Collaborative and Distributed E–Research:
Innovations in Technologies, Strategies and Applications

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Investigating eResearch:
Collaboration practices and future challenges

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**ABSTRACT**
Why and how do researchers collaborate, share knowledge resources, data and expertise? What kinds of infrastructures and services do they use and what do they need for the future enhancement of collaborative research practices? The chapter focuses on existing and potential eResearch from a ‘user’ perspective. Drawing on a study of ICT-enhanced research practices and needs conducted at seven Australian universities, it discusses how researchers engage with distributed research and use ICT for collaboration. Findings show significant current engagement of the majority of researchers in collaborative research, their acknowledgement of the potential of eResearch, and researchers’ general willingness to engage in collaborative eResearch. While there are some essential differences in the collaboration practices of research students and academics and between practices and challenges in different disciplinary domains, researchers who are more involved in collaborative research also adopt eResearch more extensively; more often use ICT-enhanced collaboration tools; share more of their data; and more often disseminate their findings via digital media.

**BACKGROUND AND AIMS**
National and international research agendas almost universally acknowledge that successful solutions of global issues and future social, cultural and scientific innovation fundamentally rely on distributed scholarly practices and research collaborations, such as sharing and integration of data, resources and knowledge, remote collaborative access to scientific instruments, and pooled human expertise (Atkins et al., 2003; Hey, Tansley, & Tolle, 2009). Many countries, including Australia, have made significant
strategic investments in developing general and discipline-specific data repositories, virtual laboratories and other shared technology-enhanced research infrastructures often known under several broad umbrella terms, such as ‘eResearch’, ‘Cyberinfrastructure’, ‘eInfrastructure’, ‘eScience’, ‘eHumanities’, ‘eSocial Sciences’ and ‘The Grid’ (ACLS, 2006; Atkins et al., 2003; DEST, 2006; e-IRG, 2009; NCRIS Committee, 2008). Some pioneering collaborative research projects have demonstrated successful uptake of new research infrastructures and significant benefits of collaborative research practices (e.g., see Hey et al., 2009). However, experiences from some other technology-enhanced collaborative projects have suggested that researchers involved in such collaborative research also face a range of challenges, and such research collaborations have not been as successful as it was initially expected (Borgman, 2006; Haythornthwaite et al., 2006; Lawrence, 2006; Meyer, 2009). Further, the uptake of collaborative research practices and new infrastructures beyond pilot projects tend to be slower and less transformative than initially planned (Foster & Gibbons, 2005). Among key questions for further development of eResearch are the widening adoption of technology-enhanced research practices and the sustainability of ‘proof-to-concept’ developed eResearch tools and services (Halfpenny et al., 2009).

eResearch infrastructure developers face significant challenges and tensions in meeting current researcher demands and simultaneously creating infrastructure for the desired future (Ribes & Finholt, 2009). On the one hand, effective technological infrastructures for data sharing, communication, remote data analysis and other distributed research tasks are important enablers of collaborative discovery and innovation. On the other hand, many barriers for collaborative research tend to be not technological, but rather social, cultural and organizational, such as lack of researchers’ willingness and engagement, difficulties managing information, ethical concerns, and legal issues (David, 2006; Haythornthwaite et al., 2006; Jirotka et al., 2005; Lawrence, 2006). Further, researchers’ scientific challenges, their ways of doing collaborative research and their needs for eResearch infrastructures and support vary considerably within and across disciplines and research fields (Bos et al., 2007; Fry, 2006; Laterza, Carmichael, & Procter, 2007). In order to create infrastructures and services that meet researchers’ expectations and epistemic practices now and in the future, eResearch implementers and funders need initially to understand existing research questions, current challenges and practices, and future research visions.

Why and how do researchers collaborate, share knowledge, resources and expertise? What encourages researchers and what prevents them from engaging in collaborative eResearch practices? What kind of infrastructures, services and support do they need? How do they envision collaborative eResearch in the future of their field?

In order to answer these questions, this chapter discusses findings about distributed research practices and collaboration from a broad survey-based study on information and communication technology (ICT)-enhanced research practices which was conducted at seven Australian universities. The chapter has three main objectives: (a) to present a snapshot of current traditional and ICT-enhanced collaboration practices in various disciplines in the Australian eResearch context; (b) to discuss researchers’ needs for eResearch services and support and their vision about the role of collaborative eResearch for future progress of their research field; (c) to explore some existing coherences and differences between ‘top-down’ collaborative research visions expressed in ‘grand’ eResearch strategies and projects on the one hand, and ‘bottom-up’ researcher experiences and views of effective collaborative practices on the other.

This exploration is both distinct and limited in several specific ways. First, it is based on empirical data collected in the Australian eResearch context, which has been little explored in mainstream sociological eResearch literature. Second, it provides an account of eResearch potential and challenges from an ordinary ‘ICT user-researcher’ perspective. This perspective is quite distinct from the accounts of eResearch developers and early adopters, which are more often reported in similar
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literature (e.g., Barjak et al., 2009), yet this user perspective is fundamental for developing productive ways forward (Ribes & Finholt, 2009).

This chapter is structured as follows. The following two sections introduce the Australian eResearch context and review ICT-enhanced collaboration practices and challenges reported in the literature. The next section describes the approach and procedure of the empirical study. The following results section provides a snapshot of researchers’ answers about their collaboration and distributed practices, and explores some differences between the practices of academics and research students, researchers from different disciplinary domains, and those already involved in various kinds of research collaboration. The final section discusses key findings and major implications. Among key insights are some noticeable discrepancies among current researchers’ ICT-enhanced collaboration practices, their short-term needs for eResearch services and support, and their thinking about eResearch potential in their research domain. Further, the section highlights a noticeable discrepancy, in researchers’ thinking about eResearch roles and challenges between two distinct modes of distributed research: (a) ‘team-based’ collaboration that extends possibilities, but comfortably fits with familiar research routines; and (b) ‘grand’ distributed collaboration that requires new coordination practices and additional efforts.

**AUSTRALIAN ERESEARCH CONTEXT**

The use of ICT in research is not a new phenomenon – in fact the development of academic networks and ICT infrastructures for research and education has been part of international and national strategies in many countries, including Australia, for several decades (De Roure et al., 2003; Korporaal, 2009). eResearch as an independent initiative in Australia emerged in the background of similar international developments, in the mid 2000s (Paterson et al., 2007). This development was marked by the launch of an eResearch Coordinating Committee that released an Australian eResearch Strategy and Implementation Framework, which outlined an eResearch vision and its key elements (DEST, 2006). As this document states,

“The vision for eResearch in Australia is that Australian researchers will enhance their contribution to world-class research endeavours and outcomes, through the use of advanced and innovative information and communications technologies. The vision encourages researchers to participate in the technological revolution that offers the power to undertake research on a scope previously unattainable – to work collaboratively and globally and improve their research as a result.” (p. vii).

This strategy resulted in a number of programs outlined in the National Collaborative Research Infrastructure Strategy’s Roadmap (NCRIS Committee, 2008) and targeted investments intended to enhance collaboration, assist researchers in managing large datasets, and provide high speed computing and innovative analysis tools. These national infrastructures and services are delivered in partnerships with state-based eResearch initiatives, such as Intersect in NSW and VeRSI in Victoria. Funded initiatives include two broad sets of programs. One group of programs covers a variety of aspects related to the development of generic eResearch infrastructure and services, such as development of research data commons, shared access methods, large data collections, high performance computing and extended bandwidth (NCRIS, 2011). The second set of programs is more focused on the development of discipline-specific services and tools, including eResearch resources for medical research, humanities, social sciences and arts. Examples of such disciplinary projects are Collaborative Visualisation Tools for Creative eResearch (Aus-e-Stage); Integration and Annotation Services for Australian Literature Communities (Aus-e-Lit); Data Management for Microscopy, Imaging, Neutron and X-Ray Facilities (DataMINX); Data Integration and Access Services for Biodiversity (DIAS-B); National Criminal Justice Research Data Network (NCJRDN); and Marine and Climate Data Discovery and Access Project (MACDDAP) (ARCS, 2011). More recently
announced eResearch Collaboration Tools and Resources and Research Data Storage Infrastructure programs, part of a new national Super Science Initiative, also aim to support both multi-purpose and more problem- and discipline-specific eResearch tools and virtual laboratories.

Concurrent with, and related to, these developments were programs addressing the accessibility, visibility and dissemination of research data and outputs. The national government recognized that accessibility to research presents significant challenges for researchers and the public and that some areas – such as data and information access, management and preservation – need significant attention and investment. It addressed this need by providing funding for a number of schemes such as institutional repositories with an early focus on accessibility and dissemination of research publications (Kennan & Kingsley, 2009), and more recently by concentrating on data curation, sharing and accessibility through the development of data commons (Clarke, Harrison, & Searle, 2009; Paterson et al., 2007).

Overall, Australian eResearch and research information infrastructure initiatives recognize that enabling infrastructures include more than just technology, but also researchers’ expertise, leadership and governance, ICT management and support. Nevertheless, much funding and attention has been directed towards development of new ‘hard’ infrastructures, tools and services rather than ‘soft’ programs for user capacity building and engagement with eResearch. ‘Social side’ and ‘social shaping’ of eResearch in Australia, has received less attention than in other countries, such as the UK, The Netherlands and other North American and European counties (Barjak et al., 2009; Ribes & Finholt, 2009; Ribes & Lee, 2010; Woolgar, 2004; Wouters & Beaulieu, 2007).

LITERATURE REVIEW: ICT-ENHANCED COLLABORATION PRACTICES AND CHALLENGES

Any understanding of ICT-enhanced collaboration practices and challenges must begin from the understanding of collaboration among researchers more generally. This section focuses on three major aspects of research collaboration: (a) the research process; (b) data sharing and re-use; and (c) research dissemination. It initially reviews some major insights from the sociological literature into practices, motives and impediments for collaborative research and then extends this discussion to include the literature on ICT-enhanced research infrastructures.

Research collaboration is complex and manifests in many ways, such as co-investigation on research projects, sharing and integration of data and information, remote collaborative access to scientific instruments, pooled human expertise and shared authorship (Borgman, 2007; Katz & Martin, 1997). Participants in collaborative research can be active or passive in one or more phases of research (Katz & Martin, 1997). Collaboration can occur simultaneously or in an indirect or serial manner (Borgman, 2006).

Previously much research has been conducted by lone researchers, or co-located teams (Katz & Martin, 1997) where most team members had similar disciplinary background, but this has changed over recent decades. Needs for more collaborative forms of research arise from factors such as the increased complexity and scope of research problems requiring multi-, inter- and trans-disciplinary approaches linking specialised expertise, needs in some scientific projects for expensive instruments and computational power, and pressure from some funders (Katz & Martin, 1997). Despite these encouragements and prevailing opinion that high productivity correlates with collaboration, it is recognised that collaboration is difficult and that collaboration over distance even more so (Barjak, 2009; Borgman, 2007; Olson, 2008).

Disciplines vary in their practices in a number of ways, from the objects of their investigations and the methods they use, to the dissemination methods and types of publications they favour and the ways
they collaborate (Meadows, 1998). Generally, researchers in physical sciences collaborate more than those in the social sciences and humanities (Becher & Trowler, 2001). Further, within disciplines experimentalists tend to collaborate more than theoreticians (Katz & Martin, 1997). Facilitating collaboration, particularly distributed collaboration, is one of the primary goals of eResearch. The scale, scope and focus of eResearch collaborations can vary from large “virtual organisations” together tackling broad global problems, such as those using the “collaboratory” model (Olson, Zimmerman, & Bos, 2008), to small scale collaborations with a narrower focus, such as teams working on specific issues and analyzing shared data sets together (Borgman, 2007; Hey & Trefethen, 2008).

Adopting ICT-enhanced collaboration practices is not an easy process, and typically demands attention and development over time (Bos et al., 2007; Jirotka et al., 2006; Laterza et al., 2007; Lawrence, 2006). For example, reviewing the process of collaborative eResearch adoption by a group of scientists and engineers, Olson and colleagues (2008) note that much of the early focus was on using the Internet to exchange large amounts of data, provide access to high-end computing resources and share instrumentation. Over time this collaboration grew to include more human interaction and a broad range of joint activities.

Sharing data is core to eResearch collaboration. Data can be re-used to reproduce and validate original findings, to advance the original research or open another line of enquiry sometimes using vast amounts of data collected over time and from various sources. The literature speaks of a “deluge” of scientific and research data (Hey et al., 2009; Hey & Trefethen, 2003; Wilson et al., 2007) and the importance of capturing and managing it for use beyond its original community, purpose and time. Data value increases as it is interconnected, networked, shared, used and re-used (Borgman, 2007). Vast amounts of complex and varied data are being generated and collected, and too often this data is lost or discarded as researchers move, projects complete and storage technologies evolve (Henty et al., 2008; Markauskaite, Hellmers et al. et al., 2009). For better collaborative exploration and exploitation of data as it exponentially grows, the data must be better understood and managed (Karasti, Baker, & Halkola, 2006).

Data is heterogeneous and some datasets can be extremely large. Different disciplines have different types of data ranging from large gigabyte-scale files in crystallography through databases and spreadsheets, to small text files of interviews in humanities research (Borgman, 2007; Carlson & Anderson, 2007; Henty et al., 2008). To re-use data, researchers need to understand its provenance, content, the conditions it was collected under, access restrictions and many other details (Edwards et al., 2009; Hey & Trefethen, 2008; Miles et al., 2007; Wu, Heok, & Tamsir, 2007). This heterogeneity can present technical and social challenges, and analysis is required of the data characteristics, its production, and the communication mores of the community the data serves before data management can occur (Cragin et al., 2010). Data sharing “…is a complex social process involving trust, incentives, disincentives, risks, and intellectual property” (Borgman, 2006, p. 360). As evidence shows, researchers rarely have the desire, skills or resources to prepare their data for deposit or public sharing in repositories (Cragin et al., 2010; Henty et al., 2008).

Data, especially in the social sciences and humanities are often “complex, fuzzy, discursive, inconsistent” (Barjak et al., 2009, p. 586). There are data licensing, privacy and confidentiality concerns which in turn may cause high costs for preparing data for sharing and re-use (Bishop, 2005; Edwards et al., 2009; Parry & Mauthner, 2005; Tan et al., 2009). At the same time, little scientific credit is gained by sharing data sets. Ownership rights in data generated in a collaborative project might be difficult to assign, yet the data themselves may have substantial financial value. Finally, new applications are typically context specific, and their transfer to new contexts brings substantial challenges. Some of these issues can be solved with the development of applications that are secure and that implement data access and rights management protocols, but these are not yet available for all types of data.
At the same time as developments in eResearch infrastructure are beginning to provide the ability to access, search and share data in digital repositories, new developments are taking place in ways of disseminating final research outputs and publications. Research builds on what has gone before, and to do so, researchers must have access to it; research is incomplete until it is communicated, used, disseminated and further developed within a community (Borgman 2007). The results of research can be documented and shared in a variety of forms from letters and memos, to journal articles and books. At present in most disciplines the primary form of scholarly communication is still via articles usually published in journals, and book chapters or disseminated at conferences (Kling & Callahan, 2003). These forms maintain their importance in dissemination as they demonstrate desirable characteristics for scholars seeking to disseminate their work: the research is accessible by others in the present and the future; there is publicity so that other interested scholars can be made aware of it (journals subscriptions, indexing, abstracting); it is demonstrated as trustworthy having gone through some sort of peer review or other certification; and it registers and acknowledges who carried out the work (Borgman, 2007; Kling & McKim, 1999; Prosser, 2005).

Changing technologies from the 1970s - computers, the Internet, and search engines - have shifted the dominant form of dissemination from printed journals to electronic journals (Kling & McKim, 1999). The online provision of scholarly publications comes in many formats, such as individual electronic journals, publisher collections of journals, aggregator collections of articles (often subject-based and provided by commercial organisations as an adjunct to their existing indexing and abstracting services). While access channels and media have changed, the basic structure and relations of production of scholarly communication or dissemination have not much changed. Journals and other research outputs are mainly available to those who pay for subscriptions or whose institutions do so (Houghton & Oppenheim, 2010; King & Tenopir, 2011). An open access movement which promotes free online access to research outputs and data has developed, providing an alternative access to some scholarly outputs through the infrastructure of institutional and disciplinary repositories and connected networks of those repositories, indexed and searchable over the internet (Lynch & Lippincott, 2005).

A great deal of work has gone into the development of repositories (Payette et al., 1999; Smith et al., 2003; Van de Sompel et al., 2004). There is some evidence that increased access through open access repositories may potentially increase the use of the work, its visibility, and therefore its impact and citations of research (Brody, Harnad, & Carr, 2006; Swan, 2010). However, many repositories are less than comprehensive. Studies that examine open access typically find that communication of findings, recognition of work, promotion and tenure are major motives for researchers to publish, and they do not always see these aims being furthered in open repositories. Among their reported concerns are lack of interest, knowledge or time, issues with copyright, and concern about plagiarism (Kennan, 2007; Rowlands & Nicholas, 2006; Swan & Brown, 2005).

The Internet has fostered other developments such as e-lists, blogs, wikis, RSS Feeds, chat technologies and other Web 2.0 tools, which enable more democratic collaboration and dissemination. These tools and ‘grey literature’ associated with informal scholarly communication and collaboration do not undergo traditional peer review or other institutionalized certification. However, as their use matures, new forms of more informal, dynamic peer review may emerge (Hey & Trefethen, 2008). To bring together our discussions on data and dissemination, it is evident that the Internet and eResearch infrastructure can do more than just disseminate or make available the full text of research papers and data. In principle, they can integrate data with the literature to create a world that allows researchers and readers to see the whole knowledge production cycle (Fink et al., 2008; Hey, Tansley, & Tolle, 2009; DeRoure & Frey, 2007; Seringhaus & Gerstein, 2007). For example, readers of publications can not only see and use the original data, but also redo the analysis or combine the data with other data for other purposes. As Lynch (2009) says, such scholarly communications can be a “vehicle for building up communities and for a form of large-scale collaboration across space and time” (p. 178).
Infrastructure, service and support requirements will differ depending on the discipline and the nature of the research. Borgman (2007) observes that whereas almost all research data are created by, and for, scientific purposes, a significant portion of data used in social research consists of data created by other parties for other purposes, for example, government, business and mass media. Furthermore, the social sciences and humanities use highly heterogeneous datasets. This creates complex semantics and interoperability challenges and makes “one size fits all” approaches to infrastructure development and support unsuitable for research in these domains (Barjak et al., 2009).

Studies investigating eResearch uptake provide some initial insights into several aspects that might support broader researcher engagement with eResearch. For example, Dutton and Meyer (2009) report that while respondents believe that many new scientific questions will require eResearch tools to answer them, many researchers are still uncertain, or have no opinion, about what these questions are. They also notice that recent graduates are more likely to be interested in, and knowledgeable about, eResearch. This, and other research (Pearce, 2010), also found that disciplinary differences were not a barrier in the uptake of eResearch tools, and that a wide variety of tools were already in use. Some researchers who collaborate using eResearch infrastructure, do so largely because colleagues or potential collaborators encourage them to. Other catalysts include seed funding, interesting research that requires eResearch infrastructure (Barjak et al., 2007), the connection between eResearch projects and their potential user communities, and support infrastructure such as developers to hand and training resources. Differing research communities have differing needs, so analysis of the practices, communication and collaboration relations, and social organization of different research fields is required to find out how these needs can be supported (Barjak et al., 2009). Successful collaboration projects in eResearch development were found to have strategies in place ensuring that domain and computer scientists work together in co-development of technologies and services (Barjak et al., 2009). Researchers report that barriers to the adoption of eResearch collaboration practices include lack of information on usefulness and applicability to research problems, perceptions about insufficient practicality and applicability, and perceptions about infrastructures being developed by technologists in isolation from the researchers who will use them. Benefits of eResearch are most likely to reach new communities of scholars via highly regarded researchers in their own field, and eResearch initiatives are encouraged to engage these highly regarded researchers to assist in promotion (Barjak et al., 2007). Other barriers include lack of funding, costs, lack of qualified staff and the need for more information and training (Barjak et al., 2007; Dutton & Meyer, 2009).

However, little is known about how researchers’ engagement with different research collaborations relates to specific ICT use for collaboration practices; how researchers view the role of collaborative eResearch in the future of their field; and what kinds of support might assist them to attain their eResearch visions.

With this background, we now turn to results from our study.

**APPROACH AND PROCEDURE**

The study called “Co-developing eResearch infrastructure: Technology-enhanced research practices, attitudes and requirements” was conducted using a web-survey. It covered three main eResearch areas: (a) data management, retention and sharing; (b) technology-enhanced research methods, tools and services; (c) research collaboration and dissemination. Participants were asked to respond to 40 questions, most of which required them to choose from a range of options and allowed a short comment, while eight questions asked participants to provide open narrative answers. About 10 questions focused on distributed and collaborative research practices, such as data sharing, research
communication and dissemination (Appendix 1). The main results from the analysis of participants’ answers to these questions are presented in this chapter.

The survey was administered in two phases at seven Australian Universities in the state of New South Wales: (a) four universities completed the study in May-June 2009; and (b) three others did so in October-November 2009. Email invitations were distributed to all academic staff, research students and research support staff via universities’ internal mailing lists. The survey was targeted at all researchers and research students, including those who do not use ICT for research yet, therefore the invitation explicitly stated that “We are interested in your research practices and opinions, whatever your discipline, and whatever the extent of ICT use in your research.”

After the survey was closed, the multiple-choice questions were analysed using relevant statistical techniques with SPSS. On the basis of participants’ answers, five grouping variables were created: (a) disciplinary clusters; (b) career stage; (c) degree of collaboration; (d) scale of collaboration; and (e) nature of collaboration (Table 1). These variables were used to explore some major differences between answers of: researchers from different disciplinary areas; research students and academic staff; and researchers involved in different kinds of collaboration in various degrees. Only differences that were significant at level $p < .05$ are discussed in this paper.

Table 1. Grouping variables and categories used in the analysis of survey data.

<table>
<thead>
<tr>
<th>Grouping variables</th>
<th>Categories</th>
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<tbody>
<tr>
<td>Disciplinary clusters</td>
<td>1. Social fields – humanities, arts and social sciences</td>
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<tr>
<td></td>
<td>2. Biomedical fields – biological, health and medical sciences</td>
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<tr>
<td></td>
<td>3. Physical fields – physical sciences, chemical sciences, IT, engineering and mathematics</td>
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<td></td>
<td>4. Multidisciplinary – a combination of all three or any two of the above categories</td>
</tr>
<tr>
<td>Career stage</td>
<td>1. Research students – full time and part time postgraduate research students</td>
</tr>
<tr>
<td></td>
<td>2. Academic staff – full time, part time and honorary academics at all stages of career: early career, middle career and experienced researchers</td>
</tr>
<tr>
<td>Degree of collaboration</td>
<td>1. Nearly all research is individual</td>
</tr>
<tr>
<td></td>
<td>2. About half research is collaborative</td>
</tr>
<tr>
<td></td>
<td>3. Nearly all research is collaborative</td>
</tr>
<tr>
<td></td>
<td>Note: This category is based on participants’ answers to the question without further regrouping.</td>
</tr>
<tr>
<td>Scale of collaboration</td>
<td>1. International – participants involved in research collaborations on international scale, such as partnerships with universities from other countries</td>
</tr>
<tr>
<td></td>
<td>2. National – participants involved only in research collaborations that occur within the country, including other national universities and non-university partners</td>
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<tr>
<td></td>
<td>3. Local – participants involved only in research collaborations that occur within their institution, including their research group, other research groups within their faculty and other faculties within their university</td>
</tr>
<tr>
<td></td>
<td>4. Individual – participants not involved in collaborative research</td>
</tr>
<tr>
<td>Nature of collaboration</td>
<td>1. Beyond university – researchers engaged in some collaborations with non-university partners, such as non-university research agencies and non-academic partners</td>
</tr>
<tr>
<td></td>
<td>2. University – researchers engaged in collaborations with university</td>
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Answers to the open-ended questions were explored for patterns independently using both manual coding and automatic text visualisation. First, written answers were categorised using human coding and explored for most-common categories using statistical techniques. Second, written texts were pre-processed and visualised creating “word clouds” with Wordle web-based software (Feinberg, 2009). Most frequent words and phrases used by participants in their answers were further explored and triangulated with the results of human coding. To obtain more contextualised visual representation of answers, texts were initially pre-processed by detecting 10-15 most frequently used adjectives and linking these adjectives to the following nouns, forming phrases. For example, words “Digital” (adj.) and “Repository” (noun) were linked into the phrase “DigitalRepository”.

It is important to note some limitations. First, the sample of this study was not representative of the whole university research population in Australia or NSW and findings cannot be generalised to this population. For example, the ratio of academic staff and research students was about 3.5 in the sample, while the ratio of academics and research students in all Australian universities is about 1.4 (i.e., 49,942 academics and 34,821 research students, full-time equivalent as at 2008) (Universities Australia, 2010). However, the survey sample was large (864 respondents) compared with similar studies that have been completed in this domain (e.g., Barjak et al. (2007) – 560 responses, Dutton and Meyer (2009) – 526 responses), and it had participants from various disciplines, with different levels of research experience and involved in various kinds of research collaboration (see next section). Therefore, the results for these subgroups were examined separately, and presented findings primarily aim to provide insight into the differences between these subgroups.

Second, three different grouping variables were used to investigate how different aspects of research collaboration were related to researchers’ use of ICT-enhanced collaboration technologies, data collection, sharing and dissemination practices. While these variables reflected distinct aspects of collaboration, as it could be expected, they were interrelated (Spearman's rho was between 0.17 and 0.25, with the largest association between the scale and degree of collaboration). As these variables reflected distinct aspects of collaboration they were all included in analysis and analysed separately. Possible implications from those associations were, when possible, made explicit in the results section and should be taken into account in the interpretation of findings.

RESULTS
Participants’ Background
In total, 864 participants took the survey and 703 (81%) of them completed it to the end. Varying disciplines were well represented in the sample. The largest percentage of participants (22%) indicated Medical and Health Sciences as one of their major disciplines. Between 10% and 12% of participants indicated one or several of the following four disciplines: (a) social science, humanities, arts; (b) biomedical sciences; (c) information computing and communication sciences; and (d) education. Overall, three major disciplinary clusters were almost equally represented in the sample. Similar numbers (29%) of participants were from social fields and biomedical fields, and slightly fewer participants (25%) were from physical fields. As researchers were allowed to indicate all relevant disciplinary areas in which they specialise, about 18% of them listed disciplines that belonged to different disciplinary clusters indicating that they were involved in multidisciplinary research. A number of participants in the latter category listed computer sciences as one of their disciplinary areas, but overall this category included diverse combinations, such as medical sciences and mathematics.
About 70% of participants were academic staff; 20% were postgraduate research students; 8% were other university staff (mainly general staff, librarians, research assistants, and ICT and research support), and the remaining 2% were visiting and honorary academics. Different levels of research experience were quite evenly represented among the academic staff: 27% of participants were early career researchers; 22% were middle career researchers and 21% were senior researchers.

About 42% of participants answered that they had heard of the term eResearch before the survey, while other 58% had not heard this term before, indicating that the respondents represented different levels of awareness about eResearch. Overall, only one-third (33%) of research students were aware about eResearch; this was followed by a larger proportion of academic staff (42%) and other university staff (58%). Such relatively high awareness among other university staff reflected that some of participants from this category were involved in provision of information services, ICT support and other services related to eResearch.

**Research Collaboration Practices: Extent, Loci and Scale**

Respondents were asked to indicate how much of their research was collaborative. Almost half (46%) the participants indicated that nearly all their research was collaborative, about one-third (32%) indicated that about half of their research was collaborative, while the remaining 21% responded that nearly all their research was individual (Figure 1). Researchers from social fields were involved in collaborative research least often, with more than one-third (35%) of them stating that nearly all their research was individual and less than one-third (32%) of them indicating that nearly all their research was collaborative.

![Figure 1](image.png)

*Figure 1. Involvement of academics and research students in collaborative research in different disciplines*

There were striking differences between research students and academic staff. While more than two thirds (68%) of research students indicated that almost all their research was individual, only 12% of academics gave this answer. While significantly larger proportions of students from biomedical,
physical and multidisciplinary fields were involved in collaborative research than students from social fields, nevertheless differences between academics and research students were significant in all disciplinary fields.

Participants who were more involved in collaborative research were also more likely to indicate that they had heard about eResearch. These answers ranged from 34% of researchers nearly all of whose research was individual, to 46% of those almost all of whose research was collaborative.

Participants were asked to indicate places in which their research collaborations typically occurred. The majority of researchers collaborated within their research groups (70%), with other universities within Australia (52%), and internationally (51%). Fewer researchers collaborated outside their research group but within the same faculty or other faculties within the same university, 37% and 30% respectively. Overall, a majority of researchers were involved in more than one kind of partnership, and only 7% stated that they did not collaborate at all. Significantly fewer research students than academics were involved in all kinds of collaboration and about one third (31%) of students indicated that they were not involved in any collaboration. Nevertheless, more than half (54%) of students indicated that they collaborated in their research group and about one quarter (24%) said that they collaborated with universities outside Australia. Only a small minority of students (9%-16%) were involved in all other types of local and national collaboration.

According to the largest scale of collaboration, the loci of partnership were grouped into four embedded categories: (a) individual (i.e., no collaboration); (b) local; (c) national; and (d) international (see Table 1).

Only 7% of participants were not involved in any collaboration, 12% collaborated only locally, 30% on the national scale and 51% collaborated internationally (Figure 2). In physical fields the majority (59%) of researchers collaborated on the international scale and about three times fewer (19%) researchers collaborated only nationally. In the other two clusters, and in multidisciplinary fields, fewer (43%-53%) researchers were involved in international collaborations, whereas about one third (32%-35%) collaborated on the national scale. There were also significant differences in the loci of collaboration between academic staff and research students. Most noticeably, a significant proportion of students collaborated only locally (25%), while just 9% of academics collaborated only on this scale.
Research partnerships also ranged across university and non-university sectors. A slightly larger percentage (51%) of researchers collaborated only within the university sector, and a slightly smaller percentage (49%) collaborated within and beyond the university sector. In the latter group, one third (33%) of collaborations involved non-academic partners and just above one-fifth (22%) of collaborations involved non-university research agencies. A majority of researchers from multidisciplinary fields and about half of researchers from biomedical fields collaborated beyond academia, 63% and 51% respectively. However, only 44% of researchers from social and physical fields were involved in such partnerships. Fewer than 1% of researchers who collaborated beyond the university sector did not collaborate within it.

**Communication Technologies in Collaborative Research**

Respondents were asked to indicate what kinds of technologies they used for communication and project management in their collaborations and how often they used them. Face to face meetings remained an important form of communication that was used often by 60% of participants and occasionally by the other 38%. The most common media for research collaboration used often or occasionally by more than 93% of respondents were emails and telephone. Between 29% and 57% of researchers also at least occasionally used various ICT-based tools for synchronous communication, such as audio and videoconferencing, but fewer than 15% of researchers used these tools often. Collaboration media for asynchronous communication (other than email) were used less often and by fewer researchers. For example, fewer than one third of participants used Web2.0 tools (33%), collaborative document writing (26%) and social networking (18%) even occasionally, and only between 12% and 14% used any of these tools often. Further, about 95% of respondents did not use virtual research environments and about 88% did not use special project or task management tools.

Various communication tools were used differently in various disciplinary clusters. In particular, researchers from biomedical fields more often than researchers from physical fields used some traditional media communication tools, such as the telephone. For example, more than 63% of
researchers in biomedical fields used the telephone often and only 2% did not use it; meanwhile only 37% of researchers in physical sciences used telephone often and nearly 18% of researchers did not use the telephone at all. In contrast, a significantly larger proportion of researchers from physical disciplines than those in the biomedical disciplines often used ICT-based communication and sharing tools, such as Web2.0 (20% and 2%, respectively), file sharing (24% and 9%), collaborative writing (11% and 2%), and videoconferencing (24% and 2%). This was despite the fact that researchers in physical fields were generally less intensively involved in collaborative research than researchers in biomedical fields. It was interesting to note that most intensive users of social networking tools were researchers from social disciplines, where 27% of participants used this media at least occasionally. This was in sharp contrast to biomedical fields, where only 9% of researchers used this medium.

Generally, academic staff tended to use communication technologies more intensively than research students, and these differences were statistically significant for telephone, email, audio conferencing, videoconferencing and file sharing. This finding partly reflected lesser need for communication media among research students, who were generally less involved in collaborations, since researchers who were involved in collaborative research to a lesser degree tended also to use a similar range of communication tools less often. Nevertheless, students used some of collaboration tools less often than academics independently of the degree of their involvement in research collaborations. For example, two thirds (66%) of academics about half of whose research was collaborative at least occasionally used audio conferencing, whereas just above one third (35%) of research students about half of whose research was collaborative did so.

Further, it was interesting to note that 75% of researchers who were involved only in local collaborations communicated face-to-face often, while just above half (56%-58%) of researchers who collaborated nationally or internationally communicated often in this way. In contrast, the latter two groups significantly more frequently used a range of technologies, including the telephone (particularly those who were involved in national collaborations), email, audio and videoconferencing, Web 2.0 tools, file sharing and social networking (Figure 3).
Dissemination of Research Findings

Respondents were asked to indicate what kinds of dissemination methods and technologies they used and how often they used them for disseminating their findings. Conventional publishing (e.g., journals, books, proceedings) was the main form of research dissemination used often or occasionally by almost all (97%) researchers. About two-thirds (67%) of participants also at least occasionally published in online proceedings, 60% published in e-journals and 46% published in open access e-journals. Between 38% and 45% of participants used institutional, project or personal websites, blogs or wikis and institutional repositories to disseminate their research findings. However, less than one-fifth (15%-19%) of researchers used digital disciplinary repositories for disseminating their research or published in open access, commercial or scientific societies’ e-books. Overall, researchers on average indicated more than four dissemination channels out of twelve that they used at least occasionally \((M = 4.5, SD = 2.55, n = 738, Median = 4; Mode = 5)\). However, more than half (56%) of researchers often used one or two main dissemination strategies \((M = 1.9, SD = 1.78, n = 738, Mode = 1, Median = 2)\).

Similar proportions of researchers from all disciplinary fields disseminated their findings via open e-journals. Nevertheless, there were some significant differences between the disciplines in many other forms of dissemination. Most noticeably, researchers from biomedical fields more often published in traditional journals than researchers from other fields, whereas researchers from physical fields more often used various digital forms of dissemination. For example, 5% and 44% of researchers from biomedical and physical fields respectively indicated that they disseminated their research findings via digital disciplinary repositories. It was interesting to note that a relatively large proportion of researchers from social fields also used various digital forms to disseminate their findings, but the majority of them did this occasionally rather than often.
Research students tended more often than academics to disseminate their findings via e-books, while academics more often than research students used conventional publishing, e-journals and project wikis. Overall, academics on average used often or occasionally a slightly broader range of dissemination strategies: academics $M = 4.7$, $SD = 2.50$, $n = 551$; students $M = 4.1$, $SD = 2.72$, $n = 135$; respectively, $t = 2.218$, $p < .05$.

Some forms of research dissemination were also associated with the degree and scale of research collaboration. Some of these differences were distinct for academics and research students. Most notably, academics who were more involved in collaborative research also significantly more often disseminated their results via departmental and project websites, but they and less-collaborating researchers used equally often all other forms of dissemination, including conventional publishing, individual websites, wikis and repositories. In contrast, research students used all digital forms similarly often, independently of the degree of their research collaboration. However, research students who were more involved in collaborative research disseminated their findings significantly more often via conventional publishing. Specifically, more than four-fifths (82%) of students whose almost all research was collaborative used often conventional publishing, while just above half (54%) of students whose only half of research was collaborative did this and only 38% of those almost all of whose research was individual published often in conventional scholarly sources. This result indicated that research students involved in collaborative research perhaps have more opportunities to be co-authors of joint peer reviewed research papers.

Overall, some digital forms of research dissemination – such as digital repositories, departmental, project and personal websites – were apparently more often used by those who collaborated on a broader scale and particularly by those who were involved in international partnerships (Figure 4). For example, 54% of researchers who collaborated on international scale disseminated their findings via departmental websites, while only 37% of researchers who only collaborated nationally and 33% of those who were involved only in local collaborations did this.
Enhancing Digital Collaboration and Dissemination

Respondents were asked to suggest three main areas of research collaboration and dissemination that would most benefit from ICT support. The range and frequency of common words and phrases used in participants’ answers are represented in Figure 5. Among many other needs, the largest number of researchers indicated the following three areas: (a) needs related to web-based technologies, such as project websites, wikis and blogs for enhancing general online presence (36%); (b) a range of needs related to data and information handling and sharing, such as data archiving in online data repositories (33%); and (c) synchronous communication, such as videoconferencing (28%). Researchers also often indicated a range of needs related to e-publishing, and a need for tools for shared work in online spaces, such as project management software, virtual research environments, and collaborative document writing.
Data Collection and Sharing Practices

Respondents were asked to indicate how often and in which ways they obtained their data. A very large majority at least occasionally collected or created data themselves (94%) or as part of a team (89%); and a large majority (71%) indicated that they often collected data themselves. A significant majority of participants also obtained data directly from other researchers (71%), data archives and repositories (59%), and third party organisations (58%), but most researchers did this occasionally, 52%, 34% and 42% respectively. Similarly, about one quarter (26%) of participants occasionally obtained data from commercial online sources, but only 6% did this often. Overall, researchers on average indicated just less than four sources out of seven that they used at least occasionally (M = 3.9, SD = 1.43, n = 704, Median = 4, Mode = 3). However, two-thirds of researchers (66%) often obtained their data in one or two major ways (M = 1.9, SD = 1.17, n = 704, Mode = 2, Median = 2). Overall, the results indicated that the majority of researchers often collected data themselves or as a part of research teams and, while they obtained data from a variety of sources, 61% of researchers used secondary data sources only occasionally. Nevertheless, a large minority (39%) of researchers indicated at least one secondary source that they used often.

There were significant disciplinary differences in how researchers obtained their data (Figure 6). Just less than three-quarters (72%) of researchers from biomedical fields often collected their data as a part of project team, whereas just over half (55%) the researchers from physical fields and less than half (47%) from social fields did this. In contrast, a large minority (44%-48%) of researchers in the latter two fields at least occasionally re-used data collected by others, while only 27% of researchers from biomedical fields did this. It is interesting to note that researchers from the social and physical fields obtained existing data in rather distinct ways as well. Specifically, about-one third (33%) of researchers from physical fields often obtained their datasets directly from other researchers, while only 10% of researchers from social fields often obtained their data directly from other researchers. In contrast a relatively large proportion of researchers from social fields at least occasionally used data from third party research organizations (70%) and commercial online sources (46%), while fewer researchers from physical fields ever obtained their data in these two ways, 54% and 20% respectively.
The degree of involvement in collaborative research was associated with specific data collection methods in particular ways. Specifically, researchers whose larger proportion of research was collaborative, more often collected data as a part of their research teams and more often obtained data directly from other researchers. For example, a little more than half (52%) of those for whom almost all of their research was individual occasionally or often obtained data directly from other researchers, while more than three-quarters (78%) of researchers almost all of whose research was collaborative did this. In contrast, researchers for whom nearly all of their research was individual, significantly more often obtained data from archives and repositories and commercial online sources (Figure 7).

As fewer research students than academics were involved research collaborations, fewer research students than academics collected data as a part of research teams (68% and 94% respectively) or received data directly from other researchers (62% and 74% respectively). While a similar and relatively large proportion (59%) of academics and research students obtained data via third party organizations, in contrast, significantly more students than academics often obtained data in this way, 26% and 16% respectively. Many of these differences between research students and academics remained significant even when the degree of their collaboration was taken into account. For example, 62% of academics for whom about half of their research was collaborative often collected their data as a part of a team and 13% often obtained data from third party organizations, whereas only 46% of research students for whom about half of their research was collaborative often collected their data as a part of team and 29% often obtained from third party organizations.
Respondents were asked if they would allow researchers from outside their team or project to access their research data. Half of participants (50%) did not allow access to any of their data, while 41% allowed access to some of their data and only 9% provided access to all their data. The largest majority (62%) of researchers who did not allow access to the data were those from social fields. This was followed by a slightly smaller majority (55%) of researchers from biomedical fields who also did not share their data. In contrast, significantly more researchers from physical fields shared at least some of their data, and only slightly more than one-third (36%) of them did not allow access to any of their data. Researchers who were more involved in collaborative research typically also allowed access to more of their data to other researchers beyond their project team. For example, only 29% researchers nearly all of whose research was individual shared at least some of their data, while nearly double that (59%) of researchers nearly all of whose research was collaborative did so.

This latter finding was mirrored in the differences in data sharing patterns between research students and academics: while only about one-third (34%) of research students provided access to at least some of their data, more than half (54%) of academics did so. This difference reflected lesser student involvement in research collaborations and was insignificant once the degree of collaboration was taken into account. For example, quite similar proportions of research students and academics for whom almost all research was individual did not provide access to any of their data, 73% and 69% respectively.

Of those researchers who allowed access to their data, about three-quarters (74%) provided privately negotiated access. Slightly more than one-third (35%) of participants also published data online; 29% submitted data when they published in e-journals; 22% deposited their data to repositories; and only 14% provided access via a third party. Researchers in biomedical fields exhibit quite different data...
sharing practices than the other two fields. For example, only 10% of researchers from biomedical fields published data online, whereas 88% provided privately negotiated access. In contrast, 44% and 69% of researchers in social fields, and 49% and 67% of researchers in physical fields respectively published online and privately negotiated access to their data. Nevertheless, there were no significant differences between the data sharing practices of academics and research students, and these data sharing strategies were not related to the involvement in collaborative research.

Participants who applied restrictions on access to their data were asked to indicate the reasons for these restrictions. The top two reasons were privacy and confidentiality issues (58%) and competitive research advantage (43%). About one fifth of participants (19-22%) indicated other obstacles, such as commercialisation potential, ethical issues, technical difficulties, lack of incentive and licensing issues. Only 16% of researchers saw a lack of usefulness of their data for others, and only 6% of respondents had no reasons for such restrictions.

Some concerns varied across disciplinary fields. Specifically, privacy and confidentiality were an important reason for imposing restrictions on access for almost three-quarters (73%) of researchers from social fields and slightly smaller majority (64%) of researchers from biomedical fields. In contrast this was a reason for restrictions for only about one-third (36%) of researchers from physical fields. While overall other ethical issues were mentioned by fewer researchers, similar disciplinary differences were observed in their answers. Rather differently, commercialisation potential was an important reason for restricting access to their data for about one quarter (23%-25%) of researchers from the biomedical and physical fields, and only for 9% of researchers from social fields. More than one quarter (28%) of researchers from physical fields also noted technical difficulties, but this was an important concern for significantly fewer researchers in biomedical and social fields, 17% and 14% respectively. It is interesting to note that there were no differences between the obstacles indicated by academic staff and research students, except for lack of incentive. The latter reason was mentioned by 21% of academic staff and only 10% of students.

There was no association between the degree of involvement in collaborative research and reasons for restrictions, but the scale and nature of collaboration were associated with some obstacles. For example, competitive research advantage, licensing and technical difficulties were important concerns for significantly larger proportion of researchers involved in international collaborations than others. Further, those who were involved in non-university partnerships indicated commercialisation potential as a reason for restrictions almost three times more often than those who collaborated with university partners only (31% and 11% respectively).

eResearch Collaboration in Future Research Practices

In order to gain insight into researchers’ views about the potential of eResearch, participants were asked to indicate how important they thought eResearch will be for the future progress of their research field, and to describe the three specific most important applications of ICT and the three most important challenges related to this in their research field. More than two-thirds (69%) of researchers answered that eResearch is very important or important, and a further 21% said that it is moderately important. Only less than 8% of participants thought that eResearch is of little importance or unimportant, and only 2% said that eResearch is not relevant to their research. There were no significant differences between the answers of researchers from various disciplinary fields, at various stages of career or involved in various kinds of collaborative research to different extents. This indicated that researchers from all domains and with different experiences saw quite significant potential for eResearch.

Researchers indicated a broad range of future applications of ICT important for their research fields. ‘Analysis’, ‘access’, ‘storage,’ ‘data’ and ‘collaboration’ were the most frequent words used to describe these applications and emerging opportunities in participants answers (Figure 8).
Interpretative analysis and categorisation of these responses showed that the largest number (46%) of researchers who answered this question mentioned new analytical opportunities related to data-driven and computation-intensive methods, such as data mining, modelling, visualisation, as well as other ICT-based analytical tools. About one third (31%) of participants listed various applications and opportunities related to data, such as management, archiving, access and sharing. About one quarter (26%) of researchers indicated applications directly related to research collaboration, such as opportunities to work on projects with overseas partners, jointly analyse data and write papers.

Figure 8. One hundred words and phrases most often used by participants to describe the most important future applications of ICT in their research field

In the answers about the most important challenges for the application of ICT in their research field now and in the near future, participants frequently mentioned ‘support’, ‘access’, ‘storage’, ‘data’ and lack of resources, including time and funding (Figure 9). More than one quarter (29%) of researchers indicated the lack of specialised and general ICT expertise needed to harness eResearch opportunities. Slightly fewer researchers (27%) indicated concerns related to data storage, management and sharing, and similar number of researchers (27%) expressed concerns about ICT policies and administration. Only 8% of researchers indicated concerns related specifically to collaboration, such as competition or difficulties of working in a team, indicating that researchers overall did not have significant concerns that would prevent them from engaging in collaborative eResearch practices.
DISCUSSION

This chapter has analysed some findings about research collaboration from a larger study on eResearch practices and needs for support (Markauskaite, Aditomo & Hellmers, 2009, 2011), and specifically has focused on the analysis of ICT-enhanced collaboration practices and challenges reported by researchers from seven universities in the Australian state of New South Wales (NSW). The sample, as noted previously, was not representative of the university research population in Australia or in NSW, and the findings cannot be generalized to these populations. Nevertheless, the survey sample was large, and it well represented researchers from various disciplinary fields, at various career stages and involved in various kinds of collaboration. The findings, therefore, are primarily instructive for understanding disciplinary differences, and how researchers’ experience and involvement in various kinds of collaboration relate to their eResearch practices.

Less than half the researchers had previously heard about eResearch, indicating that general awareness about eResearch was rather limited, but as was found in some earlier studies conducted primarily in the European countries (Barjak, 2007; Dutton & Meyer, 2009), many researchers were positive about ICT use in research and collaboration, and acknowledged significance and potential of ICT-enhanced research practices for research progress in their fields. Many researchers were involved in some kinds of collaboration, with only 7% of participants not involved in any collaboration at all. Nevertheless, there were significant differences between research students and academics and disciplinary fields and, overall, not all researchers collaborated equally intensively. In general, results indicated that those who collaborated more intensively also tended to use ICT-enhanced collaboration tools and dissemination strategies more often, and shared more of their data than those who collaborated less.

There were essential gaps between the widespread adoption of some general purpose ICT-enhanced communication and collaboration tools, such as email, and the much less common use of specialised research collaboration tools, such as virtual research environments and project management software. Further, significant number of researchers indicated their willingness to adopt some synchronous communication tools, data and information sharing technologies, such as videoconferencing, wikis, blogs and file sharing. These tools generally do not require researchers to codify their knowledge or significantly (re)structure their data, and therefore perhaps could be more easily integrated with...
existing research practices, in comparison with other technologies for distributed research that require compliance with standards and the restructuring of data, such as integrated data repositories.

A significant proportion of researchers see virtual communication and collaboration among the three most important aspects of eResearch for research progress in their field. While many researchers indicated that they need support in this eResearch area at this stage, very few researchers mentioned that collaborative eResearch might be an important challenge in future. This positive vision nevertheless was primarily related to team-based collaboration, and did not encapsulate data management and sharing that were also perceived as important challenges.

Results of the study indicate that researchers from different disciplinary fields collaborated to different extents and were involved in different types of collaboration, confirming again that ways of doing research and patterns of collaboration vary across different research fields and disciplinary communities (Becher & Trowler, 2001; Katz & Martin, 1997; Meadows, 1998). Further, this study indicates that researchers from different fields also tend to use different media for collaborating and disseminating. The biomedical fields appeared to be intensive users of the telephone, most likely reflecting that these fields have more established collaboration traditions, while social sciences were more intensive users of social networking reflecting that these fields are more receptive to new digital scholarship practices and open forms of dissemination (Greenhow, Robelia, & Hughes, 2009). Rather differently, physical scientists were intensive users of many teamwork tools such as Web 2.0 approaches, collaborative writing and videoconferencing, reflecting that some forms of team-based collaboration, such as those captured through measures of co-authorship (Borgman, 2007), are more pervasive in this research cluster.

A number of researchers mentioned data as one of most important future eResearch application areas. Interestingly, some of them referred to storage, archiving and management, rather than sharing, integration or re-use of these data resources. A number of researchers also indicated that they see data and data management as important challenges, and that they need support in this area.

Only half of researchers provided access at least to some of their data. The largest group of researchers who did not enable access to their data were those from the social fields. As reported in the literature (Barjak et al., 2009; Borgman, 2007), data de-identification and “cleansing” for ethical reasons require substantial work and sometimes may be impossible, particularly in social sciences. Overall, the two major reasons for not sharing data were privacy and confidentiality, and competitive research advantage, with the former being a barrier for significantly larger proportions of researchers in social fields, and the latter for significantly larger proportions in biomedical and physical fields.

Traditional publishing was still the main way for disseminating findings demonstrating that changes in the form of scholarly dissemination over the last decade have not been very large (Borgman, 2007; Kling & McKim, 1999). Nevertheless, a number of researchers indicated several common areas of ICT-enhanced dissemination in which they need support. Researchers particularly saw as beneficial “in-house” dissemination approaches, such as institutional or project websites, wikis and blogs, and integrated disciplinary and institutional repositories. However, very few researchers mentioned ICT-enhanced dissemination among the most important aspects for future progress of their research field, and it was rarely mentioned as a future challenge. This finding reflects the ready availability of Web 2.0 tools and the existence of institutional repositories in Australian universities (Kennan & Kingsley, 2009). What is perhaps required more here is the time to investigate and learn to use existing infrastructure, and technical assistance with initial setup and maintenance.

Overall, while researchers still focused on more traditional one-to-many dissemination in their answers about current needs, this focus shifted towards collaborative knowledge creation practices in their answers about future eResearch potential. Least advanced, most promising and most challenging aspects of collaborative eResearch were data-related collaborative research practices. While
researchers often mentioned technical needs and challenges, many of their concerns were related to their own expertise and needs for technical support – what David (2006) called “soft infrastructure”.

Overall, there was a noticeable difference between researchers’ views about two kinds of collaboration, that we term “team-based” collaboration and “grand” collaboration. Team-based collaboration primarily includes distributed joint work on specific research projects that could be supported by videoconferencing, document sharing, collaborative authoring tools and other group work software. Such distributed yet more focused collaboration sits comfortably with familiar collaborative research routines, and was generally seen by researchers as an enabler of more productive current or near future research practices.

Large-scale “grand” collaboration encompasses shared data repositories, secure virtual organizations and other large-scale infrastructures. Such large-scale collaboration is more open and unpredictable. It typically requires new coordination efforts (e.g., adjusting research routines, standardizing data resources) and, overall, has less immediate and tangible benefits. This mode of eResearch collaboration was also acknowledged by researchers as a big future opportunity, which comes with many challenges. While development of infrastructures for such large-scale collaboration is often supported by large national investments, researchers saw it as a big challenge that requires their time, expertise, support and other efforts.

An alarming finding of this study was low involvement of research students in collaborative research. Almost two thirds of research students reported that nearly all their research was individual and about one third indicated not being involved in any collaborative research. This finding suggested several important implications. First, about half of research students collaborated in their research groups, yet this also indicated that many research students did not view their research degree supervision as collaboration. Meanwhile, as noticed in the literature, the supervisor’s role is a combination of teaching, learning and collaboration, and, in some domains, publications based on the student’s higher degree research are often co-authored by the student and supervisors (Kyvik & Smeby, 1994; Maxwell & Smyth, 2011). Second, the results indicated that students made less use of ICT collaboration tools. This finding was not surprising taking into account that students were less involved in collaborations, and supports results from the “Researchers of tomorrow” study conducted recently in the UK, which indicated that while “X generation” doctoral students might be proficient ICT users, they are risk averse and only like to use new technologies when they see a clear benefit (Carpenter et al., 2010). Nevertheless, even those students who were involved in collaborations tended to use some communication technologies less often than academics. Thirdly, students who are not involved in collaborations were significantly less often involved in established scholarly dissemination practices. This finding indicates that research students involved in collaborative research have more opportunities to gain experience of publishing in peer reviewed journals.

Taken as a whole, these findings indicated that research higher degree students gain little experience of working collaboratively in distributed (disciplinary and multidisciplinary) research teams and little experience of using communication technologies in their research work. While, overall, they express favourable attitudes about technologies and collaboration, the individualistic nature of postgraduate research provides few opportunities to engage in research collaboration.

CONCLUSIONS AND FUTURE WORK
Drawing on a study of ICT-enhanced research practices and needs conducted at seven Australian universities, this chapter has discussed how researchers engage with distributed research and use ICT for collaboration. Results show significant current engagement of the majority of researchers in collaborative research, their acknowledgement of the potential of eResearch, and researchers’ general willingness to engage in collaborative eResearch. Findings also indicate some important relationships
between researchers’ general collaboration practices and their use of ICT for this purpose. While there are some significant differences in the collaboration practices of research students and academics and between practices and challenges in different disciplinary domains, researchers who are more involved in collaborative research also more often use ICT-enhanced collaboration tools; share more of their data; and more often disseminate their findings via digital media.

Results indicate two important discrepancies and tensions between researchers’ current practices of ICT use in their research and their thinking about future eResearch opportunities and challenges. First, there are some essential differences between researchers’ current practices, their short-term needs for eResearch services and support, and their forward thinking regarding the potential for eResearch in their research domain. eResearch collaboration is reported by respondents as one of the most important eResearch opportunities for enhancing their scholarly practices. While many researchers acknowledge that they currently need support in this area, few of them consider it might be a future challenge. Secondly, there is a noticeable discrepancy between two modes of collaboration: (a) ‘team-based’ collaboration that primarily includes distributed joint work on specific projects; and (b) ‘grand’ collaboration that is open, has fewer tangible and immediate outcomes, and requires new coordination efforts. While the former mode of eResearch is generally seen by researchers as an enabler of more productive current or near future practices, the latter mode of eResearch collaboration is a future opportunity and a grand challenge that requires effort and support.

This study has provided some important insights into various aspects of research collaboration, to include researchers’ general collaboration practices, their use of communication technologies for collaborative research, ICT-enhanced dissemination of research findings, and data collection and sharing practices. As our results indicate, researchers have different needs for eResearch and experience different challenges in each of these areas of ICT use for research collaboration. More focussed follow-up studies should be conducted to investigate further most important specific issues, such as research publishing and dissemination strategies and motives, data sharing issues and incentives, and researchers’ needs for discipline-specific collaboration environments, services and support. In-depth studies are also needed to investigate research students’ ICT-use practices and reasons for their low engagement in collaborative research.

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APPENDIX: QUESTIONS FROM THE SURVEY ANALYSED IN THIS PAPER
Research Project: “Co-developing eResearch infrastructure: Technology-enhanced research practices, attitudes and future requirements”.

3. Please identify your major disciplinary area(s)
   Tick all that apply.
   21 - Science (General)
   22 - Social Sciences, Humanities and Arts (General)
   23 - Mathematical Sciences
   24 - Physical Sciences
   25 - Chemical Sciences
5. Please indicate your current primary role.

Postgraduate research student
Academic/research staff: Early career
Academic/research staff: Middle career
Academic/research staff: Senior/long experience
Emeritus, honorary, visiting or adjunct appointment
Other. If other, please specify

6. Prior to this survey, had you heard of the term "eResearch"?

Yes
No

10. How much of your research is collaborative?

Nearly all collaborative
About half
Nearly all individual

11. Indicate where your research collaborations occur.

Tick all that apply:

Within my research group
Outside my research group within my faculty
With other faculties within my university
With other universities within Australia
With universities or institutions in other countries
With non-university research agencies (e.g. CSIRO)
Beyond academia, with industry partners
None (i.e. I am not involved in collaborative research)
Other. If other, please specify
12. When you collaborate, how often do you use the following technologies for communication and project management?
   1 - Don't use; 2 - Use occasionally 3- Use often

   - Face to face meetings
   - Telephone calls
   - Email
   - Discussion fora (e.g. e-lists)
   - Audio conferencing, audio meetings
   - Video conferencing via desktop or laptop software (e.g. Skype)
   - Video conferencing in a dedicated room or facility (e.g. Access Grid)
   - Web 2.0 content management tools (e.g. wiki, blog)
   - File and document sharing tools (e.g. file repositories)
   - Collaborative document writing tools (e.g. Google Docs)
   - Special project and task management tools (e.g. trac, dotProject)
   - Virtual research environments (VRE)
   - Social networking software (e.g. Facebook)
   - Other. If other, please describe

13. Which of the following methods and technologies do you use to disseminate research findings?
   1 - Don't use 2 - Use occasionally 3 - Use often

   - Conventional publishing (e.g. journals, books, proceedings)
   - eJournals published by commercial publishers or scholarly societies
   - Open access eJournals
   - eBooks published by commercial publishers or scholarly societies
   - Open access eBooks
   - Online conference proceedings
   - Digital institutional repository or archive
   - Digital disciplinary repository or archive (e.g. arXiv, SSRN)
   - Departmental/institutional website, blog or wiki
   - Project website, blog or wiki
   - Personal website, blog or wiki
   - Other. If other, please describe

14. List up to 3 main areas of research collaboration and dissemination that would most benefit from ICT support.

16. How often do you use data obtained in the following ways?
   1 - Don't use 2 - Use occasionally 3 - Use often

   - Collected or created by yourself
   - Collected or created as part of a team
   - Acquired directly from another researcher or team
   - Acquired from academic data archives or repositories
   - Acquired from third party research organisations (e.g. the Australian Bureau of Statistics, OECD)
   - Acquired from commercial online sources (e.g. Lexis- Nexis, Financial Times, Euromonitor)
   - Other. If other, please describe

20. Do you allow researchers from outside your team/project to access your research data?
No, none of the data
Yes, some of the data
Yes, most of the data

21. If yes, in which of the following ways do you typically provide access to your data?
*Tick all that apply.*

- Publish data online (e.g. on a public project website)
- Deposit data to open data repositories
- Submit data for publishing when I publish papers in eJournals
- Allow access my data via privately negotiated access
- Access to my data is provided by a third party (e.g. the experimental facility, institution, funding body)
- Other. If other, please describe

22. If there are restrictions on accessing your data, what are the reasons for these restrictions?
*Tick all that apply.*

- Competitive research advantage
- Commercialisation potential
- Privacy and confidentiality issues
- Other ethical issues
- Licensing issues
- Technical difficulty of making data available
- Lack of incentive to make data available
- Lack of usefulness of my data to others
- Other reasons. If other, please describe
- None

29. Have you heard about or used services provided by the following Australian bodies?

1- Never heard of them 2- Heard of them 3- Used their services

- AAF - Australian Access Federation
- ANDS - Australian National Data Service
- ARCS - Australian Research Collaboration Service
- Intersect - an eResearch Consortium of NSW Universities
- NCI - National Computational Infrastructure
- NCRIS - National Collaborative Research Infrastructure Strategy

30. List up to 3 specific ICT technical or human support areas that would enhance your research capacities.

31. How important, do you think, is eResearch for the future progress of your research field?

- Very important
- Important
- Moderately important
- Of little importance
- Unimportant
- Not applicable (ICT is essentially irrelevant)
32. Write up to 3 phrases that describe the most important future applications of ICT in your research field.

33. Write up to 3 phrases that describe the most important challenges for the application of ICT in your research field now and in the near future.

REFERENCES


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KEY TERMS AND DEFINITIONS

eResearch: a set of research activities that use advanced information and communication technologies, including computer networks, large shared databases, remote research instruments, and computational power.

Research students: postgraduate university students that pursue higher research degrees, such as doctor of philosophy or professional doctorate.

Academic staff: teaching and research, and research only university academics at all stages of career.

Disciplinary clusters: three broad groups of academic disciplines and fields of study: social fields (humanities, arts and social sciences); biomedical fields (biological, health and medical sciences); physical fields (physical sciences, chemical sciences, IT, engineering and mathematics).

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1 Terms “respondents,” “researchers” and “participants” all refer to the survey sample and are used interchangeably in this paper. Term “academics” refer to academic and honorary staff only, while term “research students” refers to postgraduate research students.

2 In the rest of this chapter we include other university staff that work in specific disciplinary fields in making comparisons between disciplines, but exclude them from comparisons between academic staff and research students.

3 The rest of the chapter analyses differences separately between researchers involved in collaboration to different extents and between researchers at different career stages. However, in interpreting findings we take into account lesser involvement of research students in research collaboration.

4 Some researchers were involved in both types of non-university collaboration.

5 Word clouds produced using Wordle web-based software (Feinberg, 2009).

6 See endnote v.

7 See endnote v.

8 This number indicates question number in the original survey instrument.
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