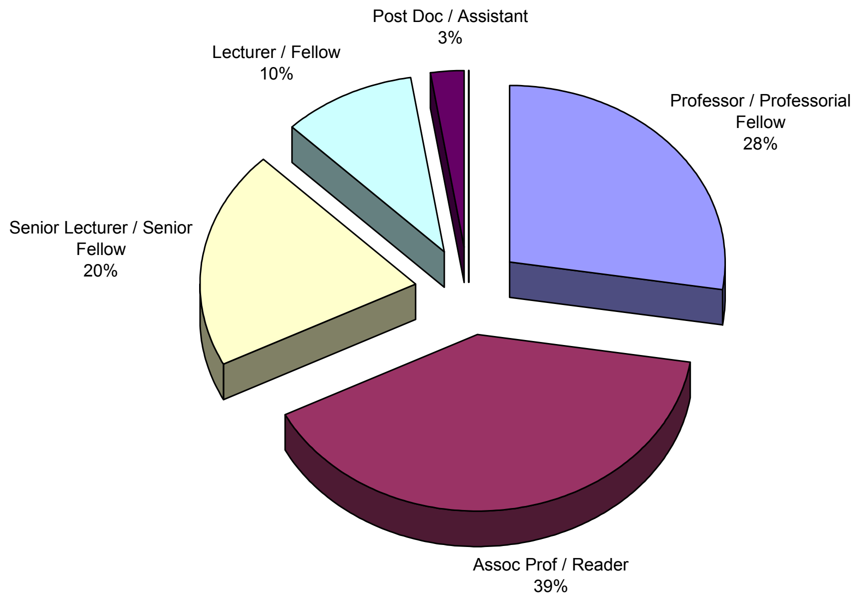
It should be noted that these criteria led to the selection of a sample that was more senior, in terms of both position and age, than would have been the case with a random sample. There were 40 useable interview records (N=40).

Workshops were held a four universities in Australia's south-eastern states. In addition to researchers from a range of fields and disciplines, workshops were attended by: representatives of the university libraries and research offices in each location, the authors and a rapporteur (Mr. Peter Morris, Telesis Consulting). Researchers attending the workshops were drawn from across the university staff communities, with an emphasis on senior researchers. They included representatives of medical and biological sciences, physical sciences and engineering, social sciences, area studies and languages, and humanities and arts. A total of 35 participated in the workshops.

4.1.1 Position and experience

The sample targeted experienced, senior researchers. Around 28% of interviewees were Professor/Professorial Fellow or equivalent, almost 40% were Associate Professor/Reader, 20% Senior Fellow/Senior Lecturer and 13% Lecturer/Fellow or below. Seventy-three per cent were male and 27% female. Interviewees had been researchers (including their PhD years) for an average of around 19 years (minimum 5 and maximum 40). On average, they had been at their current institution for almost 10 years (ranging from less than a year to 30 years).

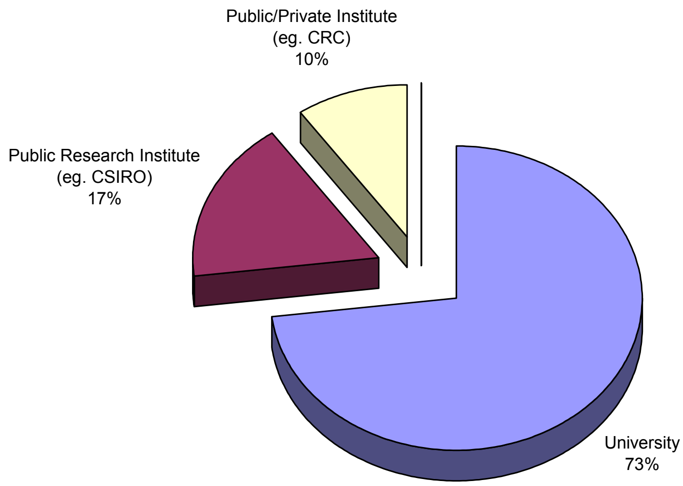
Figure 4.1 Characteristics of the interview sample: position of respondents



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

To gain insights into the practice of research in a range of institutional settings interviews were conducted with researchers from a variety of university faculty, key and special centres, the Commonwealth Scientific and Industrial Research Organization (CSIRO) and a number of Cooperative Research Centres (CRCs) and Independent Medical Research Institutes (MRIs). Some of those interviewed held positions ranging across these institutional borders, and where that was the case their principal allegiance was identified by their sources of funding. Just over 70% of interviewees were based at university faculty, key or special centres, almost 20% were based primarily at the CSIRO and the remaining 10% were operating primarily through CRCs.

Figure 4.2 Characteristics of the interview sample: institutional setting of respondents



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

There were indications of wide-ranging experience, with more than 60% reporting that they had worked as researchers in other types of institutions, and 70% indicating that they had worked overseas (excluding overseas fieldwork). Most mentions were of the United States and the United Kingdom, then New Zealand and South Africa, China and Canada, Netherlands, Germany, Switzerland, Taiwan, Philippines, Chile and Saudi Arabia. Researchers in science and medical fields were more likely to have worked overseas (80%) than those in social sciences, humanities and arts (60%), and researchers in metropolitan locations were more likely to have worked overseas (90%) than those in regional locations (60%).[8]

As might be expected, those interviewed performed a range of non-research duties. On average, they reported spending around 50% of their time on research, 25% on teaching and 25% on administration and other activities. However, standard deviations ranged from 23% (teaching) to 30% (research), with some being full time researchers (eg. Research Fellows) and others having limited research time (eg. Heads of Department or Centre Directors). However, all were active researchers –

8 In structuring the sample for interviews we sought to include a range of institutional settings and geographic locations. For the purposes of this study metropolitan refers to Canberra, Sydney, Melbourne and Brisbane, with all other locations designated regional. It should be noted that regional locations included a larger share of medical and biological sciences researchers, and metropolitan locations a larger share of social sciences researchers, and metropolitan locations included no CRCs and a higher share of universities.

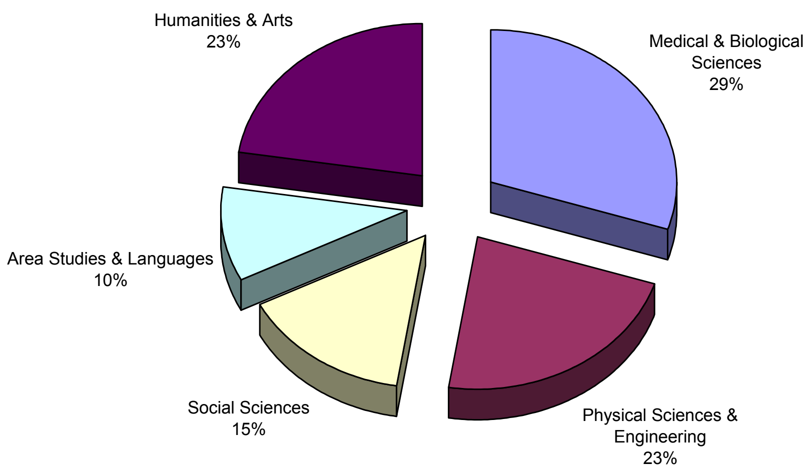
almost 30% reported no teaching activity and 22% reported no non-research related administrative activity.

4.1.2 Research fields and disciplines

Broad coverage of research fields and disciplines was a key to the sample structure. For the purposes of comparison, two systems of categorisation were used. First, five research 'clusters' broadly defining research activities. Second, the more detailed 24 category Research Fields Disciplines and Course (RFDC). See Appendix 3 for details.

By 'research cluster', 29% of interviewees were in medical and biological sciences, 23% in physical sciences and engineering, 23% in arts and humanities, 15% in social sciences and 10% in area studies and languages. However, it should be noted that many of the respondents worked in settings and ways that were profoundly interdisciplinary, such that detailed categorisation was sometimes rather difficult.

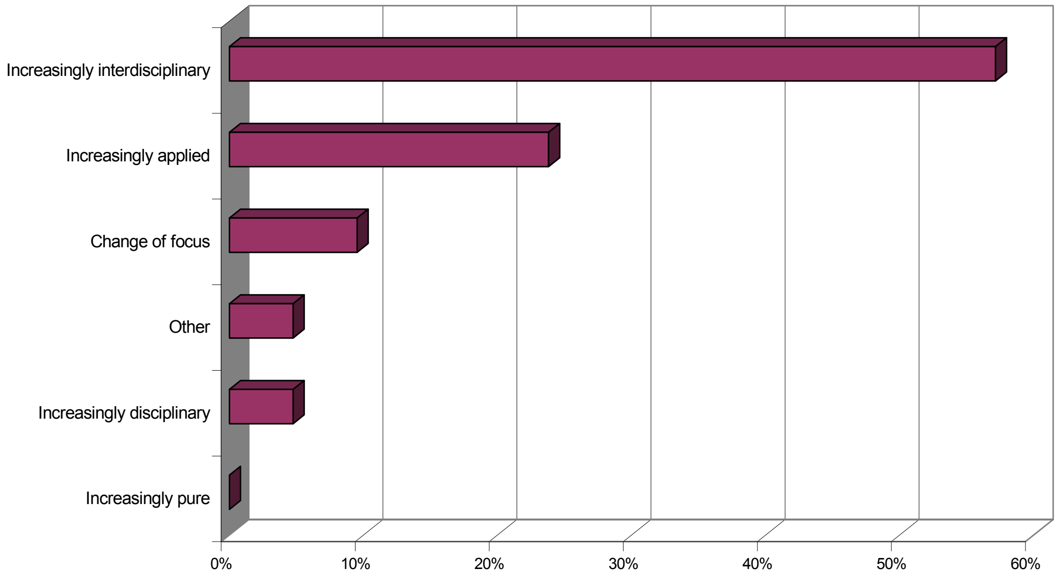
Figure 4.3 Characteristics of the interview sample: field of research



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Asked if they would describe their research as disciplinary or interdisciplinary, pure or applied, 55% said it was interdisciplinary and almost 40% said applied. Less than 10% reported a disciplinary focus. More than 50% reported that the field or focus of their research had changed over the last five years. Of these, 57% said that it was becoming increasingly interdisciplinary, and 24% said it was becoming increasingly applied. Other interviewees suggested that their work was shifting focus or 'broadening', but would not nominate whether that amounted to a more interdisciplinary approach. Just 5% suggested that their work was becoming increasingly disciplinary. These responses suggest that researchers are indeed experiencing a shift towards more interdisciplinary and applied activities (ie. towards Mode 2 research).

Figure 4.4 Changes in the nature of research over the last 5 years?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment,* DEST, Canberra.

4.1.3 Funding sources and issues

Interviewees were asked about their funding sources and changes in those sources over the last five years in order to examine whether the expectations and demands of funders influenced researchers information needs or their dissemination and publication practices. We found that in some cases they do.

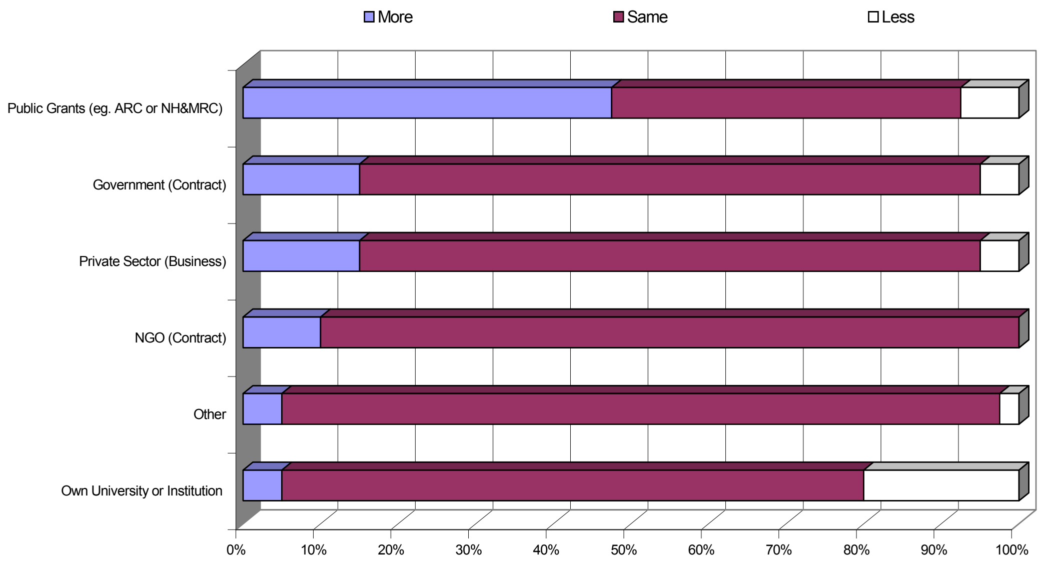
Across the sample, public research grants (eg. ARC and NH&MRC) accounted for around 45% of researchers' funding over the last year, internal institutional sources accounted for around 30%, and private and public sector research contracts each accounted for around 10%. The remaining funds came for a range of specialist sources on a contract basis, or from special legislation establishing centres or funds (eg. The Antarctic Division).

There was considerable variation within the sample, with respondents from the CSIRO, CRCs and some university centres reporting relatively high levels of internal institutional funding, and faculty-based respondents reporting much lower levels of institutional funding and correspondingly higher levels of external grant funding. Researchers in science and medical fields reported a higher share of private sector funding (14%) than their counterparts in social sciences, humanities and arts

(3%), with the latter relying somewhat more heavily on grant funding (reporting almost 50% grant funding, compared with 40% among science and medical researchers).

Almost 95% of respondents' research funding came from Australian-based sources (including the Australian branches of multinational firms). Given the level of overseas work experience and international contacts, it is perhaps surprising that a higher level of overseas funding was not reported. It is notable, however, that among those researchers reporting an increase in interdisciplinary research more than 10% of funding came from overseas sources.

Figure 4.5 Changes in sources of funding over last 5 years?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Asked about trend changes in their patterns of research funding over the last five years, 48% reported an increase in public grant funding, 15% reported an increase in government and/or NGO contract funding and 15% an increase in private sector funding. Conversely, around 20% reported a trend decline in funding from within their institution. An increase in public grant funding was reported by 43% of those in science and medical fields and by 53% of those in social sciences, humanities and arts. The observed increase in private sector funding was predominantly felt by researchers in science and medical fields.

Does funding influence research practices?

Interviews briefly explored whether researchers had any concerns about trends in funding in their field. The aim being to reveal possible pressures and influences on their research practices. As one interviewee put it:

> *There is absolutely no doubt that funding agencies influence the direction of research* (Physical Sciences).

In terms of the nature of changes, a common concern expressed by respondents was increased short-termism, fluidity and uncertainty (mentioned by around 20%). This manifested in a number of ways, but was seen by many to effect the type of research done and the quality of that research. Others saw fads (eg. IT or biotechnology) and ideological shifts within government (eg. decline in support for gender issues) as problematic. Indicative comments included:

> *Science and maths basics are ignored in favour of 'fads' like IT or biotech, and its driving the talent out of these fields* (Mathematics).

In terms of the effects of changes in research funding, the most common concern was for the 'next generation' and for the future of research in Australia. Indicative comments included:

> *[There is]…far too little money around, which makes it hard to get good young people into the field and impossible to bring back those with 3 or 4 years overseas experience* (Genetics).
>
> *There is not enough money to bring young people in, its a major problem. I am worried that there is a crisis in science in Australia. Science in no longer an attractive profession. All the best young people I get go overseas, and very few come back* (Structural Biology).
>
> *[There is a] Failure to nurture the younger researchers in the funding environment* (Sociology).

Allocation processes

A number of respondents expressed concern over the institutional operation of research funding. The areas of most concern were the funding allocation and management processes – and this independent of success in gaining funding through those processes (ie. it was not a complaint from the losers). Indicative comments included:

> *It is much harder to get ARC funds for basic research in humanities in Australia than it is in the U.K. and U.S. I am deeply concerned about the review and assessment process in ARC… its not objective… there are not enough independent people to be reviewers, its too small a pool…*(Leading Humanities scholar with a decade of ARC large grants behind him).
>
> *ARC funding is a bit ad hoc and there is too much lock-in into older perspectives and people* (An ARC Fellow in Arts and Humanities).
>
> *Peer review in the grants process is savage in Australia* (Senior Medical researcher).
>
> *[I am concerned about the] Fairness of ARC processes* (Researcher supported by an ARC large grant).

A number felt that their field was disadvantaged because it had no place within the traditional ARC structure and/or no 'representative' on any of the ARC committees. Others felt that concentration of funding within Group of Eight Universities[9] was squeezing them out. Indicative comments included:

> *Research quantum is eroding because its not sandstone* (Dean of Management).

[9] Australia's eight largest research universities.

A number expressed concerns about the foci and mechanisms of funding distribution and management. Indicative comments included:

> *The main problem is that funds go to the institutions, not the people. R&D is being stifled by bureaucracy. We must move away from block grants to institutions* (Medical Research Centre Director).

> *That ARC money does not cover the Chief Investigators is a big problem, it means they spend less time on the projects and that effects the quality. I think it is a big problem coming up* (Professor in an Arts Faculty).[10]

> *The University's cost recovery formula for contract research adds so much in overheads that it effectively prices us out of the contract research and consultancy market* (Director of Research in Nursing).

One researcher admitted that where they collaborated in research across institutions, the intellectual property (IP) management processes became so complex that they just gave up and published, giving away any IP involved.

> *I had a research project which produced a patentable idea, but my collaborator was from another institution and had been funded by them and others. It would have just been too hard [to complete the necessary agreements to patent and commercialise the work]. It can take a year to be cleared after the IP issues have been sorted out. We got the information out through publication* (Computer Science).

The role and influence of research ethics committees was also raised in one workshop. A researcher in Sociology noted the demands of human research ethics issues, both in terms of communicating with institutions and funders about the research and in terms of communicating with the subjects. She suggested that such communication could alter the nature of the research – eg. having to fully explain the research to a subject could easily influence the subject and thereby the findings.

A number of researchers felt that their research was being fundamentally influenced by the simplistically formulaic allocation of both block and grant funding. Indicative comments included:

> *I am concerned about how research is shaped to fit into rigid funding application boxes… it is pre-empted by the application. We have to collaborate to get money, regardless of whether or not it makes any sense* (Head of Department in Humanities).

She was not alone in expressing scepticism about the real value of collaboration in some areas of the humanities, or in feeling that the whole system was designed around a science-based model of research that many areas of the humanities, arts and social sciences simple do not fit.

Commercialisation

One of the major points of discussion was the heightened instrumental, economic role of research and the increased commercialisation. Indicative comments included:

> *Science is becoming an enterprise, a business* (Ecology).

[10] Since the time of interview there has been a move to cover chief investigator salaries in some circumstances.

> *The clamour for money is much more accentuated* (Sociology).
>
> *Shift to short term projects with lack of longer term support* (Sociology).
>
> *[There are] …more demanding customers with project funding* (Entomology).
>
> *Our [department] now generates over half it's income from paid research. The teaching income is constrained by a whole series of external factors – the university's administration, the government etc. The area we have seen most development in is research, particularly paid [commercial] research, because that is the area we have most control over. We are generating over a million [dollars] a year from research for [a commercial source]* (Geography).

Some respondents expressed concerns about the influence of increasing private sector funding, although these concerns were often tied to issues of the grant-to-contract shift, such as short termism and fragmentation of both sources and amounts. One researcher suggested that increased commercial support had brought:

> *More pressure for commercial outcomes… and there are some issues about confidentiality of commercial funded work* (Biological Sciences).

Workshop discussions revealed a high degree of variation in the commercial delays imposed on publication, from six months for one chemist working with pharmaceutical firms, to two years for a vulcanologist working with mining firms (perhaps reflecting the characteristic pace of developments in different industries).

One biotechnology research centre director suggested that they had unwittingly 'chosen' between grant and contract funding. He recounted the story that on more than one occasion they had been asked to delay publication until elements of the IP had been protected by patents. This introduced a delay of at least 12 months, and had twice resulted in them being gazumped on publication. The unforeseen consequence of accepting the commercial funding and its conditions has been that they are now finding it more difficult to win grant funding, inter alia, because they have not been the first to publish results at the core of their work in the traditional academic channels (ie. scientific journals). They are now becoming increasingly locked into commercial funding, but are deeply concerned about a potential catch-22. Namely, that over time, the commercial funding itself will flow to those perceived to be leaders in the field on the basis of traditional research evaluation (ie. those who are first to publish).

There is an important message in this about both the treatment of patenting vis-à-vis publishing in performance measurement and perceptions about the relative merits of patenting and publishing. Some see it as merely:

> *[A] transitional problem with researchers not being very experienced in dealing with companies, and so being caught over commercial research funding – in particular getting caught with a delay in publishing. There are an awful lot of things [in these situations] which need to be written into contracts up front, rather than being taken on trust* (Dean of Science and Engineering).

A number of participants expressed the view that there was a need for much more support in such negotiations, and for the standardisation of practices and, where possible, of contracts. Indicative comments included:

> *It is extremely time consuming to manage the relationship [with companies]. They expect everything for free and are not interested in tax concessions and other government programs. There are also IP issues. The companies will often present us with their agreement, when we should be presenting them with ours. There is not enough [IP] support and infrastructure which runs along side that to support our production of ideas* (Computer Science).

4.2 Communication and collaboration

Communication and collaboration practices lie at the heart of how research is conducted. Our interviews and workshops explored both direct collaboration on research projects (team work) and participation in broader networks of scholarship (the, so called, invisible college).

4.2.1 Collaboration on research projects

Collaboration on projects is common. Almost 75% of respondents reported working primarily as a part of project teams, and a further 13% reported a mixture of team and individual work practices. Few, primarily scholars in particular areas of humanities, work alone. All respondents in science and medical research fields reported working in teams, while just over half of the social sciences, humanities and arts respondents did so.

The average size of research teams reported was 4.2 people. However there was a high level of variation, from a humanities scholar who always works alone to an archaeological dig team of more than 20. Some 60% of reported collaborating researchers were located at the same institution and around 40% were external collaborators. More than 70% of reported collaborators were based in Australia.

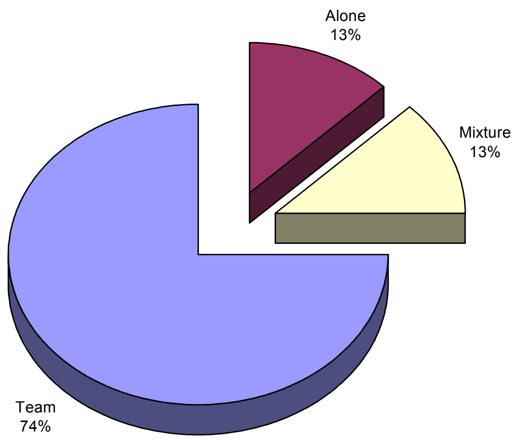
Interviews focused on recent changes in patterns and modes of collaboration. It became immediately apparent that there is increasing collaboration across an ever wider range of institutional settings. Almost 60% reported an increase in the locational diversity of collaborators, more than 50% reported an increase in cross-institutional collaboration, around 45% reported an increase in the average size of research teams, and 25% reported an increase in their own project team collaboration.

Collaboration seems to be spreading into the humanities, with 50% of respondents in social sciences, humanities and arts fields reporting an increase in their team participation, compared with just 5% in science fields. As one researcher noted:

> *There are some examples of collaboration [in Sociology]. Traditionally it has been an individualist discipline, but I think it is changing. I am currently involved in a collaboration across faculties and disciplines* (Sociology).

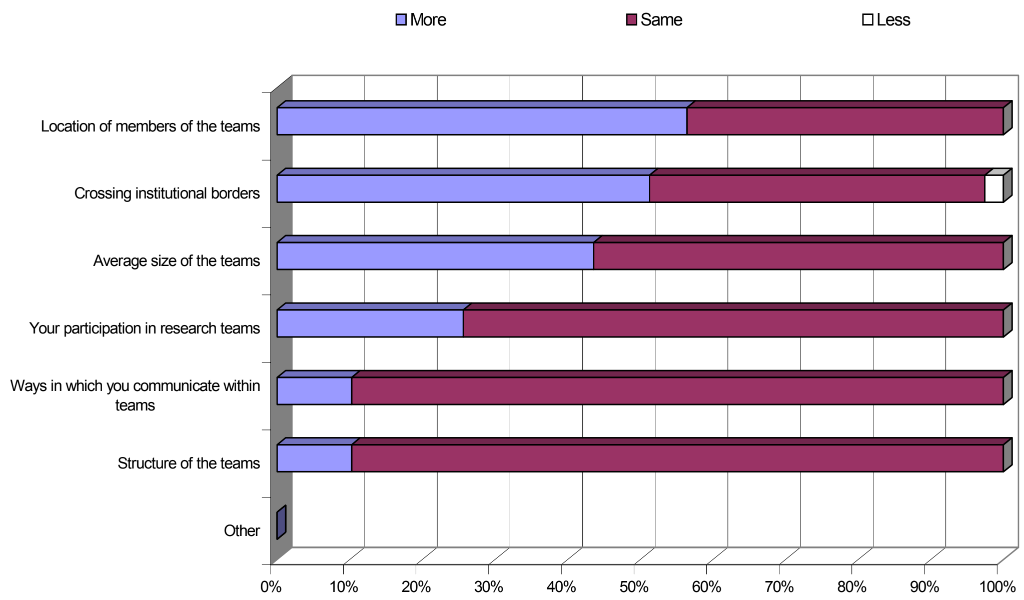
Another sociologist reported collaborating with a particular field of rural science, to explore issues of scientific training and generational change in agricultural family businesses.

Figure 4.6 Do you work primarily alone, or as part of a research or project team?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Figure 4.7 How has your team working changed over the last 5 years?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Drivers of collaboration

A number noted that there was an increasing need to collaborate, with projects involving a wider range of specialist skills – ie. that collaboration was a response to complexity, increasing interdisciplinarity and an increasingly problem rather than disciplinary oriented approach to research. In some areas, most notably health and medical, an additional driver cited was access to data, other people's work or IP and access to equipment. Indicative comments included:

> *Collaboration is much bigger… because of cost of infrastructure, complexity of questions. It can't be a single disciplinary approach anymore* (Viticulture).

> *Its more interdisciplinary; there is more intensive work on small sites with more in-depth analysis of the findings. So bigger and more varied teams are required* (Archaeology).

A number of researchers saw the encouragement by funding agencies to collaborate as a key driver of collaboration. Some even suggested that it was an example of an inflexible funding formulae distorting research by forcing collaboration whether it made sense or not. Indicative comments included:

> *There is more pressure for larger collaborative projects* (Cultural Studies).

> *Collaboration is driven by funding* (Genetics).

> *More pressure to collaborate to get ARC funding* (Asian Studies).

> *There has been a view that collaboration is the way to proceed and sometimes that is forcing collaborations which are not truly productive. Collaboration is certainly being pushed hard in the NH&MRC domain* (Biochemistry).

> *The ARC's requirement that second applications require collaborations is creating some very artificial partnerships. In many cases the collaboration seems to be mainly confined to the preparation of the application* (Chemistry).

A small minority suggested that the inflexible way that university bureaucracies treat funding works against collaboration. Indicative comments included:

> *In some areas there is less collaboration (eg. in the co-supervision of PhDs across universities) because the 'bean counters' make it harder to split the resources* (Media Studies).

> *While they [DEST and the universities] want collaborations, I don't think the system is set up to facilitate it* (Film Studies)

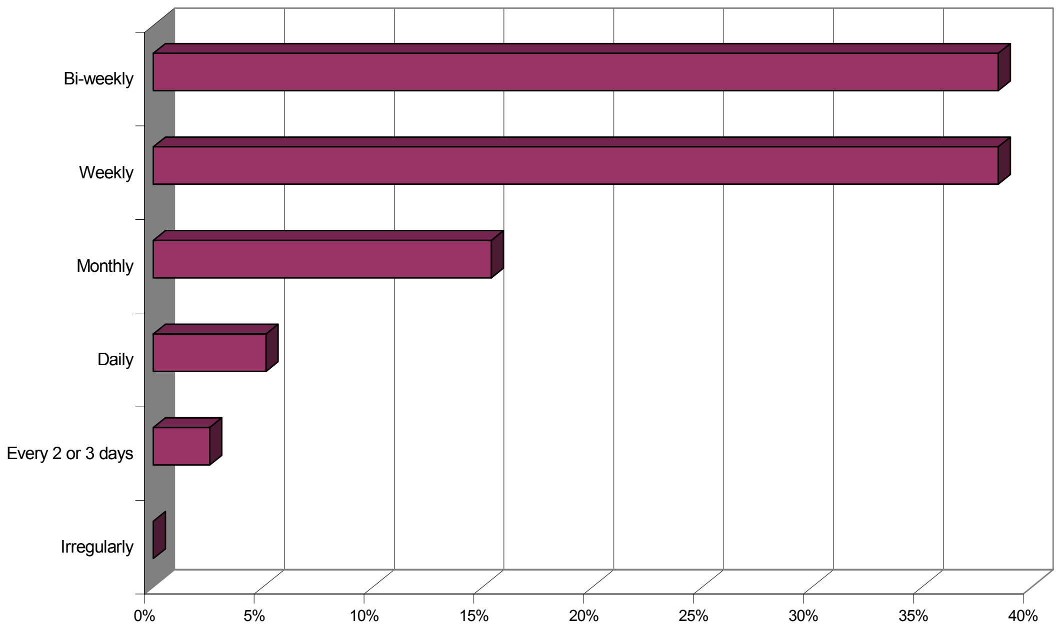
The situation regarding collaboration was well summarised by one workshop participant who said:

> *The era of the lone researcher is over. The humanities people have tended to be lone researchers, they are being increasingly cajoled into collaborative projects. The science people have always been involved in collaboration and that is getting stronger. The synergies and the different expertise people can bring make it valuable. Collaborative research teams tend to be far more successful in attracting funding, especially for international projects* (Head of Geography Department).

Communication between collaborators

Collaborators typically communicate weekly or fortnightly, with considerable variation – due to periods of intensive project activity (often during teaching breaks) and periods of relative quiet in the research (often during term time). Almost 40% reported that they typically interacted with project team members weekly, a similar number reported bi-weekly interactions and around 15% reported monthly interactions. Those in social sciences, humanities and arts that worked in teams seemed to interact more regularly than research team members in science and medical fields. No one reported project team interactions that were on average less frequent than monthly. These figure suggest that team collaboration is active and quite intense.

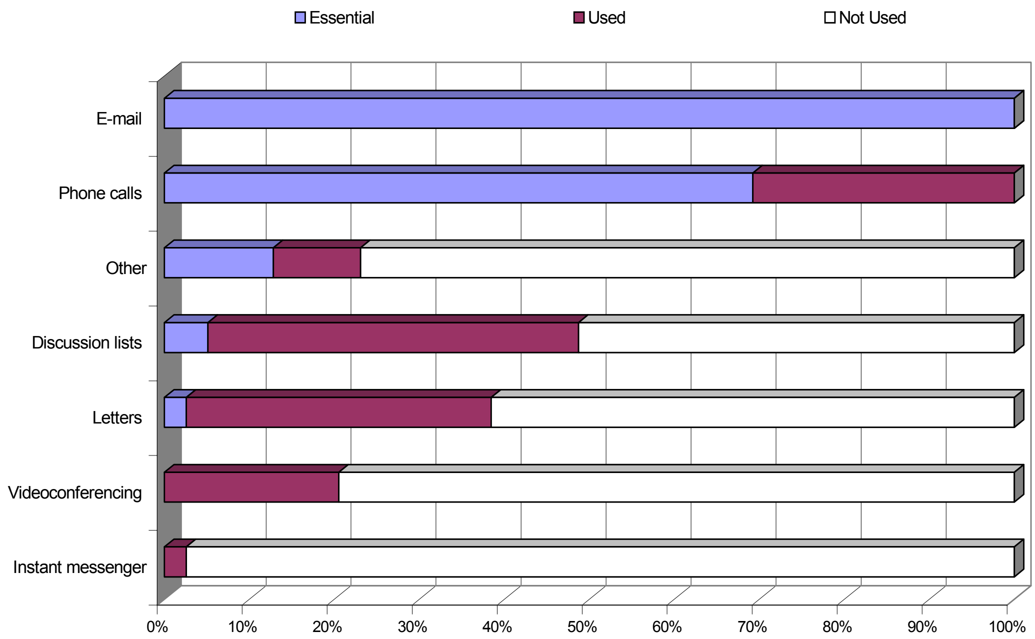
Figure 4.8 How often do you communicate with team members?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Asked how collaborators kept in touch all regarded e-mail to be 'essential'. Phone calls were regarded 'essential' by around 70%. Other means of communication play a much smaller role in facilitating research collaboration. Team discussion lists were mentioned by almost 50% of respondents, but were rated 'essential' by no more than 5%. Post was mention by one-third, but very few rated it 'essential'. In each case, these respondents had a particular reason for using mail (eg. the quality of images and the use of specific individual pictures, artefacts or prints for an Art Historian, or sending bulky items to colleagues in less developed countries where bandwidth was a limitation for a crop scientist). At the other end of the scale, very few researchers appeared to use instant messenger or similar systems to communicate within teams and, perhaps surprisingly, only around 20% reported using videoconferencing.

Figure 4.9 How do team members keep in touch?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Those opting for 'other' stressed the importance of face-to-face interactions, with a number noting quite regular project meetings, even where they involved members of the team travelling considerable distances. Indicative comments included:

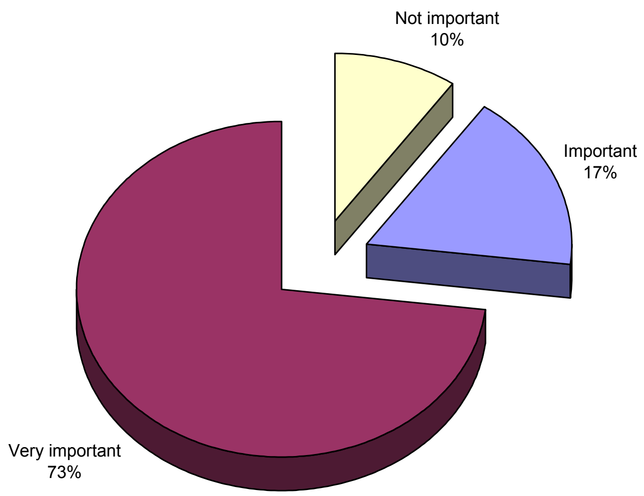
> *Communication speed has increased, but science is people-based* (Medicine).
>
> *Attending meetings and conferences is essential to stay informed. It can take three years for articles to get out… If you know what you are looking for the web is great, if you don't its far better to talk to someone* (Computer Science).
>
> *I think you get ideas by going to conferences. We can't afford to send all the people we would like to to conferences. If you want to be up on the latest in the field you have to get to the major conferences. The published papers are so far behind… Sometimes you don't appreciate the value of a new technique or a discovery until you go overseas and talk to colleagues about how they use it, you don't get that from the journals* (Genetics).

This emphasis on informal communication over formal publication is characteristic of the new mode of research.

4.2.2 Wider networks of scholarship

In addition to direct project-based collaboration, researchers were asked about their participation in a wider network of scholars – the, so called, invisible college. Some 90% saw themselves as part of a wider collegial network – 100% in science and medical fields, and 80% in social sciences, humanities and arts. More than 70% of them said it was 'very important' to their work, and a further 15-20% said it was 'somewhat important'. Comments like "*essential*" or "*vital*" were common.

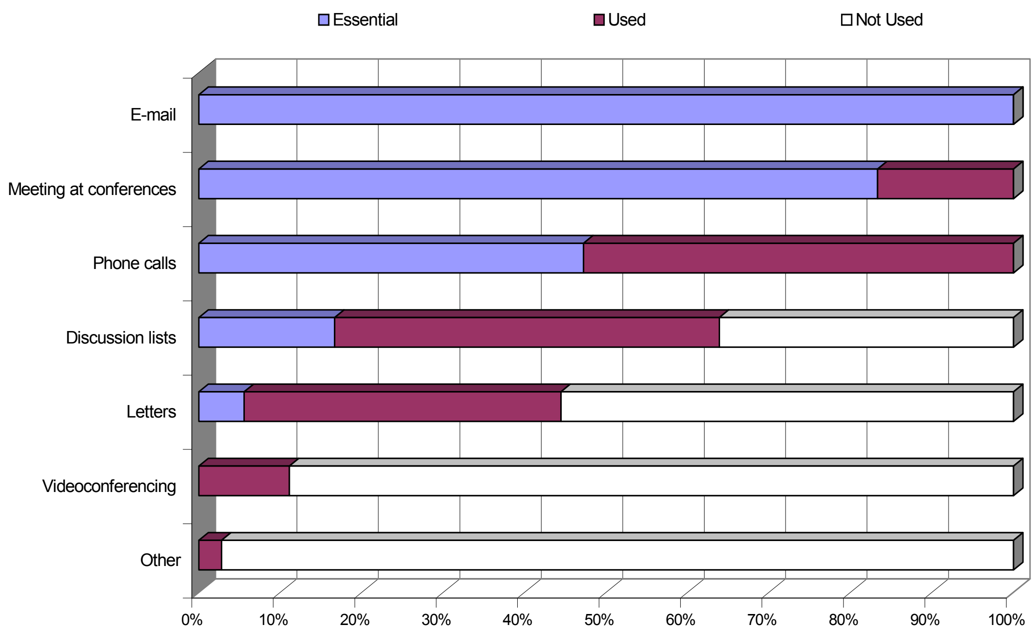
Figure 4.10 How important is this broader network to your work?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Researchers also rely on e-mail for communication within these broader networks of scholarship. Nevertheless, face-to-face meetings at conferences and other fora play a significant role in maintaining the network. Asked how members of the broader research network kept in touch, all respondents said e-mail was 'essential'. Around 80% suggested that meetings and conferences were 'essential', and a further 20% used them to keep in touch. Around half suggested that phone calls were 'essential' for maintaining the network. Only around 20% suggested the discussion lists were an 'essential' form of communication for the wider research network, although a further 50% reported using them. At the opposite end of the scale, only about 10% reported using videoconferencing. In addition to these mechanisms, professional associations and related newsletters and journals were cited in discussions as important mechanisms for the maintenance of the broader research network.

Figure 4.11 How do members of this broader network keep in touch?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

4.2.3 The impact of ICTs on research collaboration

Researchers were asked whether the new digital information environment had changed the way they collaborate, and if so how. Around 60% said that it had, with a higher proportion of social sciences, humanities and arts researchers reporting change (80%) than science and medical researchers. Noting that there was more interaction and more collaboration, most took a positive view of the impacts on their research and on research opportunities in their field. A small minority reported a sense of 'information overload'.

Most comments made in the interviews related to the speed and breadth of communication, noting the immediacy and pace of interactions by electronic means and the capacity to search more widely and more thoroughly. Indicative comments included:

> *Most historians are luddites when it comes to technology. But we use technology to distribute papers and to communicate with colleagues from around the world… Information technology has certainly encouraged collaboration and it has made it easier to get information out more easily and quickly… Traditionally historians were lonely creatures who sat alone working on their own, now I am collaborating with others from around the world* (History).

> *Access to more information means research is more exhaustive* (Philosophy).

We can take a broader view of things (Entomology).

Its helping: I am more thorough about accessing information now (Mathematics).

There is much more collaboration and from a wider base (Law).

There is more collaboration so we're getting a wider perspective… I think its good (Fisheries Modelling).

It makes it easier and more thorough when you search for things (Aboriginal History).

Looking more at changes to the pace and nature of research, other indicative comments on how the digital information environment had changed things included:

Its easier and it has changed the depth of communication and quality of the interactions… more than just superficially (Management).

Its more thorough now, and wider conceptual base. The sheer speed can make for a momentum and excitement that was not there before (Management).

Dramatically… For example, we recently put together a book of papers for a conference in which all papers were refereed and revised inside three months. It would have taken years before e-mail (Ecology).

Utterly… what you do, how quickly it can be done and the level of intellectual stimulation that comes from the pace of work (Sociology).

Absolutely… there are many useful sources, but its mainly the immediacy of e-mail. Its great, it makes it more interesting, faster, more active… (Archaeology).

Connectedness and the increased pace and immediacy of communication appear to be important developments, adding to the sense of excitement and involvement, and facilitating participation in global networks of science.

Concerns about those impacts

Asked if they had any concerns about the new forms of collaboration and communication some 38% said they had – 42% of social sciences, humanities and arts researchers, and 33% of science and medical researchers.

The time involved in handling the volume of e-mails and related information, and some potential loss of the human touch in interactions, were widely cited concerns. Indicative comments included:

The downside of the immediacy, I guess, is that its more demanding (Archaeology).

Its a flood. We have gone from 'hey that's amazing' to 'Oh God more e-mail' (Plant Pathology).

E-mail is a hassle, I spend/waste at least 2 hours every day on it (Biological Sciences).

I spend a third of my day on e-mails. And its harder to keep a paper trial of the important things. Records management has not kept pace with the ease of e-mail (Ecology).

Others reflected more specifically on the impacts of electronic communication on their field of research, noting some danger in the Western/North American and/or English language dominance of internet to date. Indicative comments included:

> *There is uneven access to internet, so the perspective is formed by the bounds of technology (ie. a developed western perspective dominates)* (Art History).
>
> *The less IT competent are left out because we tend only to deal with people online* (Cultural Studies).
>
> *Technology sometimes dictates scholarship… its done because it can be, not because its important* (Art History, echoed in Modelling, Environmental Sciences, and Journalism).

One leading researcher summed the situation up, saying:

> *I suspect that the information revolution is bigger than we think, and most researchers have not yet worked out how to make best use of the opportunities and tools that are around* (Biological Sciences).

4.3 Information search and access

Researchers' information search and access practices were explored during interviews and workshops. Questions examined sources of ideas (eg. ideas for research questions) and sources of information (eg. key inputs to their research). As before, the focus was on research rather than teaching or other activities.

4.3.1 Information sources and search practices

Interview questions sought as much detail about information sources and the mechanism used to access them as was practicable. In some cases it was not possible to go through the entire list of sources item-by-item during the interviews. On such occasions, questioning covered the major sources and explored others in a more open-ended manner (eg. by asking such questions as "Are there any other sources or searching techniques you use?"). This approach ensured that 'essential' sources were identified. However, there may remain some doubt as to the border between 'used' and 'not used' in some cases.

It should also be noted that, despite simply treating anything accessed online as an electronic source and anything accessed offline as a print source, some interviewees found difficulty distinguishing between print and electronic sources where the same source was used in both formats (eg. a journal that is available in print and online and used in both formats at different times by the researcher). Consequently, these findings should be treated as no more than indicative.

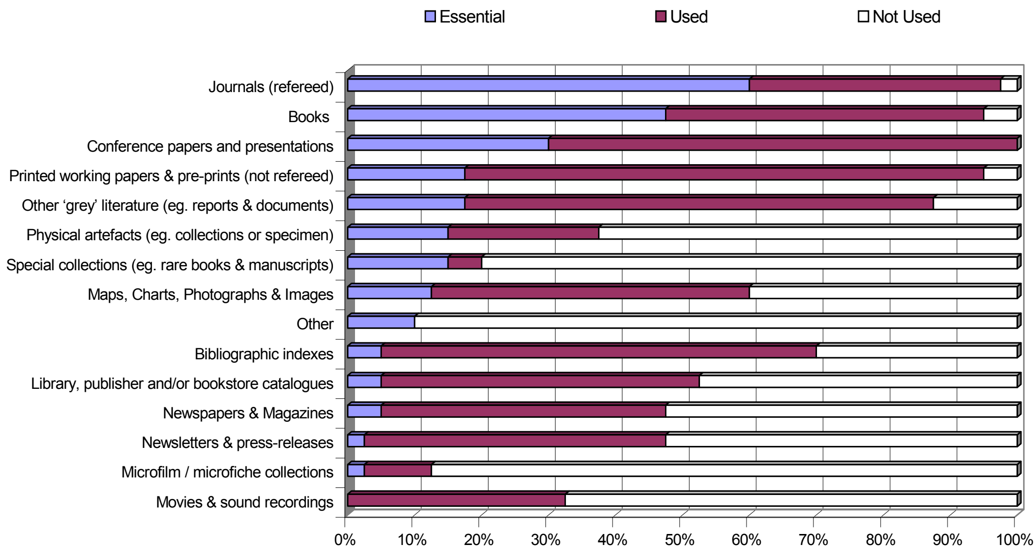
Print and physical sources

Looking first at print and physical sources we found that peer reviewed journals, books and conference papers were the most important sources. Some 60% of respondents regarded peer reviewed journals as 'essential' and a further 40% reported using them. Books were regarded as an 'essential' source by almost 50%

with a further 45% using them, and conference papers were regarded as 'essential' by around 30% with all respondents reporting using them. Printed working papers, pre-prints and other 'grey literature' (eg. government reports) were regarded as 'essential' sources by around 20% of respondents, while physical artefacts (eg. collections or specimen) and special collections (eg. rare books and manuscripts) were regarded as 'essential' by around 15%.

A number of print and physical sources that were not considered 'essential' sources by many researchers were, nevertheless, widely used. For example, bibliographic indexes appear to be used by around 65% of our respondents, but considered 'essential' by only around 5% (in print form). Microfilm and microfiche collections are not widely used, with almost 90% not using them. However, they were considered 'essential' by some (eg. in Aboriginal History, where newspaper archives provide a vital source).

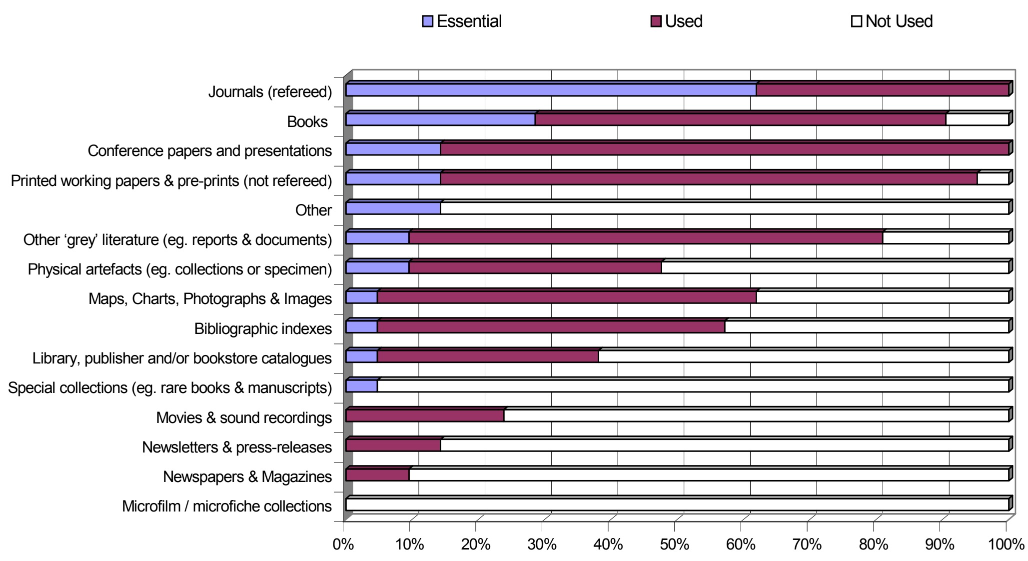
Figure 4.12 How would you rate print and physical sources in your research work?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

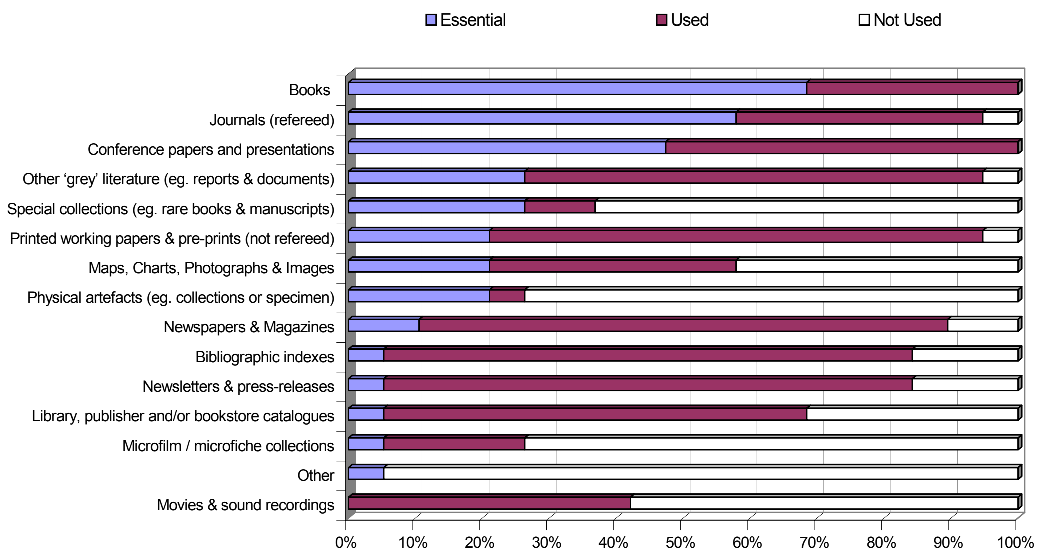
Among social science, humanities and arts researchers books ranked higher than refereed journals (print), with almost 70% regarding books as 'essential' and the remaining 30% reporting using them. Less than 30% of science and medical researchers regarded books as 'essential' and 10% seemed not to use them. Sixty-two per cent of science and medical researchers regarded refereed journals as 'essential' compared with 58% of social science, humanities and arts researchers.

Figure 4.13 Print and physical sources: sciences and medical



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Figure 4.14 Print and physical sources: social sciences, humanities and arts



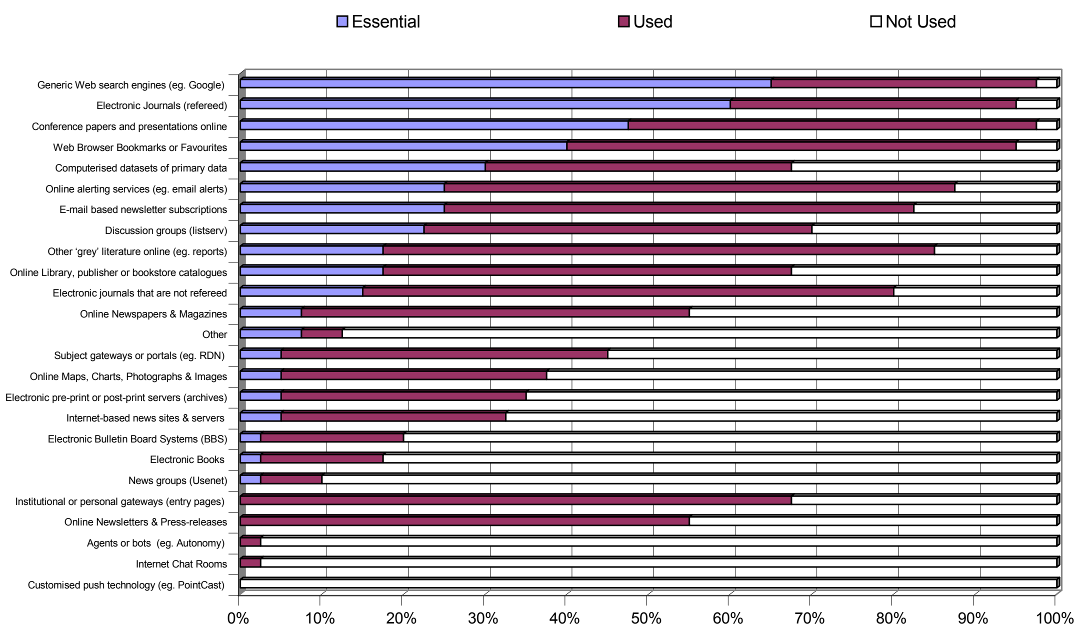
Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Looking down the list of print and physical sources it is clear that social science, humanities and arts researchers use a wider range of sources than do those in science and medical fields. Almost 50% of social science, humanities and arts researchers regarded conference papers as 'essential' compared with 15% of science and medical researchers; 25% of social science, humanities and arts researchers regarded other grey literature and special collections as 'essential' compared with 10% and 5% of science and medical researchers, respectively; and 20% or more of social science, humanities and arts researchers regarded printed working papers and pre-prints, maps, charts, photographs and images, and physical artefacts (eg. collections or specimen) as 'essential' compared with 15%, 5% and 10% of science and medical researchers, respectively. Researchers in science and medical fields also reported using a number of other sources, including reviews (eg. biological reviews) and standards information, which for some were seen as 'essential'.

Electronic and online sources

Online, generic web search engines (eg. Google) seem to be regarded as 'essential' by two-thirds of the researchers interviewed, with web browser bookmarks or favourites regarded as 'essential' by around 40%. Peer reviewed journals and papers in electronic form were regarded as 'essential' by around 60%, and conference papers were regarded as 'essential' by almost 50%. Online alerting services and e-mail-based newsletter subscriptions were regarded as 'essential' by around 30%, and discussion groups (eg. listserv) were considered 'essential' sources by 20%. However, they appear to be widely used.

Figure 4.15 How would you rate electronic and online sources in your research work?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Outside the major sources and mechanisms, perhaps the most notable findings relate to the use of electronic books and research databases. Electronic books were not widely regarded by respondents.[11] Less than 5% suggested that electronic books were an 'essential' source, and it seems that at least 80% did not use them. Conversely, databases were regarded as 'essential' sources by a third of the respondents and were used by a further third.

There are notable differences between social sciences, humanities and arts researchers and those in science and medical fields, and a somewhat higher level of usage of electronic and online sources by researchers noting an increase in interdisciplinary research. Researchers in science and medical fields report higher use of electronic journals, with 70% saying they are 'essential' compared with 45% of researchers in social sciences, humanities and arts. More than 10% of social sciences, humanities and arts researcher reported that they did not use electronic journals, and they ranked fourth as an electronic source; whereas 100% of science and medical researchers reported using electronic journals, ranking them first as an electronic source.

Among science and medical researchers, 70% regarded refereed electronic journals as 'essential', 65% regarded generic web search engines as 'essential', 50% regarded conference papers and presentations as 'essential', 45% regarded databases and datasets as 'essential', 33% regarded web bookmarks or favourites and online alerting services as 'essential', 30% regarded e-mail-based newsletters as 'essential' and 20% regarded discussion groups and non-refereed electronic journals as 'essential'. Although not regarded as 'essential' sources, institutional or personal gateways and entry pages, online catalogues and specialist subject gateways and portals seem to be widely used by researchers in science and medical fields.[12] Pre-print and e-print servers were rated 'essential' by 5%, but used by 30%. Perhaps most notable is the high level of use of databases and datasets, with more than 40% of researchers in science and medical fields rating them 'essential' and some 75% using them.

Among social science, humanities and arts researchers the level of online access appears to be somewhat lower, but its wider ranging. More than 60% suggested that generic web search engines (eg. Google) were an 'essential', almost 50% suggested that web browser bookmarks and favourites, conference presentation and papers, and refereed electronic journals were 'essential', almost 40% suggested that online catalogues were 'essential', 25% suggested that discussion lists were 'essential', 20% suggested that e-mail based newsletter subscriptions and other grey literature were 'essential' sources, and 15% suggested that online alerting services and computerised datasets were 'essential'. Online newspapers and press releases were not seen as an 'essential' source, but were used by almost 80% of social sciences, humanities and arts researchers. Similarly, institutional or personal gateways or entry pages were used by more than 70%. Pre-print and e-print servers were rated 'essential' by just 5%, but used as a source of information by up to 40%.

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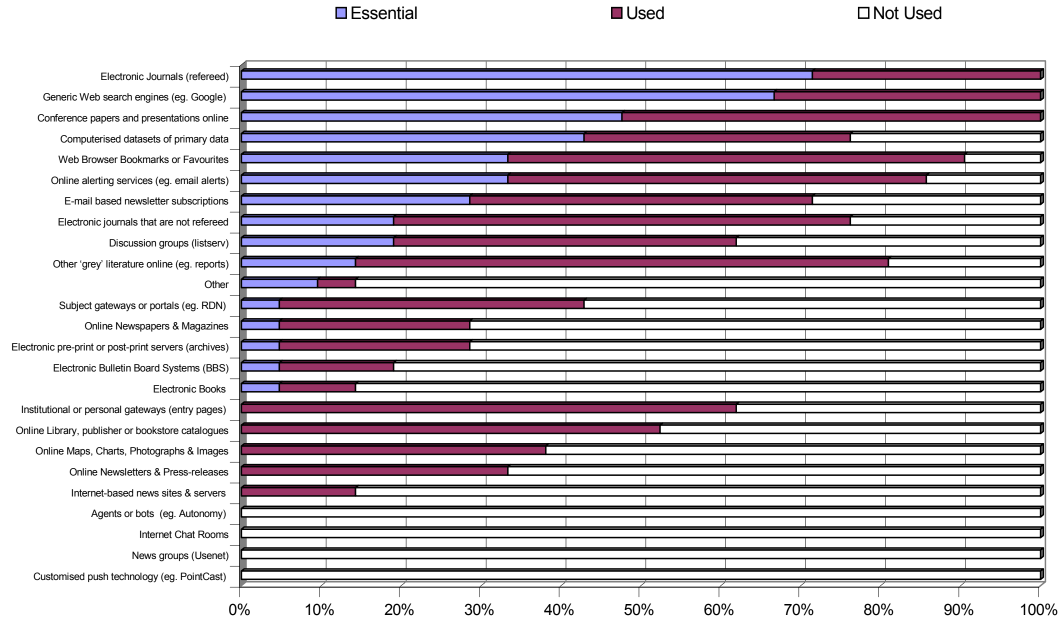
[11] No strict definition of e-books was given, with responses indicating that books in any online/electronic format were considered to be e-books.

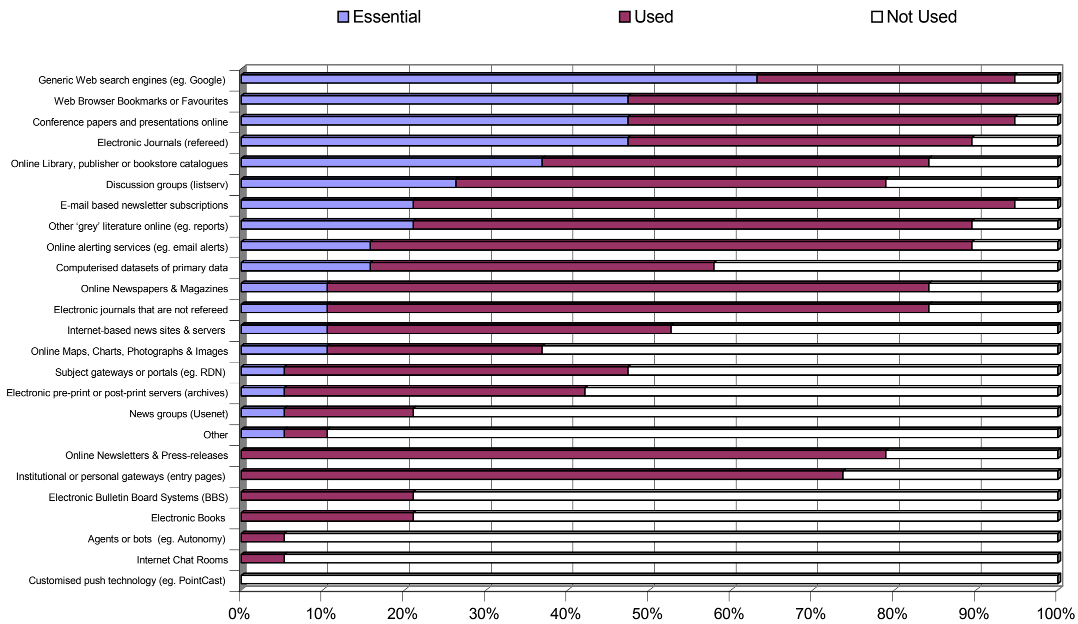
[12] It would seem from discussions that gateways and portals are probably more widely used that these data suggest, with researchers thinking more about what they go to than how they get there during interviews.

Figure 4.16 Electronic and online sources: science and medical



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Figure 4.17 Electronic and online sources: social sciences, humanities and arts



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

There appears to be a somewhat higher level of use of electronic and online sources among those working in teams than those working alone. Among team workers, more than 75% indicated that generic search engines were 'essential', more than 65% suggested that electronic journals were 'essential', and more than 50% suggested that online conferences papers were 'essential'. Again, this suggests that new modes of information search and access go with new modes of research.

Comments on sources

Interviews and workshops explored the thinking of researchers about their sources and how they use them. A number expressed a strong commitment to peer reviewed sources. Indicative comments included:

> *Peer review is the only thing acceptable in this area* (Viticulture).
>
> *Peer review is important in this area* (Plant Pathology).
>
> *You have to use refereed literature to cut out the dross* (Sociology).
>
> *Refereed journals are still the currency* (Media Studies).
>
> *I would never use anything from the Internet unless I found it in three reliable places. The peer review process is still essential. It [peer review] is an essential part of the academic process* (Psychology)

Others were less dependent on traditional peer review, and tended to rely on known names and a network of personal contacts to source information (ie. the informal mechanisms characteristic on a new mode of knowledge production). Indicative comments included:

> *Peer reviewed journals play a very limited role for me, and I suspect others in the field don't care as much these days either* (Law).
>
> *I source people, rather than content (ie. follow up leads to people)* (Art History).
>
> *The literature is old news, you don't get key ideas from journals, its from the people around you* (Medicine/Clinical).
>
> *I don't search for information, it seems to come to me… it comes from alerts, updates, etc. or from the personal network by e-mail, conversations, etc…* (Law).
>
> *I know the field and they know me. Most of what I get online comes via e-mail from people I know* (Archaeology).

Other interesting comments made about the range and use of print and electronic sources, included:

> *Pre-prints play an important part [in disseminating information] in mathematics and theoretical physics* (Physical Sciences).
>
> *I use things like genebank in some projects – datasets are vital in genetics* (Plant Pathology).
>
> *I use gateways/portals a lot, but not systematically* (Nanotechnology).
>
> *E-mail lists are big in forensics* (Forensic Science).
>
> *Discussion lists are vital in shaping agendas in some areas* (Media Studies).

Moderated lists are okay, but I wouldn't use unmoderated ones (Architecture/Design).

Discussion lists are not valuable because they generate so much useless information (Computer Science).

Discussion lists driven by some of the professional associations can be better (Chemistry).

I am on two discussion lists that are associated with standards… They are terrific, but they are closed (Computer Science).

Perhaps indicating a fundamental shift towards electronic sources a number of researchers made such comments as:

Print is to catch up in unfamiliar areas (Asian Media).

The book is still important in public health and psychology, but not for medical research. Books are used for catching up on knowledge at the edge of your area of special interest (Medicine).

I use the Net a lot, especially things like Google and Amazon looking for books, and at other catalogues (European Studies).

Having the journals online is great… It speeds everything up and makes it much easier to get a project done (Modelling).

I tend to search on keywords in Google, and look for people by name in the online journal databases (Sociology).

PubMed is very rapid for updates, Google is great for text searches. The forward referencing functions now available on many databases are invaluable for helping to keep on top of all the material (Biomedical).

The better referencing and other tools are making a big impact in managing the flood of information (Chemistry).

I no longer go the library, I can get what I need electronically on my desk (Computer Science).

4.3.2 Print versus electronic

Researchers were asked to estimate approximately what percentage of the sources they currently used were physical/print and what percentage were electronic/online, and then asked to do so for both the activities of 'searching and browsing' and 'reading and studying'. Not surprisingly, few read for long periods from a computer screen, with most printing things they find online before studying them in-depth. Increasingly, however, researchers are searching and reviewing abstracts online and in real time.

Two workshop participants described their practices as follows:

The time pressures are getting so great that article abstracts are all that are being read. The combination of time pressures and the weight of material being produced… make it difficult to do much more (Biochemistry).

The process [of searching the literature] is often that you will do a search and it will throw up 100 articles, you read the abstracts and select the 2 or 3 to read in full text which *look most interesting and are available. That is the reality of the environment today* (Medicine).

Searching and browsing

It would seem that across the sample of interviewees an average of around 75% of searching and browsing was conducted online, with an average 25% of done in print form. However, there was considerable variation between researchers – with use of print sources for searching and browsing varying from 5% to 90%. Those with a high use of print and physical sources during searching and browsing often had special needs and used special collections for a significant part of their work (eg. Archaeology, Aboriginal History and Arabic Literature).

Researchers in science and medical fields appear to do more of their work online. During searching and browsing more than 80% of science and medical researchers are online, compared with around 70% of social sciences, humanities and arts researchers.

Reading and studying

An average of almost 90% of reading and studying was conducted using printed documents.[13] When it came to reading and studying, variation across the sample was lower (standard deviation 10%). When it comes to reading and studying a slightly higher proportion of social sciences, humanities and arts researchers reported doing so online – 14%, compared with 11% of researchers in science and medical fields.

Exploring the reasons for printing prior to reading and studying a few respondents mentioned the difficulty of reading from a screen. However, a larger number mentioned the desire to place stickers and/or write notes on what they were reading, or the inclination to read at home over the weekend. This suggests that the barrier to reading online might relate more to note taking and portability than to difficulties related to screen-based reading *per se*. However, a number of respondents also mentioned their preference for 'holding' a printed copy in their hands and being able to keep a printed copy in a personal library. While this may reflect a culture of print that will fade over time, there is clearly a substantial demand for print-on-demand services that provide a quality printed version of material that is more attractive than are bundles of self-printed pages.

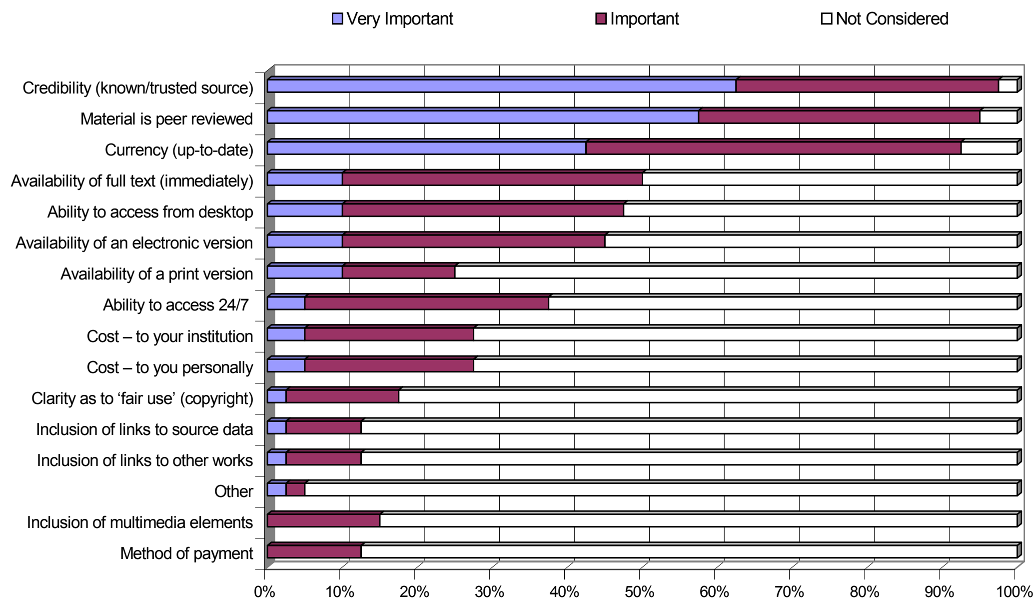
4.3.3 Choosing sources

Researchers were asked to discuss and rate the factors influencing their choice of information sources. Again it should be noted that in some cases it was not possible to go through the entire list of factors during interviews. As in other such cases, questioning covered the major factors and explored others in a more open-ended manner.

[13] These include material found in electronic form and printed by the user.

The things considered most important across the sample were credibility, peer review and currency. Credibility (ie. known/trusted sources) was regarded as 'very important' by 60% of respondents and as 'important' by a further 35%. That the material is peer reviewed was regarded as 'very important' by almost 60% of respondents and as 'important' by a further 35%. Currency (ie. being up-to-date) was regarded as 'very important' by around 40% of respondents and as 'important' by a further 50%.

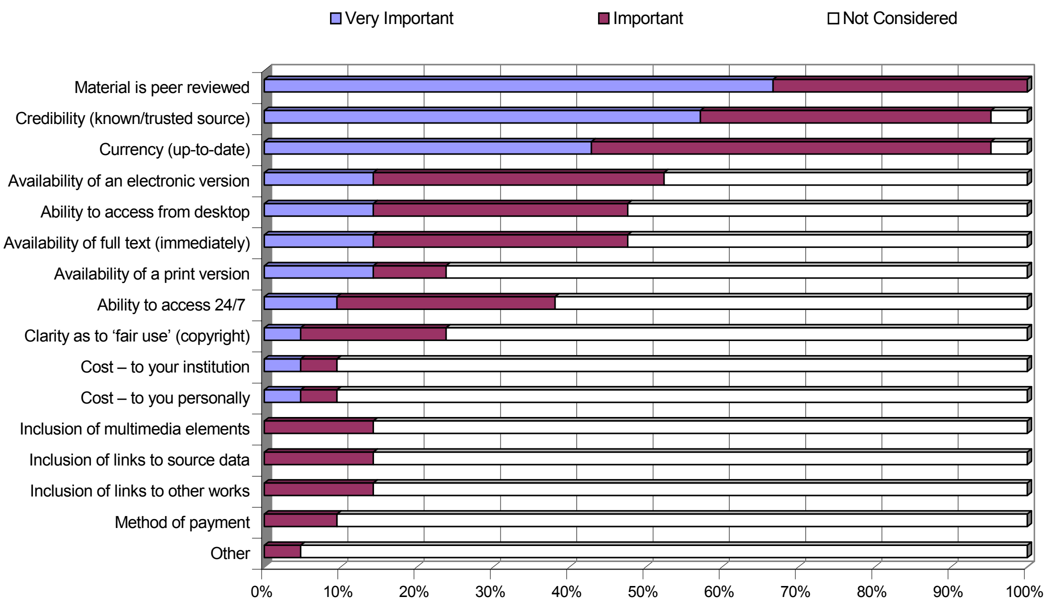
Figure 4.18 What factors influence your choice of information sources?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

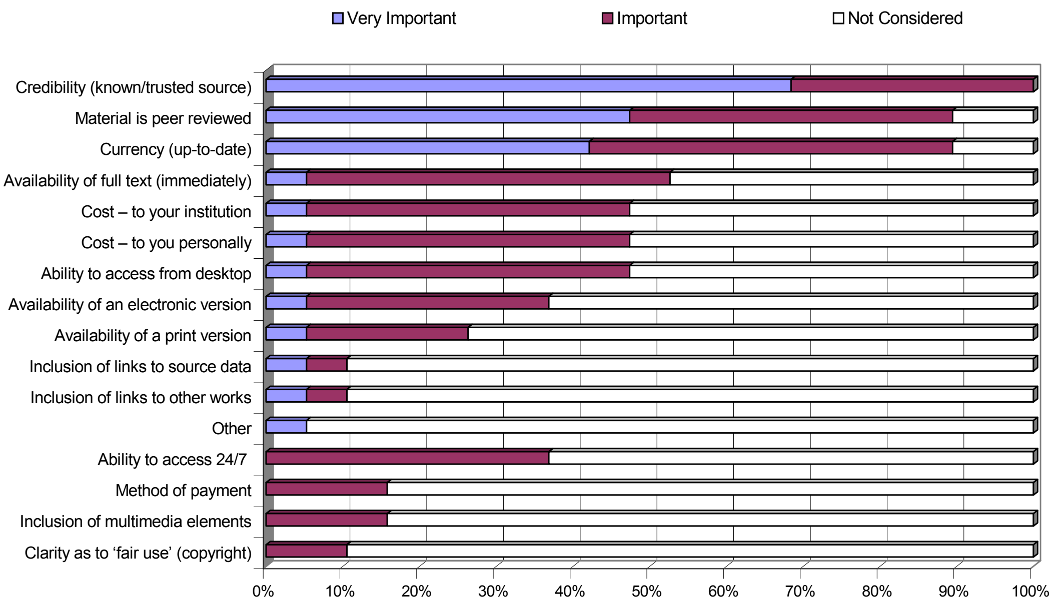
The availability of full text (immediately), the ability to access from the desktop, the availability of an electronic version and the ability to access 24/7 were all factors considered to be 'important' by one-third to a half of the respondents, but seemed to be rarely considered 'very important'. Cost, either individually or to the institution, was considered 'important' by around 25% of respondents, but was not considered an issue at all by some 70%. Method of payment and the ability to include multimedia elements seemed to be the least important of the listed considerations.

Figure 4.19 What factors influence choice: science and medical



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Figure 4.20 What factors influence choice: social sciences, humanities and arts



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Researchers in science and medical fields put more weight on peer review, with 67% suggesting that peer review was 'very important' and the remaining 33% suggesting that it was 'important', compared with 47% and 42% of researchers in social sciences, humanities and arts, respectively. Among researchers in social sciences, humanities and arts credibility (defined more broadly than peer review) was seen as the most important factor in choice of sources. Researchers in science and medical fields appear to rate the availability of an electronic version, desktop access and the availability of full text somewhat more highly than do researchers in social sciences, humanities and arts. Around 25% of researchers in all fields saw the availability of a print version as important.

Comments on the factors influencing choice of sources included:

> *There is too much emphasis on journals and peer review, much of the material is in books and there is a lack of really good journals* (Management).
>
> *I like to think its reviewed in some manner, not just an individual putting things on the web* (Modelling).
>
> *Who the authors are is the most important thing* (Structural Biology).
>
> *Time is more important than the cost* (Software Engineering).
>
> *If we are working in a particular area and we want to keep an eye on our competitors then we just do a keyword search. The only reason for keeping hard copies is for material we can't get online. [Interviewer: Is it the journal or the article which is more important?] Definitely the article* (Chemist).

Asked what kinds of sources they were using more and what less, compared with five years ago, most said more electronic and less print. In most cases, part of the point being made was that many of the sources had not changed much, but they were now more readily available online.

4.3.4 Personal subscriptions and collections

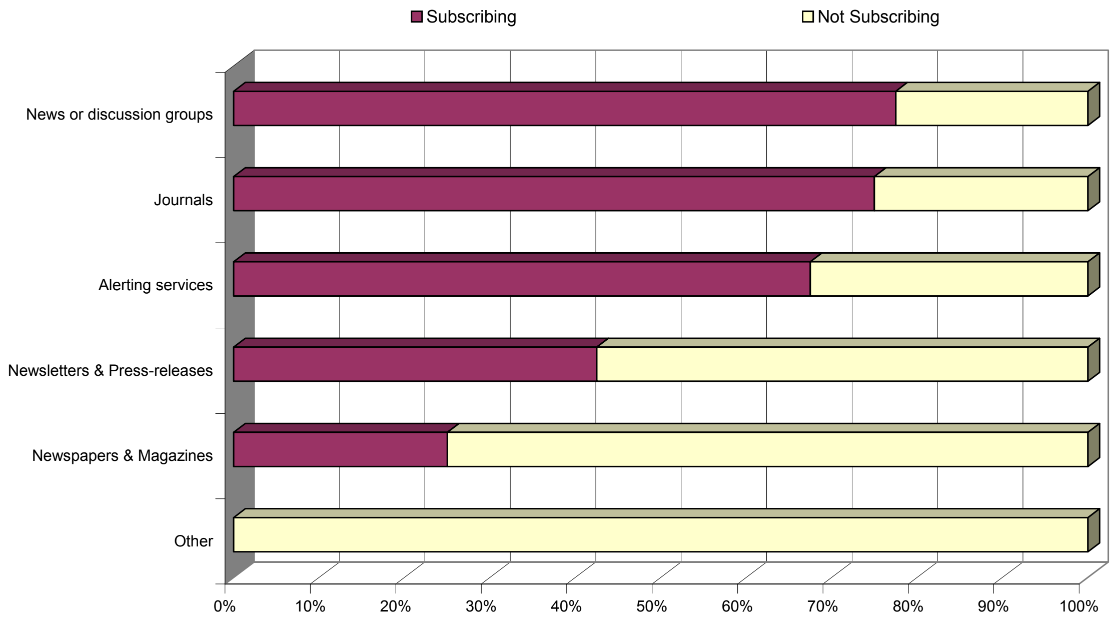
Personal subscriptions and collections held by researchers have played an important role and been an important source of information. There has been interest in whether personal subscriptions and collections act as substitutes for library collections and services or complements, and it is interesting to speculate about the role of electronic alternatives.[14] Are they adding a further dimension of substitution and/or complementarity?

[14] If researchers collect core materials themselves and request their institutional library to collect those things around the edges that they cannot justify purchasing from their personal resources, then the collections are complementary. If, on the other hand, they request their institutional libraries to collect the core material too, then the collections are substitutes. Making sense of library usage patterns requires an understanding of which of these phenomena is at work. With the advent of electronic collections, there is a further dimension of substitutability and complementarity. So do online access patterns reflect complementarity (ie. browsing around the edges), or do they reflect substitution (ie. replacement of personal collections)?

Personal subscriptions

Across the sample of researchers in Australia, around 80% reported having personal subscriptions to news and/or discussion groups, around 75% reported having personal subscriptions to journals and almost 70% subscribed to alerting services. Subscriptions to news and discussion groups and alerting services were primarily electronic and free. However, around 70% of journal subscriptions appear to be paid, with around 25% being free and the remainder are a mixture of both.[15] All recorded personal journal subscriptions were to print format.

Figure 4.21 Do you have any personal subscriptions, and if so how many and of what type?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

There are some differences in personal subscription habits between fields of research.

- Among science and medical researchers, 75% reported subscriptions to altering services and journals, and around 65% reported subscriptions to news or discussion groups. Almost 90% of social sciences, humanities and arts researchers reported subscriptions to news or discussion groups, around 75% reported subscriptions to journals and 60% to alerting services.
- Among researchers in science and medical fields, all journal subscriptions were to print and around 70% were paid, all newspaper and magazine

[15] It should be noted that there was some variation in researcher perceptions as to whether or not membership of a professional association which includes a journal constituted a ‘paid’ subscription. As far as possible, the clarification given by the interviewer was that it did.

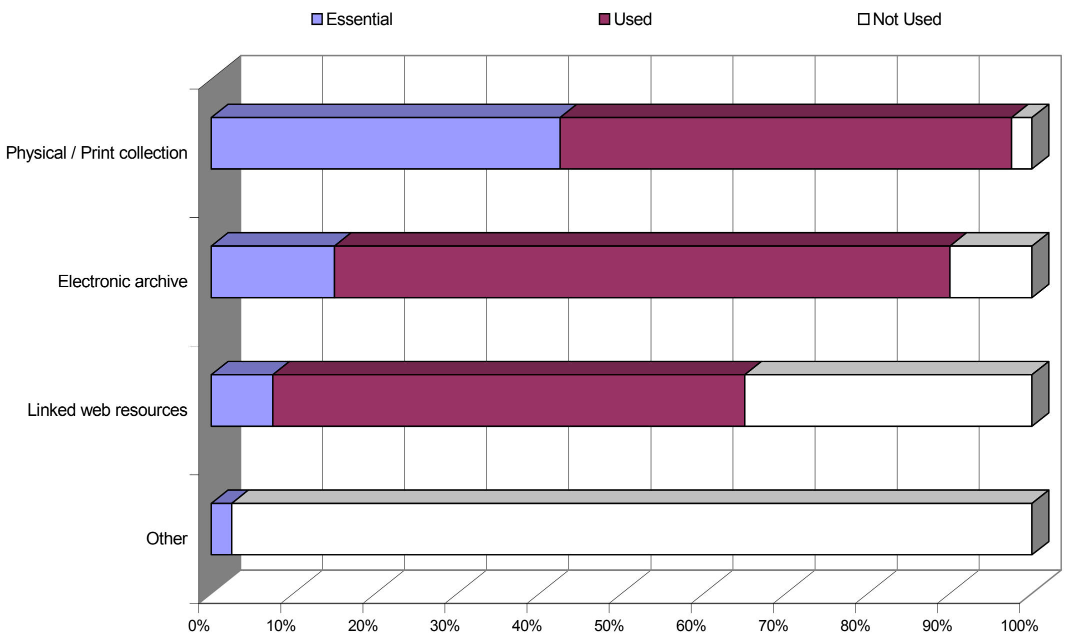
subscriptions were to print and were paid, around 75% of subscriptions to newsletters and press releases were electronic and free, and all recorded subscriptions to news or discussion groups and alerting services were electronic and free.

- Among researchers in social sciences, humanities and arts fields, all journal subscriptions were to print and around 70% were paid, 60% of newspaper and magazine subscriptions were to print and 70% were paid, around 80% of subscriptions to newsletters and press releases were electronic and 70% free, and all subscriptions to news or discussion groups and alerting services were electronic and free.

Personal collections

Asked if they maintained a personal library or collection in either print/physical or electronic/online form, almost all those asked reported having a physical or print collection, around 90% reported maintaining an electronic archive and around 66% reported using linked web resources. A small number reported having special collections of images (eg. Art History), sound recordings (eg. Oral History) and/or video-recordings (eg. Mechanical Engineering). All social sciences, humanities and

Figure 4.22 How important is your personal library or collection?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

arts researchers reported maintaining a print collection, compared with 95% of science and medical researchers; and 75% reported maintaining linked web resources, compared to less than 60% of science and medical researchers.

Asked about the importance of their personal collections for their research work, around 45% indicated that their physical or print collection was 'essential' and a further 50% appeared to use such a collection. Around 15% said their electronic archive was 'essential' and a further 75% indicated that they used one. Personal collections appear to be more important to social sciences, humanities and arts researchers, with more than 60% indicating that their physical/print collection was 'essential', 25% indicating that their electronic archive was 'essential' and 10% indicating that their linked web resources were 'essential'. By comparison, only 25% of science and medical researchers indicated that their physical/print collection was 'essential', and only around 5% rated their electronic or linked web resource collections 'essential'.

Comments on personal subscriptions and collections

Commenting on their subscription and collection practices a number noted that they were reducing them – because of the cost involved and because of the increased ease of access to material online and/or through library subscriptions to electronic collections. Indicative comments included:

> *I am cancelling some personal subscriptions because its too expensive* (Management).
>
> *I rely on the library because its too expensive otherwise* (Sociology).
>
> *Its too expensive, I can get papers from search and abstracting services* (Viticulture).
>
> *I am cutting down journal subscriptions because I can get them easily online now* (Sociology).
>
> *Its too expensive, and its too hard to keep up-to-date that way* (Viticulture).

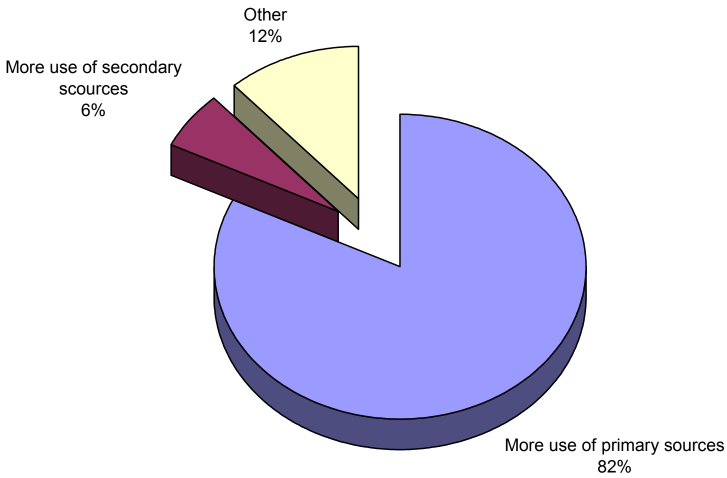
Asked what they were now collecting more and what less than they were five years ago, comments suggested that the 'more' was electronic (everything) and the 'less' was print (everything).

4.3.5 Research databases

Preliminary discussions led to the inclusion of a question about the use of research databases in order to explore some of the less apparent but potentially significant impacts of ICTs on research practices. As noted, a third of all respondents saw databases as 'essential' and a further third reported using them. The use of research databases is higher in the sciences – with 75% of science and medical researchers reported using databases and more than 40% suggesting that they were 'essential'. Nevertheless, almost 60% of social sciences, humanities and arts researchers reported using databases, with 15% regarding them as 'essential'.

Just over 40% of interviewees reported that they had perceived a change in the relative importance of primary source datasets vis-à-vis secondary sources – 37% in social sciences, humanities and arts, and 47% in science and medical fields. Asked about the nature of that change, as many as 80% reported noticing an increase in the use of primary data – 100% of those in science and medical fields noting a change, and around 60% of those in social sciences, humanities and arts fields noting a change.

Figure 4.23 Change in use of primary sources?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Some noted significant changes in both how research was being done and what was being done. Some suggested that access to primary data, related software and computer power was changing their field of research in important ways. Indicative comments included:

> *It changes the nature of research, with much more primary material used because it is now available* (Cultural Studies).
>
> *Some of the key databases are now central tools* (Medicine).
>
> *Much more use of satellite data* (Environmental Science).
>
> *Genetics data is opening new areas of research* (Genetics).
>
> *Databases (eg. gene, protein, etc.) are changing things. Datamining gives leads as to what to look at* (Structural Biology).
>
> *We do things now that were just not possible before, due to both data and the computer power to crunch the numbers. We now realise that a lot of what we thought we knew was not sound* (Modelling).
>
> *There is more 'virtual fieldwork', partly because of the increased pressure to publish and get work out quickly* (Asian Studies).

> *Things like the 'virtual reconstruction' of sites have taken off in Archaeology, and help in analysis and teaching. There is much more analysis of the data generated from digs… more is collected. They are much more intensive these days* (Archaeology).

Modelling appears to have entered a number of fields and be used widely across disciplines. For example, interviewees noted a:

> *Proliferation of modelling in silico rather than experimenting* (Mechanical Engineering).
>
> *Somewhat less field work now, and more modelling* (Geophysics).
>
> *Evidence-based data is now being used… mined* (Pharmacy and Nursing).

In workshops participants noted that they accessed a good deal of publicly available data, and occasionally private subscription access data (eg. Celera's gene data), and that they often did so outside the institution's library and information system (eg. linking out of PubMed). Indicative comments included:

> *Different types of computer work are having a big impact on medicine and science generally, tools that help in pattern recognition and predictive work in particular are becoming extremely important* (Medicine).
>
> *There are a number of very important information resources (databases and datasets) around the world which have made a huge difference to our work. A number of foundations… [have] been important in making a great deal of information available to the public* (Medicine).
>
> *In atmospheric science, thank God for the U.S., because they are very generous with the amount of material they make available* (Geography).
>
> *In Molecular Biology there has been a huge change in the way research is being done. The most important changes are in gathering data and making it available, mainly by putting it on the web… We have moved from analysis to synthesis, we are talking to mathematicians and others, looking for patterns. Research is sometimes moving away from hypothesis to much more 'suck it and see' work. Now you can do in a shorter space of time an examination of thousands of bits of information which would have taken much longer in the past* (Genetics).
>
> *There are new challenges being thrown up by the existence of these databases as the scope, the type and the kind of research is changing significantly. Some of the new empirical observations which are now possible, due to computing, often throw up the need for more theoretical work, revisiting old assumptions* (Economics).
>
> *There are shared databases [in the speech recognition area] which you have to contribute to to get access. If you are a private company you have to pay a fee of $60 000 to $70 000 for the same access* (Computer science).
>
> *I think there is a substitution underway from thinking to information gathering, checking first on how everyone who has done anything on this has handled it. There is a shift to running a whole lot of hypotheses because it is easier to test, rather than thinking hard about it* (Economics).

A number of researchers also talked about the software they needed to analyse the newfound wealth of data. In some cases access is open, in others it is much more guarded. One workshop participant reported that access to data was rather guarded and access to the necessary software was even harder – requiring very strong personal networks and some purchasing. Others found the software easier to acquire.

> *I have a feeling that the time between the need arising and the [software] tool being available is shortening. In fact, it is sometimes the case that it is there before you know you need it* (Genetics).

> *People are guarded about sharing data and related software. You have to use the network [of research colleagues] or buy it. My department spends thousands of dollars a year* (Neuro-science/Bio-chemistry).

Access to data, related software and analytical objects is clearly vital – as is the management and dissemination of information created. In the words of one workshop participant:

> *What has changed is the access to databases, which has lessened the necessity to read journals* (Chemistry).

4.3.6 The impact of ICTs on search and access

Asked if the increasing access to information online had changed the way that they and others in their field searched for and accessed information, around 80% said it had. Others suggested that having more available online had made things much easier, but had not really changed what they did or what sources they used. Indicative comments included:

> *Its a useful tool or aid, but it has not transformed research in the area* (Art History).

> *Its wider online… but not really different* (Media Studies).

> *Its online, but its not really different content* (Education).

Positive comments, indicating more fundamental change to work in their fields included:

> *In a lot of ways research has not changed with the Internet. What has changed is the process, not the actual research itself. Because the price is lower we communicate more and I think that travel to conferences has become even more important. In a sense the new technology has been terrific for Australia because it has made a lot more information available* (History).

> *Finding things used to be more happenstance, now it can be more exhaustive* (Entomology).

> *More comprehensive searches, so more exhaustive* (Philosophy).

> *More thorough now, and wider conceptual base. The sheer speed can make for a momentum and excitement that was not there before* (Management).

> *Now there is more data to work with and its easier to model* (Modelling).

> *Much more datamining now, for leads* (Structural Biology).

> *The net is great… it has changed what I do. Absolutely!* (European Studies).

Concerns about online search and access

A small proportion of researchers voiced some concerns about the impact of the online search and access environment. Typically, these concerns centred around the quality of what is online, loss from view of material that is not online, and the potentially negative effects of more information on research in their fields. Some also lamented the loss of the ability of 'browse the stacks' and find things they were not really looking for. Indicative comments included:

> *Quality of information on internet is a concern. Too much information, too easy to find leads to sloppy scholarship. Information does not make one a scholar* (Art History).
>
> *Quality issue, peer review is vital. I would never quote something from the web* (Ecology).
>
> *The quality of what is online… its rubbish. Sometimes it seems that every whacko in the world has published their ideas on what Stonehenge is for* (Archaeology).
>
> *Lack of history – no papers cite anything older than 1995, and a lot is being lost* (Plant Pathology).
>
> *Some concern that the young only see electronic stuff, not the 'classics'* (Genetics).
>
> *Younger people find only what is online… older papers matter. Faraday did some important things* (Nanotechnology).
>
> *There is a syndrome that if its not online it doesn't exist… people miss a lot of the old material which is still very relevant* (Biological Sciences).

4.4 Dissemination and publication

The third topic on which interviews and workshops focused was dissemination and publication practices. Rather than try to impose a strict definition of publishing a more 'ethnomethodological' approach was adopted, in which respondents' definitions were used. This allowed us to focus on respondents' motives.[16]

4.4.1 Publication practices

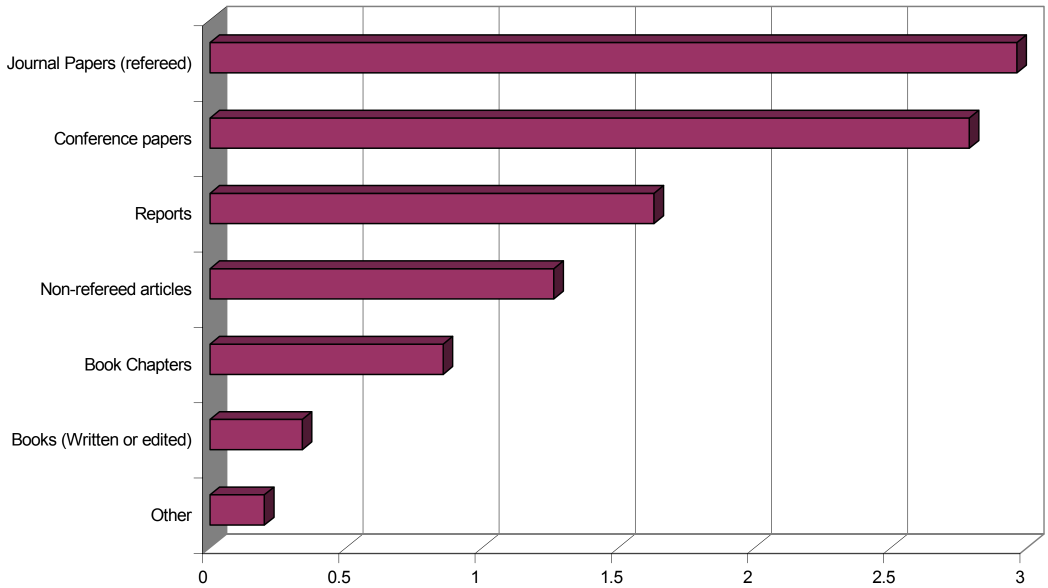
Asked how many of various sorts of publication they produced in the average year/last year, respondents revealed that across the sample they produced an average of around 3 journal papers per year, 2.8 conference papers, 1.6 project reports, 1.3 non-refereed articles and completed an average of just less that one book chapter. Around 10% also reported patenting.

Researchers in science and medical fields produced somewhat more journal papers (3.4) and conference papers (3.0) than did researchers in social sciences, humanities and arts (2.5 and 2.6, respectively). Conversely, researchers in social sciences, humanities and arts fields produced somewhat more books and book chapters.

[16] Information about the number and form of publications derived from interviews was supplemented with similar information available from such sources as institutional and personal websites, department and research centre annual reports.

Those researcher reporting team-based researchers report somewhat high publication counts than those working alone, reflecting greater levels of joint authorship (more than 90% of team-based researchers report joint authorship, compared with 75% across the sample). Among team-based researchers the average publication outputs were 3.3 journal papers and 2.0 conference papers.

Figure 4.24 How many do you publish per year (Average Number)?

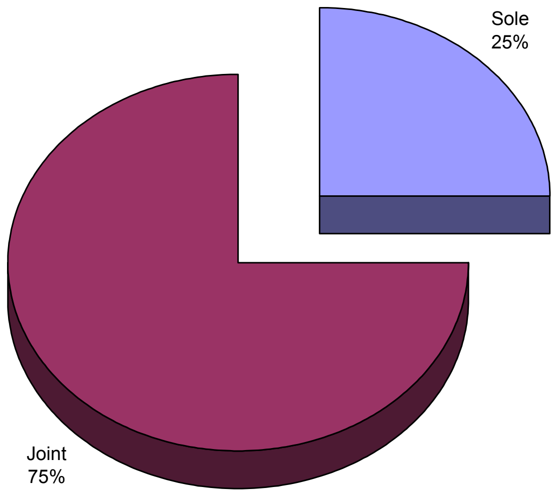


Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

A high level of collaboration was reflected in the level of joint authorship. More than 75% of respondents indicated that they were typically joint authors. On average, among those who typically publish joint authored works, there were 2.3 authors – with a range from a minimum average of 1.5 to a maximum average of 7 (standard deviation 1.2). Among researchers in science and medical fields 100% reported that the were typically joint authors, and that there were an average 3.4 authors per publication. Among researchers in social sciences, humanities and arts less than 50% were typically joint authors, and the average number of authors was 1.2.

Some 40% of respondents suggested that their patterns of authorship had changed over the last five years, with all citing an increase in the number of authors and/or in the proportion of their published output that is joint authored. Among science and medical researchers just less than 40% noted a change in authorship patterns, while closer to 50% of those in social sciences, humanities and arts researchers noted a change.

Figure 4.25 Are your publications typically sole or joint authored?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

The main reasons for this increase in joint authorship appear to be encouragement to collaborate in research through funding requirements, and the increasing complexity of problems demanding a wider range of skills on research projects. In some areas, most notably health and medical, an additional drivers were access to data and/or other people's work and access to equipment. Indicative comments included:

> *Collaboration is encouraged in funding, wider skills are needed in the analysis and patient numbers are required for trials… so we pool our findings from different areas* (Pharmacy).

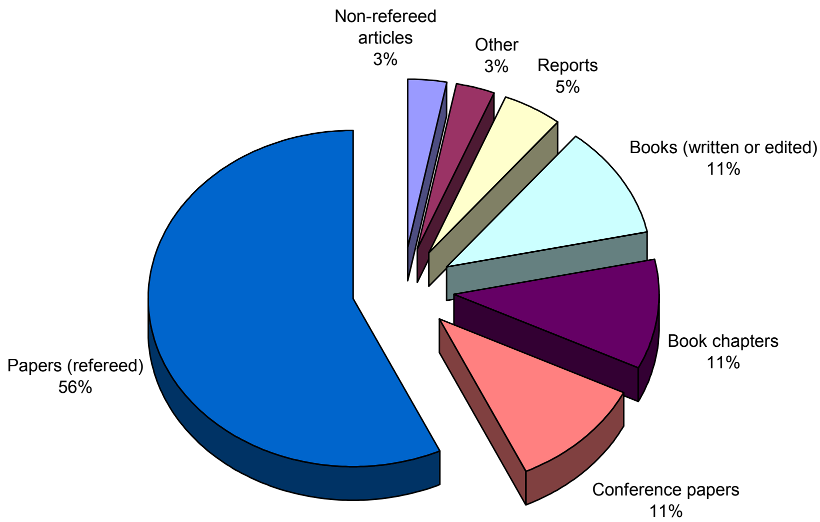
4.4.2 Preferred publication medium and format

Researchers were asked what their preferred medium and format of publication was (eg. whether they preferred to publish journal papers or books, and whether they preferred to publish in print or electronic formats). Most simply nominated one preference, but a few nominated more than one.

Preferred medium

Researchers across the sample revealed a strong preference for publication in peer reviewed journals, with more than 90% suggesting that refereed journals were one of their preferred media for publication. Book chapters, books (authored or edited) and conference papers were each nominated as a preferred media by around 20%. Averaged across the sample, referred journal papers amassed almost 60% of the researchers' expressed preferences, while book chapters, books (authored or edited) and conference papers were each amassed around 10% of expressed preferences.

Figure 4.26 Preferred medium for publication?



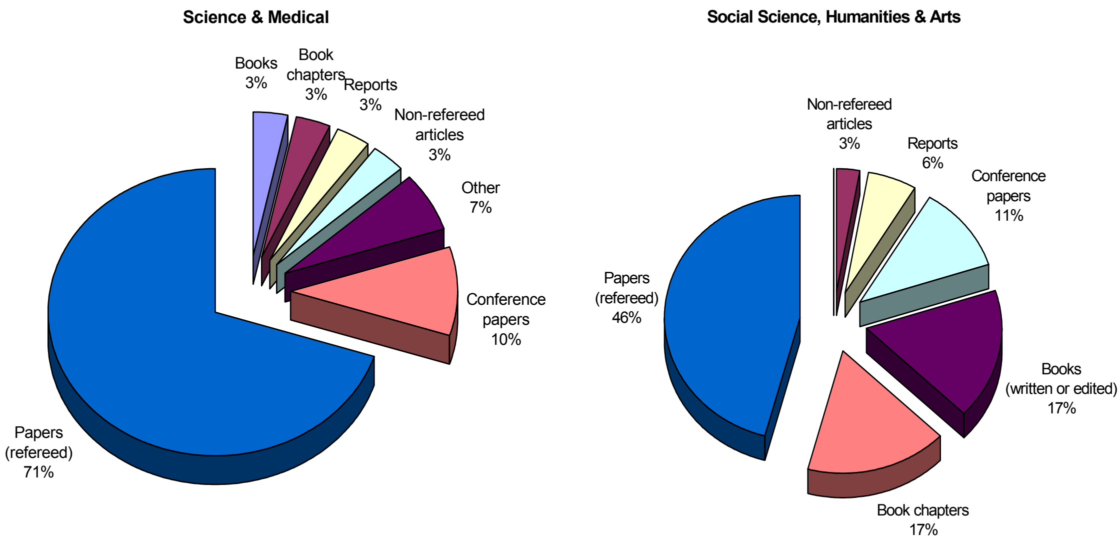
Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Among researchers in science and medical fields there was a stronger preference for publishing in peer reviewed journals. All expressed a preference for publishing in journals, and just 15% nominated conference papers. Among researchers in social sciences, humanities and arts 85% expressed a preference for publication in refereed journals, 30% for publication in books and 20% for publication in conference proceedings.

Preferred format

Format preferences varied from medium to medium. For journal papers, around 80% said they would prefer them to be available in print, 5% expressed a preference for electronic and the remainder would like them to be available in both print and electronic formats. For books and reports, all expressed a preference for print. Conversely, around 40% expressed a preference for their conference papers to be available electronically.

Figure 4.27 Preferred medium for publication: by field of research



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Researchers in social sciences, humanities and arts fields revealed a somewhat higher preference for print than did those in science and medical fields. Among social sciences, humanities and arts researchers 75% of those expressing a preference for publishing conference papers wanted them to be available in print, 88% of those preferring journal papers wanted the to be available in print, and all wanted to see books and reports in print. By comparison, only 33% of science and medical researchers expressed a preference to see their conference papers in print, and 80% wanted to see their journal papers in print. Again, however, all wanted their books a reports to be available in print.

When discussing medium preferences it was clear that people publish in the way that earns them the most points – ie. in the medium *and* format recognised by funding agencies, the Department of Education, Science and Training (DEST) and employing institutions (be they universities or research institutes).[17] Indicative comments included:

> *Its got to be print, and journals because that's what DEST counts* (Mathematics).
>
> *It must be print, must be refereed, because that's what the University supports* (Software Engineering).

[17] It should be noted that funding agencies recognise electronic publication as equivalent to print for equivalent publications. Nevertheless, researchers' perceptions indicate that purely electronic publication is not yet seen to be equivalent. Presumably they carry that perception into their refereeing activities (of publications and funding applications).

> *We must publish in refereed journals for the DEST points* (Sports Psychology).
>
> *Only things in the ARC [Australian Research Council] A1 list* (Geology).
>
> *There are good reasons for people to publish on the top journals. We could publish on our personal web sites, but that is not the way you get grants…* (Chemistry).
>
> *Journal articles are the main way to go. Books are very slow and too big a project for a single author with much teaching to do. The pressure is on to publish, so journals are better… they are quicker and get DEST points* (Asian Studies).
>
> *DEST points and research grants drive the focus on journals, but its also quicker than books and there is a need to be more visible more often these days because things are just moving faster* (Archaeology).
>
> *E-presses are a great innovation, but they have to 'count' for DEST points or it will never work* (European Studies).

Other factors in determining preferences related to establishing a portfolio of publication that demonstrates a range of talents, focusing on the prestige of the journal title and impact factors, going to a journal where the work will best fit and aiming for a specific audience.

Asked to explain the format preferences researchers pointed to the relative perceptions of print versus electronic publications. Indicative comments included:

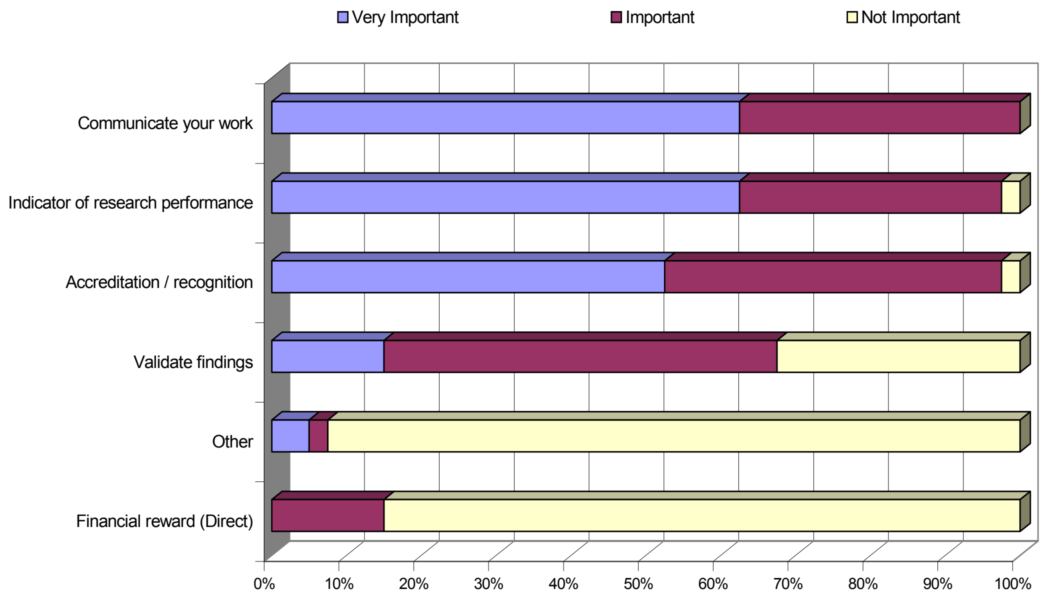
> *Electronic journals are not perceived to be fully refereed* (Forensic Science).
>
> *Print journals have more credibility with reviewers and funders* (Genetics).
>
> *Only use refereed print!* (Ecology).
>
> *Journals are vital, books less so. The big issue is that no one in Philosophy takes electronic journals seriously. They are very poor* (Philosophy).

4.4.3 Reasons for publishing

Exploring the reasons behind publication, revealed that communication of work and measuring research performance were both considered 'very important' – by around 60% of respondents. Accreditation and recognition (within the research community) was considered 'very important' by around half. Few considered direct financial reward important. Those doing so were thinking of their centre rather than themselves – using revenue from centre publications to generate a little funding to support conferences, etc.

There were difference between fields of research, with communication of work rated 'very important' by less than 60% of researchers in science and medical fields and ranking third behind indicator of performance (rated 'very important' by 62%) and accreditation and recognition (rated 'very important' by more than 70%). By comparison, communication of work was rated 'very important' by almost 70% of researchers in social sciences, humanities and arts, ahead of indicator of research performance (rated 'very important' by more than 60%) and accreditation and recognition (rated 'very important' by just 30%).

Figure 4.28 What are the main reasons for your publishing?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Comments on motivations for publishing focused on communication with specific audiences and performance measurement. For example:

> *I am driven by getting it out and demands for publication as an output indicator* (Sociology).
>
> *Being first to publish is everything, everything flows from that – recognition, funding, etc.* (Medicine).
>
> *Credibility and points are the main issue – fortunately [in terms of communication] the better journals have higher circulation* (Genetics).
>
> *DEST points are critical* (Sports Psychology).
>
> *Need credibility for grant applications* (Mechanical Engineering).
>
> *You have to consider the DEST points* (Asian Studies).
>
> *Everyone now looks at the impact factors of the journal they are thinking of publishing in, because of the importance of that for career progression. That did not happen ten years ago* (Genetics).

The few who said that publishing performance measures did not matter to them, followed up with explanations like: "*I don't care any more… I've got tenure*" or "*I've given up… anyway I'm retiring next year*". Many noted that the performance indicator issues were much more important for early career researchers (Note: the interview sample was drawn from senior, established researchers).

Workshop discussions involving groups from various fields of research brought out difference in publication practices and perceptions. One particular exchange was interesting. A senior researcher in Chemistry declared that he was all for quantity when it came to publication, while a colleague in a Biomedical centre disagreed, saying that a few top quality articles were better than lots of articles in lesser journals. Indeed, he made it clear that he regarded long publication lists as less impressive than quality short ones. Indicative comments included:

> *I publish a lot, but it is not for me, it is for my students who need those publications to get a start in their careers* (Chemistry).
>
> *The goal of publishing your research is to get funding for further work and that is not going to happen publishing in low-level journals. Particularly if the work is broken up, it will be seen as dilution. A single article in a highly regarded journal will have much more impact* (Biomedical).

Later in discussion it emerged that they both acted as referees for ARC/NH&MRC and felt no difficulty doing so outside their immediate field of research (including each others fields), despite clearly applying very different standards in their judgement of publication practices.

A number of workshop participants and interviewees were critical of the performance indicator system(s): being based on quantity with little or no account taken of quality; because of what does and what does not 'count'; and because of the limitations of citation and impact analyses. Others recounted a series of stories about works that did not count as publications, and were not recognised in impact factor analyses. For example:

> *There are a lot of business people who come to engineering conferences and who get ideas there, but there will be no citations arising from it even though its impact may be considerable* (Computer Science).

Other examples included: TV documentaries (Cultural Studies); data submitted to databases, such a gene sequences (Biomedical); reports prepared for international agencies (Economics); and a range of work for government agencies, such as policy analysis and development, economic, social and environmental impact studies. As one senior research noted:

> *There is a very fuzzy area between what used to be professional practise and research. Where do you draw the line between the production of an innovative piece of music and a scientific paper? [Interviewer: Are you saying that you are forced to write a paper about music rather than composing a piece?] Yes* (Visual Arts and Music).

While the visual arts and music are special cases, this problem is by no means isolated. Knowledge production has become more diverse, but performance and impact measures have not yet entirely recognised the changes, or kept pace with them.

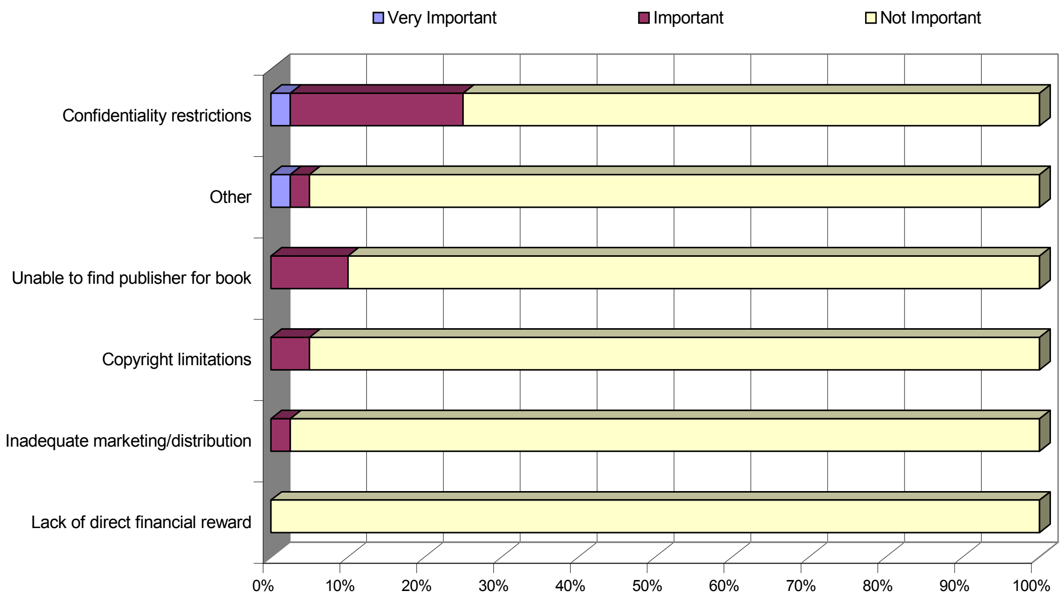
4.4.4 Barriers to publishing

Few had experienced any difficulties getting published. A small number had experienced some difficulties finding a publisher for a book for which there was perceived to be a limited specialist market. The only significant barrier felt were restrictions placed on publication by commercial funders. Around 25% said they had confronted confidentiality restrictions, and around 5% cited copyright limitations.

As noted above, the commercial delays imposed vary considerably. Indicative comments included:

> *There are some commercial delays on some things* (Plant Pathology) .
>
> *Patenting and commercial restriction create delays in publication* (Structural Biology).
>
> *In the medical area, if you are dealing with pharma [ie. a pharmaceutical company] they will tell you inside six weeks whether they want to patent the findings or not* (Medicine).
>
> *I have had to wait as much as a year to get a response [from a company over whether they want to patent research they have sponsored or not]* (Chemistry).
>
> *I have done one consultancy that could not be published for 2 years* (Ecology).
>
> *Most of the work has a 2 year delay on it because its commercially funded* (Geology).

Figure 4.29 What are the main barriers you face when publishing?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

One researcher commented on the role of peer review and tied it to the restrictions introduced with commercial funding, suggesting that:

> *It is critical to have peer review and conferences for the discussion of ideas. Commercial confidentiality sometimes means that there is actually less information communicated. [Consequently] there is not enough questioning and reviewing by fellow scientists. This is*

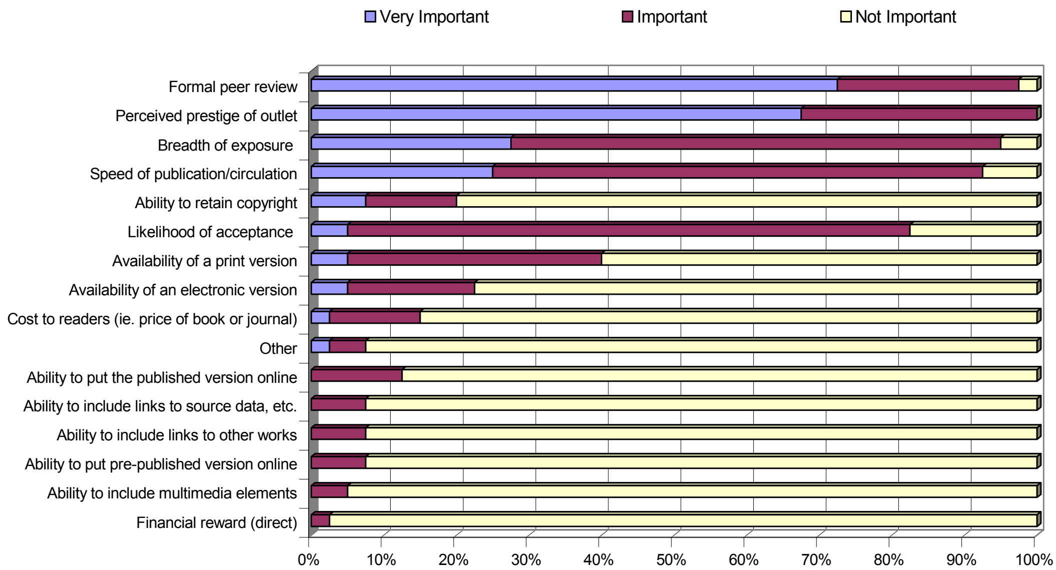
> *a real danger, and in the long run is not efficient. The capacity for self-delusion is great. It [science] must be open to public scrutiny…* (Structural Biology).

This kind of concern could be addressed to some extent with greater use of open access repositories.

4.4.5 Factors in choosing a publishing outlet

Asked what factors they consider important when choosing between publishing outlets respondents indicated that formal peer review and the perceived prestige of the outlet where the most important things, with breadth of exposure and speed of publication also seen to be important.[18]

Figure 4.30 When choosing between publishing outlets what factors do you consider?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Around 70% of respondents indicated that formal peer review was 'very important' and a further 25% indicated that it was 'important'. The perceived prestige of the outlet seemed to be 'very important' for around two-thirds, with a further 35% indicating that it was 'important'. By comparison, breadth of exposure and speed of publication appeared to be 'very important' to around 30% of respondents, with a further 65% suggesting that they were 'important'. Interestingly, the availability of

18 Again it was not always practicable to go through the entire list of factors with some interviewees, and the same strategy was adopted as before – ie. asking about the factors that were generally considered most important specifically, and then using more open-ended questioning to explore what other factors they considered.

an electronic version and the ability to retain copyright did not seem to be important considerations.

Peer review and the prestige of the outlet appear to be more important publishing considerations for researchers in science and medical fields than for those in social sciences, humanities and arts. Ninety per cent of researchers in science and medical fields indicated that they thought formal peer review 'very important' and the remainder thought it 'important'. Eighty per cent of science and medical researchers indicated that they thought the perceived prestige of the outlet 'very important' and the remainder thought it 'important'. Other considerations appeared to rate much lower, with speed of publication and breadth of circulation each seen as 'very important' by around 20%. By comparison, only just over 50% of researchers in social sciences, humanities and arts indicated that the perceived prestige of the outlet and formal peer review were 'very important'. Breadth of exposure and speed of publication were correspondingly higher in the consideration of researchers in social sciences, humanities and arts.

It is interesting to note that formal peer review and the perceived prestige of the outlet were considered more important than breadth of exposure. In debate about pre-print and e-print archives, it is often assumed that a, if not the, most important thing for researchers is to communicate their findings as widely as possible. Our findings suggest that this may not be so. Clearly, communication is only one part of the story.

A number of interviewees suggested that the main issue for them was who the audience is that they want to reach. They then seek to publish appropriately to reach that audience. Importantly, that audience may be quite small, with perhaps just a handful of specialists in the field worldwide. Indicative comments included:

> *The main issue is who is the audience you are trying to reach with any particular work* (Asian Studies).

> *It depends on what audience you are trying to reach* (Archaeology).

Asked if she thought there was a contradiction in her claim that she published to communicate her work, but did so in a specialist journal with a likely circulation of no more than around 1 000 worldwide, one engineering and technology researcher said:

> "*There are only about 30 people in the world working on this… and I bet they all read this journal.*" (Software Engineering).

This clearly suggests that wide dissemination may not be the goal of many researchers, and that, for the purposes of communication at least, e-mailing a network of colleagues might be just as effective. Obviously, however, it would not bring the recognition and funding that publication does.

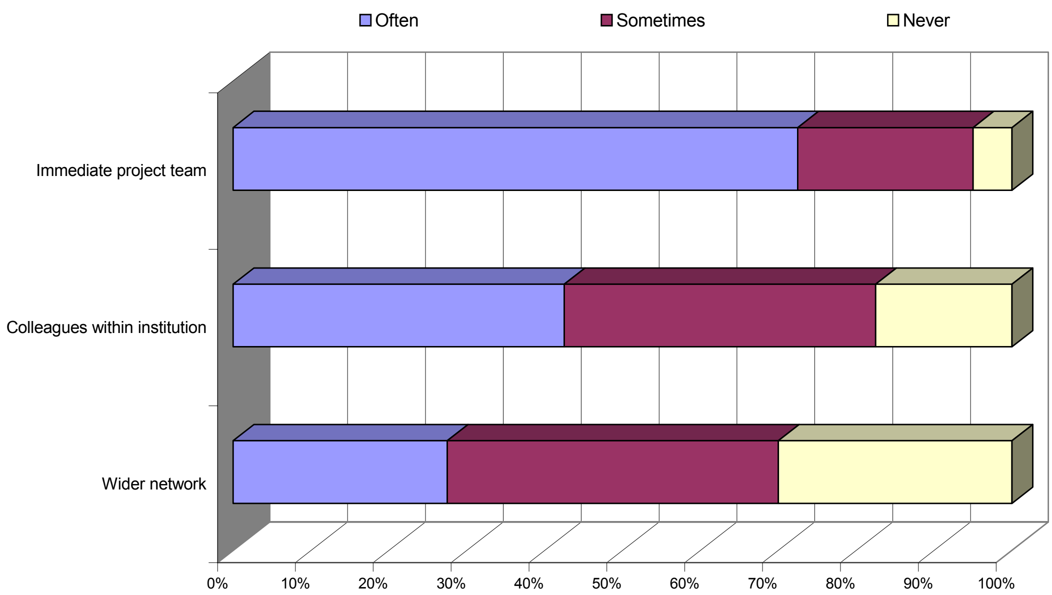
One workshop participant joked that:

> *The ideal is a journal that accepts quickly and publishes at leisure, because then it is on your C.V. without you having to take responsibility* (Evolutionary Biology).

4.4.6 Informal dissemination

To explore dissemination outside formal publishing researchers were asked whether they circulated pre- and/or post-publication material to colleagues, how often and by what means. All but two said they did circulate draft and other material. Around 70% said the 'often' circulated material within the immediate project team and a further 20% said the 'sometimes' did so, around 45% said they 'often' circulated material among colleagues within their own institution and a further 40% said they 'sometimes' did so, and around 30% said they 'often' circulated material among a wider network and a further 45% 'sometimes' did so.

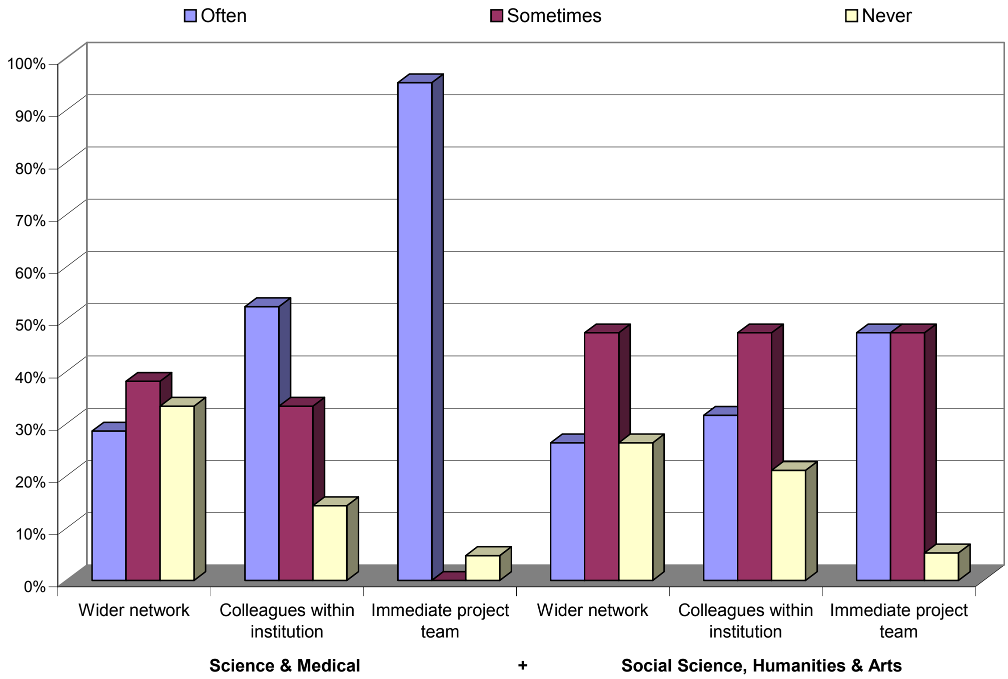
Figure 4.31 Do you circulate drafts or completed works informally?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Practices vary between fields of research. It seems that circulating papers among immediate colleagues and those within their institutions is somewhat more common for researchers in science and medical fields, while somewhat fewer circulate papers to a wider network.

Figure 4.32 Circulation practices: by field of research



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment*, DEST, Canberra.

Comments also suggested that practices vary significantly, with some very open and others much more cautious about revealing their work prior to publication. Institutional practices vary too, with some indication that there is an increasing awareness of the need for 'author support' in the form of an internal review process (such as that operating within CSIRO). Indicative comments included:

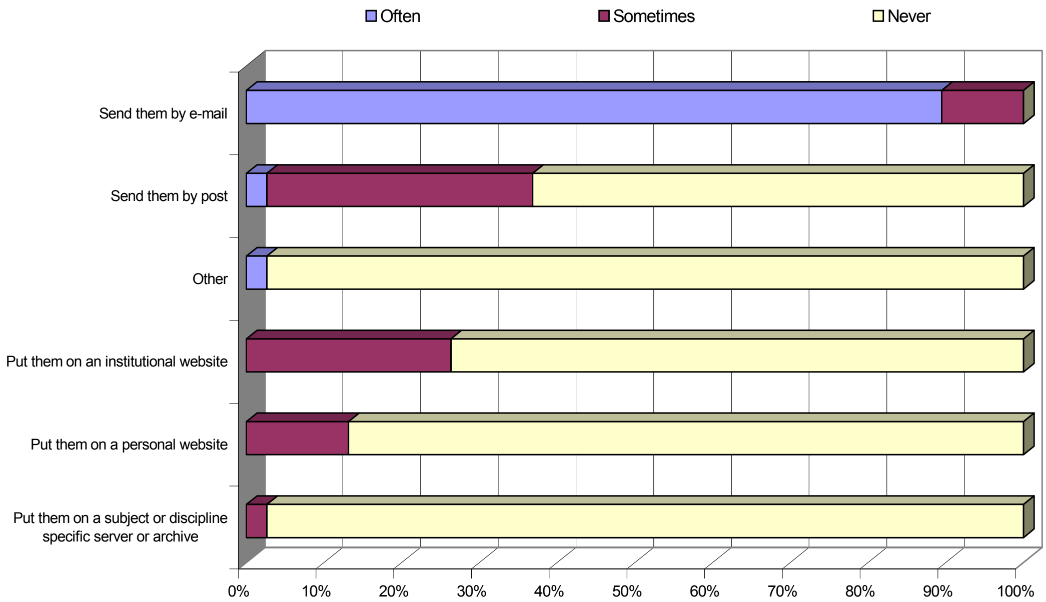
> *I check with people in other areas of expertise, in case of misunderstanding things at the edges of the discipline* (Art History).
>
> *I have and use a very wide network, and often circulate drafts repeatedly* (Media Studies).
>
> *I send book manuscripts to leaders in the field before giving them to publishers…[so] they are pre-reviewed and it really eases the process* (Architecture/Design).
>
> *I increasingly try to circulate for review internally* (Viticulture).
>
> *You must be careful, people are a bit guarded* (Structural Engineering).
>
> *Have to be careful not to give ideas away* (Medicine/Clinical).
>
> *Cautiously, among friends… I would like to but I am worried about plagiarism* (Asian Studies).
>
> *Have to be careful beyond the internal review process… you need to safeguard IP* (Structural Biology).

Means of circulation

Not surprisingly, e-mail is the principal means of circulation within both internal and the wider networks. Around 85% suggested that they often circulated material by e-mail and a further 10% suggested that they sometimes did so. Post is still used, but is not the preferred means for most. Few indicated that they put material on institutional or personal websites, with around 25% saying they would sometimes put material on an institutional website and 15% saying they sometimes put material on personal websites.[19] Few seem to use pre- or post-print servers or archives.

Among researchers in science and medical fields, 95% indicated that they often circulated papers by e-mail, 40% sometimes put them on an institutional website, 30% sometimes sent them by post, and 20% sometimes put them on a personal website. By comparison, 75% of researchers in social sciences, humanities and arts indicated that they often circulated material by e-mail, 10% suggested that they sometimes put material on an institutional website, and 5% indicated putting material on personal websites and disciplinary servers or archives.

Figure 4.33 How do you circulate drafts?



Source: Interviews conducted for Houghton, J.W. et al. (2003) *Changing Research Practices in the Digital Information and Communication Environment,* DEST, Canberra.

19 The interviews were conducted with senior researchers, department heads and research centre directors. It is quite possible that other, more junior staff put their work online on institutional websites, servers or archives without their knowledge. However, a 'straw poll' search for online papers by respondents seemed to confirm what they said. Relatively few were found online.

4.4.7 The impact of ICTs on dissemination and publication

Some 40% said that the electronic information environment had changed the way that they and others in their field publish and disseminate findings. Others said that it had not really changed what they were doing. Things were much easier and quicker, and they were now publishing online, but it was the electronic version of the same thing (eg. similar papers in the same journals). Notably, only 20% of researchers in science and medical fields indicated that they thought that the digital information environment had changed the way that they and others in their field publish and disseminate findings, compared with 50% of those in social sciences, humanities and arts.

Only around 20% of interviewees thought that electronic publishing was really challenging the dominance of print. Most felt that electronic alternatives were supplementing print and helping to speed up the dissemination process, but suggested that the basic process of peer review and print publication were likely to survive for some time to come. Indicative comments included:

> *Electronic publishing supplements, but its not a revolution* (Art History).
>
> *There is more electronic, but not all that much change in the form* (Law).
>
> *Its just electronic version of the same material* (Education).
>
> *There are more opportunities to use the web, but at the fringe… its not yet a core part of the publishing thing* (Aquaculture/Fisheries).
>
> *There are increasing opportunities with things like virtual reconstruction of sites and multimedia formats in the broader area, but in terms of the academic discipline nothing has really changed… few Archaeologists publish online* (Archaeology).
>
> *I communicate through journals, but I am trying to also put versions on the web to find a wider audience… because it may help me find external consulting type funding* (Sociology).
>
> *We are putting more online to increase the reach of our work* (Geophysics).
>
> *There are more and broader opportunities to communicate* (Aboriginal History).
>
> *It will diversify… print is not being replaced* (Cultural Studies).
>
> *Its parallel, not a replacement* (Management).
>
> *Print will hang around for some time yet… they are really complementary not alternatives* (Biological Sciences).
>
> *Not yet, electronic is seen as second rate* (Management).
>
> *It will improve access, but will not challenge the refereeing process…that is vital* (Ecology).
>
> *The key is to change how Universities recognise the points… people will not change until then* (Forensic Science).
>
> *We still need peer review, funding is based on it* (Management).

Online dissemination and publishing concerns

Asked whether they had any concerns about emerging electronic dissemination and publication options around 60% said they did. The main areas of concern were quality and perceived difficulties judging the authenticity and accuracy of material online. Indicative comments included:

> *Quality – its too easy to find rubbish on internet* (Plant Pathology).
>
> *Quality – finding rubbish is just too easy* (Architecture/Design).
>
> *Quality is an issue… and the explosion of material is intimidating in terms of volume* (Asian Studies).

Others were concerned about loss of control over intellectual property, plagiarism, etc. Indicative comments included:

> *Plagiarism – I always use locked .pdfs… which probably has no real effect* (Law).
>
> *Control over copyright… and authors' rights* (Software Engineering).
>
> *Protecting IP, its too easy to cut and paste now* (Management).
>
> *Who owns the ideas if its done in a very collaborative and interactive way?* (Viticulture).

Still others were concerned that online publishing meant more publishing, with all the volume, quality and value issues that that implies. Indicative comments included:

> *Too much is published. It is easier to get published now because there are more titles. Rejection rates are falling and there is a decline in quality. The consequence is that the gems are getting harder to find* (Cultural Studies).

4.5 Summary of findings

Interviews and workshops conducted for this study involved around 75 researchers from a range of fields and institutional settings. They were wide-ranging and explorative, focusing on the reasons behind changing research practices. They explored the impacts of funding and institutional changes on research practices, and then examined changes in communication and collaboration, information search and access, and dissemination and publication. The following summary is included to help navigate the wealth of material uncovered.

We found that researchers in Australia are operating in an increasingly institutionally diverse and interdisciplinary environment, in which collaboration is encouraged, competition is intense, performance is closely monitored and both scholarly and commercial outcomes are expected. Their research practices are similar to those reported in international studies. By no means is what is happening in Australia unique (See international comparisons – Appendix 2). Our contribution is to further understanding of the drivers and shapers of evolving research practices.

The impacts of funding and institutional changes

The major recent trends in funding include a shift from internal funding to competitive grants (felt across the board) and an increase in commercial funding (felt most in science and medical fields). The shift to competitive grant and commercial project-based funding is seen to bring greater competition, uncertainty, fluidity and short-termism. Many are concerned about the impact of these changes on the 'next generation', feeling that it is becoming more difficult to support young researchers as they build a career. Others sense a globalisation of research and increased international competition.

In terms of the allocation of funding, there are concerns about the perceived adherence to simplistic, formulaic funding models based on the sciences which often ill suited to the social sciences, humanities and arts; and perceived weaknesses in funding allocation processes, in terms of both the fairness of those process and their perceived bureaucratisation.

A number of researchers reported concerns about the fairness of the peer review of research proposals in a small country with limited numbers of specialists in any given field, the perceived over-representation of disciplinary representatives on research council committees, and difficulties reviewing interdisciplinary proposals. There are also concerns about the amount of 'red tape' involved, to the extent that some feel that research is "stifled by university bureaucracy". On occasions the procedures appear to have backfired, with one case emerging in which IP was given away rather than commercialised through processes that researchers felt too complex to face and which they have limited motivation to tackle.

A number of researchers perceive a potential conflict between the needs to publish and commercialise, with dangers for them in becoming too dependent on commercial funding. There is an important message in this about both the treatment of patenting vis-à-vis publishing in performance measurement, and perceptions about the relative merits of patenting and publishing in their communities. Some see it as merely a transitional problem, but a number expressed the view that there was a need for much more support in commercial research contract negotiations and for the standardisation of practices and, where possible, of contracts.

Communication and collaboration

Communication and collaboration lie at the heart of research. Collaboration on projects is common. Almost 75% of interviewees reported working primarily in project teams, and a further 13% reported a mixture of team and individual work practices. Very few work entirely alone.

There is increasing collaboration across a wider range of organizational settings. Almost 60% reported an increase in the locational diversity of collaborators, more than 50% reported an increase in cross-institutional collaboration, around 45% reported an increase in the average size of research teams, and 25% reported an increase in their own project team collaboration. Collaboration also seems to be spreading into the humanities, with 50% of respondents in social sciences, humanities and arts reporting an increase in their team participation.

A number of researchers see encouragement by funding agencies as a key driver of collaboration, with agencies seeking scale, quality and performance. Others see an increasing need to collaborate, with projects involving a wider range of specialist skills, such that collaboration is a response to complexity, increasing interdisciplinarity and an increasingly problem oriented approach to research (ie. an increase in Mode 2 research). For some collaboration is driven by a need to access intellectual property, data, specialist instruments, large scale facilities, sample populations and trials.

Communication between project team members is regular, suggesting that collaboration is quite intense. Almost 40% reported that they typically interacted with project team members weekly, a similar number reported bi-weekly interactions. All respondents saw e-mail as 'essential', and phone calls were rated 'essential' by around 70%. Other means of communication play a much smaller role in facilitating research collaboration. More than 20% stressed the importance of face-to-face interactions, reporting quite regular project meetings, even where they involved team members travelling considerable distances.

Fully 90% saw themselves as part of a wider collegial network – 100% in science and medical fields, and 80% in social sciences, humanities and arts. More than 70% said that these networks were 'very important' to their work, and a further 15-20% said they were 'important'. Researchers also rely on e-mail for communication within these wider networks of scholarship. Nevertheless, face-to-face meetings at conferences and in other fora play a significant role in maintaining the network. Discussion lists are widely used, but not very highly regarded. Few seem to use videoconferencing.

Asked whether the new networked information environment had changed the way they collaborate, around 60% said that it had – with a higher proportion of social sciences, humanities and arts researchers reporting change than those in science and medical fields. The time involved in handling the volume of e-mails and related information, and some potential loss of the human touch in interactions, were quite widely cited concerns. Others reflected more specifically on the impacts of electronic communication on their field of research, noting some danger in the Western/American and/or English language dominance of the internet to date, both in terms of participation and perspective.

Nevertheless, most took a positive view of the impacts on their research. Connectedness and the increased pace and immediacy of communication appear to be important – adding to the sense of excitement and involvement, and facilitating participation in global research networks.

Information search and access

Peer reviewed journals, books and conference papers are the most important physical/print sources. Some 60% of respondents regarded peer reviewed journals as 'essential', and a further 40% reported using them. Books were regarded as an 'essential' source by almost 50% with a further 50% using them, and conference papers were regarded as 'essential' by around 30% with all respondents reporting using them.

There were notable differences between research fields. In social science, humanities and arts books ranked higher than refereed journals (print), with 70%

regarding books as 'essential' and the remaining 30% using them. Less than 30% of science and medical researchers regarded books as 'essential', and 10% seemed not to use them at all. Conversely, a higher percentage of science and medical researchers regarded refereed journals as 'essential' than social science, humanities and arts researchers.

In the online world, generic web search engines (eg. Google) were regarded as 'essential' by two-thirds of the researchers interviewed, with web browser bookmarks or favourites regarded as 'essential' by around 40%. Peer reviewed journal papers in electronic form were regarded as 'essential' by around 60%, and conference papers were regarded as 'essential' by almost 50%. Online alerting services and e-mail-based newsletter subscriptions were regarded as 'essential' by around 30%, and discussion groups (eg. listserv) were considered 'essential' by around 20%. All appear to be widely used.

Among science and medical researchers, 70% regarded refereed electronic journals as 'essential', 65% regarded generic search engines as 'essential', 50% regarded conference papers as 'essential', 40% regarded research databases as 'essential', 33% regarded bookmarks or favourites and online alerting services as 'essential', 30% regarded e-mail based newsletters as 'essential', and 20% regarded discussion groups and non-refereed electronic journals as 'essential'.

Among social science, humanities and arts researchers the level of online access appears to be somewhat lower, but access is wider ranging. More than 60% suggested that generic search engines were 'essential', 50% suggested that browser bookmarks and favourites, conference papers and refereed electronic journals were 'essential', 40% suggested that online catalogues were 'essential', almost 30% suggested that discussion lists were 'essential', 20% suggested that e-mail based newsletters and other grey literature were 'essential', and 15% suggested that online alerting services and research databases were 'essential'.

The majority of researchers exhibit a strong preference for peer reviewed sources, despite perceived flaws in peer review processes. Others were less dependent on traditional peer review, and tended to rely on known names (both individual and institutional) and a network of personal and professional contacts to source information. Outside these sources researchers are cautious.

Perhaps indicating a fundamental shift towards electronic sources, a number of researchers indicated that they used print sources to catch up with things outside their immediate field of interest, and for teaching. For an increasing number of researchers, it seems that printed sources are more of an historical record than the current 'dialogue'.

An average of around 75% of searching and browsing is conducted online. Researchers in science and medical fields appear to do more searching and browsing online – 80% compared with around 70% in social sciences, humanities and arts. However, an average of almost 90% of reading and studying is conducted offline, using printed documents. A slightly higher proportion of social science, humanities and arts researchers report reading and studying online – 14% compared with 11% of researchers in science and medical fields.

When choosing sources, credibility, peer review and currency are the most important considerations. Credibility (ie. known/trusted source) was regarded as 'very important' by 60%, peer review was regarded as 'very important' by almost

60%, and currency was regarded as 'very important' by around 40%. The availability of full text, the ability to access from the desktop, the availability of an electronic version and the ability to access 24/7 were all factors considered to be 'important' by one-third to a half of the respondents, but were rarely considered 'very important'. Cost, either individually or to the institution, was not considered an issue by some 70%.

Researchers in science and medical fields put more weight on peer review, with two-thirds suggesting that peer review was 'very important' and the remaining third suggesting that it was 'important'; compared with 47% and 42% of researchers in social sciences, humanities and arts, respectively. Among humanities researchers credibility (defined more broadly than peer review) was seen as the most important factor. Researchers in science and medical fields appear to rate the availability of an electronic version, desktop access and the availability of full text somewhat more highly than do researchers in social sciences, humanities and arts. Around 25% of researchers in all fields saw the availability of a print version as important.

Asked what kinds of sources they were using more and what less, compared with five years ago, most said more electronic and less print. In most cases, part of the point being made was that the actual sources have not changed very much, but they were now more readily available online.

Around 80% of those interviewed reported having personal subscriptions to news and/or discussion groups, around 75% reported having personal subscriptions to journals and almost 70% subscribed to alerting services. Subscriptions to news and discussion groups and alerting services were primarily electronic and free. However, around 70% of personal journal subscriptions appear to be paid, and all personal journal subscriptions were to print format.

There are differences in personal subscription habits between fields of research. Among science and medical researchers, 75% reported subscriptions to altering services and journals, and around 65% reported subscriptions to news or discussion groups. Almost 90% of social sciences, humanities and arts researchers reported subscriptions to news or discussion groups, around 75% reported subscriptions to journals and 60% to alerting services.

Almost all those asked reported having a personal print collection, around 90% reported maintaining an electronic archive and around 66% reported using linked web resources. Around 45% indicated that their physical or print collection was 'essential', and a further 50% appeared to use such a collection. Some 15% said their electronic archive was 'essential', and a further 75% indicated that they used one. Personal collections appear to be more important to researchers in the social sciences, humanities and arts than they are to those in the sciences.

A number noted that they were reducing their personal subscriptions and collections, because of the cost involved and because of the increased ease of access to material online. Asked what they were now collecting more and what less than they were five years ago, comments suggested that the 'more' was electronic (everything) and the 'less' was print (everything).

Asked if the increasing access to information online had changed the way that they and others in their field searched for and accessed information, around 80% said it had. Others suggested that having more available online had made things much easier, but had not really changed what they did or what sources they used.

A small proportion of researchers voiced some concerns about the impact of online search and access. Typically, these concerns centred around the quality of what is online, loss from view of material that is not online, and the potentially negative effects of information overload on research in their fields. Some also lamented the loss of the ability of 'browse the stacks' and find things they were not really looking for.

A third of all respondents saw research databases as 'essential' and a further third reported using them. The use of databases is higher in the sciences, with 75% of science and medical researchers using databases and more than 40% suggesting that they were 'essential'. Nevertheless, almost 60% of social science, humanities and arts researchers reported using databases, and 15% regarded them as 'essential'.

Just over 40% of interviewees reported that they had perceived a change in the relative importance of primary source datasets vis-à-vis secondary sources – 37% in social sciences, humanities and arts and 47% in science and medical fields. Asked about the nature of that change, as many as 80% reported noticing an increase in the use of primary data – 100% of those in science and medical fields noted such a change, compared with around 60% of those in social sciences, humanities and arts.

A number of researchers suggested that access to primary data, related software and computer facilities was changing their field of research in important ways. Workshop participants noted that they accessed a good deal of publicly available and private subscription data, and that they often did so outside their institution's library and information systems. A number also talked about the software they needed to analyse that data. In some fields access is open, in others it is much more guarded. Some spend many thousands of dollars a year on software.

Dissemination and publication

Across the interview sample, researchers published an average of around 3 journal papers, 2.8 conference papers, 1.6 project reports, 1.3 non-refereed articles and completed an average of just less that one book chapter per year. Around 10% also reported patenting. Researchers in science and medical fields publish somewhat more journal and conference papers, while researchers in social sciences, humanities and arts fields publish more books and book chapters.

A high level of collaboration is reflected in joint authorship. More than 75% of respondents indicated that they were typically joint authors. Among researchers in science and medical fields 100% reported that the were typically joint authors, while among researchers in social sciences, humanities and arts around 50% were typically joint authors. Some 40% of respondents suggested that their patterns of authorship had changed over the last five years, with all citing either an increase in the number of authors or in the proportion of their published output that is joint authored.

Researchers across the sample revealed a **s**trong preference for publication in peer reviewed journals, with more than 90% suggesting that refereed journals were their preferred medium for publication. Book chapters, books (authored or edited) and conference papers were each nominated as preferred media by around 20%.

Among researchers in science and medical fields there was a stronger preference for publishing in peer reviewed journals. All expressed such a preference, and just 15% nominated conference papers. Nevertheless, among researchers in social sciences, humanities and arts more than 80% expressed a preference for publication in refereed journals, and just 30% for publication in books.

Format preferences vary from medium to medium Around 80% said they would prefer their journal papers to be available in print, and 100% wanted their books and reports to be in print. Conversely, around 40% expressed a preference for their conference papers to be available electronically.

When discussing medium preferences it was clear that researchers publish in the way that earns them the most 'points' – ie. in the medium *and* format recognised by their peers, funding agencies and employing institutions. Other factors in determining preferences related to establishing a 'portfolio' of publication that demonstrates a range of talents, focusing on the prestige of the journal title and impact factors, going to a journal where the work will best fit, and aiming for a specific audience.

Exploring the reasons behind publication, revealed that communication of work and measuring research performance were both considered 'very important' by around 60% of respondents. Accreditation and recognition (within the research community) was considered 'very important' by around half.

There were difference between fields of research, with communication of work rated 'very important' by less than 60% of researchers in science and medical fields, and ranking third behind indicator of performance (rated 'very important' by 60%) and accreditation and recognition (rated 'very important' by more than 70%). By comparison, communication of work was rated 'very important' by almost 70% of researchers in social sciences, humanities and arts, ahead of indicator of performance (rated 'very important' by more than 60%) and accreditation and recognition (rated 'very important' by just 30%).

Comments on motivations for publishing primarily focused on communication with specific audiences and performance measurement. A number were critical of the research evaluation system – being based on quantity with little or no account taken of quality, because of what does and what does not 'count', and because of the limitations of citation and impact analyses. Knowledge production has become more diverse and often more closely linked to its context of application. Performance and impact measures have not kept pace with changes and with the emergence of a new mode of knowledge production.

Few experienced difficulties getting published. Some humanities researchers noted difficulties publishing books which do not appeal to major North American and European publishers. The more significant barrier experienced was restrictions placed on publication by commercial funders. These 'commercial delays' imposed vary considerably (from a few weeks to two years).

Formal peer review and the perceived prestige of the outlet where the most important factors when choosing between publishing outlets, with breadth of exposure and speed of publication also seen to be important. Interestingly, the availability of an electronic version and the ability to retain copyright did not seem to be important considerations.

Peer review and the prestige of the outlet appear to be more important for researchers in science and medical fields. Other considerations appeared to rate much lower, with speed of publication and breadth of circulation each seen as 'very important' by around 20%. By comparison, only just over 50% of researchers in social sciences, humanities and arts indicated that the perceived prestige of the outlet and formal peer review were 'very important'. Breadth of exposure and speed of publication were correspondingly higher in the consideration set of those researchers. It is likely that considerations reflect concerns, with certain aspect of the process taken for granted by some (eg. speed of publication in the sciences).

In debate about pre-print and e-print archives, it is often assumed that a, if not the most important thing for researchers is to communicate their findings as widely as possible. Our findings suggest that this may not be so. A number of interviewees suggested that the main issue for them was the audience that they want to reach. They then seek to publish appropriately to reach that audience. Importantly, that audience may be quite small, with perhaps just a handful of specialists in the field worldwide. There were also signs of 'market segmentation', with authors choosing particular outlets for particular types of communication.

Almost all said they circulated draft and other material informally. Around 70% said the 'often' circulated material within their immediate project team and a further 20% said the 'sometimes' did so, around 45% said they 'often' circulated material among colleagues within their own institution and a further 40% said they 'sometimes' did so, and around 30% said they 'often' circulated material among a wider network of friends and colleagues and a further 45% 'sometimes' did so.

Practices vary between fields of research. It seems that circulating material among immediate colleagues and those within their institutions is somewhat more common for researchers in science and medical fields, while somewhat fewer circulate papers to a wider network than is the case in social sciences, humanities and arts. Institutional practices also vary, with some indication that there is an increasing awareness of the need for 'author support' in the form of an internal review process (such as that operating within CSIRO).

Not surprisingly, e-mail is the principal means of circulation within both project teams and the wider networks of research and scholarship. Post is still used, but is not the preferred means for most. Few indicated that they put material on institutional or personal websites, and few seem to use pre- or post-print servers or archives for dissemination and publishing.

Most felt that electronic alternatives were supplementing print, not replacing it. Nevertheless, some 40% said that the networked information environment had changed the way that they and others in their field publish and disseminate findings. Others said that it had not really changed what they were doing – things were much easier and quicker, and they were now publishing online, but it was the electronic version of the same thing (eg. similar papers in the same journals).

Asked whether they had any concerns about emerging electronic dissemination and publication options around 60% said they had. The main areas of concern were quality and perceived difficulties judging the authenticity and accuracy of material online. Others were concerned about loss of control over intellectual property and plagiarism. Still others were concerned that online publishing meant more publishing, with all the volume, quality and value issues that that implies.

5. Discussion and conclusions

In the context of the emerging knowledge-based economy, innovation and the capacity of the national innovation system to create and disseminate scientific and scholarly information are increasingly fundamental determinants of national prosperity. In their foundational work on National Innovation Systems, the OECD observed that prosperity in a knowledge economy depends as much, if not more, on the knowledge distribution power of the system than it does on its knowledge production power (OECD 1997, p43). This makes the infrastructure supporting research communication and collaboration, information search and access, and dissemination and publication a key element of the national innovation system. It is essential, therefore, to provide cost-effective access to, and dissemination of scientific and scholarly information in support of research and its economic, social and environmental applications.

This study examines evolving research practices, focusing on how practices are changing and what the implications of those changes are for scholarly communication and the future development of the research infrastructure. This chapter presents a brief summary of our findings and a discussion of issues arising. It then outlines a coherent agenda for the evolutionary development of a sustainable research information and scholarly communication infrastructure.

5.1 Approach

Wide-ranging statistical and literature reviews provide a framework for analysis. Interviews were conducted with a structured sample of senior researchers in a range of research fields and institutional settings. Findings were confirmed and extended in a series of workshops. Both interviews and workshops targeted the leading edge of research in order to shed light on the direction of development and future needs. They focused on *why* researchers do what they do, rather than simply on *what* they do, because it is only by understanding the evolving needs of leading researchers that we can effectively resource research activities in the future.

Analysis focuses on three key areas of research activity: communication and collaboration, information search and access, and dissemination and publication. The key questions posed are:

- How do researchers conduct their research, and how is that changing?
- What are their major information sources, and how are those sources changing?
- How do researchers access, use and manage information, and how is that changing?
- How do researchers use their sources in the creation of new content, and how that is changing?

- How do researchers communicate with colleagues and publish their findings, and how are scholarly communication activities changing?
- How do researchers use technology, especially Information and Communication Technologies (ICTs), and how is it changing their activities?
- What are the implications of evolving research practices for those tasked with resourcing research and providing the necessary research information resources and communication infrastructures?

5.2 Key findings

We find that there is a new mode of knowledge production emerging, changing research practices and bringing new information access and dissemination needs. Adjustments will be required to the existing research information and scholarly communication system to accommodate these changes, but new opportunities are emerging for more cost-effective and sustainable information access and dissemination. To fully realise these opportunities, however, it will be necessary to take a more holistic approach to the development of the research information infrastructure and scholarly communication system.

A new mode of knowledge production is emerging

A new mode of knowledge production has emerged over recent years, characterised by Gibbons et al. (1994) as Mode 2. With the emergence of Mode 2 research there is: increasing diversity in the location of research activities; an increasing focus on interdisciplinary, multidisciplinary and transdisciplinary research; an increasing focus on problems, rather than techniques; greater emphasis on collaborative work and communication; and greater emphasis on more diverse and informal modes of communication.

The existing research information infrastructure has evolved over many years, during which traditional disciplinary Mode 1 research has been the dominant mode of knowledge production. Consequently, the existing infrastructure is better suited to the traditional than it is to the new mode of knowledge production. The key to developing research infrastructure for the future is to think through the implications of the changes in research practices implied by the emergence of Mode 2 research and the development of e-science.

There are new information access and dissemination needs

The emergence of a new mode of knowledge production is bringing with it new information access and dissemination demands. There is increasing demand for access to a wider range of more diverse sources; access mechanisms that cut across disciplinary silos; and access to, and management of non-traditional, non-text digital objects. Research databases, related software and other analytical objects are now core tools, as the very nature of discourse shifts from hypothesis testing towards collecting, processing and analysing primary data.

As the U.S. National Research Council noted:

> *The rapidly expanding availability of primary sources of data in digital form may be shifting the balance of research away from working with secondary sources such as scholarly publications. Researchers today struggle to extract meaning from these masses of data, because our techniques of searching, analyzing, interpreting, and certifying information remain primitive. New automated systems, and perhaps new intermediary institutions for searching and authenticating information, will develop to provide these services, much as libraries and scholarly publications served these roles in the past.* (National Research Council 2001, p5).

New digital object access management systems will be required, and there will be increasing demand for collaborative research support applications and research support systems that enable researchers to bring together the increasingly disparate digital objects used in research in such a way as to facilitate enhanced integrated analysis.

The system for the creation, production and distribution of scientific and scholarly knowledge must be viewed holistically

Many factors have influenced the development of the present research infrastructure and scholarly communication system. Its elements have evolved and are often considered separately. As a result, developments have been somewhat piecemeal and there are sometimes conflicting forces at work.

It will be essential to take an holistic approach to 're-engineering' the system, which treats the creation, production and distribution of scientific and scholarly information, the management of information rights and access, systems of evaluation and the underlying infrastructure as parts of a single research information infrastructure and scholarly communication system.

Research practices are directly shaped by systems of evaluation, changing funding patterns and priorities. Existing evaluation and reward structures tend to lead to conflicting incentives in relation to scientific and scholarly communication. Establishing a coherent structure of incentives that operates system-wide is an essential step towards providing cost-effective access and dissemination in support of both research and its economic, social and environmental applications.

Emerging dissemination and publication pathways offer new opportunities

Scientific and scholarly publishing is now evolving along two distinct paths – one in which large multinational commercial publishers are increasing their dominance in such areas as 'branded' journal titles and access to scientific publication, and the other in which there are a variety of open access initiatives.

Open access digital repositories, operating in parallel with existing commercial publishing mechanisms, may provide a major opportunity to develop a sustainable information infrastructure for both traditional and emerging modes of knowledge production. Together, they provide the foundation for effective and efficient access to, and dissemination of scientific and scholarly information.

5.3 Issues arising

While there are many issues arising from such a wide-ranging study, three areas were particularly striking – namely, those relating to resources, processes and incentives.

Resources

Given extensive recent coverage of resourcing issues it was not a topic on which we focused. Nevertheless, it was clear from interviews and workshops that the time and resources available for research are stretched to the point where the quantity and quality of research in Australian universities is in danger of being compromised. In briefly outlining the history of Australian universities, Margison (2002) noted that between 1975-76 and 1997-98 student load in higher education rose by 127.9% while total public funding of higher education rose by just 26.1%, such that by the late 1990s core public funding of higher education per student was less than half the level of two decades earlier (Margison 2002, p114).

During interviews for this project researchers were asked how their time was shared between research and other activities, and whether they had any concerns. A number reported that they typically worked late into the night and at weekends in order find the time to keep up with the reading they felt necessary to keep abreast of their field and to progress their research. Indicative comments included:

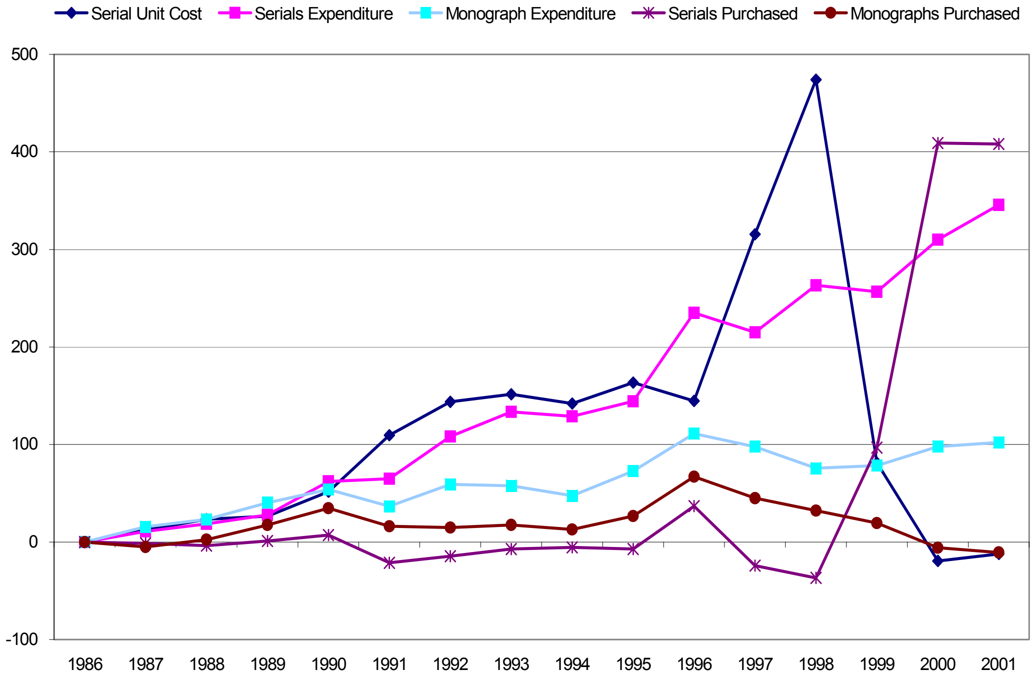
> *Continued cuts are hurting* (Environmental Science).
>
> *Lack of dollars, but lack of time is probably a bigger problem* (European Studies).
>
> *Fall of funding for research assistance and support* (Art History).
>
> *Lack of university resources is effecting the quality* (Media Studies).

Time pressures, lack of equipment and lack of support are forcing changes to research practices, as researchers look for ways to do more with less. Increased use of information technology has helped, but information resources have been effected by funding cuts and rising content prices.

Between 1986 and 1998 the median unit price of serials titles purchased by Australian research libraries increased by 126%, while median monograph unit prices increased by 52% (current prices). Over the same period there was an 18% decline in the median number of monograph titles purchased, and a 24% decline in median serials subscriptions. Nevertheless, median monograph expenditures increased 25%, while median serials expenditures increased 71%. The total number of serials titles purchased declined by almost 37% between 1986 and 1998, but total serials expenditures increased by 263%, and aggregate serial unit costs by no less than 474%.

Since 1998 the subscription to 'Big Deal' serials databases has brought a rapid change in the total number of serials titles purchased, and thereby in the price paid per title. Nevertheless, serials expenditure continues to increase – up 345% between 1986 and 2001 to AUD115 million. The number of monographs purchased was almost 10% lower in 2001 than it had been in 1986, but monograph expenditure increased by more than 100% over that period. With tighter acquisition budgets total monograph purchases by Australian research libraries declined by more than 30% between 1998 and 2001.

Figure 5.1 Australian Research Libraries, 1986-2001 (% change)



Note: There is a discontinuity in the data circa 1998, with some revisions to the criteria for counting electronic serial subscriptions.
Source: CAUL Statistics. Available www.caul.edu.au accessed March 2003. Own Analysis.

The 'Big Deal' subscriptions, which collect together in aggregated form the journal offerings of multinational publishers, have offered a wider range of serial titles to the research community. Consortial deals in Australia have benefited many researchers, but the common two-part subscription model of paying for access and then again for title subscriptions means that subscriptions and access to full-text at smaller universities are sometimes quite limited. As the Information Infrastructure Advisory Committee (2002) noted:

> *Collaboration among libraries has improved the effectiveness of institutional investment and, combined with access to libraries internationally, provides some Australian researchers with the majority of published information required for their research.*
>
> *This access is not universal and some researchers, particularly those at smaller or regional institutions and those in specialised or emerging disciplines, often have difficulty accessing required information resources. Their difficulties are compounded by changes which are occurring in the scholarly communication process. Although there are now improved mechanisms for discovering the existence of information resources, access to them is often restricted by cost, licences and other conditions…*
>
> *Computing and communication technologies provide new opportunities for the creation, management, storage and dissemination of information. Their use, however, requires infrastructure investment, the acquisition by researchers of different skills and the re-assessment of many aspects of the scholarly communication process* (IIAC 2002, pp3-4).

If the knowledge distribution power of the system is as important as its knowledge production power, then the system for scholarly communication and the dissemination of research findings is of enormous economic significance (Houghton 2000, p1). It is important, therefore, to ensure that there are mechanisms and systems in place to identify priorities, engage stakeholders and raise awareness of the importance of these issues.

Resource Priorities

Support the development of an holistic approach to research infrastructure and scholarly communication issues.

Establish a mechanism for the identification systemic priorities, which represents all stakeholders and is able to gain support for identified initiatives.

Support an advocacy program to inform and engage, which focuses on: researchers' awareness of, and access to collaborative support systems and the development of collaborative project management skills; raising awareness and equipping researchers with the skills necessary to maximise the benefits of emerging information search and access possibilities; and encouraging researchers to license publishers rather than giving away copyright.

Processes

The current policy settings for research and research training were introduced in 1999 and phased in from 2000. The 1999 policy statement noted that:

> *The processes for allocating funds for research and research training should be competitive in nature, as simple as possible to administer, and be readily intelligible to researchers, institutions, students and the wider community. All funding allocation decisions should be free from conflict of interest. The claims made by researchers and institutions regarding their performance should be open to scrutiny and verification. Taxpayers should be able to identify how public funds have been used and to what effect. The true costs of research and responsibility for meeting those costs should be apparent. Clearly, there are many challenges ahead in achieving such a vision for research* (Kemp 1999, p7).

Interview and workshop discussions highlighted some concerns with peer review, research management and administration processes.

Peer review

Peer review has worked on the principle that scholars give their time to review the work of others in return for the same service. Time pressures, the increasing drive for accountability and performance, and the huge increase in the number of journal papers and research proposals requiring review have made it difficult for some to give the time to peer review activities that is necessary if they are to be done well.

While the vast majority of researchers are wedded to the peer review model, many see short-comings. A number of those interviewed for this study expressed concern about the review and appraisal processes used by granting agencies in the assessment of funding proposals – and this independent of success in gaining funding through those processes (ie. it was not a complaint from the losers). A number suggested that the pool of possible assessors was too small in Australia for the process to be free of personal jealousies and competition between research groups and centres. As one humanities researcher put it:

> *I am deeply concerned about the review and assessment process in the ARC, its not objective. There are not enough independent people to be reviewers, it is too small a pool…*(Humanities scholar with a decade of ARC large grants behind him).

Others felt that their field was disadvantaged because it had no place within the traditional ARC structure or no 'representative' on any of the ARC committees. There are also concerns about the assessment of interdisciplinary work (eg. Grigg 1999). As more and more research funding is allocated through competitive grants heightened competition for grants is likely to inflame the situation. While these perceptions may well be based on historical experiences, before recent reforms, every effort should be made to ensure that 'justice' both be done, and be seen to be done.

Concerns were also expressed about the peer review process in publication. One interviewee complained that:

> *Too much is published. It is easier to get published now because there are more titles. Rejection rates are falling and there is a decline in quality* (Cultural Studies).

One might expect some difficulties in interdisciplinary areas and in areas of the humanities where interpretation plays a more important role, but doubts are now being expressed about peer review of scientific journals (Rennie 2002; Williamson 2003). In 2002, a special issue of the *Journal of the American Medical Association*, devoted an entire issue to peer review. It concluded that the peer review process is weak. A recent study for the Cochrane Collaboration produced further evidence on the ineffectiveness of the peer review system in improving the quality of published biomedical research (Jefferson 2003). Cochrane Collaboration (2003) concluded that: "At present, there is little empirical evidence to support the use of editorial peer review as a mechanism to ensure the quality of biomedical research." This prompted the editor of the British Medical Journal to say: "The more we study peer review the more we find evidence of its deficiencies, but we have no good evidence of its benefits." (Hagan 2003). Many are now calling for changes which seek to introduce greater care and transparency, including open review (where the reviewers are named), published review (where reviews are published along with the papers), payment for reviews, and increased recognition of review activities in performance assessment and evaluation.

Research management and administration processes

A number of researchers also expressed concern about the mechanisms of funding distribution and management. Indicative comments included:

> *The main problem is that funds go to the institutions, not the people. R&D is being stifled by bureaucracy. We must move away from block grants to institutions* (Medical Research Centre Director).

Others noted difficulties with intellectual property (IP) management processes, the role and influence of research ethics committees, and the influence of simplistic funding formulae (ie. feeling that the whole system was designed around a science-based model of research that many areas of the humanities, arts and social sciences simple do not fit). There are multiple layers of accountability and differences between funding sources, which add to the burden on researcher time and tend to create a bureaucratic burden at the institutional level. It is, perhaps, indicative that some 54% of university staff in Australia neither teach nor research. Nevertheless, researchers commonly note a lack of support and an increased administrative burden.

While much progress has been made in such areas as proposal assessment following recent reforms to ARC practices, some further review and development of assessment processes might be worthwhile. There are clearly things that government and research organization managements could do to resist and reduce the bureaucratisation of research activities – such as, for example, the development and implementation of best practice standards, standard contracts, and the development of common compliance and reporting systems across funding sources.

Process Priorities

Explore ways to encourage reforms to peer review, which seek to introduce greater care and transparency while retaining the benefits of the system – such as, for example, open review (where the reviewers are named), published review (where reviews are published with the paper), increased payment for reviews, and increased recognition of review activities in performance assessment and evaluation.

Examine the need for further reforms to research council proposal review and assessment processes – such as, for example, expanding international reviewer possibilities through reciprocal arrangements at the national level.

Pursue initiatives that seek to reduce the bureaucratisation of research activities – such as, for example, the development and implementation of best practice standards, standard contracts and the development of common compliance and reporting systems across funding sources.

Incentives

The system of incentives shapes what happens. Researchers publish, *inter alia*, because it is expected, measured and rewarded. Researchers accept accountability, but want to feel that the system works and that their performance is measured in ways that make sense. Governments, on behalf of citizens, seek to ensure that funding goes to those making the most valuable contribution. Given the links between funding and evaluation it is an issue of considerable importance.

There are a number of pointers to problems in the system of incentives faced by researchers. This creates dilemmas and shapes behaviour in ways that may not be desirable. Interviews and workshops revealed particular concerns in relation to research evaluation, intellectual property rights and licensing. Research organizations are best placed to determine how their activities can be enhanced in practice, but governments have the responsibility for setting the basic rules and institutional frameworks that reflect the public interest and provide the right incentives.

Research evaluation

The OECD (2002) recently noted that:

> *Public research institutions are being asked to contribute to economic development but also to be more responsive to evolving societal concerns such as food safety, environmental degradation, and health issues…What is put into question is both the sole focus on scientific excellence and the criteria for judging this excellence when evaluating public researchers and research institutions. Evaluation of research must evolve for at least [two] reasons. First, its scope must be broadened in response to the considerable expansion of the commercialisation activities of universities and public research institutes (eg. licensing offices, venture funds, spin-offs). Second, evaluation criteria must take into account that excellence in research and training of graduates has become, at least in some disciplines, more tied to applications in industry* (OECD 2002, p55).

The first requirement of a performance-based research evaluation system is that it correctly measures performance, but performance is multi-dimensional – quality, quantity and 'relevance' to national research priorities are all important.

The first step in (re)designing a research evaluation and performance measurement system is to recognise the trend changes in research practice outlined above. A performance measurement system should be designed in such a way as to take account of both traditional disciplinary research and the emerging mode of knowledge production (ie. Mode 2 research). This implies a need for greater recognition of: a wider range of activities and outputs; team-based work and collaborative activities; scientific, social, economic and environmental impacts; and wider and more diverse communication and dissemination mechanisms – linking to performance and practice as well as 'further research'. It is also important to take account of the motivations and practices of researchers in response to the performance measures and the criteria by which they perceive that they are judged (eg. the possibility of 'gaming' (See Roberts 2003, p4)).

The U.K. Research Assessment Exercise has some notable strengths, when compared to the current Australian system (See RAE 2001). For example, it focuses on units or groups rather than individuals (taking account of collaborative activity) and on quality rather than quantity. It considers a wider range of outputs, and judges what the researcher or organization choses to be judged on. Nevertheless, there are obvious weaknesses (See Roberts 2003). For example, the RAE takes little account of other elements of the system – being a system to allocate government funding, which takes no account of the impacts of changing patterns of public funding on the availability and distribution of other funding sources. The notion of excellence is self-referential with no independent benchmark – such that the system is based on perceptions, which may lag reality and be subject to branding and image management. It is innately conservative, and tends to have a disciplinary, rather than interdisciplinary or transdisciplinary focus; it takes little account of national research priorities, or what might be called 'relevance'; and is a system that leads to convergence, rather than specialisation and diversity, unless that convergence is made impossible by a heavily skewed allocation of funds.

A research evaluation and performance measurement system must be seen as a part of an holistic approach. It should:

- Be designed as one element of a system, with consideration given to its interrelationships with other elements of the system (ie. an holistic approach);
- Combine quantitative, qualitative and 'relevance' factors;
- Define research to include synthesis and problem oriented research, as well as investigation in order to gain knowledge;
- Take account of a wide range of outputs – including books, papers, journals, recordings, performances, data (eg. gene sequences), software, electronic and multimedia content (eg. television documentaries), etc.;
- Take account of a wide range of activities – including, for example, editing, refereeing and reviewing, moderating discussion lists, etc. and enterprise activities relating to application and commercialisation;
- Take account of a wide range of impacts – including scientific (citations), economic, social, and environmental;
- Take account of the longer-term financial sustainability of research and research centres; and
- Recognise collaborations and partnerships across institutional and sectoral boundaries (ie. judge teams as well as individuals, and judge collaborations as well as centres or departments).

Intellectual property rights

The ownership of intellectual property rights (IPRs) provides a strong incentive for application and commercialisation. In nearly all developed countries there has been a marked trend towards transferring ownership of publicly funded research results from the state (government) to the (public or private) agent performing the research. The underlying rationale for such change is that it increases the social rate of return on public investment in research. Where countries differ is in the allocation of ownership among performing agents (ie. research institution *versus* individual researchers), in licensing practices, in the allocation of resulting royalties, and in provisions for ensuring that the nation benefits from the patentable results of public research (OECD 2002, p48).

In many cases the initial drive to develop an idea and enable its commercialisation comes from the researcher(s). Often it is only the researcher(s) that can see the possibilities and undertake the initial work. It is, therefore, important that researchers have an economic interest in development and commercialisation. The most direct mechanism is for researchers to share in the intellectual property and/or resulting royalties. In Australia, ownership of intellectual property is vested in the research organizations except where funding agreements state otherwise (ARC et al. 2003). Indeed, it has been reported that only in two Australian universities can researchers claim any part in the ownership of intellectual property (Christie et al. 2003). In most cases, the researcher(s) cede intellectual property to their employers.

The apparent convention is that royalties be shared equally between inventor, laboratory or department and organization (OECD 2002, p48). Whether this convention is universally applied and widely understood, and whether it offers sufficient incentive are open questions. OECD (2003) noted that: "licensing revenues provide strong incentives for researchers to explore the commercial applications of research." (OECD 2003, p14). When compared with outcomes in the U.S. under the system flowing from the *Bayh-Dole Act* and *Stevenson-Wydler Act*, Australia's performance would suggest that further reform of the structure of incentives may be necessary.

Incentive System Priorities

Adjust performance measurement and evaluation systems to take account of both traditional and emerging modes of knowledge production, by giving greater recognition to: a wider range of activities and outputs; team-based work and collaborative activities; scientific, social, economic and environmental outcomes; and wider and more diverse communication and dissemination linking to performance and practice as well as further research.

Explore the possibility of basing research evaluation on quality, quantity and 'relevance', and extend the evaluation period to move away from a 'procurement model' towards a system that is based on investment in people.

Examine whether current intellectual property rights practices provide sufficient incentives for application and commercialisation of research outcomes – focusing on practices relating to the distribution of both property rights and licensing revenues between institutions, centres/departments and individuals.

Encourage the use of non-exclusive, but royalty bearing licensing, so as to minimise potential tensions between publication and commercialisation.

Expand the focus of intellectual property rights management to include copyright, as well as patents and licensing.

Provide greater support to researchers in contract negotiation and through the promulgation of standard contracts and conditions.

There is also a need to move beyond patentable IP to copyright over research outputs across all fields of research. ICT developments promise to enhance the dissemination of research and enable greater access to research findings by both researchers and research users (discussed in greater detail below). One critical element will be copyright, but Gadd et al. (2003b) found a relatively low level of knowledge about copyright and licensing among academic authors in regard to their publications. We also found that researchers pay surprisingly little attention to copyright issues. To facilitate the development of open access institutions will need to assume responsibility for copyright over the outputs of their employees. This is a change to convention rather than law, which while controversial, might be accommodated by greater sharing of royalty and usage revenues.

Commercial restrictions on publishing sometimes create problems for researchers operating within a 'publish or perish' research evaluation framework. It is widely held that, for a variety of reasons, publicly funded research organizations should be encouraged to favour non-exclusive, but royalty bearing licenses. Among other things, these encourage the wide diffusion of knowledge, and do not entail restrictions on the freedom to publish (OECD 2002, p53). Nevertheless, there remains an important balance to be struck between open access to, and the rapid and wide dissemination of research findings on the one hand, and protection of intellectual property during the developmental phase leading to commercialisation or application on the other. At the very least, research organizations should standardise and promulgate practices reflecting agreed aims which are implemented, *inter alia*, through an agreed and coherent structure of incentives.

5.4 Research information infrastructure

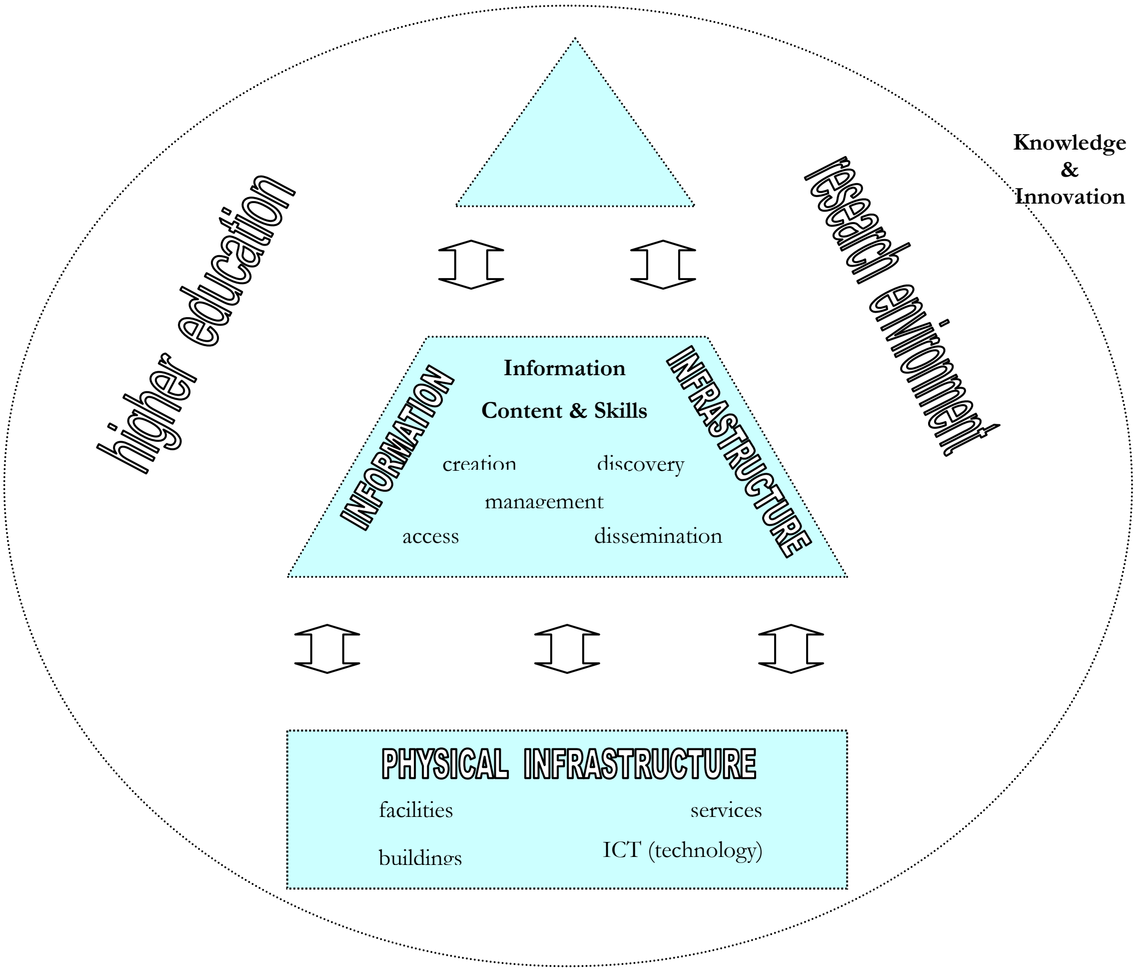
Renaud (2000, p12) defined social science infrastructure as the collective structures that enable, enhance, embody and structure research – including data itself, facilities for its effective and efficient management, research tools such as computer hardware and software, activities that facilitate communication both within the research community and beyond, and the internal structure of organizations that promote and facilitate research. He stressed that, in order to become more effective, social science infrastructure must be expanded to an international level, promote international sharing of data and resources from different countries and disciplines, and bridge the gaps among data producers, users, policy makers and the public.

The Information Infrastructure Advisory Committee (2002) put forward a similar model of the information infrastructure for higher education in Australia. They noted that:

> *A relevant model for the research information infrastructure is one which has at its centre, information content and the skills necessary for its use. This core is dependent on the provision of enabling technologies and facilities (such as computer systems and access networks…). At the apex are the products which are derivable from the content – knowledge and innovation…*
>
> *There are five main interactions which are fundamental to effective information infrastructure provision:*
>
> - discovery – *provision of mechanisms (such as portals, gateways and metadata repositories) to facilitate access, skills to locate and analyse data and information;*
> - access – *to exisitng information resources, irrespective of physical format, which have been arranged in some logical manner – this includes print publications, video, sound recordings, images (such as photographs, paintings), maps, databases, digital publications;*
> - creation – *of new resources including publications, databases and repositories of non-bibliographic information;*
> - management – *of access to information resources and the protection of associated intellectual and copyright rights including authentication, authorisation and digital rights management systems as well as tools developed for the organisation and retrieval of data; and*

- dissemination – *to make available newly created resources including the development of non-traditional scholarly communication mechanisms.*

Figure 5.2 Research information infrastructure



Source: Information Infrastructure Advisory Committee (2002) *Information Infrastructure Framework for Australian Higher Education*, DEST, Canberra, p13.

> *The model shows the interrelation of the technology, facilities and services which will enable the Australian higher education sector to develop, maintain and use an information infrastructure which meets international [best] practice. Irrespective of their institutional affiliations, geographical location or academic discipline, members of the Australian higher education community should have access to information infrastructure resources which optimise the research activities of their institutions* (IIAC 2002, pp6-7).[20]

20 See also the committee's more recent report: Higher Education Information Infrastructure Steering Committee (2003) *Report of the Higher Education Information Infrastructure Steering Committee,* Department of Education, Science and Training, Canberra. Available www.dest.gov.au/highered/otherpub/heiisc03/ accessed August 2003.

The following comments are intended as an input to thinking about future research information infrastructure initiatives.

Communication and collaboration

It has often been observed that Mode 2 research is conducted in a more fluid and informal way, with more emphasis on informal networks of communication, discovery, access and dissemination, and somewhat less emphasis on the traditional journal literature. Clearly, there is a need to develop and extend mechanisms that support collaborative research and communication across organizational and sectoral borders, international borders and time zones, disciplines and fields of research. It would also be desirable to take greater account of increased collaboration in performance evaluation, which at the moment is entirely focused on individual performance (this despite almost universal team-based research and joint authorship).

E-mail plays a crucial role in the operation of research teams and networks. A number of those interviewed commented on difficulties and lack of support in areas like records management in relation to e-mail and phone communication, which tends to be ephemeral. There is a need to pay greater attention to handling e-mail communication within systems that enable the ready recording, storing, securing and tagging of attachments. A range of other technologies also contribute to communication and collaboration at all levels of research, such as desktop-based videoconferencing and emerging grid applications. To date, these do not seem to have realised their potential in research support applications.

The emerging grid computing supports geographically and institutionally distributed research projects, particularly complex and multidisciplinary projects. The development of grid computing is being driven by the need to harness computer processing power, gain access to the large research databases now being produced and used in many fields of research, collaborate nationally and internationally, access 'big-science' instruments, and develop shared visualisation environments. GrangeNet (Grid And Next GEneration NETwork) was established in 2002 and has a number of programs for the development of grid services – including grid computing, collaborative visualisation, cooperative environments and digital libraries. GrangeNet aims to support Australian research communities that require high bandwidth – eg. in such areas as computational physics and engineering, bio-informatics, environmental and climatic modelling, media services, and astronomy. The aim is that, through GrangeNet, Australian researchers will be able to access supercomputers, distributed datasets, scientific instruments and infrastructure (AARNet 2002).

Sargent (2002) identified the need for increased bandwidth in Australia's research network, in view of the emergence of grid applications and sustained growth rates in demand for bandwidth of the order of 50% per annum over a number of years (Sargent 2002, p5). To that end, the Australian Research and Education Network (AREN) is being developed as a next generation AARNet, to provide bandwidth for researchers in the higher education sector. The continued development of AARNet as the AREN should significantly increase bandwidth availability at universities, particularly those in regional areas (AARNet 2002). These network and grid initiatives provide the backbone facilities for research communication and collaboration. They should be complemented by development and implementation of research support applications.

Researchers require access to sufficient bandwidth to enable ready communication and collaboration, systems to enable them to handle and track files received via e-mail and downloaded, and system that enable handling of data and related software and analytical objects. Researchers should be encouraged to identify priorities, and support be made available to develop applications across all fields of research.

Research Collaboration Priorities

Support the development of high bandwidth research networks and grid applications (eg. AREN and GrangeNet) with encouragements for researchers to push application development across all fields of research.

Encourage the development of collaborative research support applications in such areas as electronic records management, desktop videoconferencing, etc.

Investigate the possibility of developing and implementing research support systems which enable researchers to bring together the increasingly disparate digital objects used in research in such a way as to facilitate enhanced integrated analysis.

Develop advocacy initiatives focusing on researcher awareness of, and access to collaborative support systems and the development of collaborative project management skills.

Information search and access

Two obvious consequences of an increase in problem oriented, interdisciplinary or transdisciplinary research are (i) the need to search for and access information across disciplinary borders, and (ii) the need to tackle different problems at different times. Much of the sense of information overload felt by some researchers is due to the increase in the amount of information, but part is due to the need to cover a broader range of material and sources. No longer can a researcher claim to get everything s/he needs from half-a-dozen journals.

There are many indicators of these emerging patterns of demand, including:

- the popularity of generic web search engines and the relatively lower use of subject gateways, except in areas where they tend to be problem oriented (eg. medical and health) or where the discipline remains strong (eg. mathematics);
- the popularity of databases of electronic journals and, as reflected in usage patterns, the scope they offer to cross disciplinary boundaries and access a much wider range of articles than before (crossing both titles and disciplinary boundaries); and
- the increasing use of research databases and the shift from hypothesis testing to "suck-it-and-see science", which is leading some to use traditional source (eg. journals) less as they gain better access to primary sources.

There is a need to pay greater attention to non-disciplinary modes of search and access. This might imply, for example, focusing on developing generic front-end searching to enable researchers to cut across disciplinary silos of information; developing gateways and portals that are problem rather than discipline oriented; and enabling greater delivery to the desktop, which is often shorthand for the ability to access information from a range of geographic and institutional settings.

Looking ahead, the level of use of research databases found across a wide range of research fields suggests that this should be a key area for future focus. Interview and workshop discussions suggested that many access these databases independently. Further research is required into their current use and the likely future data access needs of Australian researchers before we will be in a position to develop specific access initiatives. As we do, we must keep in mind the need to integrate disparate data into coherent collections, which will require standards for management within distributed domains. Australian researchers must also have the ability to create datasets, that can be stored securely and accessed by other researchers across domains.

Moreover, it should not be forgotten that one key to making use of these databases is access to (and development of) related software and other analytical objects. As Smith (2003) observed:

> *…an important feature of new-model scholarship is a blurring between…research "information" and research "tools." An analog information resource such as a book represents a highly sophisticated technology for information transmission that does not depend on an array of peripheral technologies for use. The tools for mining information from a monograph, for example, include things embedded in the physical object, such as page numbers, indexes, tables of contents… In the digital realm, those search and retrieval tools are behaviors that are embedded in the software but are not, strictly speaking, in the data themselves that are recorded in the digital object. Nonetheless, the tools or instruments needed to use the data must be conveyed with the digital objects* (Smith 2003, p11).

Workshop discussions suggest that practices in relation to such software and analytical objects vary considerably between research fields. In some, the software (and data) are freely and publicly available, in others access is more guarded and proprietary. Practices vary from downloading from open source and object libraries, through 'milking' personal networks for the necessary software, to (re)developing and/or purchasing the necessary software.

Discovery and Access Priorities

Pay greater attention to non-disciplinary modes of search and access (eg. generic front-end searching, and problem oriented, rather than disciplinary gateways).

Facilitate access to research databases, related software and analytical objects – with identified priorities feeding into action as soon as needs assessments have been completed.

Focus advocacy initiatives in this area on raising awareness and equipping researchers with the skills necessary to maximise the benefits of emerging information search and access possibilities.

Researchers require: access to research databases; the availability of sufficient bandwidth to enable their use; access to the necessary software to enable analysis; the availability of systems to enable versioning, securing and archiving both data and related software and other analytical objects; and systems to enable publishing to databases and software libraries, and local publishing of data and related software (eg. open access digital repositories).

Dissemination and publication

In the new mode of knowledge production research is highly dependent on information and communication networks, and its emergence has been facilitated by recent developments relating to the internet – including the web, electronic search and access, electronic publishing, etc. As a result of the increasing domination of multinational publishers in scientific and scholarly publishing, particularly in the sciences and rapidly rising content charges, there has been a drive to further harness ICTs to develop more open information access structures. Importantly, these have the potential to provide more effective support for interdisciplinary, problem oriented research. Publishing is now evolving along two distinct paths. One in which large multinational commercial publishers are increasing their dominance in such areas as 'branded' journal titles and access to scientific publication, and the other in which there are a variety of open access initiatives.

Pre- and e-print archives have developed rapidly in some fields, while being much slower to take off in others. The development of free, publicly accessible journal article collections in such areas as physics (eg. arxiv.org) and medicine (eg. www.pubmedcentral.nih.gov) has demonstrated how the internet can change scholarly publishing (Lynch 2003). The Open Archives Initiative has developed and promoted the use of standards that facilitate the dissemination of content and open access to it. There are now a number of OAI-compliant systems available as freeware, which enable open access through author and institutional archiving (eg. GNU EPrints and DSpace) (Buckholtz 2003, p2). As a result, open access digital repositories are now being established for both self-archiving and institutional archiving.

These developments provide a major opportunity for both traditional and new modes of knowledge production. As Lynch (2003) observed:

> *Our institutions of higher education have overlooked an opportunity to support our most innovative and creative faculty for at least a decade now, to the detriment of both the faculty members and the institutions themselves. These faculty have been exploring ways in which works of authorship in the new digital medium can enhance teaching and learning and the communication of scholarship; such innovations are essential to keeping scholarship vital and effective, and they must not only be supported but nurtured* (Lynch 2003).

Lynch defined institutional repositories as a set of services that a university offers to the members of its community for the management and dissemination of digital materials created by the institution and its community members. To date, there have been only piecemeal approaches through a variety of institutional and institutionally hosted departmental and personal websites, but the tools are now emerging to better manage and make available institutional material to a worldwide audience. Institutional repositories more effectively disseminate the research of the institution, raising its visibility and providing an avenue for increasing its impact. Institutional repositories feed into existing and emerging dissemination and publication mechanisms, be they pre-/e-print archives or traditional print-based publishing. Perhaps more importantly, however, open access digital repositories are transdisciplinary. They are particularly adept at supporting new research practices which emphasise data, related software and other analytical objects as an integral part of the record and discourse of scholarship (Lynch 2003).

Information Infrastructure Advisory Committee (2002) set the establishment of repositories as a priority, although their emphasis was mainly on e-print publishing. A somewhat broader open access digital repositories initiative is required in order to recognise and accommodate the needs of both traditional and emerging modes of knowledge production. It should also be noted that neither subject nor institutional archives are the preserve of higher education. They can be adopted in any institutional setting in which knowledge production occurs.

To operate successfully, systems for the management of digital rights and metadata must be built into repository initiatives. Metadata management is critical to providing access to information, while digital rights management is essential in providing the optimum level of access and disclosure – too much disclosure of certain type of information renders it economically useless, while too little disclosure may mean that economic, social and environmental benefits are lost (Information Infrastructure Advisory Committee 2002). Mechanisms for striking a balance between open access and commercialisation must be built into the system, such that access limits can be applied where and for as long as necessary, while at the same time giving researchers the same level of support whether they are engaged in pure/basic research or research with potential commercial, social or environmental application for which the protection of intellectual property is important.

Varied and somewhat uncertain treatment of intellectual property rights, particularly copyright, is an important barrier to the population of open access digital repositories. As noted, the general trend has been to vest intellectual property in institutions. However, this convention has not yet extended to copyright in academic papers and books, for which copyright is still typically vested in the author(s) – who then often sign it away to publishers in order to get published. We found that few researchers pay much attention to copyright. They often assume that their personal future use of the material will be covered by 'fair use'. Similar findings have been reported elsewhere (eg. Gadd et al. 2003b).

Throwing responsibility back to individual researchers, and demanding that they sign warranties of non-breach before posting to a repository is unlikely to encourage postings. Standardised and explicit guidelines for treatment of copyright will be required, and institutions need to take responsibility. Whether that requires institutions exercising copyright ownership over their employees is debatable, and highly controversial. Given that academic and research employment is being increasingly casualised, with many placed on short-term contracts, and co-authored works often involve researchers from different institutions, exercising institutional rights may prove extremely difficult.

To date, the take up of repositories has been disappointing, but given their potential it would seem reasonable to explore ways to inform researchers and encourage their use for both discovery and access *and* for dissemination and publication. Four paths could be pursued in parallel:

- Awareness – promoting awareness of their purpose and potential;
- Support – providing the necessary support to enable use;
- Design – to encourage use (eg. quality and access control); and
- Recognition – providing incentives that reward researchers for adopting the systems (eg. through research evaluation, funding distribution, career advancement, etc.).

A first obvious step is to systematically harvest institutional and related personal websites for appropriate material to populate open access digital repositories, thereby propelling them towards critical mass.

There are a number of factors that need to be borne in mind when designing and establishing open access digital repositories. There needs to be a distinction made as to the various categories within the repositories, which can include e-prints, pre-prints, grey literature and other originally created material. Perhaps the most important feature, given the strong adherence to peer review and widespread concerns about quality control, will be quality control of the material populating repositories and clear standardised means for identifying the level of quality control that each item meets.

Communication and Dissemination Priorities

Encourage the development a system of scholarly communication and research dissemination built on the principle of open access.

Establish an integrated open access digital repositories initiative, based on Australia's higher education and research institutions, which recognises and accommodates the needs of both traditional and emerging modes of knowledge production, and is built on clear strategies for digital rights management, metadata management and access control.

Encourage the population of repositories through initiatives that seek to: promote awareness of their purpose and potential; encourage retention of copyright and standardised licensing to publishers; provide the necessary support to enable use; and provide incentives that reward researchers for adopting the systems.

Explore the development of new metrics, which exploit the ability of digital repositories to provide a range of new metrics for research evaluation that are better suited to the 'measurement' of the outputs and impacts of both traditional and new modes of knowledge production.

Layered control of access is also likely to be an important feature for the successful implementation of repositories. It is important to understand what authors are trying to achieve with their publishing (Day 2003). As noted, the audience they are trying to reach with a particular piece of work or form of expression might be small (eg. 20-30 specialists worldwide), such that they may have little interest in changing to broad communication technologies. Moreover, as also noted, the particular expression may be tailored to a particular audience, and tailored differently for different audiences. Where such 'market segmentation' strategies are being used by authors there is likely to be some resistance to broad 'scattergun' communication technologies and greater need for layered access options.

Open access digital repositories also provide the opportunity to develop a range of new metrics for research evaluation which are better suited to the measurement of both traditional and new modes of knowledge production. Whereas citation indexes measure only use in further research, hits/downloads measure use in application as well. This provides a better indication of the impact of research in both the domains of research and of application.

Many researchers, both as authors and readers, express a desire to see and hold the work in printed form. To overcome this barrier to the adoption and use of open access repositories they should be supported by print-on-demand facilities, which are likely to become a common cost effective mechanism for dealing with born digital objects, particularly in monographic form.

5.5 The challenge

The process of knowledge production is cumulative, with knowledge applied to knowledge, such that knowledge is both an output and an input. How researchers source that knowledge input, how they communicate with each other and how they communicate and disseminate findings are crucial, not only for the progress of knowledge but also for the capacity of the national innovation system to underpin prosperity in the global knowledge economy. As the traditional systems of knowledge production and dissemination are disrupted and alternative modes of knowledge production emerge the future development of research infrastructure and the provision of information resources becomes more challenging – perhaps even more challenging than many have yet realised.

There are many challenges ahead. There is a need to:

- Establish a mechanism for the identification of research information infrastructure priorities that is representative of all stakeholders and able to gain support for identified initiatives;
- Stimulate informed debate about research infrastructure and scholarly communication issues, collaborating internationally where appropriate;
- Stimulate innovation through reforms to incentive systems – including, *inter alia*, research evaluation, intellectual property rights, grant allocation and peer review mechanisms;
- Encourage institutional leadership to facilitate access to, and management of digital repositories; and
- Support ongoing research into evolving research practices, research infrastructure and scholarly communication needs.

5.6 The way ahead

To meet these challenges and develop a sustainable research information infrastructure and scholarly communication system it will be necessary to take an holistic approach and pursue a coherent agenda. That agenda should focus on:

- Creating a coherent structure of incentives based on an holistic approach to the system for the creation, production and distribution of research information;
- Providing the infrastructure and tools to support collaborative research activities in both traditional and new modes of knowledge production;
- Enabling access to necessary information access mechanisms and resources, and equipping users with appropriate information skills to enable their use; and
- Encouraging the development a system of scholarly communication and research dissemination built on the principle of open access.

Mechanisms and processes

There is a need to put in place mechanisms and processes that engage all stakeholders and enable consensual outcomes based on an holistic approach to research information infrastructure development. We call on stakeholders to:

- Support the development of an holistic approach to research infrastructure and scholarly communication issues;
- Establish a mechanism for the identification of systemic priorities, which represents all stakeholders and is able to gain support for identified initiatives;
- Pursue initiatives that seek to reduce the bureaucratisation of research activities – such as, for example, the development and implementation of best practice standards, standard contracts and the development of common compliance and reporting systems across funding sources; and
- Support an advocacy program to inform and engage, which focuses on:
    - researchers' awareness of, and access to collaborative support systems and the development of collaborative project management skills;
    - raising awareness and equipping researchers with the skills necessary to maximise the benefits of emerging information access and dissemination possibilities; and
    - encouraging researchers to license publishers rather than giving away copyright.

The incentive structure

There is a need to stimulate innovation through reforms to incentive systems – including, *inter alia*, research evaluation, intellectual property rights, grant allocation and peer review mechanisms.

Research evaluation

In respect to research evaluation there is a need to:

- Adjust performance measurement and research evaluation systems to take account of both traditional and emerging modes of knowledge production by, for example, giving greater recognition to:
    - a wider range of activities and outputs;
    - team-based work and collaborative activities;
    - scientific, social, economic and environmental outcomes; and
    - wider and more diverse communication and dissemination, linking to performance and practice as well as further research; and
- Explore the possibility of basing research evaluation on quality, quantity and 'relevance' factors, and extend the evaluation period to move away from a 'procurement model' towards a system that is based on investment in people.

Incentives

In respect to incentives there is a need to:

- Examine whether current intellectual property rights practices provide sufficient incentives for the application and commercialisation of research outcomes – focusing on practices relating to the distribution of both property rights and licensing revenues between research institutions, centres/departments and individuals;
- Encourage the use of non-exclusive, but royalty bearing licensing, so as to minimise potential tensions between publication and commercialisation;
- Expand the focus of intellectual property rights management to include copyright, as well as patents and licensing; and
- Provide greater support to researchers in contract negotiation and through the promulgation of standard contracts and conditions.

Peer review

In respect to peer review of both grant applications and publications there is a need to:

- Explore ways to encourage reforms to peer review, which seek to introduce greater care and transparency while retaining the benefits of the system – such as, for example, open review (where the reviewers are named), published review (where reviews are published with the paper), increased payment for reviews, and increased recognition of review activities in performance assessment and evaluation; and

- Examine the need for further reforms to research council proposal review and assessment processes – such as, for example, expanding international reviewer possibilities through reciprocal arrangements at the national level.

Research infrastructure

It is necessary to provide the infrastructure and tools to support collaborative research activities in both traditional disciplinary and new modes of knowledge production, and to enhance access to necessary information resources. We call on stakeholders to:

- Support the development of high bandwidth research networks and grid applications (eg. through AREN and GrangeNet) with encouragements for researchers to push application development across all disciplines and fields of research;
- Encourage the development of collaborative research support applications – such as, for example, electronic records management, desktop videoconferencing, etc.;
- Investigate the possibility of developing and implementing research support systems that enable researchers to bring together the increasingly disparate digital objects used in research in such a way as to facilitate enhanced integrated analysis;
- Pay greater attention to non-disciplinary modes of search and access – such as generic front-end searching, and problem oriented rather than disciplinary portals and gateways; and
- Facilitate access to research databases, related software and analytical objects, with identified priorities feeding into action as soon as a research needs assessment has been completed.

Open access

We must encourage the development of a system of scholarly communication and research dissemination built on the principle of open access. To that end there is a need to:

- Establish an integrated open access digital repositories initiative based on Australia's higher education and research institutions, which recognises and accommodates the needs of both traditional and emerging modes of knowledge production, and is built on clear strategies for digital rights management, metadata management and access management;
- Encourage the population of repositories through initiatives that seek to:
    - promote awareness of their purpose and potential;
    - encourage retention of copyright and standardised licensing to publishers;

    - provide the necessary support to enable use; and
    - provide incentives that reward researchers for adopting the systems; and

- Explore the development of new metrics, which exploit the ability of digital repositories to provide a range of new metrics for research evaluation that are better suited to the 'measurement' of the outputs and impacts of both traditional and new modes of knowledge production.

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Appendix 1 Key findings

There is a new mode of knowledge production emerging, changing research practices and bringing new information access and dissemination needs. Adjustments will be required to the existing research information and scholarly communication system to accommodate these changes, but new opportunities are emerging for more cost-effective and sustainable information access and dissemination. To fully realise these opportunities, however, it will be necessary to take a more holistic approach to the development of the research information infrastructure and scholarly communication system.

A new mode of knowledge production is emerging

A new mode of knowledge production has emerged over recent years, characterised by Gibbons et al. (1994) as Mode 2. With the emergence of Mode 2 research there is: increasing diversity in the location of research activities; an increasing focus on interdisciplinary, multidisciplinary and transdisciplinary research; an increasing focus on problems, rather than techniques; greater emphasis on collaborative work and communication; and greater emphasis on more diverse and informal modes of communication.

The existing research information infrastructure has evolved over many years, during which traditional disciplinary Mode 1 research has been the dominant mode of knowledge production. Consequently, the existing infrastructure is better suited to the traditional than it is to the new mode of knowledge production. The key to developing research infrastructure for the future is to think through the implications of the changes in research practices implied by the emergence of Mode 2 research and the development of e-science.

There are new information access and dissemination needs

The emergence of a new mode of knowledge production is bringing with it new information access and dissemination demands. There is increasing demand for access to a wider range of more diverse sources; access mechanisms that cut across disciplinary silos; and access to, and management of non-traditional, non-text digital objects. Research databases, related software and other analytical objects are now core tools, as the very nature of discourse shifts from hypothesis testing towards collecting, processing and analysing primary data.

As the U.S. National Research Council noted:

> *The rapidly expanding availability of primary sources of data in digital form may be shifting the balance of research away from working with secondary sources such as scholarly publications. Researchers today struggle to extract meaning from these masses of data, because our techniques of searching, analyzing, interpreting, and certifying information remain primitive. New automated systems, and perhaps new intermediary institutions for searching and authenticating information, will develop to provide these*

> *services, much as libraries and scholarly publications served these roles in the past.* (National Research Council 2001, p5).

New digital object access management systems will be required, and there will be increasing demand for collaborative research support applications and research support systems that enable researchers to bring together the increasingly disparate digital objects used in research in such a way as to facilitate enhanced integrated analysis.

The system for the creation, production and distribution of scientific and scholarly knowledge must be viewed holistically

Many factors have influenced the development of the present research infrastructure and scholarly communication system. Its elements have evolved and are often considered separately. As a result, developments have been somewhat piecemeal and there are sometimes conflicting forces at work.

It will be essential to take an holistic approach to 're-engineering' the system, which treats the creation, production and distribution of scientific and scholarly information, the management of information rights and access, systems of evaluation and the underlying infrastructure as parts of a single research information infrastructure and scholarly communication system.

Research practices are directly shaped by systems of evaluation, changing funding patterns and priorities. Existing evaluation and reward structures tend to lead to conflicting incentives in relation to scientific and scholarly communication. Establishing a coherent structure of incentives that operates system-wide is an essential step towards providing cost-effective access and dissemination in support of both research and its economic, social and environmental applications.

Emerging dissemination and publication pathways offer new opportunities

Scientific and scholarly publishing is now evolving along two distinct paths – one in which large multinational commercial publishers are increasing their dominance in such areas as 'branded' journal titles and access to scientific publication, and the other in which there are a variety of open access initiatives.

Open access digital repositories, operating in parallel with existing commercial publishing mechanisms, may provide a major opportunity to develop a sustainable information infrastructure for both traditional and emerging modes of knowledge production. Together, they provide the foundation for effective and efficient access to, and dissemination of scientific and scholarly information.

Appendix 2
International comparisons

There have been few studies taking a research perspective to information issues, but there are a small number of international studies that do bear on some aspects of the material covered herein. These are used to compare and contrast Australian and international findings on key indicators, and to shed further light on evolving research practices. It should be noted, however, that the foci of the various studies and the specific questions asked vary, as does the timing of the surveys. Hence, comparisons are no more than indicative. Nevertheless, it is evident that there are many common elements to changing research practices around the world. By no means is what is happening in Australia unique, or even unusual. That being so, it is likely that the reasons behind what is happening are also common, and the issues global.

Communication and collaboration

The level of project team collaboration found in Australia is similar to that elsewhere. For example, Education for Change et al. (2002, p16) found that in a sample of more than 1 400 researchers drawn from the United Kingdom's 2001 Research Assessment Exercise Census, 41% reported working in teams – compared with 75% in Australia reporting working 'primarily' in teams. In the U.K. sample, 71% of those in medical and biological sciences and 57% of those in other sciences reported working in teams, compared with 100% of Australian medical and science researchers. Similarly, 36% of U.K.-based social sciences and 7% of humanities and arts researchers reported working in teams, compared with around 50% of Australian social sciences, humanities and arts researchers.

In terms of wider research networks, Brockman et al. (2001) suggested that wider collegial networks were important for humanities scholars in the United States, and implied that the level of collaboration in humanities is higher than had been thought. They went on to note that the use of e-mail has changed the level of this sort of networking. As noted above, some 90% of Australian researchers interviewed for this study saw themselves as part of a wider collegial network – 100% in science and medical fields, and 80% in social sciences, humanities and arts. More than 70% of them said it was 'very important' to their work, and a further 15-20% said it was 'somewhat important'. Robertson and Young (2003) also noted this use of personal networks in their study of Australian research practices at Queensland University of Technology. We have also found that these networks depend on e-mail, with 100% of Australian respondents saying e-mail was 'essential' for their collaboration.

In the United Kingdom, Education for Change et al. (2002) found that around 45-50% of researchers reported regular use of discussion lists, but few regarded them as 'essential'. Brockman et al. (2001) also noted that there was limited enthusiasm for discussion lists among their sample of U.S.-based humanities scholars. Our interviews with Australian researchers suggested that discussion lists were not as widely used as other means. Team discussion lists were mentioned by around half of the Australian sample, but only 5% regarded them as 'essential'. When it came to communicating with the wider 'collegial network' more than 60% of Australian researchers indicated that they used discussion lists, but less than 20% regarded them as 'essential'. However, when asked directly about their personal subscriptions 75-80% of Australian researchers indicated that they held subscriptions to news and/or discussion groups.[21]

Information search and access

Education for Change et al. (2002) found that: printed refereed journals were regarded as 'essential' by 95%; books by 82%; bibliographic tools, abstracting and indexing services by 71%; electronic journals and other sources by 53%; full text services by 52%; electronic pre-print archives by 30%; and computerised datasets by 25% (See Table 3.1 above). Key Perspectives (2002, p39) noted that 94% of respondents to their international survey reported that knowing that the material had been reviewed by experts was a very important feature for electronic journals. Interviews with Australian researchers suggested that around 95% regard knowing that the material is peer reviewed as important.

Electronic journals were rated as 'essential' by 53% of the U.K. sample (Education for Change et al. 2002), compared with around 60% in Australia. Friedlander (2002) found that researchers in the U.S. used multiple on- and offline sources to support research and teaching, with more than 80% of biological and physical sciences researchers in her U.S. sample reportedly using electronic journals, as did around 75% across the sample.

Seven per cent of U.K. researchers rated pre-print archives 'very important' as a search method (Education for Change et al. 2002), compared with around 5% of Australian researchers (See also Robertson and Young 2003). In the U.K., 30% of all researchers regarded pre-print archives as important sources (Education for Change et al. 2002), compared with some 35% indicating their use in Australia. Internationally, Key Perspectives (2002) reported that 32% of the researchers they surveyed suggested that pre-print archives were important in their area of research, and 62% said re-print (e-print) archives were important.

It is clear from a number of recent studies that there is rapid growth in the use of research databases. In a study of U.K.-based academic researchers, Education for Change et al. (2002), found that 48% of the researchers they surveyed were using computerised datasets of primary data, and 34% thought that their use would increase in the future. They found that use was higher in the sciences, but still considerable in the arts and humanities. By research field:

- 31% of U.K.-based medical and biological sciences researchers considered datasets to be essential to their research, a further 24% used them and 44% believed that their use would increase;

[21] It should be noted that discussion in interviews suggested that researchers were distinguishing, as asked, between research and other activities.

- 28% of physical sciences and engineering researchers considered datasets to be essential to their research, a further 23% used them and 39% believed that their use would increase;
- 27% of social science researchers considered datasets to be essential to their research, a further 24% used them and 31% believed that their use would increase;
- 33% of areas studies and languages researchers considered datasets to be essential to their research, a further 12% used them and 23% believed that their use would increase; and
- 14% of arts and humanities researchers considered datasets to be essential to their research and a further 23% used them (Education for Change et al. 2002).

In a survey of scientists and engineers in the United States, the National Science Foundation (Atkins et al. 2003, pB5) found that 34% reported using digital libraries and data repositories, and a further 23% expected to do so in the future. Similarly high levels of use of research databases are evident in Australia, where they are used by around two-thirds of researchers, with one-third regarding them 'essential'. More than 40% of Australian researchers in science and medical fields rated databases 'essential', and some 75% reported using them.

In the United Kingdom, generic web search engines were rated 'very important' by 45% of researchers, compared with 65% in Australia. All Australian respondents reported using generic search engines. Friedlander (2002) found that when searching for material to study, more than 80% of the faculty and students in her U.S.-based sample searched for information online. Similarly, web browser bookmarks or favourites were considered 'essential' by around 40% of Australian researchers, while no more than 10-15% of U.K. researchers rated personal portals as 'very important'. However, institutional gateways and portals, online catalogues, and subject gateways and portals were somewhat more highly regarded in the United Kingdom.

A number of studies support our findings regarding the importance of personal subscriptions and collections. For example, Friedlander (2002) found that researchers in the United States valued their personal libraries and journal subscriptions highly, with 56% reporting that they were the most important way to stay current. Brockman et al. (2001) noted that in the U.S., humanities:

> *Scholars build their own personal libraries to support not only particular projects but also general reading in their field. They buy or make photocopies of materials when possible so they can consult them frequently, mark passages, and write annotations on them* (Brockman et al. 2001, p8).

There is also support for our finding that personal subscriptions are declining. Tenopir et al. (2003) found that the proportion of reading from personal subscriptions was declining, with the number of personal journal subscriptions among their sample of U.S.-based scientists falling from around 5.8 in the early 1990s to 2.8 subscriptions per scientist by 2001-02. They also found a high, but recently declining level of print among personal subscriptions.

Dissemination and publication

Although looking only at journal publication, Swan and Brown (1999) provided insights into the publication motivations of authors in the United Kingdom and elsewhere. They found that:

> *The main objective for publishing work remains communication with the author's peers. Enhancing career prospects is the second most common reason, followed by gaining personal prestige and funding for future work. Direct financial reward was only given as a reason by a tiny minority of respondents. Authors from the sciences and arts differ with respect to the importance of publishing their work on future funding. For scientists, this is an important reason for publishing, but is much less so for authors in the arts fields* (Swan and Brown 1999).

These findings accord with ours, showing that communication of work and indicator of research performance are both seen as 'very important' by around 60% of Australian researchers interviewed, and recognition among peers seen as 'very important' by around half. Direct financial reward was considered by no more than around 15%. We also found that communication is more important to social science, humanities and arts researchers, than it is for science and medical researchers. Conversely, the latter attach more importance to accreditation and recognition (70%) and indication of research performance (60%).

When choosing where to publish (ie. which journal), Swan and Brown (1999) found that authors consider a range of factors:

> *First among these is the reputation of the journal. Its impact factor, international reach and the coverage by abstracting and indexing services follow, very close together. The journal's circulation, subject coverage and publication speed were also cited by substantial numbers of respondents. There are… differences between authors working in various fields… Scientists are much more concerned about the availability of an electronic version of the journal than are workers in the arts. Publication speed is also significant to scientists, particularly chemists, whereas it is much less important to people working in social sciences or the humanities* (Swan and Brown 1999).

We found that around 70% of Australian researchers suggested that formal peer review was a very important consideration in choosing a publishing outlet, with a further 25% indicating that peer review was important. These findings accord with those of Key Perspectives (2002, p27), who found that 74% strongly agreed that peer review was preferred and a further 22% agreed that it was. After peer review, we found that the perceived prestige of the outlet was the most important factor for researchers in Australia in choosing where to publish. Breadth of exposure and speed of publication where also important considerations for Australian researchers. Around 40% of Australian researchers indicated that the availability of a print version was important, and around 20% indicated that the availability of an electronic version was important. We also found that the availability of an electronic version is somewhat more important to researchers in science and medical fields than it is for those social sciences, humanities and arts. Key Perspectives (2002) noted that internationally, 50% of authors saw the availability of a print version as very important, and 26% saw the availability of an electronic version as very important.

Despite relatively widespread awareness and use in research, pre- and e-print archives seem to be less widely used for publishing. We have found few researchers in Australia reporting that they posted material on subject or discipline specific archives, and only around 15% reporting posting them on institutional websites. In their international survey, Key Perspectives (2002, p69) found that no more than 11% reported posting papers on pre- or e-print archives.

Looking at concerns in relation to publishing, Swan and Brown (1999) found that copyright, publication delays and peer review were the main areas of concern. In Australia, the copyright and publication delay issues are intertwined, with commercial funding being one of the causes of both concerns – imposing IP restrictions and delaying publication for anything from a few weeks to a few years.

Looking to the future of publishing, we found that only around 20% of Australian researchers saw electronic publishing really changing things, with most suggesting that they saw electronic publishing supplementing print, but not replacing it. Key Perspectives (2002) received a similar response from their international sample, 91% saw traditional print and electronic journal publishing as important – twice as many as chose either all print or all electronic alternatives.

Swan and Brown (1999) also concluded that most researchers see the publication process, based around peer review, staying much the same, while being conscious that publishing is increasingly about building the author's C.V. and somewhat less about communication that was formerly the case. They observed that:

> *Looking forward to the future, more than two-thirds of authors wish to see scholarly publishing continue broadly in its present way, but the most popular expectation (and also hope) for the future was that electronic publishing with a rapid peer review system might develop further than at present. ...two-thirds of authors agree that the purpose of scholarly publishing does seem to be changing. It is seen as moving away from knowledge dissemination to the building of an author's C.V./resumé or reputation* (Swan and Brown 1999).

In the words of two of the Australian researchers interviewed for this study:

> *Being first to publish is everything, everything flows from that – recognition, funding, etc.* (Medicine).

> *Everyone now looks at the impact factors of the journal they are thinking of publishing in, because of the importance of that for career progression. That did not happen ten years ago* (Genetics).

Appendix 3 Sample by RFDC

Table A.1. Characteristics of the sample: Research Fields, Disciplines and Courses

Description	*RFDC Division*	*Interviewees (No)*	*Workshop Participants (No)*
Science - general	21	1	1
Social science, humanities and & - general	22	1	1
Mathematical sciences	23	1	1
Physical sciences	24	1	1
Chemical sciences	25	1	3
Earth sciences	26	3	-
Biological sciences	27	4	3
ICTs	28	1	5
Engineering & technology	29	1	-
Ag, Vet & environmental	30	4	-
Architecture & building	31	1	-
Medical & health	32	4	3
Education	33	1	-
Economics	34	1	1
Commerce, management & tourism	35	2	-
Policy & political sciences	36	1	1
Studies in human society	37	2	1
Behavioural & cognitive	38	1	1
Law & justice	39	1	-
Journalism & media	40	2	1
Arts	41	1	-
Language & Culture	42	3	2
History & archaeology	43	1	1
Philosophy & religion	44	1	-
Librarians	-	-	7
Research Office Staff	-	-	2
Total		*40*	*35*

Appendix 4 Interview Guide

Basic Identification

Name

Gender

a) Male	
b) Female	

Age (approx)

a) <30	
b) 31-40	
c) 41-50	
d) >50	

Position (level)

a) Professor / Professorial Fellow	
b) Assoc Prof / Reader	
c) Senior Lecturer / Senior Fellow	
d) Lecturer / Fellow	
e) Post Doc / Assistant	
f) Other	

Type of Institution

a) University	
b) Public Research Institute	
c) Private Sector	
d) Government	
e) Other…	

Location of Institution

a) Metropolitan	
b) Regional	

Discipline or field of research

a) Description	
b) Cluster	- Please Leave Blank -
c) RFDC	- Please Leave Blank -

1. How long have you been a researcher, including PhD (years)?

2. How long have you worked at your current institution (years)?

3. Have you worked in different types of organizations… if so, which?

a) University	
b) Public institute (eg. CSIRO)	
c) Private (business)	
d) Government	
e) Other, please describe…	

4. Have you worked overseas… if so, where?

Yes 1	
No 0	
Country	

5. How is your time divided between research, teaching and other activities… can you give an approximate percentage breakdown?

	%
a) Research	
b) Teaching	
c) Other (eg. Admin)	

6. Would you describe your research as mainly…

a) Disciplinary	
b) Interdisciplinary	
c) Pure	
d) Applied	

7. Is the field or focus of your work changing… If so, in what ways?

Yes 1	
No 0	
c) More disciplinary	
d) Less disciplinary	
e) Change of discipline / field	
f) More pure	
g) More applied	
h) Other, please describe…	

8. What are the main *sources of funding for your research*… over the last year or so. Could you give approximate percentages from the following list?

	%	Comment
a) Own University or Institution		
b) Public Grants (eg. ARC or NH&MRC)		
c) Private Sector (Business)		
d) Government (Contract)		
e) NGO (Contract)		
f) Other, please describe…		
What percentage is:		
g) Australian %		
h) Overseas %		
What percentage is:		
i) Grant-based %		
j) Contract %		

9. Has that changed over the last 5 years… If so, which sources of funding are increasing and which decreasing?

	(3) More	*(2) Same*	*(1) Less*
a) Own University or Institution			
b) Public Grants (eg. ARC or NH&MRC)			
c) Private Sector (Business)			
d) Government (Contract)			
e) NGO (Contract)			
f) Other , please describe…			
g) Australian			
h) Overseas			
i) Grant-based			
j) Contract			

10. Are there any issues that concern you in the way in which research funding is changing?

Yes 1
No 0

Communication and Collaboration

Research Teams

11. Do you work primarily *alone, or as part of research or project teams*?

a) Alone	
b) Team	
c) Mixture	

(If *alone*, skip to RESEARCH NETWORKS – Q17)

12. How many people are there in the teams (typically)?

13. Where are team members located? Could you give approximate percentages for the following locations:

	%	*Comment*
a) Same institution		
b) Different institution		
c) In Australia		
d) Overseas		

14. How often do team members interact (typically)?

	Tick	*Comment*
a) Daily		
b) Every 2 or 3 days		
c) Weekly		
d) Bi-weekly		
e) Monthly		
f) Less often than that		

15. How do team members keep in touch? Could you indicated whether the following are 'Essential', 'Used' but not essential, or 'Not Used':

	(3) Essential	*(2) Used*	*(1) Not Used*
a) Letters			
b) Phone calls			
c) E-mail			
d) Discussion lists			
e) Instant messenger (AOL)			
f) Videoconferencing			
g) Other, please describe…			

16. Has your team working changed over the last 5 years… in terms of:

	(3) More	*(2) Same*	*(3) Less*
a) Your participation in research teams?			
b) Average size of the teams?			
c) Structure of the teams (eg. peer vs hierarchical)?			
d) Location of members of the teams?			
e) Way in which teams cross institutional borders?			
f) Ways in which you communicate within teams?			
g) Other, please describe			

Research Networks

17. Do you see yourself as a part of a *broader research network (eg. a collegial network of scholars)*?

Yes 1	
No 0	

(If not, skip to Q22)

18. How do members of this broader network keep in touch? Could you indicated whether the following are 'Essential', 'Used' but not essential, or 'Not Used':

	(3) Essential	*(2) Used*	*(1) Not Used*
a) Meeting at conferences			
b) Letters			
c) Phone calls			
d) E-mail			
e) Discussion lists			
f) Instant messenger (AOL)			
g) Videoconferencing			
h) Other, please describe…			

19. How important is this *broader network* to your work… Would you say it was:

	Tick	*Comment*
3) Very important		
2) Important		
1) Not important		

20. Has the emergence of the of the networked information environment *changed the way you, and others in your field, collaborate and communicate* with colleagues in the conduct of research?

Yes 1
No 0

If so, in what ways…

21. Are there any issues relating to new forms of communication and collaboration that concern you?

Yes 1
No 0

If so, what are they?

Information Search and Access

23. How would you rate the following *information sources* in your research work…

Could you indicate whether they are 'Essential', if you 'Use' them but they are not essential, or if you 'Don't Use' them… first for *printed and other physical sources*, and then *electronic sources*:

24A. Printed and Physical Sources:

	(3) Essential	*(2) Use*	*(1) Don't Use*
a) Journals (refereed)			
b) Books			
c) Printed working papers & pre-prints (not refereed)			
d) Conference papers and presentations			
e) Other 'grey' literature (eg. reports & documents)			
f) Newspapers & Magazines			
g) Newsletters & press-releases			
h) Maps, Charts, Photographs & Images			
i) Movies & sound recordings			
j) Special collections (eg. rare books & manuscripts)			
k) Physical artefacts (eg. collections or specimen)			
l) Microfilm / microfiche collections			
m) Bibliographic indexes			
n) Library, publisher and/or bookstore catalogues			
o) Other sources, please describe…			

24B. Electronic Sources:

		(3) Essential	(2) Use	(1) Don't Use
a)	Electronic Journals (refereed)			
b)	Electronic journals that are not refereed			
c)	Electronic Books			
d)	Electronic pre-print or post-print servers (archives)			
e)	Conference papers and presentations online			
f)	Other 'grey' literature online (eg. reports)			
g)	Online Newspapers & Magazines			
h)	Online Newsletters & Press-releases			
i)	Online Maps, Charts, Photographs & Images			
j)	Internet-based news sites & servers			
k)	E-mail based newsletter subscriptions			
l)	Customised push technology (eg. PointCast)			
m)	Online Library, publisher or bookstore catalogues			
n)	Computerised datasets of primary data			
o)	Online alerting services (eg. e-mail alerts)			
p)	Electronic Bulletin Board Systems (BBS)			
q)	Discussion groups (listserv)			
r)	News groups (Usenet)			
s)	Internet Chat Rooms			
t)	Subject gateways or portals (eg. RDN)			
u)	Institutional or personal gateways (entry pages)			
v)	Generic Web search engines (eg. Google)			
w)	Agents or bots (eg. Autonomy)			
x)	Web Browser Bookmarks or Favourites			
y)	Other sources, please describe…			

24. Approximately what percentage of the sources you currently use are *physical / print* and what percentage are *electronic / online*?

	Searching & Browsing %	*Reading & Studying* %
a) Physical / Print		
b) Electronic / Online		

25. What factors influence your choice of information sources… Could you indicate which of the following are *very important*, *important* or *not considered*:

	(3) Very Important	*(2) Important*	*(1) Not Considered*
a) Currency (up-to-date)			
b) Credibility (known/trusted source)			
c) Material is peer reviewed			
d) Availability of a print version			
e) Availability of an electronic version			
f) Availability of full text (immediately)			
g) Ability to access from desktop			
h) Ability to access 24/7			
i) Inclusion of links to other works			
j) Inclusion of links to source data			
k) Inclusion of multimedia elements			
l) Clarity as to 'fair use' (copyright)			
m) Cost – to you personally			
n) Cost – to your institution			
o) Method of payment			
p) Other, please describe…			

26. How have your search and discovery practices changed over the last 5 years… what things are becoming more important, and what less so?

(1) More	*(2) Less*
a)	*a)*
b)	*b)*

27. Do you perceive any change in the relative *importance of primary sources (eg. databases) vis-à-vis secondary sources (eg. journals)*?

Yes 1
No 0

If so, what changes?

a) More use of primary sources	
b) More use of secondary sources	
c) Other, please describe…	

28. Do you have personal ***subscriptions*** to any of the following… If so, could you indicate *how many*, whether they are *free or paid*, and whether they are *print or electronic*:

	(n) *Number*	*Paid (2), Free (1), Both=(0)*	*Print (2), Electronic (1), Both=(0)*
a) Journals			
b) Newspapers & Magazines			
c) Newsletters & Press-releases			
d) News or discussion groups			
e) Alerting services			
f) Other, please describe…			

29. Do you maintain a *personal library or collection* (*in physical or electronic form*)… If so, could you indicate whether the following are 'Essential', 'Used' but not essential, or 'Not Used'

	(3) *Essential*	*(2)* *Use*	*(1)* *Don't Use*
a) Physical / Print collection			
b) Electronic archive			
c) Linked web resources			
d) Other, please describe…			

30. Has your *personal collecting and/or subscribing* changed over the last 5 years… If so, what do you have more of, and what less?

(1) More	*(2) Less*
a)	a)
b)	b)

31. Has increasing access to information online *changed the way you, and others in your field, search for and access information*?

Yes 1
No 0

If so, in what ways… can you give some examples?

32. Are there any issues relating to this increase in online information that concern you?

Yes 1
No 0

If so, what are they?

Dissemination and Publication

33. How often do you publish… Could you indicate the approximate *average number of publications per year* of the following types?

	Number	Comment
a) Journal Papers (refereed)		
b) Books (Written or edited)		
c) Book Chapters		
d) Reports		
e) Conference papers		
f) Non-refereed articles		
g) Other, please describe…		

34. Are your publications typically sole or joint authored?

a) Sole
b) Joint

35A. If joint, how many authors would there be (on average)?

Number?

35B. Has that changed over the last 5 years… if so, how?

Yes = 1
No = 0
How?

35. What is your preferred *medium* & *format* for publication (Select 1 only)?

	(3) Print	(2) Electronic	(1) Both
a) Papers (refereed)			
b) Books (written or edited)			
c) Book chapters			
d) Reports			
e) Conference papers			
f) Non-refereed articles			
g) Other, please describe…			

36. What are the main reasons for your publishing? Could you indicate which of the following list are *very important, considered*, not *important*.

	(3) Very Important	(2) Considered	(1) Not Important
a) Communicate your work			
b) Validate findings			
c) Accreditation / recognition			
d) Indicator of research performance			
e) Financial reward (Direct)			
f) Other, please describe…			

37. What are the main barriers you face when publishing? Could you indicate which of the following list are *very important, considered*, not *important*.

	(3) Very Important	(2) Considered	(1) Not Important
a) Unable to find publisher for book			
b) Inadequate marketing & distribution by publisher			
c) Copyright limitations			
d) Confidentiality restrictions			
e) Lack of direct financial reward			
f) Other, please describe…			

38. When choosing between publishing outlets what factors do you consider? Could you indicate which of the following list are *very important, considered*, not *important*.

	(3) *Very Important*	(2) *Considered*	(1) *Not Important*
a) Likelihood of acceptance			
b) Perceived prestige of outlet			
c) Formal peer review			
d) Speed of publication/circulation			
e) Breadth of exposure			
f) Availability of a print version			
g) Availability of an electronic version			
h) Ability to retain copyright			
i) Ability to put pre-published version online			
j) Ability to put the published version online			
k) Ability to include links to other works			
l) Ability to include links to source data, etc.			
m) Ability to include multimedia elements			
n) Financial reward (direct)			
o) Cost to readers (ie. price of book or journal)			
p) Other, please describe…			

39. Do you circulate drafts prior to publication or completed works after publication?

Yes 1
No 0

40A. If so, do you circulate them:

	(3) *Often*	(2) *A Little*	(1) *Never*
a) Among immediate project team members?			
b) Among colleagues within your institution?			
c) Among a wider network?			
d) Other, please describe…			

40B. If so, how? Do you:

	(3) *Often*	(2) *A Little*	(1) *Never*
a) Send them by post			
b) Send them by e-mail			
c) Put them on a personal website			
d) Put them on an institutional website			
e) Put them on a subject or discipline specific server or archive			
f) Put them on a generalist server or archive			
g) Other, please describe…			

40. Do you think electronic publishing will fundamentally challenge the dominance of the traditional journal and the peer-review process?

Yes 1
No 0

If so, in what ways…

41. Has the emergence of the of the networked information environment *changed the way you, and others in your field, publish and disseminate findings*?

Yes 1	
No 0	

If so, in what ways…

42. Are there any issues relating to these emerging dissemination and publication options that concern you…

Yes 1	
No 0	

If so, in what ways…

Overview and summary

43. What are the major trends and changes in your area of research?

44. Do you have any comments you would like to add?