OCCASIONAL PAPERS

Collaborating across the sectors

The relationships between the humanities, arts and social sciences (HASS) and science, technology, engineering and medicine (STEM) sectors

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Australian Government

Department of Education, Science and Training

Preface

The world's problems have scant respect for disciplines or knowledge sectors. Key issues now confronting us — global warming, energy insecurities, terrorism—require solutions that harness the talents of all, wherever intellectually located.

Most people feel secure within the narrow confines and well-trodden paths of their own upbringing. For researchers and educators, the disciplines remain powerful units of organisation. Moreover, cross-disciplinary approaches rely upon strong disciplinary expertise.

Similarly, the broad sectors of knowledge—science, technology, engineering and medicine (STEM) and the humanities, arts and social sciences (HASS)—provide time-honoured yet segregated playgrounds for discovery and interpretation.

These sectors uphold different economies and promote different methodologies. Our biggest challenge is to find ways in which these sectors can collaborate better and turn their differences of perspective into pan-disciplinary strengths.

This study has brought together linguists and technologists, engineers and economists, in probing the current limits of cross-sectoral collaboration and proposing less constricted ways of moving forward. Our findings are so unsensational as to border on common sense, yet our recommendations will still be hard to implement. They confront current high rewards for atomised and niche-based thinking. At the same time, the report recognises that collaboration is not appropriate in all situations.

If Australia does truly want to safeguard itself—to 'future proof' itself by being a smart nation—then it will have to find ways forward similar to those now recommended. Cross-sectoral collaboration will need to be a priority in research and in education. And the people who facilitate that collaboration, the 'boundary spanners', will need to be recognised as new heroes.

As well as advocating ways forward, this report provides many examples of current best collaborative practice and policy-making. These examples are provided in boxes in the main text and are also gathered together in Appendices C and G.

I commend these examples as today's valiant attempts to address tomorrow's big issues by cutting across yesterday's inheritance of disciplines and knowledge sectors.

Malcolm Gillies
President
Council for the Humanities, Arts and Social Sciences

17 September 2006

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Executive summary

Some of the most exciting research and education today has little regard for traditional disciplinary boundaries. For example, research to help Australia's ageing population profile brings together medical science, basic biology, engineering, social science and arts and humanities.

The world is turning to multi-disciplinary collaborations to deal with the big issues we face, critical problems such as water shortages, global climate change and threats to national security, human health and economic sustainability. No single discipline has all the answers: we need to provide the flexibility to ensure that the research and education community can pursue investigations across the whole landscape, regardless of discipline or approach.

This report focuses on one particular form of collaboration: 'cross-sectoral collaborations' which combine the talents of the humanities, arts and social sciences with those of science, technology, engineering and medicine. It has looked at the actual and potential benefits of such work, and illustrates these benefits with examples from Australia and overseas.

It identifies the characteristics of successful collaborations: the policies, attitudes and funding that allow collaborations to succeed. It examines the reasons why they sometimes fail: the institutional, cultural and funding settings that impede and stifle collaborative activity.

The report concludes that cross-sectoral collaboration will not flourish in Australia without positive actions by government, funding institutions, researchers and industry. A recent UK initiative, an investment framework for Science and Innovation, calls for "an enhanced culture of interdisciplinary and multidisciplinary research".[1] Our recommendations address this issue by focusing on changing the mindset of those involved in collaborative activity through education and training.

The UK framework highlighted the need for "peer review and funding infrastructure that is supportive of such work". Our report identifies the higher transactional costs of cross-sectoral collaboration and the need for funding and reviewing bodies to take these costs into account.

The recommendations aim to remove disincentives for the research and education which occur at the interface of two or more disciplines. They seek to ensure that the peer review process is fair and appropriate, that reward systems recognise these activities appropriately, and that cross-sectoral collaborations do not fall between the gaps.

The report calls for a 'whole of knowledge' approach, embracing both the humanities, arts and social sciences disciplines and those of science, technology, engineering and medicine, to address the 'whole of government' research priorities.

1 Research Councils UK, Cross-Council Funding Agreement—August 2006. <http://www.rcuk.ac.uk/research/prrcremits.htm>

Key findings

1. Cross-sectoral collaboration provides solutions to problems, commercial products, community services, a more engaged public and end users, and more diverse education opportunities.

2. Cross-sectoral collaboration involves higher transactional costs than other types of collaboration (such as between institutions). Additional time and resources are needed to connect with and understand other disciplines, develop common goals and approaches, and communicate.

3. Participants in such collaborations tend to be disadvantaged by the discipline-based focus of publications and other reward mechanisms such as academic recognition and promotions.

4. Teams and individuals who collaborate across the sectors gain from the process of collaboration. Collaboration promotes creativity and innovation, broadens social and professional networks, and may lead to wider recognition of the work.

5. The seven key ingredients for successful collaborations relate to individuals, teams and disciplinary sectors. These ingredients are desirable for all collaborations, but essential for cross-sectoral activity. Particularly important is an appreciation and acknowledgement of differences in approach between the two sectors. The seven key ingredients are:
   - *Structure and team management* that provide an opportunity for all team members to contribute, with clearly defined roles and a well-structured research plan involving end users
   - *Power distribution* that encourages team members to participate, and a flat management structure that offers scope for the team to take risks and experiment with new approaches
   - *Resources and support* that include specific funding for cross-sectoral collaboration, and infrastructure that recognises the degree of personal interaction required to make the collaboration work
   - *Understanding of commonalities and differences* that encourage team members to establish shared goals in an environment where different approaches and cultures are understood and appreciated
   - *Communication* that is open, with clear processes to guarantee networking opportunities for sharing ideas and discussing problems
   - *Personal traits of team members* that make them suitable for collaboration, such as experience in collaboration, a willingness to build trust and understanding between team members, and enthusiastic champions or leaders
   - *Status and recognition* through publication, promotions and publicity for individual and team achievements; and support and promotion by funding bodies, universities and other institutions so that the value and outcomes of the collaboration are recognised.

Recommendations in summary

1 Promote a new mindset

- Explore cross-sectoral opportunities at a summit of national and state government agencies, universities, relevant R&D organisations, and business and industry groups, with a view to implementing programs to provide incentives and opportunities for increased cross-sectoral work.
- These programs could include support for multidisciplinary conferences, workshops and seminars, and cross-sectoral workshops modelled on Europe's COST program.
- Adopt the European use of the term 'science' to include the social sciences and the humanities (as the European Science Foundation does).

2 Change research behaviour

- Remove institutional impediments to cross-sectoral collaborative research at the organisational and disciplinary levels, by making cross-sectoral research a priority for funding bodies and in national research programs.
- Encourage cross-sectoral research through funding which recognises the real cost of this research, and by establishing a structure to stimulate education, research and development on the big issues confronting Australia.

3 Educate for greater collaboration

- Encourage undergraduate students to develop a better understanding and appreciation of other disciplines and sectors and 'to think outside the box', by participating in cross-disciplinary courses without risk to their career development.
- Develop new teaching courses that cross disciplines and inform wider teaching and research practices; and amend the DEST information survey and the weighting of the HECS scheme in order to place a higher value on these courses.
- Mandate a balance of disciplines in the final two years of school education.

4 Train 'boundary spanners'

- Train the 'boundary spanners', the Masters and PhD students working with a foot in both camps, through a semester program in communication, team management, and the different approaches of different disciplines.

5 Coordinate and advocate cross-sectoral collaboration

- Establish an institute for collaboration, to train, coordinate and advocate for cross-sectoral collaboration through short-courses, seminars and events. It would develop good practice in collaboration. This body would become a champion for collaboration, showcasing examples of successful collaboration through the media, at events or festivals, and at conferences.

The recommendations are set out in detail in Section 6 below.

1. The research project

The Council for the Humanities, Arts and Social Sciences (CHASS) was established in 2004 as a peak representative body for the humanities, arts and social sciences sector.

In December 2005, CHASS was commissioned by the Department of Education, Science and Training (DEST) to undertake a research project 'The relationships between the humanities, arts and social sciences (HASS) and the science, technology, engineering and medical (STEM) sectors'.

CHASS contracted Econnect Communication to implement the project in association with Communication Partners from the University of Queensland. A Reference Committee was appointed to advise on the scope and methodology, identify areas for investigation, disseminate project ideas, suggest case studies and provide advice, particularly on the case studies. (See Appendix H for a list of committee members).

1.1 The importance of cross-sectoral collaboration

The challenges of the 21st century have increased global initiatives and programs to strengthen national economies through innovation and creativity. Traditionally, such programs have relied on science and technology to provide the solution.

The March 2004 DEST report, *Review of closer collaboration between universities and major publicly funded research agencies*, looked at different forms of collaboration and its benefits, barriers, drivers and facilitators. The focus was on collaboration in science and technology organisations, a point illustrated in its background section:
Improved research outcomes are critical for the Australian Government's overall science and innovation policy objectives. These can be achieved from more efficient use of resources through enhanced critical mass and strengthened institutional performance.

This emphasis on innovation in the STEM sector is a manifestation of the 'two cultures' divide—the rift between the sectors in the wake of an exponential knowledge explosion and the subsequent hyper specialisation of knowledge and disciplines (Snow 1959).[2] The divisions created in this environment lead to significant problems, such as the increasing disconnection between the problems Australia faces and the discipline-based institutions and resources available to address them (Cunningham 2005; PMSEIC Working Group 2005.)

Calls for a fresh approach to innovation in Australia have been persistent (Cunningham 2004; Gillies 2005). Solving many of our big problems—water conservation, security, climate change and Indigenous health—requires flexible and meaningful cross-sectoral collaboration that draws on the best resources available. This does not discount the importance of single-discipline approaches or other types of collaboration, but cross-sectoral collaboration have advantages in dealing with complex problems.

Imagine Australia (the Prime Minister's Science, Engineering and Innovation Council PMSEIC, 2005) called for more recognition of creative industries within the research environment to achieve greater innovation. Increasing collaborative activity was a key recommendation: 'Realise Australia's full creative and innovation potential by undertaking measures to promote broader cross-disciplinary and cross-sectoral teaching and research'. Cross-sectoral collaboration also featured in other recommendations in the report.

2 All works cited in this report are listed at the end of the literature review in Appendix A.

This report builds on work that investigates collaboration in the STEM sector, and on calls for more recognition of the role of the HASS sector, by examining the value of collaboration across the sectors.

One view that emerged from our research is that cross-sectoral collaboration is necessary to solve Australia's social, environmental, health and economic problems. Problem solving was one of the main motivators that drove collaborative activity.

Problem-solving case study: Tsunami warning system

An independent working group of the Prime Minister's Science, Engineering, and Innovation Council (PMSEIC) produced an integrated approach to tsunami science in Australia. The group included experts in geosciences, meteorology and social sciences, and emergency services, community assistance organisations and related groups.

Its report was presented to the Prime Minister at the 14th meeting of PMSEIC on 2 December 2005. The report sets out practical initiatives and recommendations to improve emergency management coordination, encourage scientific collaboration, and raise community awareness.

More information:
http://www.dest.gov.au/sectors/science_innovation/publications_resources/profiles/tsunamis.htm

1.2 The purpose of the project

The purpose of the project was to identify the key ingredients of successful HASS–STEM collaborations and use these to develop strategies to increase success in future collaborations. We set out to:

- describe the HASS–STEM collaborative environment in Australia and overseas
- scope the breadth of HASS–STEM collaboration
- identify the key ingredients of successful collaborations, as well as the main barriers and impediments
- identify situations in which collaboration is effective
- devise best-practice strategies for researchers, practitioners, institutions, other research agencies and government to help facilitate successful collaboration
- explore other areas of research, education and practice where collaborative approaches would be useful.

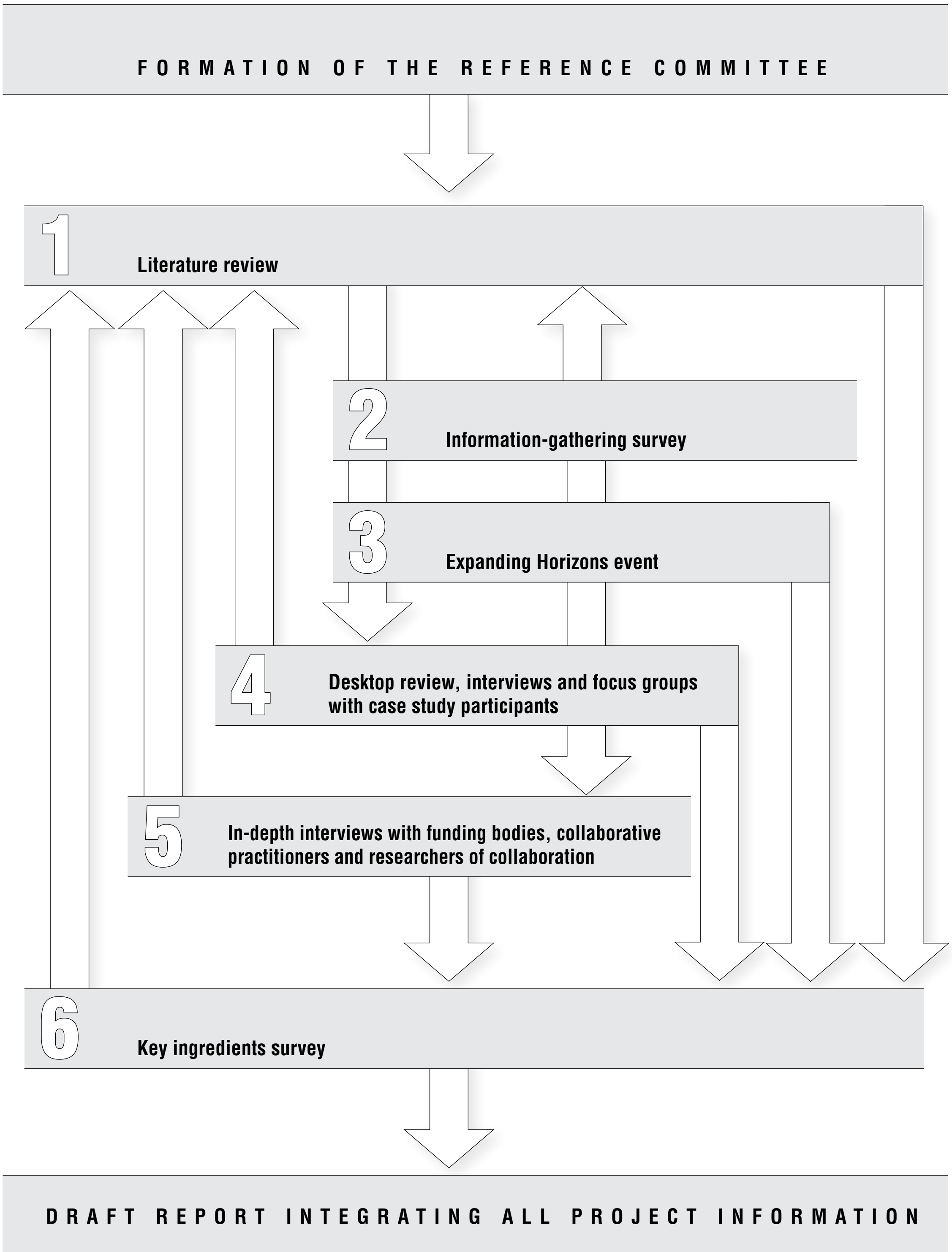
1.3 How we carried out the research

The research questions called for a mix of qualitative and quantitative methods. The project was broken down into a number of data collection 'phases' (see Figure 1), with the results of earlier phases informing the later phases. Data was gathered through surveys, focus groups, workshops and structured interviews. The results were 'triangulated', with the findings of one research tool testing the results of the next phase.

The most important phase involved the case study research (step 4 in Figure 1). The two web-based surveys (steps 2 and 6) were useful for gathering general information about cross-sectoral collaboration to inform the project and check data, but they are not truly representative of cross-sectoral collaboration in Australia, so caution is needed in their interpretation. Time and resource constraints limited the degree and depth of critical data analysis that could be carried out.

Details on the aims and methodology employed in collecting and analysing data in each phase is contained in Appendix J.

Figure 1: Phases of the project



2. The current collaborative environment

2.1 HASS–STEM relationships

Collaboration depends significantly on the development of effective relationships, both between members of collaborative teams and between the HASS and STEM sectors. It is important to begin with a clear definition of cross-sectoral collaboration. Over time, the HASS and STEM sectors have developed useful and productive relationships that operate at a number of different levels.

In many cases these relationships are simple and one-directional, with one sector using the tools of the other. For example, tools from the social sciences can make the physical sciences of genetics, nanotechnology and environmental science more palatable to the community—HASS is brought in to help STEM. Similarly, advances in science and computer technology provide creative artists with new tools and inspiration. While these relationships may be useful and productive, they are not collaborations across the HASS and STEM sectors.

Collaboration across sectors occurs when one or more members of each sector combine their efforts to solve common problems and reach common goals (Reback et al 2002). Complementary but dissimilar resources, approaches and skills are brought together, so the whole is greater than the sum of its parts. Cross-sectoral collaboration can also be more cost-effective, although high transactional costs need to be acknowledged (this aspect is explored in more detail in Section 3).

Cross-sectoral collaborations may act as a catalyst for new projects and activities that provide economic prosperity and better quality of life. With time, they can also result in the creation of newly conceptualised subject areas, such as environmental management, medical humanities and science communication. But while emerging fields link HASS and STEM in new ways, they do not necessarily involve collaboration, for example when the approaches and practices of both sectors can be combined in a single individual who takes the tools of one sector to apply to the other.

Research organisations such as CSIRO and Land & Water Australia are supporting major 'integration' initiatives to build more substantive and in-depth cross-sectoral collaboration. Researchers from the Australian National University are investigating and supporting a new transdisciplinary area of integration and implementation sciences to gather and harness knowledge that currently falls between the disciplines (Bammer 2006).

Integrating HASS and STEM: Recycled water acceptable to society

Determining the social, economic and technical viability of water reuse is vital for Australia's future. A major collaborative project between social psychologists, engineers, water researchers, hydrologists and the water industry is investigating water reuse in Western Australia.

Reuse will only be socially and economically viable with the support of the affected communities in the state's southwest. The project is being carried out by Water for a Healthy Country, a CSIRO National Flagship.

It integrates information on water reuse technology, including social acceptability, capital and operating costs, water quality, opportunities to link with waste energy, potential scale, human health risk, environmental impact, and waste discharge and management.

More information: http://www.healthycountry.com.au/SWWesternAus/WaterReuse/index.htm

HASS–STEM relationships can overlap in some fields. For example, technology makes new forms of expression possible, and new technologies make the creative process easier (Centre for Creative Communities 2006). In a highly competitive international environment, creativity needs to be usable within a country's innovation system. Some of the most exciting developments in the arts are using multimedia and cybertechnology at the boundaries of HASS and STEM in genuine collaborations between the sectors. In some cases, this results in an emerging field.

An emerging field: Spatial and information architecture

The way we understand space is emerging as a new field: spatial and information architecture.

The Suburban Communities project aims to develop tools to help households, community groups and neighbourhoods use information and communication technologies to design better community spaces in urban areas. The project is supported by the Spatial Information Architecture Laboratory based at the Royal Melbourne Institute of Technology.

The laboratory is a transdisciplinary education and research centre that brings together artists, architects, designers, composers, computer scientists, geospatial scientists, performers, social theorists and philosophers to research strategies for viewing and managing information.

More information: http://www.sial.rmit.edu.au

There is debate about the placement of some disciplines in HASS or STEM, particularly about mathematics, statistics, psychology, science communication, environmental science, epidemiology, science education and engineering education (Halsey 2004).

Studies of cross-sectoral collaboration use terms such as 'interdisciplinarity', 'multidisciplinarity' and 'transdisciplinarity'. The literature reveals inconsistent use of these terms, but there are some generally agreed working definitions:

- Researchers undertaking *multidisciplinary* activities work in parallel within the different disciplines, without altering their disciplines' approaches or developing a common framework. Any integration happens at the end of the project or is provided by the reader of the work.
- *Interdisciplinarity* is defined as a type of academic collaboration that draws specialists from two or more different academic disciplines to work together in pursuit of common goals. It requires a small number of disciplines working in the overlaps between disciplines, and through this collaboration new fields are formed.
- It is less common for *transdisciplinary* research to develop into a new field. Grigg (1999, 4) quotes the Organisation for Economic Co-operation and Development's definition of transdisciplinarity (OECD 1998) as 'at once between the disciplines, across the disciplines and beyond all disciplines'.

Our project focused on collaborative work that includes interdisciplinary and transdisciplinary activities, rather than multidisciplinary work.

Innovation is defined as the generation, translation and implementation of new ideas into practices (Roberts and Bradley 1991, 212). The Australian Research Council (ARC), referring to collaboration across universities rather than across sectors, sees collaboration as crucial to innovation:

Collaborative links stimulate innovation by facilitating crosscutting interactions and a free flow of ideas and knowledge. Innovation generally occurs more rapidly and with greater intensity in situations in which there is a higher degree of collaborations. (ARC 2003)

2.2 Policy environment

The recent report *Creative community building through cross-sectoral collaboration* gives an overview of European Union, United Nations Educational, Scientific and Cultural Organisation (UNESCO), Council of Europe and OECD policies and funding programs (Centre for Creative Communities 2006). Each of these initiatives acknowledges the need to create political, economic, social and technological infrastructure that facilitates cross-sectoral collaboration; each calls for new innovation models with policies and funding programs that encourage sectors to work together.

Many countries recognise the need for a more integrated approach to innovation systems, and the consequent demand for policies to make cross-disciplinary and HASS–STEM research collaborations easier.

Australia's current policy environment for collaborations tends to emphasise science as the sector that will secure our social and economic future. For example, the government's 2004 Budget initiative, *Backing Australia's Ability—Building our Future through Science and Innovation*, which provides $5.3 billion over seven years, has an obvious science focus. But one component that focuses on the government's National Research Priorities is relevant to cross-sectoral collaboration: CSIRO National Flagships, which provide $305 million for large-scale collaborative research partnerships that reflect the National Research Priorities. Three of the six National Flagships have substantial collaborative streams that involve significant social science components—Water for a Healthy Country, Wealth from Oceans, and Energy Transformed.

Current National Research Priorities

1 An environmentally sustainable Australia

2 Promoting and maintaining good health

3 Frontier technologies for building and transforming Australian industries

4 Safeguarding Australia

The current priorities were announced in 2002 and refined in 2003 'to take greater account of the contributions of social sciences and humanities research'.

(http://www.dest.gov.au/priorities/)

CSIRO further responded to the National Research Priorities by developing the Social and Economic Integration initiative. This supports a range of innovative cross-sectoral projects, such as the 'greener cities' project, which brings together remote sensing data and social and demographic information to provide new insights into the health impacts of urban design.

A CSIRO interviewee in our project said:

If we want to understand complex systems that have people in them, you need to understand the social component. It's a dynamic part of these systems. For example, how much water we should secure from the Murray River. The issues are environmental, legitimacy and fairness issues around this research. These issues *highlight collaboration as a crucial and integral part of the whole research agenda, rather than something that facilitates 'post-research' adoption. Most of the work [the Social and Economic Integration initiative] supports or encourages is around getting a better understanding of these research problems where people are an integral part of the system.*

The HASS sector in general has fewer resources available to respond directly to policies like the National Research Priorities. It has less infrastructure and resources to attract STEM collaborators or industry partners or to commercialise its work.

For example, research by industry involving the humanities, arts and social sciences is specifically excluded from the R&D tax concession. In the Round 2 of the 2005 ARC Linkage projects, based on RFCD (research fields, courses and disciplines) codes, 168 grants involving STEM research were provided, compared with 82 grants for HASS activities.[3] While cultural institutions are often industry partners in ARC Linkage projects, to be eligible for the Australian government's R&D tax concession, organisations must be registered companies and activities must be aimed at solving technical problems or resolving technical uncertainty. This is judged under current Government settings to be the sole prerogative of the sciences.[4]

Australia's National Research Priorities have been criticised for their science-centric focus, and lack of recognition for the contribution of the humanities, arts and social sciences to the nation's wellbeing. The case for recognising the commercial and public-good benefits of HASS work has been made a number of times, recently in the PMSEIC report *Imagine Australia* (2005). This report says that, with advances in information and communication technologies, there is a need to include the cultural sectors as powerful engines of sustainable economic growth. We note that the Priorities are scheduled to be reviewed.

The need to stay competitive, together with the desire to sustain problem-solving capacities and resources, is driving Australian innovation policy towards a more comprehensive and integrated strategy (PMSEIC Working Group 2005). This would help main our competitiveness with the world's exemplary innovation economies such as the United Kingdom, Finland, Canada, China and New Zealand.

The call to link HASS and STEM in the context of education is also becoming stronger in Australia. 'Education is the very incubator of innovation', said Malcolm Gillies in his 2005 address to the National Press Club, 'Rethinking Australian innovation'. He said we need to connect these sectors more closely to develop potential talent. Measures to promote broader cross-disciplinary and cross-sectoral teaching and research suggested by the PMSEIC Working Group (2005) include introducing integrated arts, science and humanities programs for university undergraduates; creating PhD placement programs with businesses; and encouraging interdisciplinary and creative research in universities.

Jannie van Deventer, Dean of Engineering at the University of Melbourne, announced recently that 70% of students were taking combined degrees including engineering, arts or commerce (Cervini 2006). He believes that combined degrees broaden students' experience and are welcomed by industry.

Responses to the Research Quality Framework preferred model, including the ARC's response (ARC 2005), have emphasised the importance of managing cross-disciplinary research (including cross-sectoral research) for its acceptance in the research sector. The discipline-based structure of the preferred model means that each panel is likely to face a number of cross-disciplinary proposals (between 25% and 55%) and will require among its members individuals with broad expertise in the disciplines involved. If panel members cannot refer to other national or international experts or add additional members where specific proposals require extra expertise, cross-disciplinary and cross-sectoral proposals may be disadvantaged. This could be overcome to an extent if proponents of cross-disciplinary projects had the opportunity to provide additional evidence in support of their proposed collaborative approach.

3 http://www.arc.gov.au/pdf/LP05_Rd2_listing_RFCD.pdf

4 See http://www.ausindustry.gov.au/index.cfm on R&D tax concession eligibility rules.

Music and medicine: New undergraduate degree

Since 2003, the University of Sydney has offered a postgraduate Medical Humanities degree, enabling students from any first degree background to undertake study in the arts and humanities, medicine and science, taken together.

From 2007, the university will also offer a double degree in music and medicine, in addition to an arts–medicine degree. The undergraduate music degree includes physics and biology subjects as well as sub-units in communication and ethics, and two projects that combine medicine and music.

B O'Keefe, 'Syncopation of music and medicine hits the right note', *The Australian*, 7 June 2006, p 35

There are a number of international initiatives to extend national capacity for innovation through encouraging cross-sectoral activity. Since the beginning of the 21st century, many countries (such as the United Kingdom, Canada, Austria, Korea, Taiwan and Singapore) have launched whole-of-government initiatives and policy changes to foster innovation (SCST 1999). Changes include the introduction of new incentives for investment, educational reform, entrepreneurship and cross-sectoral collaboration in research and development (R&D).

In a new protocol announced in August 2006, Research Councils UK made

significant amendments to their collaboration on the peer review and funding of research projects that straddle their remits. The aim is to ensure that no gaps develop between the Councils' subject domains … All responsive-mode research grant applications that extend beyond a single Research Council's remit will be assessed by peer reviewers from across the relevant domains, thereby ensuring fair and rigorous assessment. Beyond this stage, decisions will be made through a single Council's peer review process, but any significant element residing within another Council's remit will be funded by the Council(s) concerned. This will avoid the 'double jeopardy' of additional review, whilst ensuring that funding allocations reflect Research Councils' different missions, imperatives and approaches.[5]

Finland's innovation policy is at the forefront of developments in comprehensive and integrated innovation systems. That country has moved from a '2nd generation' policy (an interactive model characterised by schemes that encourage collaboration, networking, and innovation) to a '3rd generation' policy (a holistic model characterised by cross-sectoral and mixed schemes that include international clusters to foster coherence, learning and experimentation).

Another type of government initiative, often applied in the United States, focuses on specific regions and specific creative industries, rather than on whole-of-government initiatives.

Research infrastructure funding in Canada is organised through a different model. The Canada Foundation for Innovation, an independent corporation created by the Canadian Government, uses money from the government to fund up to 40% of a project's infrastructure. The remainder comes from partnerships with eligible institutions. This project-based, rather than discipline- or sector-based, funding system lets institutions set their own research priorities in response to Canada's needs.

The United Kingdom's Department for Education and Skills recognises the growing value of links between disciplines to achieve breadth of skills and innovative, interdisciplinary research (Hodge 2001).

A number of overseas primary and secondary curriculum developments emphasise both the humanities and the sciences as creative processes (see Appendix A).

5 Research Councils UK, Cross-Council Funding Agreement – August 2006. http://www.rcuk.ac.uk/research/prrcremits.htm

2.3 Supporting structures for collaboration

Drivers and supporters of collaboration include:

- philanthropic support, driven by a desire for cultural and community benefits
- large-scale research centres that encourage research across sectors
- university programs that encourage interaction across traditional disciplines
- public exhibitions and performances that bring together a number of disciplines to better engage audiences
- organisations set up specifically to support collaborative projects.

Some philanthropic funds have been set up specifically to support cross-sectoral collaboration, especially in the United States. For example, the Daniel Langlois Foundation for Art, Science and Technology aims to further knowledge of arts and sciences by combining the two with the help of technology.

Large-scale cross-sectoral research centres have been set up in some countries. Examples include the Centre for Technology, Innovation and Culture in Norway; the Design Laboratory at Massachusetts Institute of Technology in the United States; and the Cambridge Genetics Knowledge Park in the United Kingdom. On a smaller scale, the MARCS Auditory Laboratories at the University of Western Sydney bring together researchers from a variety of disciplines to solve common problems (we include the laboratories as one of our case studies).

MARCS Auditory Laboratories checks out the effect of music on infants in neonatal intensive care

A collaborative project involving the MARCS Auditory Laboratories at the University of Western Sydney and the Royal Children's Hospital Melbourne tested the effect of music therapy on the physical and psychological development of vulnerable, long-term hospitalised infants.

Traditionally, the long-term care of infants in hospitals has focused on their medical needs, but there is increasing awareness that their developmental needs must also be met.

The project used the skills of neuropsychologists, music therapists, biomedical engineers, information technologists, nurses and psychiatrists. They investigated whether a music therapy intervention, such as singing to infants in ways that make them respond, could help the babies recover, and they analysed the developmental factors that are affected when music therapy is used with babies in neonatal intensive care.

The project produced good-quality data through a unique data collection software system developed at MARCS Auditory Laboratories.

More information: http://marcs.uws.edu.au/research/music/mtiwsi.htm

Dedicated spaces for collaboration are important mechanisms. SymbioticA at the University of Western Australia brings artists and scientists together in one space, and the Australia Council's Synapse initiative uses residency programs for the same purpose (see Section 2.3.1 for more on Synapse).

SymbioticA: Exploring the ethics of biological research through art

Artists and scientists at SymbioticA—a research laboratory located in the School of Anatomy and Human Biology at the University of Western Australia—are working together to explore scientific and technical knowledge from an artistic and humanistic perspective.

The laboratory enables artists to perform in vitro experiments that explore developments in science and technology (particularly developments in the life sciences, such as genetic engineering) that are having profound effects on society, its values and belief systems, and the treatment of individuals, groups and the environment.

Immersed in the laboratory environment, artists are dealing with bioengineering and its controversial ethical implications from a position of knowledge. Both the artists and the scientists gain insights into the ethics and community understanding of the science and the art.

More information: http://www.symbiotica.uwa.edu.au/

An increasing number of conferences and workshops are targeting interdisciplinary rather than single-discipline participants. The recent international conference on interdisciplinary social sciences held in Greece (July 2006) discussed cross-sectoral work. The Constellations Conference in Sydney in April 2006 enabled artists and scientists to meet in a large forum to celebrate collaboration and share ideas. Journals are looking beyond single disciplines. For example, *Leonardo*, published by the International Society for Arts, Science and Technology, gives those working at the intersections of the arts, science and technology opportunities for peer-reviewed publication.

In the past few years, a number of structures and programs have developed in Australia and overseas to support, fund or facilitate collaboration. Most of the Australian examples below focus on facilitating collaboration, but not necessarily cross-sectoral collaboration. The international examples were chosen because they involve cross-sectoral collaboration.

2.3.1 Australia

Australian Research Council

www.arc.gov.au

The ARC supports some research projects and activities involving collaboration across the HASS and STEM sectors. Projects can be considered to cross the HASS and STEM sectors when applicants categorising their research in their proposals nominate at least one RFCD code from each of the HASS and STEM discipline areas. In 2005, 105 such projects received funding for 2006, under the ARC's *Discovery Projects* and *Linkage Projects* schemes, out of a total of 1317 funded in those schemes.

The ARC also supports a number of centres of excellence, ARC centres and research networks that include cross-sectoral work. The Special Initiatives scheme (including e-Research and the recently announced Thinking Systems project) and the Synapse project funded jointly with the Australia Council also support cross-sectoral collaboration (see below for more on Synapse).

ARC Centre of Excellence in Coral Reef Studies

The ARC Centre of Excellence in Coral Reef Studies program is expected to provide new ways to manage resilience and cope with change, uncertainty, risk and surprise in complex social–ecological systems. Its objective is to improve the governance and management of natural systems and build their capacity to sustain human and natural capital.

The program combines expertise on coral reef biology, management, governance, economics and social sciences. It provides information, guidelines and tools for coral reef managers and planners on climate change risks and adaptation options. The program's scope is global.

More information: http://www.coralcoe.org.au

The ARC Linkage Projects grants program funds research collaboration between universities and industry, to advance the Australia's innovation system and drive the nation's development as a knowledge-based economy and society.

ARC Research Networks is a new program designed to encourage collaborative approaches to research in interdisciplinary settings. The networks are platforms for generating new knowledge in areas that span traditional disciplinary boundaries, linking researchers, research groups and others involved in innovation, nationally and internationally.[6]

In response to our interview questions, the ARC said:

Recent analysis … has indicated that the proportion of research proposals in the major ARC schemes that may be considered cross-disciplinary in scope is increasing, and their success rate is at least as high as that of single discipline proposals. It is clear that much cutting-edge research is likely to cross traditional disciplinary boundaries, including the HASS–STEM boundaries.

6 http://www.arc.gov.au/apply_grants/research_networks.htm

While also noting that it does not specifically prioritise cross-disciplinarity in its assessment processes, the ARC stressed that excellence in research is the most important criterion for funding research projects and that cross-disciplinarity per se is not rewarded. However, a number of ARC initiatives are cross-disciplinary by definition, as they were specifically developed to produce outcomes that could not be obtained with a single-discipline approach. Examples include ARC Centres of Excellence and Thinking Systems.

National Health and Medical Research Council

www.nhmrc.gov.au

The National Health and Medical Research Council (NHMRC) has a Collaborative Research Centre that funds collaborative projects, programs and grants. Multidisciplinary work is high on the NHMRC agenda and most of its work includes collaboration across a range of sectors in some form. Many are collaborations across the STEM sector, rather than collaborations between STEM and HASS. For example, the Human Frontier Science Program, with an annual budget of about $53 million, emphasises 'novel collaborations bringing together biologists and scientists from fields such as physics, mathematics, chemistry, computer science and engineering to focus on problems at the frontier of life sciences'.

One very new NHMRC program that does fund cross-sectoral research is the Preventive Healthcare and Strengthening Australia's Social and Economic Fabric Award. It encompasses social science, humanities, health and medical research 'to produce outcomes that contribute directly or indirectly to improved health for the Australian population through evidence-based primary prevention strategies'. The program has relatively modest funding of $10 million over five years.

Cooperative Research Centres Program

www.crca.asn.au and www.crc.gov.au

The Cooperative Research Centres (CRC) Program was established in 1990. It was set up to provide closer linkages between R&D providers and end users, including industry, through limited-lifetime CRCs. The program emphasises the importance of collaborative arrangements to maximise the benefits of research and has a strong education component with a focus on producing graduates with the skills that industry needs.

The involvement of the HASS sector in CRCs is limited, and this is reflected by the fact that only one of the 18 members of the CRC Appraisal Panel is a HASS researcher. Some social scientists are involved in CRCs with a 'public good' focus (such as the Coastal CRC, the term of which recently expired).

Case study 11, the Bushfire CRC, involves both HASS and STEM disciplines. The CRC perhaps most strongly based on HASS disciplines is the Australasian CRC for Interaction Design (Case study 3).[7]

Bushfire CRC: Managing bushfires at home

Collaborative bushfire research aims to protect people whose homes or lives are under threat. The Bushfire CRC is identifying impediments and suggesting improvements to the Australasian Fire Authorities Council's 'stay or go' policy. The CRC is also developing recommendations for town planning and building standards in fire-prone areas. This integrated approach combines the skills of mathematicians, geographers, economists, policy analysts, social scientists, and materials and manufacturing scientists and engineers.

The Bushfire CRC's seven-year, $100 million research program brings together state fire and land management agencies; eight universities; CSIRO; Australian Government agencies, including the Bureau of Meteorology, Emergency Management Australia and the Australian Building Codes Board; and New Zealand fire and forest research agencies.

More information: http://www.bushfirecrc.com/centre/about/index.html

The current Deputy Chair of the CRC Association, Mark Woffenden, when asked about the extent of HASS–STEM collaboration across the CRCs, said:

7 http://www.interactiondesign.com.au

I would suggest that it is relatively limited compared to what happens within STEM. Part of that I suspect is cultural and deep-rooted … but as the CRC Program places more emphasis on outcomes providing economic, lifestyle or environmental benefits for Australia, it will have to take a conscious policy effort to bring HASS into the relationship.

Woffenden also said that HASS was important for his own CRC, especially when tackling industry problems.

Australia Council's art and science initiative, Synapse

www.ozco.gov.au/arts_in_australia/projects/projects_new_media_arts/synapse_artscience_initiative

The Australia Council for the Arts' Synapse initiative encourages creativity and innovation by providing opportunities for artists and scientists to work together. Synapse has three streams: ARC Linkage Grant Industry Partnerships, Synapse residencies, and the Synapse database for linking artists with scientists. The residencies program, of which SymbioticA is an example, encourages collaboration between the arts and sciences by placing artists in scientific institutions.

Andrew Donovan, director of the Inter-Arts Office that manages the initiative for the Australia Council, says:

Each of the programs has been able to see not only the artist's research, but also the research of the influencing science … Once the scientist understands what the artist wants to do, then it broadens their ideas. Both the artists and scientists should be influenced.

Donovan mentions the Fish–Bird project as an example of collaborations delivering useful outcomes for both sectors (see box).

He says the Australia Council tries to take a whole-of-government approach to cross-sectoral collaboration:

[For example], if there is a water problem, art and culture can help address that issue, whether it be through interaction with science or by helping to communicate an issue.

The Fish–Bird project: Robotic wheelchairs interact with humans

A team of robotics designers and a media artist have developed robotic wheelchairs that interact dynamically with humans. Funded by an ARC Linkage grant and the Synapse initiative of the Australia Council for the Arts, the Fish–Bird project has not only received international acclaim for its artistic innovation in public exhibitions, it also offers advances in wheelchair technology and monitoring systems that may be applied in a variety of hospital and aged-care environments.

Fish and Bird, the two robots in the exhibit, read and react to human body language by moving about and writing text.

The project promotes a positive social view of wheelchairs in the community by encouraging people to confront their own ideas about the human–machine interface.

More information: http://www.araa.asn.au/acra/acra2005/papers/rye.pdf and http://www.ozco.gov.au/arts_in_australia/projects/projects_new_media_arts/synapse_fish_bird_-_mari_velonaki/

National Academies Forum

www.naf.org.au

The National Academies Forum is the peak organisation for the four Australian learned academies: social science, humanities, science, and technological sciences and engineering. Founded in 1995, it promotes a unified, cross-sectoral, national vision, helping to overcome the difficulties that have often separated science, technology and engineering from the social sciences and the humanities. The forum is funded by a grant-in-aid from DEST, and seeks supplementary sponsorship for specific programs and activities.

Dr John Dodgson, Chief Executive Officer of the Academy for Technological Sciences and Engineering, says:

The relationship between the sciences and social sciences is very important, especially as the community role becomes more important—we're taking more notice of what they are saying. If you look at scientific activities, for example the nuclear issue … you have the science and technology input, but the social science is just as important.

Rural Research and Development Corporations: Land & Water Australia

www.lwa.gov.au

Land & Water Australia (LWA) is one of 14 rural research and development corporations (RDCs) within the Australian Government's Agriculture, Fisheries and Forestry portfolio. The rural RDC model encourages the inclusion of natural resource management issues with production issues to ensure the adoption of profitable and environmentally sustainable management practices. Each RDC invests in high-priority issues for its commodity and in collaborative efforts that address generic questions.

Cross-sectoral research is becoming more important for RDCs. This is particularly true for LWA. Executive Director Andrew Campbell says:

The spirit [of cross-sectoral research] is infecting all our programs; all have a social and institutional dimension … we believe those issues are fundamental drivers of natural resource management. We don't think there are many other funding sources for this sort of work—integration across disciplines … Natural resource management is about people management … it's about people's decisions, aspirations, beliefs, knowledge.

LWA receives about $13 million a year in appropriation funding, but leverages another $30 million or more from other RDCs and partners. Most of its research is cross-sectoral and involves biological and ecological sciences with law, political science, social science, philosophy and demography. It also funds work that looks at how the arts can communicate natural resource management ideas.

Australian Network for Art and Technology

www.anat.org.au

The Australian Network for Art and Technology (ANAT), a voluntary not-for-profit organisation based in Adelaide, supports the merging of art and culture with science and technology. It encourages artists working with new media, the internet, video, sound and performance to create new work and build national and international networks. ANAT provides financial support for members to attend conferences and workshops to discuss collaboration with others. Membership is open to anyone with an interest in art, science or technology. ANAT is supported by the Australia Council and the South Australian Government.

Melissa Rackham, Executive Director of ANAT, says:

There is a lack of innovation in keeping all the ideas in the discipline and an absolute advantage in getting perspectives from different disciplines … from an artist's perspective, they are good at seeing the gaps and what is discarded by the rationalist scientific method.

2.3.2 International

Wellcome Trust

www.wellcome.ac.uk

The United Kingdom's Wellcome Trust funds medical research and runs the SciArt Program. In 2006, SciArt is offering £500,000 to support and encourage innovative public arts projects investigating biomedical science and its social contexts. Beneficiaries are required to innovate, experiment and stimulate fresh thinking and debate in both disciplines. The Wellcome Trust also funds public engagement and associated events.

Anthony Woods, head of the trust's Medical Humanities section, says:

Looking at science in the social context is valid … the research affects people and society and we need to hear the public's voice … people's own experiences of medicine are as valid as what happens in the laboratory and we need to understand that more.

Wellcome Trust: Summer school on 'Neuroscience, genetics and Society' for early-career researchers

In 2005, the Wellcome Trust gathered researchers from a wide range of backgrounds to learn about the ethical, legal, social and policy implications of advances in neuroscience and psychiatry.

The School worked with a committee of researchers from ethics, law, social science and psychiatry. It provided an opportunity for 20 junior researchers to debate the emerging issues in this area and to learn more about the techniques of ethics research. They also developed outline research proposals.

Anthony Woods and Verity Slater, the Wellcome Trust

National Endowment for Science, Technology and the Arts

www.nesta.org.uk

The United Kingdom's National Endowment for Science, Technology and the Arts (NESTA) was set up by an Act of Parliament in 1998 to encourage the nation's creative and innovative potential. NESTA is funded by an endowment from the National Lottery and uses the interest to support collaborative projects. National programs on the scale of NESTA are uncommon.

NESTA supports projects that it believes have the potential to enrich the nation, long-term as well as short-term. Projects may have commercial benefits, but NESTA is also interested in their social and cultural value. For example, the Cape Farewell project takes teams of scientists, artists, oceanographers, journalists and teachers on a voyage to the Arctic seas. Collectively, they interpret and explain global warming, reaching a much wider audience than could scientists alone.

European Cooperation in the Field of Scientific and Technical Research

www.cost.esf.org

The COST Program (European Cooperation in the Field of Scientific and Technical Research) networks researchers and research groups across Europe. COST is a 'bottom-up' flexible networking mechanism currently operating about 200 Actions (networks) in which support is provided for meetings, workshops and conferences, exchange visits and training schools, and high level research conference partnerships.

Its strength lies in non-competitive research, and in solving environmental and cross-border problems and problems of public utility. COST funds exploratory meetings, which may in time develop into research projects. One of its aims is to bring together people from different disciplines.

2.4 Australian HASS–STEM collaboration

Two surveys informed the report. The first was an on-line information-gathering descriptive instrument to understand the extent of cross-sector collaboration in Australia. Who is conducting cross-sector projects and why; the outcomes of the projects; the factors that facilitate or hinder collaboration; and things to avoid when collaborating.

The second survey was designed to test the key ingredients that emerged from the literature review, information-gathering survey, New Horizons event, case studies and interviews. What experience had the respondents had in collaborative work? Was collaboration a factor in the success (or not) of the project? Respondents were asked to describe the collaboration: the number of people involved, how potential partners were identified, the sources of funding. The factors contributing to a successful project emerged after detailed analysis.

Both surveys filled out a picture of the nature and extent of collaborative activity in Australia. Results are summarised in the appendices, and the full results and the methodology is set out in the extended appendices available online. Care should be taken in interpreting these results because survey respondents were self-selecting.

First survey

The first survey drew 606 responses, 330 from HASS, 159 from STEM, 108 from both, and 9 from 'other' disciplines. The bias to HASS respondents is probably indicative of the fact that the project originated from within the HASS sector. It is unlikely to mean that there are more HASS people than STEM people collaborating in Australia.

Three quarters of all respondents stated that they had participated in cross-sectoral collaborations. The collaborative disciplines identified most frequently were social sciences and arts, and from the STEM sector, health and medical people. Least frequently mentioned as collaborators were those involved in policy, political science, philosophy and religion, or from the chemical sciences.

One third of those involved in collaboration were from universities, with state government agencies, other government authorities, art galleries, industry groups and CSIRO in that order. The largest sources of funding were government agencies, ahead of universities, the ARC and private sources.

Second survey

The second survey asked a more targeted series of questions, and sought to identify the characteristics that determined the success of a collaboration. These 'key ingredients' are explored in more detail in section 3 of this report.

Sixty per cent of the 688 respondents to the second survey indicated they had participated in a cross-sectoral collaboration, and their experiences were contrasted with those who had been involved in collaborative activity within their own sector. On average, more funding sources were reported for cross-sectoral projects than for within-sector projects. While collaborative projects in total were most likely to attract funding of less than $50,000, cross-sectoral projects were more likely than within-sector projects to have funding of over $1 million.

Those involved in cross-sectoral collaboration tend to be more advanced in their careers than people involved in within-sector work; and cross-collaborative activity appears to be a mark of career maturity. It involved more research areas, and generated more outcomes.

Collaborators identified potential colleagues through existing networks and friendships, and by activities carried out by organisations to facilitate collaboration.

The two top areas of collaborative activity were 'Promoting and maintaining good health' and 'Appreciation of cultural and historical heritage'. The five top outcomes for cross-sectoral collaboration identified by respondents to both surveys were:

1. gathering knowledge and understanding
2. improving current strategies
3. publications
4. education
5. developing guidelines and models.

3. Benefits and costs of collaborating

This section uses the collected data to paint a picture of the benefits and costs of collaboration, as perceived by those involved in cross-sectoral collaboration, by those supporting it, and by those researching it.

The literature review (see Appendix A) identified the following benefits of cross-sectoral collaboration:

- delivering commercial outcomes
- solving complex problems that require the skills, approaches and tools of both sectors
- providing services to the community
- engaging the public or industry in debate, activities or projects
- encouraging creativity and innovation for research, community and commercial outcomes.

The perceived benefits can be divided into two groups: outcome-based benefits, and benefits flowing from the process of collaborating. The benefits described below were common from all the data. Organisations supporting collaboration tended to favour outcomes as key benefits, compared with practitioners and researchers directly engaged in collaboration. This group also referred to benefits from the process of collaboration.

Some benefits from collaboration were seen to be at an individual level; others were at a team, project or organisational level. While some were about adding value to individual disciplines, many were about creating wider national impacts.

The perceived costs were largely transactional, such as the time and resources needed to establish and maintain working relationships across the sectors. These costs have largely been unrecognised or unacknowledged by those involved in cross-sectoral collaborations.

3.1 Outcome-based benefits

3.1.1 Knowledge

One of the benefits from cross-sectoral collaboration was reported to be the ability to manage the increasing amount of knowledge created by research, as well as the creation of new knowledge at the intersections between disciplines.

Analysis of the case study and interview data indicates that one benefit from working with different disciplines was in allowing collaborators to contribute different and perhaps conflicting knowledge to a project, or that creating new knowledge that could not easily be generated within one sector or discipline:

One key importance of inter-disciplinary work is not that the approaches fit or agree—it is the friction that is critical. The real value is that science, humanities and technology people see things differently and think about things differently.

Angkor research develops new information monitoring for World Heritage sites

Researchers are developing an information monitoring system for World Heritage site management, based on one of the world's most important cultural heritage sites—Angkor in Cambodia.

The Greater Angkor Project is developing the information monitoring system by bringing together new perspectives from archaeologists, historians, soil scientists, palaeobotanists, climatologists and computer modelling experts.

More information: http://felix.antiquity.arts.usyd.edu.au/angkor/gap/

3.1.2 Commercial products and services

From a commercial perspective, some participants reported that collaborating across sectors gives industries access to new approaches and more appropriate responses to their markets. It is also important for developing new commercial products, especially in fields such as new media.

Fans collaborate in developing online games

Auran Technologies, an Australian-based gaming company, pioneered the idea of involving games fans in developing the successful online game, Trainz.

Gaming companies have always needed to combine creative business with the technical aspects of gaming. Including fans as co-creators of the game in online forums and in developing prototypes adds a further humanities dimension to the generic cross-sectoral collaboration inherent in the games industry.

While the games industry in Australia is going through difficult times, Auran Technologies has maintained its intellectual property and market share by focusing on massive multiplayer online games—the area of growth and innovation globally.

More information: http://www.auran.com/

3.1.3 Problem solving

Many cross-sectoral collaborations are driven by a need to deal with a major social, environmental or health problem that cannot be solved using the expertise, skills, resources and knowledge of only one sector. Those supporting or funding cross-sectoral collaborations recognise the value of collaborations across sectors to deal with problems such as salinity, water supply and quality, and public health. For example, Land & Water Australia's Executive Director, Andrew Campbell, says, 'I can't think of a single project that is just biophysical … [for example] it's an absolute nonsense to do just ecological research about Indigenous people's management of the floodplain'.

Solving problems: Digital media offers non-drug alternative for children with burns

Young burns victims can become distressed about having their medical dressings changed. This happens several times a day, and designers and medical practitioners are prototyping a product that distracts children from this unpleasant medical treatment.

The prototype uses a computer tablet with a series of characters that tell a story. Children interact with the characters in the story by helping them complete a task, such as 'look and find'. This engages the child, diverts their attention and reduces their anxiety.

Initial clinical trials have been very promising, and prototypes of the technology are generating commercial interest. The technology may be used in other situations involving anxious children.

More information:
http://www.interactiondesign.com.au/news/in_the_news/media_release_20051018.htm

The participants in the Expanding Horizons event (see Appendix F) saw the benefits of collaboration after working in small groups during the event. Of the 20 groups, 18 reported they had devised a potentially viable cross-sectoral project which addressed the current National Research Priorities, with 10 projects addressing multiple priorities. All groups felt that the projects required collaboration across the HASS and STEM sectors.

3.1.4 Community service

Collaborating across sectors provides additional services, develops new programs and trains service agency staff and volunteers. This is especially true of universities and commercial enterprises that include community service in their mandate.

Community service: Indigenous child health program ensures workforce for the future

Aboriginal child health is affected by asthma, allergies and respiratory diseases, birth defects, cancer and leukaemia, developmental disorders, mental illness and infectious diseases.

As part of the Rio Tinto Child Health Partnership, Indigenous communities, the Australian Government, state governments, health and medical practitioners and researchers are working together to prevent child health problems. The partnership aims to improve the health and wellbeing of Indigenous mothers and children in Western Australia, Queensland and the Northern Territory to ensure a healthy and viable community and workforce for the future.

Rio Tinto is a major partner, contributing $1.5 million over seven years to this $5.2 million project. In collaboration with the Telethon Institute for Child Health Research, the project is supporting Indigenous health workers in local areas where Rio Tinto has significant operations, and translating the work of the Telethon Institute into policy, practice and interventions.

More information: http://www.wafuturefund.riotinto.com/news-item-live.asp?newsID=166

3.1.5 Engaging the public and industry

Cross-sectoral collaboration enables more effective engagement of the public or industry in research projects and outcomes. This benefit was mentioned a number of times in interviews, even when participants were talking about projects not directly aimed at engaging the public or industry.

While some respondents feared that HASS could be seen as the 'handmaiden' of STEM, brought in to help incorporate psychological, social, cultural and institutional factors to shape favourable public attitudes towards STEM at the end of the project, most projects documented in this research demonstrate the emergence of genuine collaboration across sectors in projects designed to better engage the public and industry.

As a representative of a government science organisation said:

Interdisciplinary research is very good at getting to answers that incorporate the social context of the question. In reality, most of our 'science' questions do, to various degrees, need to be considered in the broader context … it makes a lot of sense first up to use interdisciplinary measures to frame these research questions or broader research agendas.

Many of the cross-sectoral collaborations reported benefits from involving end users in the project to ensure greater ownership of the final outcome, service or product. Some also thought cross-sectoral collaboration to be a useful way to engage and motivate industry.

Making science and technology relevant to everyday life

Questacon (the National Science and Technology Centre) provides ways for 'ordinary' people to play a meaningful part in discussions about their future. Questacon demonstrates how science and technology are relevant and important to our everyday lives.

Employing more than 200 staff and 65 volunteers from the sciences, social sciences and humanities, Questacon is Australia's leading interactive science and technology centre and outreach program. Collaborators include the Centre for the Public Awareness of Science and Shell Australia.

More information: http://www.questacon.edu.au

3.1.6 Education

Research participants saw big benefits for education in cross-sectoral collaboration.

University students involved in cross-sectoral collaborative activities were considered to benefit by improving their understanding of other disciplines, as well as their own, from the different perspectives brought to collaborations:

A lot of students are coming in—graduates—there is a good geographical spread—but they are brought together for the purpose of getting them to understand their own discipline from another point of view and to understand other disciplines, to integrate them into program delivery.

We expose the [STEM] students to the [HASS] students—it wakes them up—it is terrific for them.

Students allow collaborative projects to link to other groups and organisations and provide better networks between teaching, education and industry. The ability of these projects to accommodate students from different backgrounds is a key benefit from the collaboration, as is attracting international students to take part in the collaboration. New collaborative courses—graduate diplomas and vocational training—were also being developed.

3.1.7 More collaboration

Respondents cited the willingness of the collaborative team to carry on working together after formal collaboration ends as one of the major benefits. Team members can help to establish the collaboration as a stronger and better-recognised area of research or practice, using their wider networks. A strong team encourages ongoing collaboration, providing opportunities to change the project direction and come up with new ways of researching.

As an example, the Fish-Bird project team members who created the robotic wheelchair have continued to work together. They have formed a group within the Centre for Field Robots dedicated to Human/Machine Interactions and are looking at formalising this into a larger Centre.

3.2 Benefits of taking part in the collaborative process

3.2.1 Creativity and innovation

Creativity and innovation are difficult concepts to measure, but participants in the case studies considered them to be major benefits of the process of cross-sectoral collaboration. Creativity was identified as an important element in all discovery, in the sciences as well as the humanities and arts. The tensions created by cross-sectoral collaboration are thought to enhance the creativity of all the disciplines involved. For example:

Cross-contamination—understanding how other people work; the whole process of how the knowledge is being applied and gathered from a [STEM] perspective—gives the [HASS people] important insights that they were aware of at an external and superficial level and vice versa with the [STEM people]. They understand the broader and cultural implications of the science.

Participants also thought that the new perspectives created through cross-sectoral collaboration were very important for dealing with the problems the research was intended to address.

3.2.2 Social networks and friendships

Collaborators involved in the case studies identified the benefits of developing wider professional and social networks through collaboration:

We are still in contact and exchanging information with a group that I did not know existed previously—a broader network.

3.2.3 Team benefits

Collaborators described the value of sharing resources and working with others in different and interesting areas and overcoming the tendency to work in isolation. Some thought the more flexible structures of collaborative research, working across disciplines, gave them a degree of independence from traditional disciplinary structures:

We had a retreat and decided that we don't want to be a program—it becomes a discipline. So we are sitting outside the disciplines to offer a route to transdisciplinary work without loss of territory.

3.2.4 Wider recognition

Individual collaborators can gain greater recognition from demonstrating how knowledge from another sector can be applied to issues common to other fields:

My name has gone further—people are going to conferences and presenting our work. People in the past who I have been at loggerheads with are now promoting my work.

Some found unexpected rewards from being published in journals from other disciplines and from reaching and making the work relevant to a wider group of people than might otherwise have been the case.

3.3 Costs of collaboration

Collaboration, especially cross-sectoral collaboration, has high transaction costs, so the benefits need to be significant (Irvin and Stansbury 2004). Collaboration is most likely to be profitable when the issues or problems being tackled cannot be dealt with by one sector alone.

The following factors as likely to increase transaction costs for cross-sectoral collaboration:

- Team members are widely geographically dispersed.
- Team members are inexperienced in collaboration.

- Team members have limited or no experience in working with each other.
- Team members have a high degree of personal connection to their own discipline, worksite, or both.
- The collaborative team is large (although larger teams were more successful than smaller teams).
- Team members have other priorities or commitments that take precedence over the collaboration.
- Complex technical knowledge from one or both sectors is required by the team before it can move forward.
- Team members have used the 'tools' of the other sector previously without genuine collaboration.
- Team members belong to organisations with rigid administrative and reporting requirements.

One funder of collaborative work noted:
There are high transaction costs involved in collaboration: travel, meetings, partnership agreements … I employ more staff per R&D money going out [compared to other R&D funders] as most [of our research] is funded through multi-party collaboration.

The costs create the need for more time and funding to make the collaboration a success. The time requirement both to train people (both staff and students) and to understand how others' skills and knowledge contribute to the collaboration can be onerous. Collaborators must make time for informal contact, to sort out commonalities and develop a common language:
A collaboration is one to two years of working together and it requires hard work and commitment, coming back time and time again where you have got to solve problems. When you have different groups of people speaking different languages, it takes time to make sure everyone is speaking the same language and working towards the same thing.

This can put a lot of pressure on those taking part, especially for the leader if they are also a full-time academic:
There is pressure on academics to publish, but it is quite frustrating to see people with no teaching relief carrying projects that require full-time support.

Administration absorbs time, particularly in universities and organisations with similar discipline-based internal structures:
I'm employed through [a university faculty] but the money for my project comes from [another faculty]. I have to go through two faculties. The amount of time you waste on administration is quite significant.

Participants reported that administrators did not appreciate collaborative activities in teaching and research take more resources than single-discipline activities. Legal and commercial bottlenecks, for instance, are more pronounced in cross-sectoral research:
[There are] legal issues to getting projects started in collaborative research—lawyers who have no concept. They look at it and say 'why haven't you got [HASS person] to do the community relations thing?' But [the HASS person] needs the [STEM results] to be able to work.

The possibility of people leaving the team before the project is complete is another potential; cost to factor in. This is particularly pronounced if that person is the 'champion' for the project:
The internal champion in organisations can move on and that changes the dynamic and priorities and volume with which things are spoken about. Internally within [our collaborative organisation] we are trying to divorce the delivery of research from that crucial dependency on the individual.

The pressure to allocate funding up front can make it impossible to take advantage of future opportunities:
The collaboration is working well when working on problems—but when new issues and ideas come up, then it's difficult to fund this; the [organisation] allocated all their money up front. There is a funding problem in that new opportunities don't fit within [the collaborative organisation] as it is.

There are costs to the individual participant, including the suppression of individual creativity for the sake of the team; the need for co-authorship of publications; opportunity costs in pursuing individual disciplinary work; and less chance of being recognised by disciplinary peers.

Efforts put into cross-sectoral collaboration can make it difficult for people, especially early-career researchers, to be promoted within their own disciplines—taking part can be at the expense of pursuing an academic career. One senior academic said that, if he were advising early-career researchers who wanted to advance in academia, he would suggest:

If you've just finished a PhD, then it is best to lock yourself in a room and write two prestigious articles a year for the next couple of years. Keep re-writing stuff from your PhD in different journals.

4. Incentives and impediments to collaboration

Section 3 indicated some benefits and costs of collaboration; this section focuses specifically on incentives and impediments, and an examination of the seven factors that informed the identification of the key ingredients for cross-sectoral collaboration:

1. structure and team management
2. power distribution
3. resources and support
4. commonalities and differences
5. communication
6. personal traits of team members
7. status and recognition.

Some people interviewed for this report considered that the incentives and barriers, and hence the key ingredients for success, were the same for any collaboration and not just for collaboration across sectors. Our view is that there are two differences between within-sector and cross-sectoral collaboration. The first is a matter of degree: the factors that affect within-sector collaboration are likely to have an even deeper effect on cross-sectoral collaboration. The second and more important difference relates to perceptions of the different approaches and theoretical frameworks that each sector brings to a collaborative project.

Some participants believed that STEM disciplines take the traditional hypothesis approach, tested by experimentation, to tackle problems or create new information, whereas some HASS disciplines identify themselves with hermeneutics, gaining knowledge through interpretation. For example, a case study participant from a social science background commented:

The physical sciences are definitely dominant in the [organisation]. The approaches of empirical studies—hypotheses setting and deductive approaches—are dominant in biophysical sciences. The interpretative and constructive approaches of social sciences don't mesh with this.

Many HASS disciplines also adopt the hypothesis approach, so HASS and STEM cannot be defined along these methodological lines. However, perceptions of differences in the basic philosophies and approaches can cause the greatest tensions in cross-sectoral collaboration. The diversity that defines the collaborative group makes cooperation more difficult (Suzuki 1998), and can deepen problems of communication, conflict resolution, the status of team members and competition for resources.

Table 1 summarises the impediments and incentives to cross-sectoral collaboration.

Table 1: Impediments and incentives to collaboration

Factor	Impediments	Incentives
1. Structure and team management	Geographically dispersed Lack of leadership Inflexible organisations Rigid administration procedures Low attachment to group Focus on individuals Poor decision-making processes No conflict resolution process Other loyalties and priorities take precedence Collaboration too formal or too informal	Flexible risk-taking environment Opportunity for all team members to contribute Clearly defined roles Well-structured research plan Members contribute to all phases of the project Agreed project goals Champion or leader for the collaboration Leaders understand the needs of all disciplines to be involved 'End users' involved
2. Power distribution	Lack of commitment by at least some to the collaboration Uncertainty about job security of some members Disciplinary/faculty jealousy and rivalry Lack of respect for methods of other sector Unequal number of members from each sector Unequal workloads Perceived unequal status Hierarchical structure Members pushing own agenda	Long-term expectations of collaboration Disciplinary support for collaboration Members feel able to participate based on current skills and knowledge Clearly defined roles Flat management structure that is also accountable Scope to take risks and experiment
3. Resources and support	Discipline-based funding programs Difficulties in assessing cross-sectoral projects Lack of time to engage, especially at start; busy, overcommitted people Lack of administrative support Competition for resources between sectors Unable to gain ongoing funding after start-up Lack of commercial opportunities Lack of industry, public and/or government support Difficulties in measuring or evaluating outcomes Competing demands of other projects Inadequate opportunities to influence strategic direction of organisation	Permanent infrastructure (for long-term collaboration) Space for co-location Specific funding for cross-sectoral collaboration Simple and appropriate financial and administrative system Changing government priorities supportive of cross-sectoral collaboration Independent sources of funds
4. Commonalities and differences	Diversity of members Different cultures and norms Different approaches and methods Members based in single-discipline departments or organisations Lack of shared knowledge Different value judgments Assumptions about the other sector Unrealistic expectations	Staged collaboration supported—initial stage for developing commonalities Members with shared interests and goals Training of team to develop common goals and approaches Students encouraged to participate Project compatible with individual values and work practices Understanding of each other's approaches and culture

Factor		Impediments	Incentives
5.	Communication	Different 'language' and jargon No or limited direct contact Little opportunity for informal networking	Networking opportunities People who can communicate across sectors Open processes for sharing ideas and issues Clear communication processes Members expect long-term interaction
6.	Personal traits of team members	Arrogance Isolation of individuals Lack of faith in others and other disciplines Inflexible people Lack of trust	People experienced in collaboration part of team Members already know each other and have established trust Enthusiastic, passionate champion
7.	Status and recognition	Lack of academic acceptance of cross-disciplinary research High value put on publications that are discipline-based for recognition and promotion Pressure on early-career researchers to publish in disciplinary journals No obvious rewards for collaboration Negative promotion prospects for collaboration Lack of credit for contributions	Recognition for individual and team achievements Credibility built through promotion and publishing Members compensated for any costs incurred in collaborating Results from collaboration clear and observable to those outside group Wider recognition for work outside own discipline

The best guide to incentives and impediments to cross-sectoral collaboration emerge from an exploration of the case study and interview data. These influencing factors relate to all levels of collaboration: individuals, project teams, organisations, and funding programs.

4.1 Individual incentives and impediments

The status of people involved in multidisciplinary research can be an issue. For example, is someone a multidisciplinary economist or a 'real' economist? It is difficult for people collaborating to give up their links to mainstream disciplines. Universities are still rooted in disciplines, despite their attempts to move on from this, and people who do not fit strictly within a discipline can find it difficult to advance their careers. One person said:

I think in some ways it is politically dangerous to take on [collaboration] … even though the upper executive of universities want everyone to engage in post-disciplinary research clusters, in the ranks there is a need to hang on to existing bodies of knowledge in the disciplines.

People who lack faith in others and other disciplines can be a major barrier to successful collaboration:

There are deep-seated cultural differences between the social sciences and the physical sciences. If you contemplate these differences, [you will see that] HASS is about people outcomes and STEM is about a 'thing' outcome. HASS is perceived to be less rigorous than STEM, which is a disparity that can be destructive to potential collaborations.

People with a common interest and a developed trust are more likely to engage in collaboration; those with less trust or respect for the other sector are less likely to collaborate.

One of the major barriers to developing a strong collaborative team was a lack of belief in the team. Individual disciplinary focuses of collaborating members can mean lost opportunities:

I can't think of any example where collaboration didn't work; it's more a case of missed or lacking opportunities to make it work better. Initially, the [collaborative organisation] was set up with separate projects, and for something like [this structure] you need to have this sort of set up initially. One thing that might emerge as there is more collaboration is difference in theoretical perspectives and methodologies.

One way to overcome these difficulties is to ensure that all members of a cross-sectoral collaboration participate in all aspects of the project (Lamb et al 1998). The case studies emphasised the benefits of getting people around the table talking:

The thing that is most apparent to me is that at [the collaborative organisation] we are at the hub of a lot of different networks. We often find ourselves in a position as an organisation where we are getting a lot of people together doing similar things but they don't talk to each other—their networks don't cross—they don't sit down together to discuss these matters. I'm starting to appreciate how powerful it can be to get a whole lot of people around the table to talk about these issues.

Talking included holding regular meetings to draw out thoughts and concerns:

The only time when I might have thought that I wasn't 100% happy was when there was a long gap when we got together. It is terribly important to have regular meetings; it is critical, otherwise you can get out of touch. I don't think it was a problem for us but it could be.

It is important to compensate members for any costs associated with the collaboration, and to provide appropriate incentives. These measures will make collaboration more desirable. Other incentives include building credibility for the research (through promotion and publishing), developing a well-structured research plan with which to approach other members, being open to sharing ideas and resources, and encouraging free movement of ideas across sectors and providing flexible risk-taking environments (PMSEIC Working Group 2005).

Beneficial experiences can make individuals more supportive of collaboration. The Expanding Horizons teams said their participation in collaboration exercises made them think in new ways, and that collaborating was easier than they first thought. They discovered they could create shared understandings and a common language in a short time, and that a sense of humour was a great asset. They enjoyed speculating about hypothetical research agendas and saw collaboration more positively than they had before the session.

4.2 Team or project incentives and impediments

Strong identification with a group or organisation and a social sense of belonging to a group can facilitate communication, trust and innovation (Tushman 1982). This can be difficult to achieve in cross-sectoral collaborations, to the point where they can fail when members do not recognise the value of the collaboration (Madhok 1998), when other loyalties and priorities take precedence (Scott 1997), or when resource allocations lead to conflict.

Having a flexible structure to overcome the rigidity of discipline-based structures is an important incentive:

The extent of collaboration over the [collaborative organisation] varies a lot. There are still some people in the [organisation] who work in silos. Perhaps their project is narrowly defined and they don't need to collaborate; but perhaps they are not seeing opportunities. The [organisation] has only being going for three years so this might happen.

Flexible structures allow collaborators to be associated with a collaboration to varying degrees:

The team has quite fractal boundaries—who is within or outside the team? There are people collaborating on projects—quite difficult to diagram without going into detail—quite fuzzy. People quite enjoy their association with [the collaborative team].

There can be a problem if the collaborative project structure is too informal:
One problem we came across was that our collaboration wasn't formal so it was difficult to make time and have meetings, to find where funding was coming from.

High-quality leadership is an important incentive and a project with leadership opportunities for many provides incentives for members to contribute more fully.

Regular face-to-face communication is an important incentive for teams, especially geographically dispersed teams, but it needs to be resourced adequately:
We met as a whole team twice yearly, for 0.5 to one day. It would have been better for [the leader] if we'd had videoconferencing—he ran out of money for travel.

Other incentives identified were:

- expectations of future interactions
- long-term contact between collaborating members
- a common goal consistent with individual values, past experiences and needs
- a perception of collaboration as better than current practice within a discipline (Sonnenwald et al 2001)
- a perception that the complexity of the collaboration is manageable
- a supportive environment in which risks can be taken without undesirable consequences.

Many collaborations identify leadership as an issue. An inspiring leader whom members do not want to disappoint can be a big incentive for involvement. Such a leader can provide dispassionate criticism, important for moving the collaboration forward, and can also keep the collaboration on track:
[The leader] was skilful with leading from the back and steered it well … others had their moments. There wasn't a hierarchy, [rather] inclusive leadership that ebbed and flowed. No one appeared to be too mangled as this changed; there was turn-taking.

The literature states that effective leaders can adapt their style to accommodate characteristics of their collaborators, the specific context in which they work and the broader environmental context (Dubrin and Dalglish 2003; Goleman 2005). Hogg and Terry (2000) suggest that the communication style of leaders contributes to members' commitment by fostering cooperation, sharing and trust, and support for shared norms and values. The leader's communication style contributes to the acceptance of member diversity in cross-sectoral collaboration (Schneider and Northcraft 1999), and is often better oriented to shared decision-making rather than to authoritarianism (Block 1993).

4.3 Disciplinary incentives and impediments

Other challenges relate to differences in disciplinary concepts, questions and methods.

Some disciplines, such as archaeology, appear more collaborative because they recognise that the problems they are dealing with require the expertise of others in addition to their own. They see value in incorporating many perspectives and knowledge bases: the discipline's work requires collaboration across the sectors.

Many interviewees not involved in collaborations said this was because either the discipline's questions did not require it or because the discipline did not realise that it could benefit. It was not because their discipline was less collaborative by nature.

Reframing problems using interdisciplinary knowledge can lead to better research outcomes and application. This includes involvement with end users (such as the community, industry and the market):
[There is a need to bring] about a cross-disciplinary understanding of problems. By having the HASS involved, you get a better understanding of the history of the problem, and power relations between stakeholders. You get a

much better feel for how the disciplines can redefine the problem so it becomes much more meaningful to people out there in the community. Cross-disciplinary understandings are often richer than those coming from any single discipline.

There are other reasons why disciplines do not collaborate: perceived hierarchies (snobbery); lack of understanding and distrust of other disciplinary practices; different and incompatible ways of 'knowing' (for example, science's absolute truth versus a socially constructed world); and power-sharing issues. Respondents to this study said:

There are no incentives to overcome disciplinary boundaries and you have to do it by willpower. I can only do it because I have been doing it for 30 years—and I have done it through establishing trust rather than institutional support.

Challenges can be overcome if the problem is framed so that both sectors can see that collaborating is the best way forward. One way to overcome the disciplinary divide is to integrate the disciplines at the start by locating them in the same program, rather than getting them to collaborate from their own disciplinary programs. This is one reason why cross-sectoral collaboration can be difficult in CRCs set up with a discipline-based program structure. It is also the reasoning behind CSIRO's new integration program.

Participants in collaborations need to work at building an understanding of the behaviour and culture of all the disciplinary groups involved. The different disciplinary languages and their associated jargon can make communication difficult (Duncker 2001) leading to a lack of trust, lack of interdependence and problems with the social structure of the project (Jackson 1977). Activities that promote informal communication and dialogue—conferences, group meetings, discussion forums, conversational activities and so on—can help this communication (Spear and Rawson 2002).

Training can help overcome cross-sectoral boundaries (Mintzerg 1979) and achieve a common belief or framework. Manathunga et al (2003) investigated two interdisciplinary research centres based at the University of Queensland and found that reflective techniques are an important part of education for higher degree students involved in interdisciplinary research. These techniques, such as annual review processes with supervisors and portfolio building, help students recognise the skills they are developing as cross-sectoral researchers and the influence of their disciplinary backgrounds on decision-making and actions.

Another mechanism is the employment of 'boundary spanners'—people who can communicate across sectors (Petronio et al 1998). But the long-term sustainability of cross-sectoral collaboration depends to some extent on individual disciplines rewarding and recognising the value of such efforts (Shanken 2005). One way is through the education system, through interdisciplinary courses or subjects, by providing spaces for interdisciplinary dialogue (Manathunga et al 2006), and by building cross-disciplinary reflection into postgraduate programs.

4.4 Organisational incentives and impediments

Collaborative ventures can fail because of rigid university departmental silos and bureaucratic administrative work units (Kezar 2005), the culture in which they operate and the physical arrangement of participants. Collaborative activity can be encouraged by organisational security and support for risk taking.

It is important for host organisations or faculties to understand that effective collaboration takes time. Geographic dispersion is a problem, and co-locating people allows them to engage daily and build trust and interest in each other's work. Participants identified this as a major incentive that organisations could provide:

Social networks [are important] … [but] you can't bring people together once and expect collaboration to work … put them in a room for a day and let them out and expect the collaborations to continue … If you are a stranger to people, one day won't make it different. You need trust, credibility, honour. I see a lot of rationalism—making people collaborate by rules and guidelines.

4.5 Funding incentives and impediments

The current funding environment was seen as offering little encouragement for cross-sectoral collaborations, but instead setting up a number of significant barriers. Collaborations require flexible structures, a risk-taking culture and sympathetic administration. They need an evaluation system tuned to the possibilities and challengers of collaborative activity. Participants in the study were not positive about the current structures, and saw potential threats in the Research Quality Framework.

Many saw current funding schemes as a major barrier to cross-sectoral collaboration. This particularly applied when it came to evaluation, and proposals for cross-sectoral collaborations were seen as being disadvantaged in having to compete against proposals based on a single-discipline:
A project rooted in one discipline and evaluated by people from that discipline gets higher scores than a project that seeks to integrate across disciplines. There is a limitation of highly qualified evaluators to look at both the technical and social aspects of a project.

A barrier also applied in the attitude of funding bodies towards risk-taking. Many collaborators considered the ability to take risks to be an important incentive and were disappointed by the reluctance of bodies to fund more adventurous work:
The blue sky thinking—taking a risk on something you do not know will work—is important. To be really excited about it—it is that excitement that is contagious.

The attitude of funding bodies inhibits risk taking:
There needs to be more risk-taking on collaborative projects on behalf of funding bodies … not forcing people to produce outcomes. Outcomes will come anyway but they discourage people from exploring and taking risks … the best way of learning about things is to test and see whether they work or not.

Participants did not see the funding situation improving, and were concerned that opportunities might become more limited under the Research Quality Framework and its draft proposals on assessing research proposals:
I am concerned that this will drive us back to disciplinary boxes, because it is easier.

A workshop on collaboration across the sectors, held as part of CHASS's Directors Conference, discussed this concern.[8] Several senior university academics mentioned that 'anticipatory' concerns about the Research Quality Framework were already changing their organic, dynamic and cross-sectoral approach to collaboration, to an approach within rigid disciplinary frameworks.

Another barrier was the lack of flexibility in funding structures for salaries, compared with the informal nature of developing cross-sectoral collaborations. It was difficult to fund new ideas emerging from collaborations once the money was allocated:
[The collaboration] grows and bifurcates, but [we] can't follow them because the money is not there.

Competition for funding, especially between universities, was seen as a significant impediment to cross-sectoral collaboration. Some incentives for moving forward in such an environment were thought by our research respondents to be related to:

- an ability to gain funding or in-kind support from other, independent sources (philanthropists, industry, the community, etc)
- the team's passion and enthusiasm for their project, despite not having the funding they would like (this was true of many of our case studies, but some warned that it was not sustainable in the long term).

Participants felt that, with no long-term view of collaboration by universities and no faculty funding for applied research, it was difficult for some collaborations to progress beyond the achievements they had already made.

8 The CHASS Directors Conference, 'Scaling up for greater impact', was held on 3–4 July 2006. Jenni Metcalfe facilitated two workshops on cross-sector collaboration.

5. Key ingredients for successful collaboration

5.1 What is 'successful' collaboration?

Measures of success will differ according to the type of collaboration, the desired outcomes, the relationships that have developed, and the person or organisation making the assessment. Participants in the project offered different views. The first, from a funding perspective, suggested five indicators:

1. evidence that collaboration has occurred
2. commercial outcomes, real or potential, that can support a case to government
3. the quality of the outcomes (for example, the quality of an artistic work)
4. the extension of relationships developed through the collaboration beyond the period of funding
5. the leveraging of additional funding.

A second view emphasised the importance of achieving agreed milestones as well as developing quality relationships:

[There are] clear behavioural indications that the people are working together: talking to each other; going to each other's place; observe an exchange of ideas; constructive not destructive behaviour; a willingness to acknowledge the contribution of another party; actively seeing opportunities for synergy rather than promoting individual cause … A report that says or demonstrates: 'We've come up with a solution that we couldn't come up with on our own'.

A third, from a researcher looking at collaborative research in universities, points to the combined importance of outcomes and research processes:

[An indicator of success is] an outcome that all parties are happy with … [But] it is not just one outcome or output for the academics concerned. They don't just want an applied outcome; they need some more fundamental innovation acknowledged … [It is] not just applied research but engaged research.

The key ingredients survey confirmed other project data by identifying the following success factors:

- We have assembled an appropriate mix of collaborators.
- The conceptual framework for the project is well understood by project members.
- We have gained funding for the project.
- The project team members have increased their creativity, inventiveness and innovativeness.
- The project team is producing outcomes such as new knowledge, products, services, publications or displays.
- We have gained recognition for our work from peers and industry.
- The value of our project has gained national or international recognition.
- We have solved the problem that the project was designed to address.
- We have presented the outcomes of our work to relevant bodies.
- Our project work has engaged the public.

- Our project work has influenced the work of others nationally and internationally.
- We have developed an extensive network that will help future projects.
- The project's success will lead to future collaborative projects.

The key ingredients described below are informed by the individual, team, organisational and national benefits discussed in Section 3.2. They will have different applications for different people involved in the collaboration, and link to the seven factors of incentives and impediments (see Section 4).

The survey used to test the data gathered throughout the project was also used to contrast the major elements determining the success of two different types of collaborations: those involving disciplines within a single sector, and those involving disciplines drawn from two different sectors, HASS and STEM. The details of this comparison are contained in Appendix K.

5.2 The key ingredients for success

5.2.1 Structure and team management

Participants in the key ingredients survey identified the way a team is structured and set up as a predictor of success for cross-sectoral collaboration.

For example, the partners in the collaborative project between the MARCS Auditory Laboratories and the Royal Children's Hospital Melbourne (Case study 2)[9] met initially to develop a new methodology for the collaboration, and to determine what outputs would be required for interdisciplinary publications and where to publish the results. Taking time to establish commonalities and differences was important to their subsequent success.

Team leaders or 'champions' are needed to promote cross-sectoral collaboration. It helps if the leader has high-prestige within their own discipline so they can move outside it more easily. For example, in the Angkor World Heritage site case study (Case study 1), the chief investigator spends a significant amount of time championing the project and dealing with decision makers.

Extended networks that involve end users are important for success. For example, the PMSEIC project on tsunamis (Case study 9) brought together representatives from emergency services, aid agencies, the social sciences and geoscience. Their meetings focused on how each discipline could contribute to tsunami preparedness in Australia and the Pacific. This helped the team to focus on commonalities between the disciplines rather than differences.

It is important for a team to have formal rules, including processes for conflict resolution. SymbioticA (Case study 7) manages potential tensions between biologists and artists in collaborative projects by developing contracts for the collaborations at an early stage.

Nor can the collaboration be forced. Success is much more likely if the collaboration arises and develops from a mutual trust, shared vision, clear expectations and a sense of purpose:

[Collaboration] is a means to an end, not a means in itself, and you have to define what the end is. What is the value proposition?

Flexibility in organisational and project arrangements is a key factor. It includes the ability to:

- co-opt
- recognise different working and communication styles
- create a framework that encompasses all members and disciplines involved

9 The case studies are decribed more fully in Appendix C.

- maintain autonomy and independence from disciplinary silos
- support big projects that give space for diversity
- provide opportunities to move across programs and projects as collaboration develops.

The team has to be prepared to fail. Collaborators need the freedom to try new things and possibly fail:
There was an important ethic of having 'the freedom to fail'. We all believed in this, knowing that if it didn't work out in the collaboration between us, we hadn't personally lost anything.

5.2.2 Power distribution

The favoured model is flexible and open systems in a flat management structure where collaborators are accountable for their contributions. It is important to allow for evolution, and to avoid duplication of existing disciplinary work. For example, the Spatial Information Architecture Laboratory project (Case study 6) describes itself as a resource rather than as a centre, because it does not want to create new boundaries around the field. The laboratory welcomes the involvement of anyone interested in the area of three-dimensional spatial research.

Some projects developed written contracts setting out roles, responsibilities, expectations, approaches and acknowledgment for team members.

All collaborators said it was important to have an organisational environment that supported risk. In many cases, the project could not have developed to its current scale if the university had not been willing to take a risk on an untried venture. Case study examples include the University of Western Australia's SymbioticA (Case study 7), the Royal Melbourne Institute of Technology's Spatial Information Architecture Laboratory (Case study 6), and the University of Queensland's Leximancer project (Case study 10).

It is not only the funding bodies that need to be willing to take risks, but also the supporting organisations:
We have always had a unique culture. We have the size and number of students and the resource base and we've always taken the view that if we don't take a risk we are going to die. We always take risks.

Collaborative activities can help supporting organisations become more comfortable with risk by building a continuing relationship with them:
The university could have panicked in some situations but the university was calm and courageous. They didn't throw the book at us—they knew there was risk.

5.2.3 Resources and support

Organisational support was identified as essential for successful cross-sectoral collaboration. Official recognition of the collaboration at various levels gives it legitimacy. With university-funded collaborations, higher management and the researchers are often perceived to support collaboration, but there can be difficulties with faculty and departmental administration.

This support is also essential when it comes to gaining external funding and grants. For example, ARC Linkage projects require support from the organisations hosting the collaboration. The Australian Centre for Field Robotics supported an artist to develop the Fish–Bird project, a collaborative project with other researchers (Case study 8). The group applied for ARC Linkage and Synapse grants, which required the demonstration of substantial host organisational support.

Cross-sectoral collaborations work better if funding flexibility is built in at the start. When program funding is set at the beginning, (as with the Bushfire CRC — Case study 11) it can be difficult to develop new collaborations.

All collaborations in the case studies relied on a mix of external funding and organisational in-kind funding. The organisations provided cash, time for researchers to collaborate, administrative support, and infrastructure such as buildings and equipment; and this support was crucial to gaining external funding for the collaboration. External funds came from a mix of government, R&D organisations, industry, sales, workshops or consultancies.

Many people involved in collaborative activity report being able to overcome insufficient resources through their enthusiasm for the project or by finding alternative sources of support.

Complex administrative processes for collaborative projects meant that some collaborations employed their own support people to simplify processes for researchers. SymbioticA (Case study 7) and the Spatial Information Architecture Laboratory (Case study 6) employ their own administrative personnel.

Face-to-face interaction is a key promotion to collaboration. Being in the same place can be important in generating new collaboration; for example, the Leximancer project collaborators would probably not have been involved if they had not been co-located (Case study 10).

5.2.4 Commonalities and differences

Handling relationships is a hidden transactional cost to collaborative ventures. Collaborations, especially across disciplines, require the exploration of common interests and values and, in many cases, the development of a common language. Collaborators need time to gain at least some understanding of each other's methods and approaches. This relationship-building takes time and costs money.

Sometimes these processes can be abbreviated by establishing shared goals. Having interests in common can be more important than understanding the other disciplines. Common interests make common language easier.

All collaborators in the study acknowledged the vital contribution of the other disciplines to their venture. Some indicated that they were initially apprehensive about the perceived status of their own discipline in new collaborations, but successful collaborators reported being pleasantly surprised at the openness and respect they received from their collaborators.

It is important that individuals have an opportunity to achieve their own goals within a collaboration. For example, researchers in the Fish–Bird project (Case study 8) have published separately in their own disciplines from the collaboration, as well as publishing together.

5.2.5 Communication

Communication is a critical factor in cross-sectoral collaboration, and increasingly important with the complexity and width of the venture. The group needs to agree on a common language, which could be developed by:

- adopting the language of the other discipline
- including 'boundary spanners' in the collaboration
- developing a common language from separate disciplines.

Collaborators need to develop openness, have excellent listening skills, and be able to interact formally and informally.

5.2.6 Personal traits of team members

Successful collaborations share behaviours and processes with sporting teams. The character, outlook and history of the participants, the performance of the leader, and the experience of team members were all significant. One participant stressed the importance of only including people committed to their own discipline and crucial to the collaboration:

Ensure you have the right people around the table; and if you have a fundamentalist [someone wedded to own discipline] there, it is only because they have critical expertise in that specific area; or they belong to one organisation that is fundamental to change. If you can avoid some of these people, good. It is a waste of time getting people to collaborate who hate each other or don't get on—it won't work.

'Find the right people,' echoed another respondent:

People who try to analyse these success stories want some magic formula and want a cookbook recipe but I believe it comes down to the people. If there is a message—find people that you want to work with.

'The right people' had the following characteristics:

- approachable, forthright, articulate
- enthusiastic, excited, motivated, passionate, committed
- hardworking, energetic
- team players
- curious across disciplines.

It helps if at least some members have a history of collaboration and of working with other members of the team. For example, the ARC-funded music therapy, SymbioticA and Questacon case studies (Case studies 2, 7 and 12) all included people with experience in collaboration.

Successful leaders are enthusiastic, dynamic, generous, direct and diplomatic. They listen and take criticism on board, enjoy working across the disciplines, and are experienced and respected. Particularly in the early stages, they also need flair:

The formative stage requires ideas people—creativity, lateral thinking and enthusiasm … This requires more creativity and less leadership.

5.2.7 Status and recognition

Collaborative activities tend to fall outside the normal structures. They do not sit within well-established disciplinary groupings or administrative units. They present problems for funding bodies, particularly on the issue of assessment, and are in danger of falling between the administrative cracks. Papers from collaborations may not fit neatly into the guidelines of established journals.

These factors present a particular challenge for funding and administrative organisations: how to reward the achievements of individuals and the group in terms of promotion, funding, feedback, publication and recognition.

Individual ambitions need to be recognised. A successful collaboration will identify individual goals and needs and ensure that these are met through the collaboration. This could mean individuals publishing in their own disciplines.

Early success is important. Success and recognition encourage collaborators to commit to the venture and encourages others to be involved. It supports the achievement of sustained, longer term, cross-sectoral collaborations. For example, in the project to devise a non-drug method to alleviate anxiety in children with burns (Case study 3), early recognition and support from the Queensland Government meant the collaboration moved beyond the original research to the development of a commercial product.

External recognition through funding, and awards such as fellowships, are also seen as important. Producing quality outcomes, having a reputation for success within the project and demonstrating public benefit all contribute to more committed collaborators.

International recognition of the collaboration has many benefits for its future viability:

Because we're internationally profiled, this will attract a lot of research and postgraduates from overseas and industry— they will be investing and studying here. [This is] a huge profile spin-off.

A longer term expectation of collaborating beyond the current project is an important ingredient of collaborative success. For example, the Fish-Bird project team members have formed a working group within the Centre for Field Robots dedicated to Human/Machine Interactions, and hope to build this into a larger Centre.

6. Recommendations

6.1 Promote a new mindset

Impediments need to be removed and incentives provided to allow a proper exploration of the power of cross-sectoral collaborations to deal with problems. This project has identified a myriad of areas where constructive actions would enable people in research and education to come together to work on the complex, multilayered problems which demand cross-sectoral research.

The process should begin with changing a mindset, and institutional and policy settings which have yet to appreciate fully the possibilities of cross-sectoral collaboration.

To help address the mindset issue, it is recommended that government and institutional funding be allocated for a national summit to explore cross-sectoral opportunities, with a view to implementing a series of initial programs. The summit would involve all relevant national and state departments, universities, other R&D organisations, and business and industry groups.

The summit could potentially support the following networking opportunities:

- exploring key issues in cross-sectoral workshops (similar to the European Union COST program)
- bringing together people who do not normally meet (for example, early-career researchers from the HASS and STEM sectors, as happened in the Expanding Horizons event of March 2006)
- facilitating interactions across sectors and career life cycles (as in the Wellcome Trust workshop where early-career HASS and STEM researchers explored with senior researchers the issue of research ethics)
- supporting multidisciplinary conferences, workshops and seminars where intentionally informal meetings can stimulate cross-sectoral research ideas
- adopting the European use of the term 'science' to include the social sciences and the humanities (as the European Science Foundation does).

6.2 Change research behaviour

Impediments to cross-sectoral collaborative research are institutional at the organisational and disciplinary levels, and relate to power, resource and status distribution among the different sectors. They occur at national, state and institutional levels.

It is recommended that:

1. when the National Research Priorities are reviewed, cross-sectoral collaboration be embedded as a priority process in all the identified thematic priorities (a 'whole of knowledge' approach, embracing both HASS and STEM disciplines, to address the 'whole of government' research priorities)
2. the ARC, the NHMRC and other funding bodies at national and state levels include specific cross-sectoral collaborations in their objectives and priorities
3. the ARC, the NHMRC and other funding bodies assign cross-sectoral assessment panels to review cross-sectoral research applications and outputs
4. the Research Quality Framework recognise a broader range of outcomes and outputs, beyond discipline-based publications, such as those coming from cross-sectoral research
5. the National Collaborative Research Infrastructure Scheme be modified to take more account of the needs of HASS researchers.

Funding for cross-sectoral research should cover the real costs of cross-sectoral collaboration by supporting:

- the time and resources it takes to set up cross-sectoral collaborations and to maintain face-to-face communication throughout
- flexibility in project goals, directions and personnel, including access to funds for new opportunities or tangents as they arise
- each stage that a collaborative project goes through, especially the significant set-up stage (which can take a year or more)
- integrated cross-sectoral programs and co-location (or resources to support as much face-to-face interaction as possible)
- simple and efficient administrative procedures.

Organisational and funding support for cross-sectoral collaboration is required for integrated programs in which people from different disciplines work together in problem- or issue-based teams, rather than in discipline-based programs or organisations.

It is recommended that continued support be provided for the CRCs, and encouragement for the inclusion of more cross-sectoral collaboration in CRC projects. The CRC Program should make a conscious effort through its funding guidelines to bring the HASS disciplines in the research relationships.

It is recommended that the Australian Government investigate a national structure specifically for supporting collaboration. This structure would encourage education, research and development on the big issues confronting Australia, the solutions to which transcend disciplinary and sectoral boundaries. It could be modelled on the best aspects of the United Kingdom's National Endowment for Science, Technology and the Arts and the Canadian Foundation for Innovation.

The national structure would support:

- talent, innovation and creativity between sectors
- co-location of clusters of people within collaborative centres of excellence
- cross-sectoral research with a moderate to high degree of risk, but with the possibility of high returns
- networking and educational opportunities
- blue-sky research facilities and creative incubators.

The Australian Institute for Collaboration proposed in Section 6.5 may be a suitable vehicle for coordinating many of these developments.

6.3 Educate for greater collaboration

Greater and more effective cross-sectoral collaboration will happen with cultural change which includes better understanding and appreciation of other disciplines and sectors and the development of relationships across sectors. Education at secondary and tertiary levels can help to change the culture, and promote Australia as a 'collaboration' society.

At the tertiary level, it is recommended that undergraduates be given more opportunities to 'think outside the box' of the disciplines by:

- allowing them to participate in cross-disciplinary courses without fearing that their participation will hinder their career development
- developing new teaching courses that cross disciplines and inform wider teaching and research practices
- amending the DEST information survey, which is based on preconceived notions of disciplines and effectively ignores multidisciplinary studies.

These changes could be achieved by:

- changing the weighting of the HECS scheme so cross-sectoral courses are more highly valued
- offsetting emerging disciplinary load shortfalls at undergraduate levels by higher funding for cross-sectoral or cross-disciplinary studies (for example, a student studying at least one STEM subject per semester could attract STEM-level funding for all subjects studied during that semester).

In secondary schools, it is recommended that state and territory governments mandate a balance of disciplines in the final two years of the curriculum.

6.4 Train 'boundary spanners'

Cross-sectoral collaboration suffers from problems arising from differing disciplinary languages, research approaches and cultures. Understanding across sector and discipline boundaries can be improved if people are trained to communicate across those boundaries: the 'boundary spanners'.

At the postgraduate level, it is recommended that Masters and PhD students be offered a semester program in collaborative research, similar to that now being offered in commercialisation. The program would train researchers to be boundary spanners, and would include study of:

- communication skills
- team management and leadership
- different research approaches
- different research languages.

Such training would build the capacity of Masters and PhD students to:

- communicate across discipline boundaries
- develop methods for ongoing collaboration and conflict resolution
- understand and value the contributions of each discipline involved
- work across sectors and foster new methods or approaches for innovative solutions
- become facilitators or leaders who can bring the sectors together.

6.5 Coordinate and advocate cross-sectoral collaboration

It is recommended that the Australian Government support the establishment of a new independent institution, the Australian Institute for Collaboration, to support cross-sectoral collaboration. The institute, which would aim to become self-sufficient, would help to coordinate and advocate cross-sectoral collaboration through a range of short-course training initiatives, seminars and events. It could also further many of the proposals to change research behaviour listed in Section 6.2.

Cultural change requires ongoing coordination and advocacy. To build recognition of the value of cross-sectoral research and education requires decision makers and the public to be more aware of the benefits of such work. This can be achieved by showcasing and celebrating examples of successful collaboration in the media, at events or festivals, and at conferences. This report contains many stirring examples of under-reported but highly successful collaborations.

CHASS, in collaboration with the Federation of Australian Scientific and Technological Societies, can play a key role in this coordination and advocacy.

Should a fully fledged institute model not gain support, additional funding for the growing cross-sectoral activity of the InnovationXchange could be an appropriate interim measure.

Table 2: Impediments incentives and recommendations for collaboration

Factor	Impediments	Incentives	Recommendations
Structure and team management	Inflexible organisations Low attachment to the group Other loyalties and priorities take precedence	Flexible risk-taking environment Clearly defined roles Leaders understand the needs of all disciplines involved End users involved	Promote a new mindset Educate for greater collaboration Train 'boundary spanners'
Power distribution	Disciplinary/faculty jealousy and rivalry Lack of respect for methods of other sectors Perceived unequal status Members pushing their own research agendas	Disciplinary support for collaboration Long-term expectations of collaboration Flexible risk-taking environment	Change research behaviour Educate for greater collaboration Train 'boundary spanners'
Resources and support	Discipline-based funding programs Difficulties in assessing cross-sectoral projects Competition for resources between sectors Difficulties in measuring or evaluating outcomes	Specific funding for cross-sectoral collaboration Government priorities supportive of cross-sectoral collaboration	Promote a new mindset Change research behaviour
Commonalities and differences	Different cultures and norms Different approaches and methods Members based in single-discipline departments / organisations Different value judgments Assumptions about the other sector Lack of shared knowledge	Staged collaboration Training of team to develop common goals and approaches Students encouraged to participate Understanding of each other's approaches and culture	Promote a new mindset Educate for greater collaboration Train 'boundary spanners'
Communication	Different language and jargon	People who can communicate across sectors—'boundary spanners' Clear communication processes Networking opportunities	Educate for greater collaboration Train 'boundary spanners' Coordinate and advocate cross-sectoral collaboration
Personal traits of team members	Lack of faith in other disciplines Inflexible people	People experienced in collaborative projects Members know and trust each other	Promote a new mindset Educate for greater collaboration Coordinate and advocate cross-sectoral collaboration
Status and recognition	Lack of academic acceptance of cross-sectoral research High value put on discipline-based publication No obvious rewards for cross-sectoral collaboration	Recognition for individual and team achievements Credibility built through publishing opportunities Results from collaboration clear and observable outside the group Wider recognition for work outside own discipline	Promote a new mindset Change research behaviour

Appendix A

Literature review

Collaborating across the sectors: a review of the literature on relationships between the humanities, arts and social sciences sector and the science, technology, engineering and medicine sector

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A1 Introduction

The purpose of this literature review is to investigate and describe collaboration across the sectors of the humanities, arts and social sciences (HASS) and science, technology, engineering and medicine (STEM). The review reflects the increasing volume of research on collaboration and the shift in government, organisational and community priorities towards this type of collaboration.

The review is the first step in a project funded by the Australian Government Department of Education, Science and Training (DEST) through the Council for the Humanities, Arts and Social Sciences (CHASS). The project aims to identify strategies and develop best practices for supporting collaboration across the sectors.

A2 The global collaborative environment

The rise in the number of global initiatives and programs designed to strengthen countries' future economies through innovation and creativity reflects the enormous challenges—social, economic and environmental—that we face in the 21st century. Until recently, these programs have emphasised science and technology as the providers of future solutions.

This emphasis on the STEM sector in innovation policies is one aspect of the 'two cultures' divide—the rift that has grown between science and the humanities in the wake of an exponential knowledge explosion and the subsequent hyperspecialisation of knowledge and disciplines. This specialisation has widened the rift and helped to fuel modern society's tendency to see culture as trivial in comparison to science and technology (Snow 1959).

The sectoral and disciplinary divisions created in this environment lead to key problems, such as the increasing disconnection many argue exists between the problems Australia faces and the discipline-based institutions and resources available to address them (Cunningham et al 2005; PMSEIC Working Group 2005). In this context, there are strong views about the need for a fresh approach to innovation in Australia (Cunningham 2004; Gillies 2005). Many of the big issues Australia faces require research environments that support flexible, cross-sectoral collaborations, which could best draw on all the resources available to develop solutions.

Governments and citizens feel that the changes of the 21st century (scientific, technological, economic, environmental and social) are too complex and too rapid for professionals in traditional sectors to operate in isolation (Centre for Creative Communities 2006, 1). The current innovation policies and funding programs of many countries reflect a shift to cross-sectoral collaborations that include the humanities, arts, and social sciences (see, for example, Ang and Cassity 2004, 6).

The recent report *Creative community building through cross-sectoral collaboration* (Centre for Creative Communities 2006) gives an overview of the policies and funding programs of the European Union, the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Council of Europe and the Organisation for Economic Co-operation and Development (OECD). All these initiatives acknowledge the need to create political, economic, social and technological infrastructure that facilitates cross-sectoral collaboration, and call for new models of innovation systems with policies and funding programs that encourage, rather than discourage, sectors to work together. Many countries recognise the need for a more integrated approach to innovation systems—one that includes all potential disciplinary inputs (Cunningham 2005, 21–22).

Within this shift, the call for policies to facilitate greater cross-disciplinary and cross-sectoral research collaborations between the HASS and STEM sectors (PMSEIC Working Group 2005, 5) has been one of the more recent challenges but also one of the most exciting developments in global innovation systems.

Australia's current policy environment for collaborations still reflects an emphasis on science as the sector that can secure the future for our society and economy; an example is the justification for the funding of the CSIRO National Flagship Initiative (Nelson 2003). Many have criticised the National Research Priorities for not adequately recognising the contribution of the humanities to the nation's wellbeing (McCalman 2004).

Recently, however, there have been strong tendencies to recognise the humanities and their ideas for the commercial profit they can bring, as well as for their contribution to the public good. The strongest example of this change is the recent working group paper for the Prime Minister's Science, Engineering and Innovation Council (PMSEIC Working Group 2005). That report acknowledges that Australia's current innovation policies are still based on supporting science and technology as the builders of a knowledge economy. With advances in information and communication technologies, those policies need to include the cultural sectors as powerful engines of sustainable economic growth, and recognise the contribution the HASS sector makes to Australia's research and economy. The report also opens up the field to a whole-of-government approach that could coordinate and improve the current initiatives and innovation policy: 'A comprehensive innovation strategy for Australia needs to integrate the full range of political, creative, technological, economic and scientific elements' (PMSEIC Working Group 2005, 18). To realise this strategy, one of the report's key recommendations is a Creative Innovation Fund to promote new competitive programs and support initiatives for commercial innovation and collaboration between the HASS and STEM sectors.

The desire to remain competitive in a global innovation economy with strategic policies on innovation and creativity (the United Kingdom, Finland, Canada, China and New Zealand have exemplary innovation and creativity policies), and to sustain problem-solving capacities and resources, is driving change in Australian innovation policy towards a more comprehensive and integrated innovation strategy (PMSEIC Working Group 2005, 18, 22). Since the beginning of the 21st century, many countries, such as Britain, Canada, Austria, Korea, Taiwan and Singapore, have launched whole-of-government initiatives and policy changes, including the introduction of new incentives for investment, educational reform, entrepreneurship and cross-sectoral R&D collaboration (Wyszormirski 2003; PMSEIC Working Group 2005, 31).

Finland's innovation policy is at the forefront of developments in comprehensive and integrated innovation systems. That country has moved from its '2nd generation' policy—an interactive model distinguished by schemes that encourage collaborating, networking and innovating—to a '3rd generation' policy—a holistic model characterised by cross-sectoral and mixed schemes that include international clusters to foster coherence, learning and experimentation (Romanaien 2006).

A third model, often applied in the United States, focuses on specific regions and specific creative industries, rather than on whole-of-government initiatives.

Research infrastructure funding in Canada is organised through a different model. The Canada Foundation for Innovation, an independent corporation created by the Canadian Government, is entrusted with money from the government and funds up to 40% of a project's infrastructure.[10] The rest of the funding comes from partnerships with eligible institutions. This project-based, rather than discipline- or sector-based, funding system allows institutions to set their own research priorities in response to Canada's needs.

A3 Our approach

In this review, we investigate the divide that has grown between the humanities and the sciences in Australia, and the relationships and support structures that are being developed to bridge that divide. We investigate the relationships between participants who are collaborating in projects and organisations across the HASS and STEM sectors. Our review reflects the increasing volume of research and cross-sectoral collaboration and the shift in government, organisational and community priorities.

We describe the theories and approaches applied by researchers to better understand collaboration between the HASS and STEM sectors, the benefits and outcomes, and the major barriers to collaborating across the sectors. Wherever possible, we provide empirical evidence to support the theoretical research outcomes described. We also include examples of current collaborative practice and describe the factors that are important to consider.

We refer to documents with both theoretical and empirical implications, as well as project descriptions, to provide information on:

- reasons for collaborating across the sectors
- benefits and beneficiaries of collaboration
- environments in which collaboration occurs
- factors facilitating collaboration
- organisations involved in collaboration, and their structure
- programs and funding bodies that support collaboration
- best practice in collaboration.

Our review also includes an overview of philosophical, psychological, social, management and educational research that has theorised collaborations across the sectors and collaboration in general.

Despite claims that little empirical research has been conducted on cross-collaborative activities (Weszkalnys et al 2005), there is an increasing volume of research on this type of collaboration. Shanken (2005) suggests, however, that more scholarship is needed in analysing case studies and in identifying best practices and working methods. Models and frameworks are needed for evaluating both the hybrid products resulting from collaborative endeavours and the contributions of the individuals engaged in them. As suggested by Pearce et al (2003), collaboration is a skill that needs to be identified, studied and learned. Grigg et al (2003) also call for research that focuses on how researchers in science and engineering and the humanities and social sciences work effectively together.

The national and international case studies we provide have had a demonstrable impact on commercial and community outcomes. It is noteworthy that individual Australian states and other countries differ in their

10 http://www.innovation.ca

organisational and program arrangements, such as the presence or absence of policies, funding and other support mechanisms, general community interest in collaboration, or both. However, while the specific forms of collaborative activity and structures vary, the factors involved in developing and maintaining relationships in collaborative endeavours are generalisable.

For the purposes of this review, HASS and STEM are treated as discrete sectors; however, we acknowledge that disciplines contribute to the collaborative process in different ways in both sectors and, where necessary, we describe the contributing disciplines. While science is defined as interpreting information to produce new knowledge, technology is the application of science, especially for industrial or commercial purposes. Traditionally, the humanities and social sciences have been viewed as interpreting information to produce new knowledge, while the creative arts use the tools of digital media, design, exhibition, visual arts, music, theatre, dance and improvisation to produce art works (Vickers et al 2004). Although the boundaries are blurring, it is important to acknowledge that these distinctions are based on the function of activities and what they produce. Cultural institutions such as libraries, archives, galleries, museums and arts groups are also acknowledged as part of the HASS sector (PMSEIC Working Group 2005), and we include them in this review.

Empirical research dealing with collaborative project performance across the sectors is relatively recent (Shanken 2005; Webster 2005), and many collaborative projects are just beginning to be investigated. Much can be learned over the next few years by evaluating the effectiveness of these efforts and the experiences of participants.

A4 The nature of HASS–STEM relationships

Collaboration across the HASS and STEM sectors occurs when one or more members of each sector combine their efforts to deal with common problems or to achieve shared goals. Using tools provided by the other sector, or contracting the skills of the other sector for particular tasks, is not collaboration. Sometimes collaborating across sectors can result in a new discipline, such as aesthetic computing or ecological economics. Some disciplines (such as mathematics, psychology and epidemiology) do not fit easily within either sector and may use tools and approaches from both sectors. In this section, we look at the relationship between HASS and STEM in all its forms.

A4.1 HASS–STEM interactions

According to Barlow (2006, 37), Australia's researchers are already among the most collaborative in the world, with more than 90% of research papers published by Australian scientists having more than one author, and one-third of all Australian research papers published having an international co-author. However, this tells us little about potentially useful and productive relationships that the HASS and STEM sectors may have developed.

While little systematic research has been conducted on activity between disciplines across the sectors, Grigg et al's 2003 study of Australian cross-disciplinary behaviour patterns suggests that the fields most open to cross-sectoral ideas are environmental science, ecology and evolution. The least open fields across the sectors are cognitive science and media studies.

Grigg et al acknowledge that, while cognitive science has drawn together neurobiology, psychology, artificial intelligence and epistemology, the high proportion of lone researchers (24%) may have skewed these results. Similarly, lone researchers in media studies account for 40% of the sample. In addition, biotechnology and materials sciences show little evidence of engaging with the HASS sector. In that study, most researchers did not wish to move outside their discipline or collaborate with the other sector, but were 'borrowing' the knowledge and techniques of the other sector.

Smith and Katz (2000), in their report on approaches to collaborative research, found that extensive informal and semiformal individual research collaborations form the basis of the United Kingdom's research system. While British higher education institutions were interested in facilitating collaboration, there was little monitoring of this activity within the organisations.

These findings are reflected in *Review of closer collaboration between universities and major publicly funded research agencies*, a report published by DEST in 2004. The report found extensive collaboration between the sciences in Australian universities and public sector research organisations, such as CSIRO, particularly at the individual researcher level.

This lack of information on relationships across the sectors reflects the fact that much of the interaction between HASS and STEM goes undocumented or does not fall into the category of recognised collaboration. While this work provides a useful basis for understanding research collaboration in general, if we are to understand collaborations across the sectors more effectively, we must first understand the types of relationships that exist between the sectors.

In many cases, HASS–STEM relationships can be described as fairly simple and one-directional, with one sector using the tools of the other for its own benefit. For example, advances in science and computer technology provide creative artists with new tools and inspiration—artists use digital technology (Robinson 1998) and refine it, and use technology in art forms such as choreography (Birringer 1999). Tools from the social sciences are applied to help overcome the social, moral and economic challenges resulting from scientific and technological advances in areas such as genetics, nanotechnology and environmental management.

There are many examples of projects exploring the advances of science and technology through the arts, where artists are inspired by current scientific developments. One example is space art.[11] Others involve medical professionals using literature to better understand and complement medical practices (Bonebakker 2003), and teachers using the tools of art to explain science to students—for example, using crochet models to visualise hyperbolic space (Okoniewski 2005).

There is a long tradition of using art for medical therapy; one example is the use of drawings to help adults manage their stammer (Stewart and Brosh 1997). A new magazine, *arts+science*, encourages doctors to participate more in the arts, raising awareness of the potential therapeutic benefits (Meagher 2004).

Although these examples demonstrate an important relationship between the HASS and STEM sectors, they are not collaborations across the sectors.

A4.2 HASS–STEM collaborations

Collaborations across the sectors occur when one or more members of each sector combine their efforts to solve common problems and reach common goals (Reback et al 2002). Problem solving is one of the main motivators for collaboration. For example, Australian of the Year 2005, Fiona Wood, spoke about the need for the Australian biotechnology sector to approach its future development from a problem-solving angle, and called for greater multidisciplinary collaboration at a recent biotechnology conference.[12]

Collaboration between communities, the humanities and science often also develops where regional problems need solving. An interesting example in the United States is the University of New Hampshire's Center for Integrative Regional Problem Solving. The centre is an umbrella organisation that allows key programs of the university, regional non-profit organisations, government agencies, active citizens and the northern New England community to come together and find solutions to critical regional problems, such as conflicting conservation and development needs (UNH Center for Integrative Regional Problem Solving 2006).

The need to build problem-solving capacities is an overarching driver for developing collaboration. This report describes and analyses examples of collaboration in Australia motivated by this need.

11 http://www.olats.org/space/biblio/bibliography.shtml

12 Clinical Professor Fiona Wood AM, Co-founder, Clinical Cell Culture, Australian of the Year 2005 address at the Australian Biotechnology Summit 2006, 'Putting science to work', Sydney Convention and Exhibition Centre, 26–27 July 2006.

Collaboration is also seen as crucial to innovation. According to the Australian Research Council (ARC):

Collaborative links stimulate innovation by facilitating cross-cutting interactions and a free flow of ideas and knowledge. Innovation generally occurs more rapidly and with greater intensity in situations in which there is a higher degree of collaborations. (ARC 2003).

Innovation is defined as the generation, translation and implementation of new ideas into practices (Roberts and Bradley 1991, 212). Madhok (1998) indicates that true collaboration requires synergy, or mutually advantageous conditions between two or more distinct elements. Collaboration combines complementary but dissimilar resources and skills to generate the greatest returns. Members of successful collaborative teams accomplish more than they could if they were working only with members of their own sector and, at times, do it more cost effectively. These collaborations are believed to be the catalyst for developing major new projects and activities that provide economic prosperity and better quality of life (SCST 1999).

Collaborative teams also require reflection, as Roberts and Bradley (1991, 222) state:

Coming together to attempt to accomplish something that no single party can achieve alone required readjustments and changes, at the least to ensure that joint work on the product is coordinated.

Cross-sectoral collaboration can involve scientists, engineers, artists, social researchers and cultural practitioners working together on projects as valuable as understanding how the brain perceives and responds to external signals, dealing with interactions between patients and health-care professionals, and creating more viable rural communities. These collaborations also provide new approaches for engaging the public with science and technology.

A4.3 New fields and transdisciplinarity

Over time, collaborations across the sectors can result in the creation of new fields. While Hagoel and Kalekin-Fishman (2002) describe this as transdisciplinarity—the merging of two disciplines into a newly conceptualised subject area—other researchers view transdisciplinarity differently. Grigg (1999, 4) quotes the OECD's 1972 definition of 'transdisciplinary' as 'establishing a common system of axioms for a set of disciplines'; however, there is evidence that transdisciplinarity is now better recognised for its usefulness in encompassing a wide range of useful skills and knowledge that sit outside the disciplines as they are formally taught, and that the OECD's 1972 definition refers more to interdisciplinarity. Grigg (1999, 4) quotes the OECD's more recent 1998 definition: 'at once between the disciplines, across the disciplines and beyond all disciplines'. These research forms explore the connections outside as well as between the disciplines, looking at the problem or issue from above, rather than focusing on boundary crossing.

Examples of emerging fields developed from interdisciplinary research include aesthetic computing (Fishwick et al 2005), environmental anthropology (Mulcock et al 2005), science studies (Probyn 2004), philosophical ecology (Rose 2005), media art (Sakane 2003), integral ecology (Zimmerman 2005) and ecological economics (Common 2005). While these emerging fields link HASS and STEM in new ways, they do not always involve collaboration between people from different sectors. The approaches and practices of the sectors may be combined in a single individual who takes the tools of one sector to apply to the other, as Hagoel and Kalekin-Fishman (2002) describe. Students may also specialise in an emerging field without having to identify with either HASS or STEM (Madhok 1998).

A4.4 Creativity and the 'third culture'

HASS–STEM relationships can overlap in various fields. For example, technology is making new forms of expression possible, and new technologies are making the creative process easier. The literature on creativity is large and diverse, and there are numerous disciplinary perspectives on creativity, for example biological, cognitive, developmental, organisational and economic (for a review of these approaches, see Sternberg 1999). Definitions of creativity abound. The PMSEIC Working Group report *Imagine Australia* defines creativity as fundamental curiosity and an innate and universal human trait: 'It's our imaginative capacity to generate new ideas, images and ways of thinking; new patterns of behaviour; new combinations of action' (PMSEIC Working Group 2005, 6).

A key trait of creativity is flexibility; it gives the 'capacity to cope with the advances, opportunities, technologies, and changes that are part of our current day-to-day lives' (Runco 2004, 658). In a highly competitive international environment, creativity also needs to be usable within a country's innovation system: 'creativity only becomes economic innovation when it is applied systematically within business to generate new products, services or processes for the purpose of commercial benefit' (PMSEIC Working Group 2005, 6). Software for musical composition, choreography, theatre design and architecture makes it easier to produce traditional forms of work. New technologies are also generating creative products through computer animation, sound synthesis and digital graphics. Some of the most exciting developments in the arts are using multimedia and cybertechnology that are at the boundaries of HASS and STEM. There is genuine collaboration occurring between these sectors. In some cases, collaborations result in emerging fields. An example is design and technology interacting with industry and economics—industrial designers and technologists working together, creating new products and services.

There is debate about the place of some disciplines in HASS or STEM. This debate has its historical origins in the 'two cultures' of the humanities and sciences, which CP Snow confronted in his famous 1959 Rede lecture (Snow, 1959). Some argue that this split and dispute has never ended, but that there was a significant change in the later decades of the nineteenth century. A third culture—social sciences, and particularly sociology—made it a triangular struggle.

As AH Halsey describes, sociology, during its growth as an academic field that crosses disciplinary and national frontiers, was claimed by both science and the humanities as their own (2004). Sociology's institutional history is the story of a discipline's development as an independent academic field, and the growth of the social sciences as a middle (if contested) ground—a 'third culture'. Heated debates raged, and to a certain degree still rage, over sociology's and the social sciences' methodologies, their uses and applications. Halsey also observes that this struggle is reflected in the tension between 'quantitative and qualitative research methods—the one addressing questions of what, where, when, and how, the other exploring why' (p 26; for a description of this tension in the context of collaborative projects, see DiGiacomo 1999). The outcome of these debates and tensions, according to Halsey, might well change 'the traditional struggle between scientific and cultural study' (p 200).

The debate over the disciplinary and social place of sociology has become both example and test case for discussions of the place of the social sciences in general and, from there, also for other disciplines whose place has become contested because of their evolving and changing uses within society. Such disciplines include mathematics, statistics, psychology, science communication, environmental science, epidemiology, geography, science education and engineering education.

For example, epidemiology, emerging from early medical science and originally defined as the study of epidemics, traditionally employs quantitative methods. However, many epidemiologists now recognise the impact of social and cultural factors on states of health and use many of the approaches and methodologies found in HASS disciplines such as anthropology and sociology. The more modern, agreed-upon definition of epidemiology is the study of the distribution and determinants of health-related states and events in populations, and the application of this study to the control of health problems (Last 1988). The term 'health-related' was incorporated into the definition because epidemiologists study many phenomena that are not disease-related, such as car-driving habits, physical fitness, pregnancy and, more recently, ethnicity and psychological states. Fraser (1987) describes epidemiology as a 'low-technology' science with many features of the liberal arts.

For many researchers, the revised definition of epidemiology incorporates characteristics of both HASS and STEM. This is demonstrated by the growing number of research papers dealing with psychosocial epidemiology—from 40 articles in *Medline* between 1966 and 1974 to nearly 1,200 articles in the five years from 1994 (Krieger 2001). Some researchers have attempted to preserve the boundaries around epidemiology by separating clinical epidemiology from social epidemiology, ecological epidemiology and cultural epidemiology (as described by Last 1988). Fenton and Charsley (2000) argue for incorporating qualitative methods and approaches derived from sociology into epidemiological research to complement the quantitative methods traditionally employed. They believe qualitative methods will also shape the direction of epidemiological questions and explanation strategies by helping researchers respond immediately to situations and by providing alternative theories and arguments. While this work can be viewed as cross-collaborative, or contributing to emerging fields, these researchers are spanning the sectors in order to answer questions associated with health risk, disease spread and diagnosis.

The discipline of statistics originated in the United States from a group of researchers in the fields of economics, medicine and social reform, using descriptive statistics to study society (Hunter 1996). It separated itself from the social sciences that had supported it in the 1930s, but has its place in STEM as much as in HASS. Hostility to bridging the boundaries between sectors also exists in other areas but is not well documented in the literature. Broomer (2005) is one of the few researchers to refer to the way in which areas of collaboration are viewed negatively.

These disciplinary tensions and insecurities have historical origins in the traditional split between the humanities and sciences. Bridging the boundaries between sectors requires the transfer of knowledge as well as the gaining and production of knowledge. For collaboration, there needs to be some understanding of the epistemologies of the participating sectors or disciplines.

Epistemologies are about methodologies, about how knowledge is gained and verified; as such, epistemology has been one of the crucial points in debates over disciplinary boundaries. Where the sciences are perceived mostly to practise an objective scientific method (through controlled experimentation, for example), the humanities have traditionally identified themselves with hermeneutics (that is, gaining knowledge by interpretation). Hermeneutics is a method developed originally from the interpretation of scripture or literary texts, and its subjective method has been contrasted to the objective scientific method. The split has developed further throughout the history of the disciplines, to such an extent that some question whether comparisons of them are still possible (Blackburn 1996).

While the HASS and STEM sectors cannot be defined along these methodological lines, perceptions of their differing disciplinary and methodological approaches can affect how HASS and STEM disciplines approach collaborations. The sciences, technology, engineering, the social sciences, the humanities and the arts are distinct fields of endeavour and, while they can share similar approaches, they can also operate under different epistemologies and methodologies. Claire Donovan offers informative work on how these differences are acted out in what has been termed the 'science wars' (that is, the battle over the foundations of social knowledge), in particular in the case of social science (Donovan 2005). Donovan shows that the battle over whether social science is positivist or interpretative has important implications for the governance of and policy-making for social science. Disregarding their differences in policy frameworks for cross-sectoral collaboration might have undesirable consequences (Donovan 2005).

Collaboration often involves ways of conducting research different from conventional scholarship in the collaborating disciplines. It may also result in different ways of knowledge production and different outcomes. Such changes in practice need to be addressed in funding and support frameworks (Duncker 2001; Ang and Cassity 2004). It should also be noted, however, that homogeneity, even within a discipline, cannot necessarily be assumed (Duncker 2001, 350)—hence the importance of communication in cross-disciplinary and cross-sectoral collaboration. Elke Duncker (2001) points to the importance of recognising that different disciplinary terminologies have developed within the characteristic academic division of labour and in association with particular sciences or technologies. Disciplinary terminologies are segmented and, therefore, hierarchically structured (p 355). Finding a common ground in this context of hierarchical disciplinary terminologies is crucial, particularly when writing project proposals and publishing results.

A5 The benefits of collaborating across the sectors

The key drivers for collaborating across the sectors are the benefits that can be demonstrated for those involved or those supporting the collaborations. Collaboration is beneficial for delivering commercial outcomes; solving complex problems that require the skills, approaches and tools of both sectors;

providing services to the community; engaging the public or industry in debate, activities or projects; and encouraging creativity and innovation for research, community and commercial outcomes.

Collaboration across the sectors has been praised for its ability to support and generate commercial outcomes (Gorman and Mehalik 2002; Australian Centre for Innovation et al 2002; PMSEIC Working Group 2005). Collaboration is also thought to help gain public and industry acceptance of technology, provide greater relevance to the sectors (Michael 2002) and create international and market competitiveness (Potoenik 2005).

From a commercial perspective, collaborating across sectors is believed to give industries access to new and more appropriate responses to their markets, reveal hidden or unspoken knowledge, allow members to discuss problems that are not linear, and provide simpler solutions that create a competitive edge (Naiman 2003).

From a research perspective, collaborating across sectors provides researchers with a greater capacity to solve complex research problems, it stimulates projects and intellectual activities in new areas, it increases interaction among researchers and practitioners from various groups and organisations, and it provides greater funding for research and education in a climate of declining government resources (DEST 2004; Riedlinger et al 2004). Collaboration provides ways of managing the huge amount of knowledge that science and technology have generated and will continue to generate, and ways of making sure this knowledge can be usefully applied (PMSEIC Working Group 2005). Fox and Faver (1984) described many of the advantages of collaborating in research, including joining resources and dividing labour, overcoming the tendency to work in isolation, and sustaining motivation by being accountable to others. However, they tempered their enthusiasm for collaboration by describing the many disadvantages, including time and resource costs, the level of interpersonal involvement required, and the problems associated with co-authorship.

From a community service perspective, collaborating across the sectors provides additional services, develops new programs, and trains service agency support staff and volunteers (Reback et al 2002).

Engaging the public and industry is increasingly cited as a mechanism for gaining support for and acceptance of science and technology (SCST 2002). To be successful, engagement activities must incorporate the psychological, social, cultural and institutional factors that shape public attitudes to science and technological developments (Irwin and Wynne 1996). Supporters of public engagement argue that when knowledge of human dynamics and processes, gained through HASS activities, is applied to STEM, it increases public acceptance and helps with assessments of the social impacts of these endeavours.

Terry Hillman, director of the Albury laboratory of the Cooperative Research Centre for Freshwater Ecology, believes it is essential to involve artists in the process of engaging the community in science:

Scientists have some particular knowledge but it doesn't give them any particular right to make the decisions more than anyone else. There needs to be an opportunity in the process of knowledge building to allow individuals to question the safety of the reliance on scientific knowledge. Theatre can allow the public to raise these questions and challenge these systems. (Quoted in Mills and Brown 2004).

Digital media is an area of collaboration directed at engaging the community by making art more accessible to the public. Digital technology collaborations have been particularly successful in engaging the public in issues of health and wellbeing (Sakane 2003). A new school at Stanford University is taking a collaborative approach by bringing together business, humanities, design and engineering staff and students, and commercial businesses, to focus on human-centred design (Nussbaum 2005). Traditional art practices are also being employed for collaborative efforts focused on public engagement, such as the United Kingdom's Wellcome Trust program, Pulse.[13] The program provides funding for performing artists to engage the public in biomedical science.

With the call for further development and funding of the 'third mission' of universities, engaging the public is increasingly important, alongside teaching and research. As the Business/Higher Education Round Table

13 http://www.wellcome.ac.uk/node2550.html

(B-HERT) position paper on universities' third mission states, 'with more widespread recognition, this infrastructure has the capacity to generate significant additional economic and societal value' (B-HERT 2006). In this debate about engagement, research cooperation and collaboration are seen as contributing to more connections between universities, communities and industry.

A recent Australian Institute for Commercialisation discussion paper offers recommendations on how to overcome the divide between industry and the research sector, and a detailed list of the obstacles to science–industry collaboration (Blauensteiner et al 2006). The discussion paper, however, does not address whether 'research sector' includes the humanities, and gives examples exclusively from science. Detailed studies of how HASS–STEM cross-sectoral collaborations might bridge the industry–research sector divide are yet to be conducted.

The emerging creative and digital content industries are examples of how much cross-sectoral and cross-industry collaborations can potentially contribute to Australia's innovation and economy (QUT et al 2003).

Collaborations across sectors are often supported because they are believed to encourage creativity and innovation (PMSEIC Working Group 2005). Webster (2005) suggests that scientists broaden their frames of reference by working with artists. He believes this may be what motivates scientists to collaborate, and to continue to collaborate, with artists.

But even those advocating this position believe that creativity and innovative thinking are difficult concepts to measure and understand (McDonald 2005). Quantifying the inputs and outputs of collaboration, including creativity and innovation, is difficult. It can be even more difficult to define the relationships between the many factors that are associated with 'successful' and 'unsuccessful' collaborations.

Others argue that creativity is fundamental to advances in the sciences, mathematics, technology, politics, business and all areas of everyday life (Robinson 1998). What is described as creativity in the HASS sector may be described as discovery or invention in the STEM sector (PMSEIC Working Group 2005). Creativity may change with context and be different depending on whether you are an artist or a scientist, but it is creativity nonetheless (McDonald 2005).

Collaboration should encourage innovation as, by its very nature, it brings together people who use different 'maps of the world', who challenge each other's assumptions and who borrow from each other's disciplines (Hargadon and Sutton 1997; Rickards and Clark 2006). As stated by Gryskiewicz (1999), innovation occurs at the periphery of knowledge, capitalising on the sometimes chaotic conditions at the interface of two organisations or disciplines. So, the creation of a collaborative activity will encourage innovation, but elements within the collaborating team will also encourage innovation (Ancona and Bresman 2006). These elements include the techniques used by the team for decision making, coordination and knowledge transfer, leadership style, openness and trust (Ancona and Caldwell 1992; Ancona and Bresman 2006).

Fox and Faver (1984) argue that, while collaboration generates a 'collective creativity', it can inhibit individual creativity and obstruct independent verification of the value of creative work. They believe that there must be opportunities to support all types of creative endeavour for the best interests of the research and the general community.

Yet another argument is to bring together creative practice and research in the field of digital technology (Edmonds et al 2005). Practice and research are seen as interdependent activities, and bringing artists and technologists together has mutual benefits as well as benefits for innovation in digital technology. Edmonds et al give an excellent overview of potential models for creating and supporting creative collaboration and suggest a structured process for research and collaboration (2005). They also recommend strategies for providing creative technology environments for developing, for example, network infrastructure, hardware and software platforms, and tools and applications. Innovation and creative work, they conclude, is 'a kind of exploration that needs flexible support' (p 5).

A6 The collaborative environment

Beyond the perceived inherent benefits of collaboration, a number of environmental drivers motivate collaboration. These drivers include:

- government support and funding, with an emphasis on commercial returns
- individuals who champion collaboration (although some organisational support and security is necessary for this to be sustainable)
- philanthropic support for collaboration, driven by a desire for cultural and community benefits
- large-scale research centres that encourage research across sectors
- university programs that encourage interaction across traditional disciplines
- public exhibitions and performances that bring together a number of disciplines to better engage audiences
- organisations set up specifically to support collaborative projects.

Organisations provide support for initiating or maintaining collaboration through websites, conferences and workshops, dedicated spaces, multidisciplinary journals, and residency programs in which a person from one sector spends some time working in another sector.

Researchers have used a number of theoretical frameworks to explore these collaborations across the sectors. Collaboration has been approached from philosophical, psychological, management and educational perspectives. Contributions have also come from the professional disciplines involved in engineering, health and environmental sciences.

Philosophical perspectives deal with intercultural issues and boundary crossing, whereas psychological perspectives look at notions of identity and group formation in the collaborative process. The concept of 'technological frames' is used to demonstrate that people from different sectors are likely to have different assumptions, expectations and knowledge about a particular technology. Collaboration is likely to occur when members of different sectors share a 'trading zone' or common goals and objectives, despite having different technological frames. The 'transaction costs' framework recognises that collaboration will only work where the transaction costs (time and resources) are low and the benefits are likely to be high. Non-linear approaches to problem solving and the development of creative spaces to foster innovation have been investigated by researchers concerned with education.

The professional disciplines often take a practical approach to collaboration, looking at it from problem-based perspectives where researchers have moved outside their disciplines to address questions and issues that they cannot answer alone. This method has incorporated 'Mode 2'-type approaches (described below in Section A5.16).

A6.1 The rise in cross-sectoral collaboration

Like many researchers, Sakane (2003) believes that the increase in art–science collaborations can be partly attributed to the critical writing of CP Snow's *The Two Cultures* and Georgy Kepes's essays in *The New Landscape*. Sakane considers that emerging new technologies that give both STEM and HASS new avenues to explore, including digital media technologies, have also contributed to this increase.

Other researchers point to the growing number of social issues that cannot be addressed by STEM alone. Global warming, stem cell research and emerging diseases show that science–humanist perspectives are more relevant than ever (Eisen and Laderman 2005). Hjorth and Bagheri (2006) also note a growing feeling in many quarters that science is not responding adequately to the challenges posed by society. They point to sustainable development as an area where a different approach is needed. They believe science treats sustainability as a project with an end point rather than an ongoing process intrinsic to everyday work, which requires the humanities and sciences to work together.

Leach (2005) indicates that collaborations across the sectors have arisen as a way for people to try to take control over powerful forces beyond their everyday experience; in this case, technological development and its implications for social change.

Cross-sectoral collaboration occurs in many such environments, and key influences that encourage or drive collaboration are emerging.

A6.2 Government drivers

Government funding and support for collaborations across the sectors is on the increase internationally; for example, the PMSEIC Working Group (2005) describes policy and funding programs in the United Kingdom, Canada, New Zealand, Korea, Hong Kong, Singapore and Taiwan. The report of the Humanities, Science, and Technology Working Group, *National Endowment for the Humanities*, is a helpful account of government funding of collaborations between science, arts and the humanities (SCST 2002). While philanthropic funding for collaborative research and other activities is abundant in the United States in comparison to Australia, little government funding is dedicated to collaborations across the sectors. This has resulted in science–art projects seeking science and military funding, and in various forms of corporate sponsorship, such as industrial R&D departments that function as art and technology incubators.

Australia supports a growing number of large-scale collaborations among universities, government, industry and cultural institutions. Public funding for collaboration is most frequently provided to maximise quality output, and to encourage and reward entrepreneurship (Kemp 1999). In the past, more research grants were available for scientific research, whereas humanities grants were few and far between. Scientists and engineers tended to have more practical, profitable products (Andersen 2003). However, social scientists, humanities researchers, cultural practitioners and artists are increasingly being recognised as contributing to the national economy and community wellbeing. This is reflected in the Australian Government's announcement of the National Research Priorities in November 2002, and the increasing inclusion of HASS activities in recent years. The government's emphasis on commercial return and the growing recognition of the contribution of HASS activities to the country's wellbeing have resulted in institutional changes in both HASS and STEM institutions, reflecting a greater emphasis on collaborating across sectors.

The 2004 round of funding for Cooperative Research Centres Program removed restrictions on fields of science, including social sciences, to better meet the National Research Priorities—an environmentally sustainable Australia; promoting and maintaining good health; frontier technologies for building and transforming Australian industries; and safeguarding Australia (Cooperative Research Centres Program 2004).

CSIRO responded to the priorities by forming the Social and Economic Integration initiative. The initiative supports a range of innovative cross-sectoral projects, such as the 'greener cities' project, which brings together remote sensing data and social and demographic information to provide new insights into the health impacts of urban design. In 2004, three CSIRO Flagship Visiting Fellowships were appointed with social science expertise (marketing, psychology and social health) to work with the Food Futures and Preventative Health national research flagships (CSIRO 2004).

In its recent report, the PMSEIC Working Group (2005) recommends that design, creativity and creative industries be included in the Australian Government's innovation policy and in all government-funded programs for research and innovation. The group believes this will facilitate even greater cross-disciplinary collaborations between STEM and HASS.

The Australian Government's emphasis on sourcing industry funding for research has lead to HASS areas within universities being reorganised and renamed, and to 'policy' being incorporated in many activities combining HASS and STEM theory and practice. The setting up of the Faculty of Creative Industries at the Queensland University of Technology also reflects a response to government priorities (Vickers et al 2004).

Artists, social scientists, humanities researchers and cultural practitioners are becoming more aware of commercial opportunities for their services in the public and private arenas through their exposure to government schemes, such as the ARC's Linkage grants (Gascoigne and Metcalfe 2005). Universities are encouraging commercial applications, as applied contract research now counts towards the research quantum.

A6.3 Individual drivers

Researchers such as Shanken (2005) believe successful collaboration is the result of the work and vision of key charismatic individuals. They point to examples of this in industry, such as the Xerox PARC Artists-in-Residence program and Intel's sponsorship of artistic research. However, these researchers do not describe the personal and leadership qualities of individuals who realise those collaborations, or the conditions that would lead to identifying and cultivating those qualities.

The PMSEIC Working Group (2005) believes that human talent is not replicable and that, therefore, understanding these drivers would be of little use. It believes that it is much more important to invest in policy and funding strategies that encourage individuals to support collaboration across the sectors. In addition, many social researchers believe that much happens at the group and organisational level that is overlooked because of the focus on individuals (Turner and Oakes 1986; Ashforth and Mael 1989; Lembeke and Wilson 1998). Individuals may initiate and nurture collaboration, but there is a lot more going on.

A6.4 Education

Governments are increasingly linking their need to sustain economic success to building an inclusive society and improving the lives of their citizens. In this link, they recognise the contribution of education and research in both the humanities and the sciences. For example, the United Kingdom's Department for Education and Skills recognises the growing value of links between disciplines for breadth of skills and innovative, interdisciplinary research (Hodge 2001). In the United States, the United Kingdom and Europe, primary and secondary educational programs emphasising the connections between the humanities and the sciences as creative processes are leading to less specialised curriculums, but are not widespread (Roth and Peasley 1992; Schramm 1997; Kieff and Bryant 2005). In tertiary education, there are broader programs of undergraduate instruction in both the humanities and sciences.

Eisen and Laderman (2005) believe programs incorporating the social context in which science operates are essential for the learning of science. They point to a multidisciplinary project at Emory University, Atlanta, in which researchers in medicine, theology, public health, sociology, psychology, biology, physics, history and religion came together at lunchtime meetings over a semester to develop 'science and society' seminar programs for undergraduates, graduates and the general public.

Arts and humanities subjects are now included in many medical teaching institutions in the United States, but many of these courses involve elective subjects in HASS disciplines rather than collaboration across the sectors. Internationally, some courses present model structures for collaborating in education. For example, Weller (2002) describes a visual arts course set up in a London teaching hospital in 1999. The course was developed under the theory that a medical education that did not embrace the humanities 'tended to brutalise and dehumanise' (Weller 2002). Broomer (2005) discusses a University of Oklahoma project from which the outcome was a DVD in narrative medicine for self-study by doctors. The rationale was that doctors must listen to patients' stories to glean information and need to be sensitive to what is being conveyed in stories or narratives. The project team used narratives from classical literature to develop this sensitivity.

Ateer and Murray (2003) describe a course on loss and grief for physiotherapists. It combines social science and sociological texts with scientific texts to help physiotherapists deal with patients who have lost limbs, mobility, or both. Small-group teaching of interdisciplinary courses is also occurring, such as teaching the humanities and arts to medical students at the University of California (Shapiro and Rucker 2003), and providing a broader perspective on the place of science in culture, with reference to chaos theory (Lagan and Paddy 2005).

The call to probe the humanities–science connection more deeply in education is also becoming stronger in Australia. 'Education is the very incubator of innovation', said Malcolm Gillies in 'Rethinking Australian Innovation', his 2005 address to the National Press Club, adding that we need to connect these sectors more to develop and draw on all the potential talent in Australia.

The Australian Government has begun to facilitate more collaboration between universities and other education providers, industry, business, regions and communities. It sees cross-sectoral collaboration as having the power to respond to labour market demand for new and flexible skill sets and as resulting in more efficient delivery of education. The government established the Collaboration and Structural Reform Fund from 2005–2007 and allocated a total of $36.6 million. The fund absorbs the previous Higher Education Innovation Programme, with new guidelines and additional funding (Nelson 2003, 39). Measures to promote broader cross-disciplinary and cross-sectoral teaching and research suggested by the 2005 PMSEIC Working Group report include introducing integrated arts, science and humanities programs for university undergraduates; creating PhD placement programs with businesses; and encouraging interdisciplinary and creative research within universities.

The University of Sydney has announced a double degree in music and medicine, to be offered from 2007. The seven-year course combines a bachelor's degree in music and a four-year postgraduate medical degree. The undergraduate music degree incorporates physics and biology subjects, as well as small subjects in communication and ethics and two projects that combine medicine and music (O'Keefe 2006). Jannie van Deventer, Dean of Engineering at the University of Melbourne, announced recently that 70% of students were taking combined degrees with engineering, arts or commerce (Cervini 2006). He believes the combined degree broadens their experience and is welcomed by industry.

Manathunga et al (2006) investigated two interdisciplinary research centres based at the University of Queensland and found that reflective techniques were an important part of education for higher degree students involved in interdisciplinary research. Reflective techniques, such as annual review processes with supervisors and portfolio building, help students recognise the skills they are developing as cross-sectoral researchers, where they are situated in relation to the disciplines, and the influence of their disciplinary backgrounds on decision-making processes and actions.

A6.5 Artist residency programs

Webster (2005) believes art–science collaborations commonly occur through residencies where, for example, artists reside at a scientific institute or, more rarely, scientists reside at an artistic institute. He points to examples of artist residency programs in the United Kingdom at the Wellcome Trust Sanger Institute, the Cavendish Laboratory at the University of Cambridge and the Natural History Museum in London. Also in London, the Institute of Contemporary Arts has scientists in residence (Webster 2005). Another international example is the 'Signatures of the invisible' project—a collaboration between the London Institute and CERN, the European organisation for nuclear research.[14] Scientists from CERN worked with visual artists to make original pieces of art, which the organisers believe responded to the current preoccupations of theoretical physics.

Artist and scientist residencies are also supported in the United Kingdom by scientific institutions, such as the National Institute for Medical Research, and museums. The Wellcome Trust SciArt program is supported by the Arts Council, the National Endowment for Science, Technology and the Arts (NESTA) and private foundations. The Arts and Humanities Research Council Scheme, in collaboration with Arts Council England, also supports research fellowships. To be eligible, artists must find a supportive institution and a scientist to work with. The Engineering and Physical Sciences Research Council provides funding for research networks made up of scientists and artists (Webster 2005).

In Australia, the Australia Council's Synapse initiative encourages creativity and innovation by providing opportunities for artists and scientists to work together.[15] Synapse has three streams: ARC Linkage Grant

14 http://www.arts.ac.uk/signatures/latestex.htm

15 http://www.ozco.gov.au/arts_in_australia/projects/projects_new_media_arts/synapse_artscience_initiative

Industry Partnerships, Synapse residencies, and the Synapse database for linking artists with scientists. The residencies program encourages collaborations between the arts and sciences by placing artists in scientific institutions.

A6.6 New approaches to cross-sectoral collaboration

Researchers have used various existing theories and applied them to collaborations across sectors in order to better understand the process and to help those working in collaborative projects. However, Gabriele Bammer[16] calls for an even greater understanding of research management grounded in these cross-sectoral collaborations in order to take into account their distinctive characteristics and the wide range of partners and contexts they involve. She calls for greater emphasis in research on harnessing differences between partners in collaborations, setting defensible boundaries for collaborative activities and gaining legitimate authorisation from organisations and other entities involved. Bammer believes that the tensions brought about in trying to achieve these objectives must remain salient for researchers as a reminder that there is no ideal research partnership process.

A6.7 The transaction costs framework

Collaborating across sectors is thought to make more efficient use of resources (PMSEIC Working Group 2005) and be more effective at solving common problems and reaching common goals (Reback et al 2002). However, this may only be the case when the issues or problems central to the collaboration cannot be tackled by one sector alone. Madhok (1998) believes groups and organisations will find the most efficient means of organising an activity or reaching a goal. This means minimising the transaction costs, such as the time and resources needed to undertake the project. Collaboration has high transaction costs, which makes it less attractive unless the problem is difficult or no other options are available. The transaction costs described by Irvin and Stansbury (2004) in their analysis of public participation activities provide a way to determine whether a HASS–STEM collaboration is likely to provide successful outcomes. Their model is based on resource use.

As shown in Figure A1, when transaction costs are low and the benefits of the collaboration are high, the collaboration will most likely be successful. Transaction costs are low when members agree that the project benefits the entire group; when members are not too geographically dispersed, or can easily communicate (preferably face to face); when members have enough time to contribute to the project and still perform other duties; and when the project does not require members to master complex technical information from other fields too quickly.

High benefits can be derived from collaborating across sectors when the issue is too complex to be dealt with by one sector alone; when the project manager has credibility with all project members; when the issue is very interesting for all members; and when the issue is perceived as being close to 'crisis stage' if collaborative efforts are not made.

Figure A1: Relationship between costs, benefits and success

Transaction costs	Benefits	Likelihood of success
High	Low	Low
Low	High	High
High	High	Variable
Low	Low	Low

16 'Three principles for managing research collaborations', unpublished manuscript, Gabriele Bammer, National Centre for Epidemiology and Population Health, Australian National University.

As illustrated in Figure A1, when transaction costs are high and the benefits are low, collaborating across the sectors may be ineffective and wasteful compared with working in one sector alone, or employing the tools another sector for specific tasks. Transaction costs are high when members are reluctant to get involved in what they consider to be the job of others; when the project is spread over a geographically large region or presents other obstacles to communication (such as strong loyalty to individual worksites); and when the many diverse members required make a very large collaborative group. Transaction costs are also increased when key people cannot take part because of other work priorities or commitments; when complex technical knowledge of each sector is required before members can move forward; when not all members recognise the issue as a problem; and when the potential alternatives for approaching the work are not familiar to all members.

Benefits of collaborating across the sectors are low when members have had prior success in using tools from another sector for specific tasks without genuine collaboration; when the outcomes of the collaborative project are likely to be ignored, no matter how much effort goes into their formation; and when the outcomes from the collaborative project are likely to be the same as those produced from one sector alone.

If the benefits can be increased by contributing more resources to the project, this may be a more appropriate step than abandoning the collaboration. As Madhok (1998) notes, relationship-specific costs can be an investment for the future of the work.

A6.8 The technological frames perspective

Gorman and Mehalik (2002) apply Bijker's (1987, 1995) concept of technological frames to explain the interaction of members across sectors when creating particular environmentally friendly inventions. When people make sense of technology, they develop particular assumptions, expectations and knowledge of the technology that might not be shared by others. These are described as technological frames. Innovation occurs when adjustments are made to a technological frame or a new frame is developed.

Three states of interaction across sectors can be described using technological frames. The first is a top-down model in which one person coordinates other individuals to perform tasks or take the tools of one sector to apply in another—projects within the film industry are an example. In this state, the technological frame is not shared by all members. With the second state, members of a collaboration may have different technological frames but they share a 'trading zone' that helps them work together and communicate, sharing their specialised skills and experience. Most collaborative projects involving HASS and STEM appear to be in this second state. The third state is where all members share the same technological frame and there is a shared understanding of what is to be created. If a new technological frame has been produced, these collaborations could be described as an emerging field, such as aesthetic computing and others described earlier in this paper.

Researchers view these three states as a continuum through which collaboration develops, from using the tools of the other sector to creating new technological frames that can be adopted by others.

A6.9 Intercultural approaches

Schneider and Northcraft (1999) describe many of the factors that are required for successful collaboration in teams of diverse people. Factors include equal status between members of different groups, interdependent group goals, group reward distribution systems, opportunities to dispel stereotypes, and the ability of members to see the benefits of being part of a diverse group. These factors can be described theoretically using concepts gathered from social identity theory (SIT) (Tajfel and Turner 1986; Hogg and Abrams 1988).

Social group identity is defined by Tajfel and Turner (1979) as a person's sense of belonging to certain social groups. SIT is a theoretical framework that has been used to explain links between relationship building and the breakdown of relationships that can occur between members of different social and working groups. SIT complements other theories dealing with collaboration because it focuses on relationship development, group formation and intergroup interactions. SIT proposes that communication is a marker of identity as well as a necessary activity for overcoming the constraints to relationship building that are caused by identifying with different groups, such as disciplines or sectors. Therefore, communication, from a SIT perspective, provides challenges to relationship building as well as opportunities for developing collaborative relationships. Communication is a tool for building and maintaining the boundaries of HASS and STEM groups as well as a means for overcoming them.

Researchers have shown that group identity is created, maintained and modified through communication and language (Bantz 1993; Scott 1997) and that people most often prefer to communicate with their own social or professional groups (Abrams and Hogg 1990). This can make communication difficult in collaborations that bring members of diverse groups together to work on common problems.

Suzuki (1998) looks at identification and communication in collaborative organisations, showing that the study of communication patterns reveals much about the intergroup processes operating in these organisations, including how trust is developed between members of different groups.

A6.10 A symbolic communication perspective

Duncker (2001) looks at collaborations across sectors through common language development, and employs the concept of symbolic communication to demonstrate that members in collaborations have a range of communication tools available for overcoming the challenges associated with a lack of common language, framework or practices. They develop dictionaries and 'hybrid repertoires' that may disappear at the end of the collaboration or develop into a new specialised language with continued collaboration or the advent of an emerging field. Cybernetics, for example, incorporates knowledge about communication and control in living beings and machines constructed by man. It involves disciplines as diverse as anthropology, engineering and physiology. The cybernetics hybrid repertoire includes terms such as learning, regulation, adaptation, self-organisation, perception and memory.

In the symbolic communication model, not all approaches and understandings are shared by members, but a system for communication, or hybrid repertoire, develops and allows specific information to be shared across disciplinary divides. For example, environmental and sustainability studies have linked life sciences, physical sciences and social sciences with the arts and humanities to produce new areas of study, such as human–environment interaction and the environmental affects of human systems.

Advanced hybrid repertoires develop in long-term collaborations. However, problems arise in less well-established collaborations when members use symbolic resources (such as those found in applied mathematics, or graphs, technical drawings and sketches) that are too general or abstract to be practically applied, or too concrete within one discipline or sector to be applied in different contexts.

A6.11 Creative collaborative processes

Spear and Rawson (2002) employ John-Steiner and Moran's (2002) description of the creative collaborative processes in fields such as science, art, music and literature to better understand relationships between substance abuse researchers and practitioners across the HASS and STEM sectors. John-Steiner and Moran believe collaboration requires diverse perspectives (with common vision, trust and shared control), ongoing conversations and the co-construction of knowledge in order to be successful. Through their empirical work, Spear and Rawson (2002) recommend supplementing major collaborative initiatives with other activities that promote informal communication and dialogue. Conferences, interest group meetings, discussion forums and conversational activity between meetings have led to the development of cross-collaborative projects.

A6.12 The role of boundaries

Many researchers have tried to describe the sectoral boundaries that inhibit collaboration and how these have been bridged in successful collaborations. Social psychology researchers argue that group boundaries are necessary because they help individuals define their place in a community or group and facilitate their communication with others (Petronio et al 1998).

In research collaborations, Lele and Norgaard (2005) believe that boundaries are developed and maintained around 'scientific communities' rather than specific disciplines. Hunter (1996) describes a scientific community as an association of scholars who define their field of study as distinct from other subjects and share ideas within institutions. However, a scientific community can be a group of scholars who share a characteristic such as the subject of study (society and technology, for example); a geographical region (northern Australia, for example); assumptions; models; methods, (mathematical, statistical, interpretive, ethnographic etc); or the audience they wish to reach. These scientific communities have a strong investment in maintaining the boundaries for their own survival, and provide strong points of identification for members.

A6.13 Shared norms, values and attitudes

According to Besley (2002), exchanging and managing information is essential for innovation in collaboration. However, Haslam et al (2001) indicate that, for collaboration to occur, members of a group need to understand the significance and purpose of information through shared norms, values and attitudes. Forming the basis of organisational culture, these shared norms and values are slow to develop, causing problems for new collaborations. Members of a project might believe they share a common understanding of the project, but interpret and experience it in different ways. Managers and others involved in the project can find it difficult to identify these different interpretations and experiences.

Members can also affect the 'climate' of a group through their interactions. Climate is described as the set of attributes specific to a particular project or organisation that can be identified from the way the group deals with its members and its environment (Glick 1985). Leadership approach and style are major factors affecting organisational culture and climate.

A6.14 Leadership

Collaboration demands an innovative leadership style, similar to that of an entrepreneurial leader (Hauschildt 1999). Innovative leaders walk a tightrope of tensions, addressing the needs of their members and the wider stakeholders in the collaboration, being active members of their collaborative teams, and tackling the more entrepreneurial demands of their role (Dubrin and Dalglish 2003; Rickards and Clark 2006).

The leadership literature suggests that effective leaders are those who can adapt their style to accommodate characteristics of their collaborators, the specific context in which they work, and the broader environmental context—in this case, that of cross-sectoral collaboration (Dubrin and Dalglish 2003; Goleman 2005). Hogg and Terry (2000) suggest that the communication style of leaders contributes to members' commitment to collaboration by fostering cooperation, the sharing of information, trust, and support for shared norms and values. Schneider and Northcraft (1999) believe leadership communication style contributes to the acceptance of member diversity. Leaders must also demonstrate support for members if the project climate is to be conducive to members' commitment (PMSEIC Working Group 2005).

Recent literature on leadership views it as a long-term relationship, or partnership, between leaders and their group members (Trompenaars and Hampden-Turner 2001; Dubrin and Dalglish 2003; Rickards and Clark 2006). When leadership is viewed in this way, control shifts from the leader to the group, signalling a move from an authoritarian style towards shared decision-making (Block 1993). As the group or organisation's fortunes become positive (that is, as it experiences success), leaders are often perceived as more charismatic (van Knippenberg and Hogg 2001), which is important to keep in mind when evaluating the contribution of charismatic individuals to collaborations.

A6.15 Organisational structure

Giddens (1979, 1984), through structuration theory, describes the structures that members draw on to produce and reproduce working collaborations. Distributed power systems, communication output such as written documentation, meetings, clearly defined roles and common goals, geography, size and funding are all structures that can support or inhibit collaboration. Mintzerg (1979) believes innovative organisations are organic in structure, with few established behaviours, and Moch and Morse (1977) have shown that decentralised power structures are necessary for innovation.

Kezar (2005, 832) links the 50% failure rate of collaborative ventures in universities to departmental 'silos', bureaucratic/hierarchical administrative work units and other rigid structures. Her case-study based research indicates that relationships and a university network, with associated structural and reward changes, are the most important factors for building and sustaining commitment to collaboration in university settings.

If a project attempts to incorporate too many people and is dispersed over too wide an area, this will significantly inhibit collaboration. Structures must be put in place to encourage interaction and communication. Rules specifying acceptable conduct are also structures that support or inhibit collaboration. Hjorth and Bagheri (2006) describe structures as the content and timeliness of information and the goals, incentives, costs and feedback that motivate or constrain members. Like climate, structures can be changed by members, and these changes can be unpredictable (Barley 1986).

A6.16 Problem-based approaches in context

With greater emphasis on cross-sectoral collaboration to address the complexities of health and environmental problems, researchers in projects across the sectors are reflecting on their practice in cross-sectoral collaboration. Slatin et al (2004) describe a cross-sectoral project involving natural, medical and social sciences to look at health disparities among health-care workers. The challenges they describe relate to differences in disciplinary concepts, questions and research methods. Those challenges were exacerbated by increased costs of collaborating, such as additional meetings, balancing other work requirements, and the time required for communication. However, the benefits from cross-collaborative work included the intellectual stimulation and creativity that emerged in the process of collaboration, increased networking opportunities and the potential expansion of available funding sources.

Michael Gibbons et al (1994) describe the collaborative research form of using problem-based approaches to create knowledge, incorporating the social context of the research as Mode 2 research. Mode 2 researchers create knowledge by carrying out research in the context of its application. This research form has been embraced by nations focusing on creating knowledge for prosperity and wellbeing. To succeed, such nations depend on sharing knowledge and innovation across society. Ang and Cassity (2004, 6) acknowledge the growing importance of Mode 2 research in Australia, which is reflected in the ARC's Linkage program.

By contrast, Mode 1 research is carried out within recognised disciplines and provides reliable academic knowledge, but provides little direct linkage between the research and social application. The boundaries between disciplines, universities and industries are distinct, and researchers and practitioners from these entities do not rely on each other for developing their research focus (Gibbons et al 1994).

Mode 2 research supports diverse teams of experts and practitioners working together to find solutions in specific contexts. For these reasons, it is highly pertinent as a model for cross-sectoral activities, which are often based on common problem solving. Gibbons et al (1994) describe the Mode 2 research form as transdisciplinary, socially accountable, organisationally non-hierarchical and reflexive.

A7 Barriers, challenges and favourable conditions for collaboration across the sectors

There are many barriers and challenges to collaborating across the sectors, such as the cultural and disciplinary diversity of members; the need to generate commitment; geographical dispersion; communication constraints; status differences; the need to build creativity and innovation; and lack of support (Garza and Santos 1991; Tsui et al 1992; Leonard and Straus 1997; Scott 1997; Chatman et al 1998; Lamb et al 1998; Madhok 1998; Suzuki 1998; Johnson and Chang 2000; Duncker 2001; Kramer 2002; Oetzel 2002; Andersen 2003; PMSEIC Working Group 2005).

This section summarises the challenges and barriers to collaboration and describes the factors needed for successful collaboration across sectors. Collaboration is most likely to be successful when people develop a sense of belonging to a collaborative project that does not conflict with their sense of belonging to other groups, such as disciplinary or organisational groups. Similarly, a symbolic communication perspective recognises that collaboration will be more successful with a shared language and means of communication. Informal communication was identified as being important for creative collaborative processes in research.

To be successful, a collaborative project or organisation needs to identify ways to break down the boundaries between the sectors. This means developing shared norms, values and attitudes. The management and communication style of project leaders and the structure of the project or organisation are both important for achieving this.

A7.1 Managing diversity

Philosophical theories and other theories dealing with intercultural exchange have contributed to our understanding of many of the challenges facing those collaborating across the sectors. The main disadvantage of collaboration is that the diversity that defines the members making up the collaborative group makes cooperation more difficult (Suzuki 1998). Factors unconducive to cooperation in diverse groups include less attachment to the group (Tsui et al 1992); a focus on individualism and the distinctiveness of members or disciplines (Chatman et al 1998); communication problems associated with decision making and conflict resolution (Leonard and Straus 1997); and a lack of communication management within the group (Johnson and Chang 2000). Perceived unequal status, perceived unequal numbers of members from different sectors (Garza and Santos 1991), competition for resources (Oetzel 2002), and conflicting group needs and working styles (Kramer 2002) also affect the relationships of members in collaborations across the sectors.

The Canadian Federation for the Humanities and Social Sciences states that the differing methods and approaches that are employed by disciplines must be acknowledged before collaboration can be effective (CFHSS 2006). The federation calls for flexible structures to be employed in collaborations, allowing for disciplinary and researcher independence as well as collaboration on shared goals, to meet the needs of collaboration members.

A7.2 Identification and commitment

Strong identification with a group or organisation has been shown to improve information sharing in R&D organisational settings; a sense of social group membership facilitates communication, trust and, in turn, innovation and research outcomes (Tushman 1982). However, it is difficult to achieve this identification in a cross-collaborative project. Madhok (1998) believes collaborations fail because members do not recognise the value of the collaboration and/or do not invest the level of time and resources needed to realise this value. Geographically dispersed collaborations can allow other loyalties and priorities to take precedence, while resource allocation differences can communicate group prestige, which can lead to conflict (Scott 1997). Tenure affects attachment, as the more time spent with other members, the more trust can develop (Scott 1997).

Walther (1997) noted that a shared identification with the collaborative group or organisation, even across international and organisational boundaries, was possible when members expected to have future interactions. This led to more effective working relationships. Scott (1997) showed that long-term contact can improve relationships between members of conflicting or competing groups attempting to collaborate, depending on a number of factors, the most significant being the reason members have come together. Harrison et al (1998) tried to explain this process by showing that, over time, members become more concerned with deeper-level characteristics of other members, such as their values and attitudes towards the collaboration, instead of characteristics of identity such as disciplinary identity, for example as biotechnologists or artists. If members are genuine in their willingness to collaborate and can see the potential for results, the values and attitudes of the collaborative group become more stable and clearer over time, and members identify more closely with the group.

Sonnenwald et al (2001) developed measures of success for collaborations, based on concepts described in innovation diffusion theory—relative advantage, compatibility, complexity, trialability and observability. They believe that use of these measures will ensure that members of the collaborative team commit to meeting their goals.

In the terminology used by Sonnenwald et al, relative advantage is a measure of whether the collaboration surpasses current practice. If the project does not need to have a collaborative approach in order to reach its goals, then it may be better to approach it through other means. Compatibility is important because the project approach must be consistent with the values, past experiences and needs of members. Being consistent with the fundamental or general values and work practices and contributing to the 'work satisfaction' of members is important.

Complexity must be manageable so that members can collaborate based on their current level of knowledge and skill. If too much preparation, learning or changed practice is required from them, collaborating will be much more difficult. This refers to 'ease of collaboration' or 'ease of learning from another sector'.

Trialability is the ease of experimenting within the collaboration without undesirable consequences. If too much effort is needed and the risk is high, the collaboration may be difficult to manage. Members must be able to reverse decisions and feel that the environment is safe for them to share ideas. The results of the project also need to be observable and understood by members and those outside the project.

Cross-sectoral collaborations are often dispersed geographically across regions or countries, and can involve many different organisations. This influences member acceptance and the effective functioning of the group. Communication and information sharing can be hampered when there is no direct contact, causing members to feel isolated and mistrustful of others. Dispersed collaborations may have access to more resources, ideas and approaches to problem solving and problem finding, and hence do better in tasks requiring this creativity (Nemeth 1986), but members must be willing to share ideas if innovation is to be achieved (Chatman et al 1998). Therefore, conditions must be favourable for building good relationships.

A7.3 Communication

Communication difficulties can be caused by the differing jargon and language used by the different disciplines, as described by Duncker (2001). Leaders and managers may deal with these problems by conveying only essential information to team members to avoid confusion. However, this leads to other problems, including omission of information, errors or delays in transmission, filtering of information, simplification of messages, use of multiple communication channels, and communication avoidance (Haslam 2000).

A lack of communication is a communication act in itself, and indicates deeper-level problems. These include lack of trust, lack of interdependence (common goals and agreement), unfair distribution of rewards (credit for contributions), and inability to come to agreement about the social structure of the project, such as work, authority, prestige and status relationships (Jackson 1977).

Andersen (2003) looks at differences in information-seeking behaviour in HASS and STEM members, finding that communication across the sectors requires groups to understand each other's behaviours and cultures, adjust for differences in style, and translate information into a language that is familiar to both groups. She believes that electronic mail and the World Wide Web have narrowed the gap between the two sectors, but not enough to eliminate these challenges.

Lele and Norgaard (2005) describe many of the common challenges to communication in cross-sectoral collaborative projects based on cultural differences. Challenges include taking different approaches to solving a problem, a lack of shared knowledge, the different values and practices of different communities, and commitment to theories of the sector or scientific community. Lele and Norgaard also identify value judgments in the work that remain unacknowledged, such as the approach to a 'knowable truth' in science versus a socially constructed world in the humanities, the societal value placed on the different disciplines, and their status. They believe that, for some projects, too much communication is required to bridge these gaps—the disciplinary boundaries may be too strong.

Developing favourable conditions for collaborating across the sectors is not just a matter of reversing the challenges. For example, encouraging more communication or opening up electronic communication channels does not necessarily help collaboration, as email 'flame wars' have demonstrated (Postmes et al 1998).

Merely transferring information is not enough to ensure effective communication. Members need to understand the significance and purpose of information through shared norms and attitudes, or through sharing an interpretative framework. A shared understanding of the collective self can lead to innovation (Haslam 2000). Therefore, it is important that members contribute to all phases of the project, from design to agreed outcomes. Perceived support for the norms and values of members (Clement et al 2001), agreement about mutual long-term goals (Bantz 1993), and status recognition (Scott and Timmerman 1999) all contribute to stronger and more positive relationships in collaborations. Cross-sectoral collaborators must allow for other ways of creating knowledge besides those of their scientific community or discipline. Members must come together around shared interests and problems that need types of answers different from those offered by conventional research or practitioner communities (Lele and Norgaard 2005).

Lamb et al (1998) discuss the importance of ensuring that all members participate in all aspects of the project. They also believe it is important to compensate members for any costs associated with the collaboration, and to provide appropriate incentives for collaboration. These measures will make collaboration more desirable. Other incentives include building credibility for the research (through promotion and publishing), developing a well-structured research plan with which to approach other members, and being open to sharing ideas and resources. Co-location of researchers has been suggested as one way of developing more effective collaborative networks and managing diversity. If co-location is not possible, resources must be devoted to travel and technology to enable regular communication (DEST 2004).

A7.4 Managing status and hierarchies

Differences in status, power and prestige are major challenges to collaboration (Hogg and Terry 2000). Even differences in perceptions of status relationships and disciplinary hierarchies can be a major impediment, as Duncker (2001) indicates. Using a case study, she noted that members of one discipline in the collaboration perceived their status to be higher than that of the other disciplines and refused to take on the service role that the collaboration plan had allocated to them; as a result, the collaboration failed to develop. Perceived unequal status can lead to 'professional embarrassment' or bias when working with other disciplines.

The contributions in a recent issue of *M/C Journal* focusing on collaboration examine a range of difficulties in collaborative work. Problems related to status, power and prestige (such as authorship credit), copyright, sharing of responsibility and output, and institutional and cultural hierarchies (Brien and Bruns 2006).

These challenges are also borne out in empirical research. Lamb et al (1998) showed that major challenges to cross-collaborative enterprises were organisational factors; stigma; social policy; cultural differences; funding; lack of communication, mutual respect and trust; and unresolved differences in values.

Mintzerg (1979) believed training could be used to overcome disciplinary boundaries by providing members with a common belief or framework. Other researchers have investigated ways of overcoming the boundaries that inhibit effective working relationships (for example, Coupland et al 1991), including the use of 'boundary spanners'—people who can communicate across sectors (Petronio et al 1998).

Ancona and Caldwell (1988) looked at the process of creativity and innovation in new product teams through the phases of product development—generating ideas, evaluating, analysing stakeholder needs, developing, testing, and extending to management. They found that boundary spanners take on different roles in this process—scout, sentry, ambassador or guard. Their role depends on their relationship to the group and their contribution to the collaboration. For example, in the initial phase of product development, the scouts are important because they go out and get the information needed to make the collaboration happen, whereas the ambassadors are important throughout the project for maintaining cooperation and developing relationships. These researchers found that high-performing project groups had greater communication with colleagues in other areas than low-performing groups.

Johnson and Chang (2000) suggest that boundary spanners may reach even further to create broader relationships with communities across group boundaries. Spear and Rawson (2002) call these people 'organisers' or 'bridgers', whereas Shanken (2005) calls them 'intermediaries'. All believe that boundary spanners are central to creating and maintaining collaborations. However, Shanken (2005) believes the long-term sustainability of collaborations also requires the support of the individual disciplines to gain credibility and for efforts to be recognised and rewarded.

Members must be aware of and agree to adhere to their roles and responsibilities if collaborations are to be successful (see the description of property rights theory in Milgrom and Roberts 1992). The productivity of individual members and 'shirking' are directly associated with the productivity of others, so it is also important to provide mechanisms that encourage members to work and to recognise their achievements in collaboration. Williamson (1975) described the importance of these factors through the application of agency theory.

Successful collaborations need to be equal and non-hierarchical, with two-way communication and appropriate dissemination of outcomes (Reback et al 2002). Long-term collaborations also require support for permanent infrastructure. This could be as simple as employing a full-time person for computer support or implementing activities over a number of sites (Lamb et al 1998). Madhok (1998) believes a key indicator of success for collaborative research is the number of students wanting to work in the field; therefore, encouraging students to take part in a collaborative project is essential.

A7.5 Reporting the outcomes of collaboration

Shanken (2005) believes that it is essential to address questions of interpretation and evaluation of hybrid products coming out of collaborations across the sectors, such as technology, art and publications. There is a belief that the status of interdisciplinary products and performances is low compared with the status of other products and performances. Collaborative research is seen as less prestigious if it is published in collaborative journals, but its value often goes unrecognised by disciplinary journals, which can be more conservative. For example, digital media, while providing avenues for HASS and STEM to explore and being more accessible to the public (Sakane 2003), does not have the status of more traditional art forms.

Publishing individually from collaborative research can be hampered by funding and organisational directives that require joint demonstrable outcomes. Collaborating organisations have very different ways of measuring excellence (for example, published papers versus user satisfaction), and these need to be better recognised to appreciate the real value of collaboration (DEST 2004).

The Canadian Federation for the Humanities and Social Sciences calls for ways to measure outcomes of collaboration other than publications with more than one author. The federation believes that co-authorship is not the best measure of collaboration, as some disciplines require researchers to produce sole-authored publications in order to be recognised in the area (CFHSS 2006).

A7.6 Education

The PMSEIC Working Group (2005) describes many of the challenges to collaborating across the sectors that have been dealt with theoretically by communication and social researchers. They include distance, lack of critical mass, and lack of status for some disciplines (for example, design) in comparison to others. The group also points to factors contributing to a lack of support for collaboration, which include lack of commercial opportunities, lack of industry and public support for collaborations, lack of support for informal networking, and difficulties in measuring or evaluating the outcomes of collaboration. Without a proper way to measure creative outcomes, it is difficult to encourage potential collaborators.

The lack of support begins at school level, where the sciences and arts are separated. According to the PMSEIC Working Group (2005), Australia's school curriculum, which is based on the British model, needs revising. Similar recommendations have been made about the United Kingdom's school curriculum:

We consider that the relationships between the arts and humanities and science and technology need to be strengthened further. Education is about understanding and imagination, as well as about training and skills. Yet school education in the United Kingdom, especially for 16 to 18 year olds, is still highly specialised. Large numbers of science students have very little opportunity to study arts and humanities subjects, and large numbers of arts students study very little science. The organisation of higher education is entering a period of substantial change, in which there will be an opportunity to encourage a more diverse undergraduate curriculum. (Council for Science and Technology 2001)

The PMSEIC Working Group (2005) believes creativity can be enhanced by encouraging free movement of ideas across sectors, by providing flexible risk-taking environments, and by encouraging observation and imaginative ways of thinking in school-aged children. The group acknowledges that some conditions produce more favourable conditions for collaboration than others, and that this needs to be investigated further.

As early as 1997, Michael Gibbons, in his Beanland Lecture at the Victoria University of Technology, called for new cross-sectoral approaches to education to permeate universities (Gibbons 1997, 1):

The numbers of research centers, institutes and think tanks are multiplying while faculties and departments remain the preferred form for carrying out teaching. Universities are confronted with the challenge of how to accommodate these new research practices. At the very least they will have to become more open, porous institutions vis-à-vis the wider community, with 'fewer gates and more revolving doors'.

Manathunga et al (2006, 375) believe that higher education interdisciplinary programs need to build on existing collaborative structures, incorporating reflective techniques into supervisory programs for postgraduate research degree students and creating spaces for interdisciplinary dialogue, rather than creating additional courses. Building on existing structures would acknowledge the view of many research managers and researchers cited in Manathunga et al's study that interdisciplinary skills are learned by doing rather than by being taught. In addition, these interdisciplinary programs would not put extra pressure on already stretched resources within collaborative projects and programs. Manathung et al cite Bruhn's (2000, 58) description of the skills needed for work in interdisciplinary areas as being essential for research students. These include boundary crossing; harnessing differences; leadership and project management; non-linear thinking and problem solving; common problem solving; and sharing innovative knowledge with society.

However, there is some evidence that graduate student participation in collaborative research is detrimental to PhD completion and future employment. This needs to be investigated further. The Canadian Federation of Humanities and Social Sciences recommends the collection of more detailed statistics on the application rates and success rates of large-scale collaborative research projects, in order to better understand the relationships of the disciplines to collaborative research and graduate student involvement across the sectors (CFHSS 2006).

A7.7 Working conditions

The Federation of Australian Scientific and Technological Societies' submission to the PMSEIC Working Group, *The role of creativity in the innovation economy* (FASTS 2005), states that collaborating across sectors will result in more creativity and innovation if the constraints that currently limit creativity in the STEM sector are reduced. These constraints, which apply equally to the HASS sector, include lack of job security; increased use of casual and short-term employment; the competing demands of government and clients, which can restrict the capacity to concentrate on a given scientific problem or issue; excessive competition for funding; and inadequate opportunities for researchers to influence organisational strategic direction and priority setting (FASTS 2005). It is important to note that some organisational security and support is necessary to facilitate risk taking, a major ingredient of collaboration. The lack of organisational recognition for collaborative researchers in matters of promotion and tenure is a well-recognised barrier to collaboration (CFHSS 2006).

While not referring specifically to cross-sectoral collaboration, DEST's *Review of closer collaboration between universities and major publicly funded research agencies* (DEST 2004) points to a lack of understanding by organisations of the resources and time required to collaborate. The lack of understanding and the consequent lack of resources and time are major barriers for researchers wishing to collaborate. These barriers apply equally to cross-sectoral collaborations.

Bammer believes that, while organisational legitimacy and authorisation for cross-sectoral projects are essential, particularly for large projects, they may come at a cost to researchers.[17] Restrictions may result from researchers shaping projects to fit funding priorities or agreeing to guidelines dictating if or how a project's outcomes will be implemented. Bammer calls for more work in this area of essential cross-sectoral project support to better understand the impact of legitimacy on cross-sectoral collaboration.

The PMSEIC report, *Imagine Australia*, while noting current collaborative efforts, calls for changes in political, economic, social and technological infrastructure to increase support for collaborations between HASS and STEM. The Australia Council has suggested setting up a collaborative support program similar to NESTA in the United Kingdom, while the Australian Film Commission has suggested that the Australian Government support an Australian Learning Channel based on models of digital technology from the United Kingdom (PMSEIC Working Group 2005).

A8 Best practice

There are no best practice guidelines available for collaborations across the HASS and STEM sectors. However, some research is available on worst practice.

For example, Kezar's (2005, 859) study of collaboration found that holding training sessions on collaboration within the university was not cost-effective, as very few researchers attended. Smith and Katz (2000) point to the lack of mechanisms for measuring collaboration and the inadequacy of measuring it through co-authorship, as well as a dearth of available information on the real costs of collaboration.

While researchers such as Bammer (2006) are working towards new transdisciplinary research to engage more systematically with cross-sectoral collaboration, there is a call for better recognition and understanding by support organisations and funding bodies of the costs of collaborative research (DEST 2004).

17 'Three principles for managing research collaborations', unpublished manuscript, Gabriele Bammer, National Centre for Epidemiology and Population Health, Australian National University.

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Appendix B

Information-gathering survey

B1 Summary

The appendix summarises information provided by 606 respondents to a descriptive, online information-gathering survey. The survey focused on key aspects of collaboration across the fields of humanities, arts and social sciences (HASS), and science, technology, engineering and medicine (STEM).

After we developed the draft survey, we circulated it to members of the Reference Committee for comment. We placed the final electronic survey on the CHASS website. The survey link was emailed to the extensive networks of the Reference Committee members, and was promoted to research and practice networks around Australia. We used a combination of methods to interpret the data, such as descriptive statistics, a thematic analysis and a Leximancer analysis.

Over half the survey respondents (54.5%) belonged to the HASS sector, 26.2% belonged to the STEM sector, and almost 18% classified themselves as belonging to both sectors. The respondents came from all Australian states and territories (except the Northern Territory). A small number of responses were sent from overseas locations.

As this was an information-gathering exercise, the results of the survey need to be interpreted with caution. Because respondents were self-selected, it is difficult to say that the survey is truly representative of cross-sectoral collaboration. However, the results of the survey provided us with a broad overview of a significant amount of cross-sectoral collaboration in Australia.

Approximately 75% of survey respondents had been involved in some form of cross-sectoral collaboration. The most common reasons listed for non-involvement were lack of opportunity (32.8%); difficulty making connections (27.7%); no need to collaborate (17.6%); no time to collaborate (11%); lack of resources (8%); and lack of experience (3.4%).

According to survey respondents, the key ingredients that facilitated their collaborative projects were openness, communication, project management, understanding, interests, respect, commonalities, acceptance, funding, outputs, people, goals, partnerships, time, trust, disciplines and leadership.

The major hindrances to collaborative projects related to a lack of common understanding, poor communication and links, not enough funding time, and impermeable discipline boundaries.

B2 What we did

We developed an on-line information gathering descriptive survey to understand the extent of cross-sector collaboration occurring in Australia. We wanted to find out who is conducting cross-sector projects and why; the outcomes of the projects; the key ingredients that facilitate or hinder collaboration; and things to avoid when collaborating. The survey, which can be viewed at the end of this appendix, was developed using Survey Monkey software.

Once we completed the draft survey, we circulated it to members of the reference committee for comment. We placed the final electronic survey on the CHASS web site. The survey link was emailed to the extensive networks of the reference committee members, and was promoted to research and practice networks around Australia, including:

- CHASS members
- CRCs
- CSIRO
- ARC connections
- ASC list
- university lists, including deans of arts, social science and humanities

We used a combination of descriptive statistics and thematic and Leximancer analyses to interpret the data. For the numerical questions, and the more concrete open-ended questions, simple lists of responses with frequencies and percentages are provided in the report. For the more abstract open-ended responses we have provided lists of major themes, supported by specific examples drawn from the survey.

The survey involves many optional, open-ended responses. While these responses can be coded into numerical data, trying to then conduct statistical analyses on such responses is inappropriate, given the large gaps due to missing data and the exploratory nature of the questions. These results were, therefore, analysed using a combination of thematic analysis (using the cut and paste function in word) and Leximancer Analysis. Leximancer is a tool that constructs a thesaurus of concepts from textual data and maps the relational distance between the concepts.

The overall analysis produces an accurate description of the main themes and concepts contained in the data.

B3 What we found — individual respondents

Which sector do you belong to?

Table 4: Respondents by sectors

Which sector do you belong to?	Frequency	Per cent
HASS	330	54.5
STEM	159	26.2
Both	108	17.8
Other	9	1.5
Total	**606**	**100.0**

Over half of the survey respondents (54.5 percent) belonged to the HASS sector; 26.2 percent to the STEM sector; and almost 18 percent classified themselves as belonging to both sectors. The above table reports the figures after making some manual adjustments. Many of the original 'other' responses fell into the HASS or STEM sectors. The following people were moved based on their written responses:

Moved to HASS

- administration/education
- agricultural and resource economics
- architecture and urban design
- commerce and economics
- design
- education
- education and innovation

- library
- management
- management consulting
- media
- museums
- psychology/behavioural sciences

Moved to STEM

- allied health rehabilitation
- ecology
- conservation and environmental
- environment/sustainability
- health
- nursing

Moved to 'both'

- social sciences and medicine

Left in 'other'

- botanic garden
- festivals and events
- government resource manager
- industrial design
- information studies
- local government
- marketing
- public service
- science communication and research management

Location

The respondents came from a broad cross-section of Australian locations. A small group of responses were sent from overseas. Because there was no single question in the survey that requested the respondents' location, these figures were gained from the organisations listed in the respondents' contact details.

Table 5: Location of respondents

Location	Frequency	Percent
ACT	11	5.6
NSW	65	33.0
Qld	42	21.3
SA	23	11.7
Tas	5	2.5
Vic	34	17.3
WA	10	5.1
International	7	3.6
Total	**197**	**100.0**

Have you ever collaborated with people outside your sector?

Approximately 75 percent of survey respondents had been involved in some form of cross-sector collaboration.

Table 6: Percentage of respondents involved in cross-sector collaboration

	Count	Percent
Yes	454	74.9
No	152	25.1
Total	**606**	**100.0**

It appears that people who classified themselves as 'both' or 'other' were slightly more likely to have been involved in cross-sector collaboration than people solely in HASS or STEM.

Table 7: Percentage of respondents involved in cross-sector collaboration (by sector)

Which sector do you belong to?	Have you ever collaborated with people outside your sector?				Total	
	Yes		No			
	Count	Percent	Count	Percent	Count	Percent
HASS	237	71.8	93	28.2	330	100.0
STEM	117	73.6	42	26.4	159	100.0
Both	92	85.2	16	14.8	108	100.0
Other	8	88.9	1	11.1	9	100.0
Total	**454**	**74.9**	**152**	**25.1**	**606**	**100.0**

What is the single most important reason you have not collaborated with people outside your sector?

The most common reasons listed for non-involvement in cross-sector collaboration were: a lack of opportunity (32.8 percent); difficulty making connections (27.7 percent); no need to collaborate (17.6 percent); no time to collaborate (11 percent); a lack of resources (8 percent); and a lack of experience (3.4 percent). Written responses to the question above were coded into one of six categories. The number and percentages of respondents are listed in Table 8.

Table 8: Reasons for not engaging in collaboration

Reason	Frequency	Percent
Lack of opportunity	39	32.8
Difficulty in making connections	33	27.7
No need, desire, or commitment	21	17.6
Lack of time	13	10.9
Lack of resources, funding, or support	9	7.6
Lack of experience	4	3.4
Total	**119**	**100.0**

Note: although 152 respondents reported no collaboration, only 119 provided a reason.

Table 9 indicates that HASS and STEM respondents reported similar reasons for lack of collaboration.

Table 9: Reasons for not engaging in collaboration (by sector)

Reasons for not engaging in collaboration	1. Which sector do you belong to?								Total	
	HASS		STEM		Both		Other			
	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Lack of opportunity	24	31.6	10	29.4	4	50.0	1	100.0	39	32.8
Difficulty in making connections	24	31.6	9	26.5	0	.0	0	.0	33	27.7
No need, desire, or commitment	15	19.7	6	17.6	0	.0	0	.0	21	17.6
Lack of time	5	6.6	5	14.7	3	37.5	0	.0	13	10.9
Lack of resources, funding, or support	5	6.6	3	8.8	1	12.5	0	.0	9	7.6
Lack of experience	3	3.9	1	2.9	0	.0	0	.0	4	3.4
Total	**76**	**100.0**	**34**	**100.0**	**8**	**100.0**	**1**	**100.0**	**119**	**100.0**

Note: 119 respondents (out of 152 possible) provided written responses to this question.

B4 What we found — specific projects

Number of projects reported

Table 10: Number of projects surveyed (by sector)

	Which sector do you belong to?				
	HASS	STEM	Both	Other	**Total**
Total number of projects	222	113	102	5	**442**

Survey respondents could report on up to five projects. Information gathered for each project included the following:

- title (not reported below)
- time period (not reported below)
- disciplines involved
- organisations involved
- sources of funding
- expected/actual project outcomes
- whether the project was judged to be worthwhile
- reasons the project was considered worthwhile (not reported below)
- reasons the project was considered not worthwhile (not reported below)
- important ingredients (Leximancer summary below)

- major hindrances (Leximancer summary below)
- things to avoid (Leximancer summary below)

Note: Titles and time periods are not listed in the tables below. Respondents reported wide ranges of time periods, from projects beginning prior to the 1990s through to more recent (current) projects.

Disciplines involved

In general, respondents from a wide variety of disciplines were involved in collaborative projects. Respondents could (and usually did) report more than one discipline involved in each project, so the total number of disciplines reported is greater than the number of projects.

Respondents differed in the degree of specificity with which they described disciplines. Some respondents reported very broad disciplinary fields (e.g. physical sciences), while others reported specific disciplines.

Table 11: Number of projects surveyed (by discipline)

Discipline	Frequency	Percent
The arts	75	13.8
Medical and health	60	11.0
Social sciences	53	9.7
Information, computing sciences	33	6.1
Behavioural and cognitive sciences	33	6.1
Earth sciences	31	5.7
Agriculture, veterinary and environmental sciences	27	5.0
Engineering and technology	26	4.8
Law, justice and law enforcement	25	4.6
Education	21	3.9
Economics	21	3.9
Studies in human society	19	3.5
History and archaeology	18	3.3
Sciences – general	16	2.9
Language and culture	14	2.6
Journalism, library, curatorial	12	2.2
Physical sciences	11	2.0
Architecture, urban environment, building	11	2.0
Commerce, management, tourism	10	1.8
Mathematical sciences	8	1.5
Biological sciences	6	1.1
Philosophy and religion	6	1.1
Policy and political science	5	0.9
Chemical sciences	3	0.6
Total	**544**	**100.0**

Collaborating organisations

Universities were by far the most common organisation involved in collaborative projects reported in the survey. See Table 12.

Table 12: Types of collaborating organisations surveyed

Type of Organisation	Frequency	Percent
Universities	124	31.9
State government agencies	38	9.8
Other government authorities	33	8.5
Art galleries	28	7.2
Industry groups	23	5.9
CSIRO	22	5.7
Other research centres	18	4.6
Community groups	13	3.3
Hospitals	12	3.1
Community service organisations	11	2.8
Private developers/consultants	11	2.8
Professional associations	9	2.3
CRCs	8	2.1
Government arts organisations	8	2.1
Advisory groups	6	1.5
CMAs	6	1.5
Conservation groups	4	1.0
International agencies	4	1.0
Theatre companies	4	1.0
Media	3	0.8
Artist collectives	2	0.5
Recreational groups	2	0.5
Total	**389**	**100.0**

Funding sources

Government departments, universities and the ARC were the most commonly cited funding sources. Privately funded projects (12.3 percent) and non-funded projects (5.2 percent) were also reported.

Table 13: Funding sources

Source	Frequency	Percent
Various government funding bodies (DEST, NHT, etc.)	53	21.0
University	50	19.8
ARC	41	16.3
Private	31	12.3
International (UCN; UNDP; GEF etc.)	13	5.2
None	13	5.2
Industry bodies (MRC)	11	4.4
CSIRO	9	3.6
CRC	8	3.2
Fees (student/conference)	7	2.8
NH & MRC	6	2.4
In-kind	5	2.0
Australia Council	4	1.6
Bequest	1	0.4
Total	**252**	**100.0**

Planned outcomes

Note: Although there were about 400 separate outcomes listed in the data set, only 226 are summarised here.

Table 14: Planned outcomes

Outcome	Frequency	Percent
Gathering knowledge/ understanding	57	25.2
Improving current strategies	47	20.8
Developing guidelines and models	43	19.0
Education	35	15.5
Community programs	15	6.6
Publications	7	3.1
Therapies	9	4.0
Build relationships	5	2.2
Developing a product	4	1.8
On-line databases	3	1.3
Complete PhD	1	0.4

Outcome	Frequency	Percent
Total	**226**	**100.0**

Was the project worthwhile?

As per Table 15, respondents judged that the vast majority of their collaborative projects were worthwhile.

Table 15: Percentage of projects considered worthwhile

	Frequency	Percent
Yes	425	96.8
No	14	3.2
Total	**439**	**100.0**

B5 What the thematic and Leximancer analyses told us

Q4. What do you think is the most important ingredient for facilitating collaboration across sectors?

According to respondents, the key ingredients that facilitated collaboration were openness, communication, project management, understanding, interests, respect, commonalities, acceptance, funding, outputs, people, goals, partnerships, time, trust, disciplines, and leadership.

Openness (open mind, open communication, being open to new ideas)

a. acceptance
b. encouraged through funding
c. flexibility
d. respect for other disciplines
e. desire to understand
f. face-to-face engagement

Communication (structures, flexibility, boundary spanning)

a. active listening
b. common tools
c. connections and linkages with others
d. willingness to discuss
e. desire to understand
f. shared goal/common vision
g. flexible management

Project management (at all levels, regular, relationships and trust)

a. clear understood goals
b. common vision
c. ethical framework
d. building trust
e. boundary spanning

f. champion (industry, across boundaries, for collaboration)
g. rewards for sectors
h. flexible (embracing radial ideas for interaction, respect for different ideas, team building, leadership)
i. independent project management
j. clear objects
k. face-to-face meetings
l. Skills in project management
m. communication (regular meetings, manager communication, on all levels)
n. benefits for all
o. skills
p. understanding
q. common interest
r. like-minded people
s. acceptance
t. respect

Understanding
a. project management
b. goals
c. respect (like and respect, other people and disciplines, different perspectives)
d. structure to build (funding, administration, time)
e. communication

Interests
a. common/mutual
b. expressing
c. outside discipline
d. enthusiasm

Respect
a. mutual for expertise
b. forms of knowledge
c. for discipline
d. other people's skill set
e. difference (approaches and values, perspectives, forms of knowledge, contribution of others)
f. through deep understanding of (disciplines, need to collaborate, shared project aims)
g. takes time to develop

Commonalities
a. goals (mutually agreed upon)
b. communication tools (key messages, audiences, simple language)
c. interest
d. project vision
e. commitment
f. outputs
g. time to develop commonalities

Acceptance

a. ability to relinquish boundaries and traditional approaches
b. listen and explain
c. express interest (know complex ideas don't belong to one domain, intellectual awareness that issues develop and are cross-disciplinary)
d. openness
e. outcomes (practical outputs, acceptable to peers)
f. respect, trust and communication

Funding

a. openness (partner relations, see funding encourages new ideas, across sectors)
b. leadership (effective networks with funding bodies, unbiased)
c. incentives linked to funding
d. partnerships (contacts, desire to force on behalf of funding agency)
e. understanding (trial projects)
f. networks (seed funding to encourage, with funding bodies)
g. administration (overlooking bureaucratic processes, understanding of collaboration)
h. structures (outside silos, targeting collaborative efforts)

Outputs

a. outcomes (practical to society, mutual benefit – equal, flexibility for unexpected, unified vision, motivation to achieve common, working toward clear, expected positive for all, communicated by leaders)
b. accepted by peers/discipline
c. time (structure, to reach agreement on)
d. flexibility (for unexpected)
e. quality

People

a. equality
b. like-minded
c. breadth of knowledge and skill
d. common interest
e. respect others and disciplines
f. understand need to collaborate
g. like each other (spend time together)
h. cooperative
i. interested in collaboration
j. good will
k. energetic
l. appropriate

Goals

a. communication (to reach common, regular, no jargon – good communication, to share common/ articulate)
b. trust and willingness to work together
c. complementary skills
d. clear understanding of
e. mutual embracing
f. common
g. well-defined
h. shared
i. flexibility for unexpected

Partnerships

a. for outcomes
b. friendly relationships
c. shared outcomes
d. openness (communication, face-to-face)
e. academic generosity
f. benefits for sector in accepted style
g. confidence in partnerships
h. shared understanding
i. complementary skills
j. cooperative attitude
k. interest (cross-sector topics, mutual interest in topic)

Time

a. to learn
b. for preliminary discussion
c. for process
d. to develop working relationships
e. to talk through different perspectives
f. to reach mutual goals

Trust

a. communication and guidelines
b. skills (complementary, project management
c. acceptance
d. personal contact
e. respect and openness
f. mutual interest
g. equality

Disciplines

a. communication (curiosity about other, boundary spanners/interpreters, articulating shared goal, desire to understand other)
b. openness (to ideas, concepts and approaches, other disciplines, epistemologies)
c. respect for other
d. awareness (of connections between)
e. working structures (infrastructure and collegiality)
f. funding across
g. tolerance of different views
h. flexible approaches

Leadership

a. support
b. communication (project, timeframes, resources, outcomes and deliverables)
c. networks with funders
d. unbiased
e. incentive schemes linked to funding
f. vision
g. integrity
h. enthusiasm
i. intelligence
j. project management skills
k. responsible to funding bodies/industry
l. independent
m. champion in sector
n. speak both languages
o. facilitating open communication
p. understanding sector cultures
q. bridging social and cultural differences

Q5: What do you think is the single biggest hindrance to collaboration across sectors?

Major hindrances related to a lack of:

a. things in common (ground, understanding, language, commitment)
b. understanding (other fields/disciplines, key concepts and objectives, social science, other's expertise/perspectives, proposed project, core issues of discipline that are never articulated, respect for disciplines)
c. communication and links (confusing terminology, unclear/poor, across various disciplines, different languages and frameworks)
d. funding (views interdisciplinary work simplistically, art-science difficult, do not know what is possible for cross-sector conversations)
e. time (to achieve results, for research)
f. disciplines (precious boundaries, manuscript writing/sharing funding, some viewed as peripheral, no appreciation of disciplines, no patience and resources across disciplines, no understanding of disciplinary way of knowing)

Other barriers to collaboration involved people, geography and the organisations involved.

Funding

a. time (seeking funding, in administration)
b. agencies vet publications – influences writing and publishing
c. funding criteria (rigid)
d. concern that partner may take over funding (mistrust)
e. finding funding difficult
f. administration time
g. no clearly identified outcomes at outset
h. precious of own field
i. competition for resources
j. not interest from agency until project complete
k. lack of funding without agenda – pre-conceived value of sector/disc
l. not fitting in boxes
m. no IP/seed funding
n. silo funding
o. competition
p. what counts as research

Time

a. no time to develop common understanding to develop project objectives
b. no time for cross-sector conversations
c. need time to achieve results
d. no time for academics to do research

Understanding

a. uneven attention to sectors – no common understanding (some issues core to collaboration – not articulated)
b. some disciplines viewed as peripheral
c. no university encouragement to understand disciplines
d. jealousy and territoriality between Deans
e. conflicting priorities
f. no common language
g. confusing terminology

Disciplines

a. boundaries
b. language/communication
c. perceptions – unequal
d. lack of appreciation
e. can't think outside discipline
f. lack of patience and resources across disciplines
g. lack of respect
h. no university encouragement to cross
i. conflicting priorities
j. lack info/interest on crossing boundaries

k. ingrained methods
l. ignorance of others
m. bureaucratic imaginary walls
n. ownership of knowledge claims
o. compartmentalisation
p. entrenched academic structures
q. prejudice

Communication

a. lack of communication
b. funding for
c. understanding
d. crossing disciplines
e. not listening
f. inflexible people/closed minds
g. no links across sectors

Sectors

a. resources (competition, sector size and resources different, small and large groups collaborate)
b. individual arrogance – sector has all answers
c. language
d. desire to convert/promote own discipline
e. individuals obsessed with power
f. narrow and outdated views

Project

a. lack of interest
b. some contributions peripheral
c. failure to understand other views
d. lack of understanding
e. funding
f. time needed

Language

a. lack of commonality across sectors
b. too technical

Research

a. humanities view science as irrelevant
b. lack of support for ensuring early and mid-career researchers stay in academia
c. lack funding
d. lack of appreciation disciplines
e. social sciences unable to agree why important
f. silo mentality

People
a. mistrust
b. perspective irrelevant
c. lack of commitment
d. not thinking outside the box
e. inflexible
f. lack of patience
g. collaboration not core business

Interest
a. lack of scholarly interest
b. no university encouragement
c. lack of interest in project
d. lack of interest in social science
e. university focus on own research strengths
f. self-interest – work in isolation

Geography
a. differing locations
b. no time to meet/travel
c. distance across continents

Lack of leader support
a. sector leaders fail to see benefits
b. Dean protection
c. mistrust of other sector
d. funding competition
e. encouragement of collaboration absent
f. no project management understanding
g. lack of recognised authority
h. jealousy on sharing resources
i. perception of undermining power

Organisations
a. inflexibility
b. lack of leader support

Powerful individuals
a. arrogance
b. obsessed with power
c. do not recognise independent project leader

Q6: What is the most important thing to avoid when collaborating across sectors?

Things to avoid were major problems associated with communication, sectors and disciplines, people involved, research, the quality of the collaboration, understanding and ideas.

Communication

a. lack of (across disciplines, regular)
b. no commitment
c. no communication avenues
d. specialised language
e. unresolved misunderstandings
f. vagueness – desired outcomes
g. preconceived ideas
h. making decisions with no consultation
i. focus too wide
j. protection of turf
k. not open and transparent
l. hidden agendas
m. not enough communication
n. breakdown
o. lack of clarity in responsibilities

Sector

a. funding (don't rely on external funding; lack of)
b. unequal partnerships
c. adding sectors as afterthoughts
d. closed minds
e. dominant interests – one sector
f. research in isolation
g. competition for recognition
h. tacking on work from one sector (e.g. social science) towards end of project
i. jargon
j. valuing contribution of sectors
k. lack of understanding culture and resources
l. assume uniformity
m. assumptions – time and goals
n. sectors hijacking research plan
o. only illustrating cross-sector ideas rather than thinking beyond borders
p. thinking one sector dependent on other

People

a. conservative-minded
b. moving them too quickly – takes time to trust
c. single focus in addressing problems
d. difficult to work with
e. unwilling, uncooperative, personal agendas, do not acknowledge expertise)

Research

a. unequal workloads
b. jargon alienates funding bodies
c. no clear concise agenda
d. assuming shared knowledge of research practices
e. too much focus on own area – cross-sector has bigger challenges

Collaboration quality

a. trying to work in both disciplines e.g. artist and scientist
b. benefits unclear
c. too fast for professional collaboration
d. self-promotion and not listening
e. meeting needs of one party
f. funding
g. compartmentalised funding
h. time and resources – submitting half-baked or contrived projects

Project

a. communication (open and transparent, no regular communication avenues)
b. focus too broad
c. turf protection
d. under-funding
e. focus too narrow
f. lack of understanding project and role and expectations
g. restricted MOUs – restrict publishing
h. territorialism
i. too big
j. lack of clarity in responsibility
k. being adjunct to existing projects – be there at beginning

Understanding

a. not respecting disciplinary integrity
b. avoid competition
c. no understanding or value
d. assumed knowledge
e. losing mainstream understanding

Disciplines

a. disrespect of other disciplines
b. singular approach to problem solving

Ideas

a. university administration staff grabbing hold of marketable ideas
b. limited by own ideas
c. fixed ideas

B6 The survey

The Council for the Humanities, Arts & Social Sciences is examining the relationships between the Humanities, Arts and Social Sciences (HASS) and the Science, Technology, Engineering and Medical (STEM) sectors for DEST. Specifically, we are investigating collaborations that involve one or more disciplines from each of the HASS *and* STEM sectors. For example, a collaboration between an artists' co-operative and a social policy organisation would be unsuitable for our study as both disciplines are drawn from the HASS sector. A collaboration between an artists' co-operative and a medical unit would, however, qualify for inclusion.

The project includes a literature review, a case study analysis, surveys, interviews and focus groups. The outcome is a 'best practice' manual for collaborating across the HASS and STEM sectors, and recommended strategies for researchers, practitioners, educators, governments and industry for improving collaboration across sectors.

This survey aims to gather details of where collaboration across disciplines is, or is not, already happening in Australia.

The survey should take about 10 minutes to complete.

We will use the information you provide strictly in accordance with the aims of the project, and for no other purpose without your prior consent. Access to the information will be limited to employees, subcontractors, and the Board of CHASS, the project subcontractors and key DEST personnel. Your details will remain confidential and will not be passed on to other parties.

Questionnaire

1. Which sector do you belong to?

☐ Humanities, arts, social sciences (HASS)
☐ Science, technology, engineering, medicine (STEM)
☐ Both
☐ Other, please describe: ______________________

2. Have you ever collaborated with people outside your sector?*

☐ YES
☐ NO

2a. if YES, go to question 3.

*Survey monkey can be set to automatically branch to different questions depending on the answer to question 2. For this to work the question has to be mandatory. See below for more info on mandatory questions.

2b.What is the single most important reason you have not collaborated with people outside your sector? [Respondents finished survey here if they had no cross-sector collaborative experience.]

Participants provided with a small box so they can enter 3-4 lines of text

3. Please complete the following table for each cross-sector collaborative project you took part in. [this would be entered interactively through the web survey design] #

Table 16: Questionnaire for early-career researchers at Expanding Horizons event

Project title	Time period	Disciplines involved	Organisations involved	Funding sources	Outcomes of collaboration—achieved/planned	Was the collaboration worthwhile? Why? Why not?
Developing an innovative and marketable solution for the management of pain and anxiety in young patients, as an alternative to drug-based treatments.	2005-2006	Medical research Digital media Design IT Diversionary therapy	The Royal Children's Hospital Australasian CRC for Interaction Design (ACID)	ACID	Alternative to drug-based treatment for young patients with burns through technology combining digital media and diversionary therapy	

The above table appeared as a series of questions rather than a single table.

4. What do you think is the most important ingredient for facilitating collaboration across sectors?

5. What do you think is the single biggest hindrance to collaboration across sectors?

6. What is the most important thing to avoid when collaborating across sectors?

Other suggestions

Can you suggest other individuals or organisations other than those described in your project/s that could help us with this project?

Personal details

Name

Organisation

Email

Phone

I give the project team permission to contact me for further consultation

☐ YES

☐ NO

Appendix C

Case studies

C1 Summary

This appendix analyses key aspects of collaboration across the fields of humanities, arts and social sciences (HASS), and science, technology, engineering and medicine (STEM), based on 12 case studies of activities that crossed the sectors. We chose the case studies to represent varying scales and types of collaboration, stages and structures of collaboration, and a range of disciplines across HASS and STEM, funding sources and outcomes.

We reviewed the available web and hard-copy materials relating to the case studies before gathering data through focus groups and in-depth semistructured interviews with members of the collaborations. We investigated the data to identify key ingredients for successful collaboration, the benefits and costs of collaboration, and the incentives and barriers to successful collaboration.

The major factor contributing to the success of these collaborations was the people initiating and nurturing them. Without their enthusiasm and belief in the importance of involving the other sector, it would have been difficult for these activities to establish and maintain momentum. Leadership was particularly emphasised as a key ingredient for successful collaboration by members of large and/or geographically dispersed groups.

Support in organisational backing and funding was essential to the success of all these collaborations. In many cases, the individuals involved would not have had the initial contact with their collaborators or the means for ongoing engagement without such backing. Successful collaborations relied on flexibility in funding, research and project direction; team building; and leadership from the organisations involved. Flexible organisational and project arrangements that encouraged collaboration were described as essential. However, some of the major barriers to collaboration, particularly for those collaborations closely associated with universities or government departments, were with administrative support.

A key ingredient for successful collaboration was starting with a substantial and clear research question or purpose based on an issue or goal. Having adequate time was a key factor, including time for interaction, talking, building a profile, building credibility, understanding the project, developing a good funding proposal, and getting the methodology right.

All collaborations relied on external funding and some organisational in-kind support to achieve their goals. Some collaborations were totally externally funded, whereas others generated up to 60% of their funding from external sources.

While collaborators emphasised that team building was time and resource intensive, they described it as an essential ingredient for successful collaborations. Getting people ‘around the table, talking’ was a key ingredient.

Collaborators saw significant benefits for students involved in collaborations and significant incentives for them. However, the costs and barriers to their involvement could be significant, particularly in the resources available through university schools and faculties and for the students’ ongoing career prospects.

While collaborators recognised perceived status differences between disciplines as a potential problem, such differences were not a major barrier for the participants in the case studies summarised here. Problems relating to the status of applied versus basic research and the status of end users (community, industry and the market) were more common. Involving end users and those directly affected by the research was a major theme for some case study collaborators.

Having people engaged to facilitate and translate across sector boundaries was considered essential in some of the collaborations studied. There was a real need to understand the preoccupations of the other sector for successful collaboration.

The ability of collaborators to take risks within a collaboration was a major ingredient in most of the case study projects. Recognising the contribution of collaborators and seeing tangible benefits and feedback from early success were also important.

For full details about this research, see the complete appendix on the CHASS website: www.chass.org.au

C2 The case studies

Case study 1: Managing World Heritage sites

Researchers for the Greater Angkor Project are providing new perspectives on Angkor in Cambodia (one of the world's most important cultural heritage sites) and developing an information monitoring system for World Heritage site management. The multinational, multidisciplinary project involves archaeologists, historians, soil scientists, palaeobotanists, climatologists and computer modelling experts.

Background: Professor Roland Fletcher (archaeology) initiated the project out of his theoretical interest in the limits of settlement growth. The project began with his field work in 1998, and by 2000 had become a HASS–STEM collaboration. He collaborated initially with colleague Mike Barbetti, who was involved in C14 dating and tree dating. Geoscientist Dan Penny was also brought in as a collaborator. An ARC grant for 2002–2005 allowed the team to identify the extent of the city between the 12th and 16th centuries AD. The Finnish Environment Institute looked at water management in the Angkor region (one of the institute's grant students is working on modelling the region's hydrology).

All researchers were based at the University of Sydney. In any given year, about 50 academics, professional archaeologists, volunteers and other researchers are actively involved in project activities, both in the field and at various institutions worldwide.

Collaboration stage: Collaboration is underway. The team envisages at least another five years of collaborative research. The team plans to study occupation mounds; where the people of ancient Angkor lived; and the pattern of the city's abandonment.

Funding: UNESCO and a number of other prominent Australian and international bodies are involved in funding the Greater Angkor Project. UNESCO has provided $955,000 over five years. The project also received ARC grants from 2002 to 2005, including $1 million from an ARC Linkage grant in 2004.

Partners: UNESCO Phnom Penh; Australian Government Department of Environment and Heritage; Horizon Geoscience Consulting Pty Ltd; and a Cambodian Government authority.

Outcomes:

- A new perspective on Angkor, one of the world's most important cultural heritage sites, combining archaeology with hydrological research and modelling.
- Implications for the history of low-density urbanism globally.
- A general information management system for World Heritage sites.
- A new project, 'Living with Heritage', developed as a way of managing data collected at Angkor and other World Heritage sites.

Why collaboration: Science, humanities and technology people see things differently and think about things differently. This friction of thought is critical to a project such as Greater Angkor, with its combined approaches.

More information: http://felix.antiquity.arts.usyd.edu.au/angkor/gap/

Contact: Associate Professor Roland Fletcher; (02) 9351 7813; gap@acl.arts.usyd.edu.au

Case study 2: The effect of music on infants in neonatal intensive care

The effectiveness of music therapy on the physical and psychological development of vulnerable, long-term hospitalised infants was tested through a collaborative project between the MARCS Auditory Laboratories, University of Western Sydney and the Royal Children's Hospital Melbourne.

Background: The project was instigated by postdoctoral research fellow Stephen Malloch from MARCS Auditory Laboratories. He had heard of Helen Shoemark's work and a collaborative research project looking at the effects of music therapy on hospitalised infants.

Traditionally, the long-term care of infants in hospital has focused on their medical needs. There is increasing awareness that these infants require their developmental needs to be met for their ongoing physical and psychological wellbeing.

The project used the skills of neuropsychologists, music therapists, biomedical engineers, information technologists, nurses and psychiatrists. The research team investigated whether a music therapy intervention, such as singing to infants in ways that make them respond, could help them recover. The team also analysed the developmental factors that are affected when music therapy is used with babies in neonatal intensive care.

The project produced good-quality data through a unique data collection software system developed at MARCS Auditory Laboratories.

Collaboration stage: Completed.

Funding: An ARC Linkage grant provided funding from 2002 to 2005.

Partners: MARCS Auditory Laboratories at the University of Western Sydney; Royal Children's Hospital Melbourne; Murdoch Children's Research Institute; Mercy Hospital for Women.

Outcomes:

- Understanding the role of music as a complementary stimulus to support neuropsychological and social development in hospitalised infants.
- Developing an interdisciplinary methodology for the research out of a shared passion for the project.

Why collaboration: This type of research required the real-life context of the neonatal unit. The project required researchers and practitioners who could bring practical and theoretical skills to the project, as well as people with experience in directing multidisciplinary studies that produce practical and theoretical research outcomes.

The collaboration also had access to technicians at the University of Western Sydney, who developed unique data collection software of interest to the technicians at the Royal Children's Hospital.

More information: http://marcs.uws.edu.au/research/music/mtiwsi.htm

Contact: Helen Shoemark; (03) 9345 5421; helen.shoemark@rch.org.au

Case study 3: Digital media offers non-drug alternative to children with burns

Designers and medical practitioners are prototyping a product that increases the wellbeing of child burns patients by reducing the anxiety associated with dressing changes.

Background: The project was initiated by Dr Roy Kimble from the Royal Children's Hospital, Brisbane. He was aware of similar research with adults and wanted to initiate something that could be used with children. He approached the Australasian CRC for Interactive Design (ACID) and Sam Bucolo, as he was aware that the CRC had a multidisciplinary team and expertise in virtual reality technology. The project used a visual language to overcome discipline language barriers.

The resulting prototype uses a computer tablet with a series of characters that tell a story. Children interact with the characters in the story by helping them complete a task, such as 'look and find'. This engages the child and diverts their attention, reducing anxiety.

The results of initial clinical trials have been promising, and prototypes of the technology are generating commercial interest. The technology may be used in other situations involving children and anxiety.

Collaboration stage: Initial research is complete. Prototypes have been developed and deployed, and clinical trials have begun. A commercialisation strategy will follow this additional applied research.

Funding: The state government and ACID provided $50,000 in funding as a seed grant to cover initial R&D, allowing the project team to undertake first stage clinical trials. The hospital did all the project's extensive clinical trial work as a contribution in kind. Currently, the project is entering a commercial funding phase.

Partners: Royal Children's Hospital, Brisbane; Australasian CRC for Interaction Design; Queensland Government.

Outcomes: Production of working prototype technology that significantly reduces pain from burns in children. Clinical trials have proven the prototype's effectiveness.

Why collaboration: While ACID research focuses on design-driven outcomes, this project required working with medical and computer scientists to create a product that could be used in hospital settings.

More information: http://www.interactiondesign.com.au/news/in_the_news/media_release_20051018.htm

Contact: Sam Bucolo; 0414 642 076

Case study 4: Recycled water that is acceptable for society

Determining the social, economic and technical viability of water reuse technology is vital for Australia's future. In Western Australia, a major collaborative project between engineers, social psychologists, water researchers, hydrologists and the water industry is investigating this issue.

Background: The Water for a Healthy Country Flagship was initiated by CSIRO CEO Geoff Garrett as part of the Flagship vision. In this project, one of the goals is a healthy triple bottom line (economic, social, environmental). The research looks at how people value and use water, public acceptance and supporting regional communities. Using water smarter in industry is also important.

The project is integrating water reuse as a major part of the total water cycle in southwest Western Australia. Water reuse will only be socially and economically viable with the support of the communities that use the recycled water. The project integrates all aspects of water reuse technology, including social acceptability, capital and operating costs, feedstock quality, conjunctive opportunities with waste energy, potential scale, human health risk, environmental impact, and waste discharge and management.

Research stage: Collaborative research is underway. Most Flagship programs are nearing the end of the three-year, stage 1 planning phase, and will be moving into stage 2 soon. The Flagship is supported from 2003 until 2010.

Funding: The project is funded through the Australian Government, which contributes $26 million per year (appropriation funding) to the Flagship program. External in-kind research support is worth $7 million per year. The water reuse project is supported by the Western Australian Government and the water industries.

Partners: CSIRO; 6 CRCs; 6 universities; 12 catchment management authorities; industry; multiple community groups.

Outcomes: This is a public-good Flagship project producing shareware for all. The benefits are in ensuring that Australia has a sustainable water supply (our predicted urban water shortfall will be roughly 800 gigalitres per year by 2030). The research focuses on coming up with technologies and attitudes that will allow Australia to get more use out of the available water by minimising waste, reusing water, understanding climate change, and developing technologies that will help urban water managers use water more effectively.

Why collaboration: Sustainable management of water resources cuts across multiple disciplines and research questions. Industry involvement is essential, because the Flagship aims to find solutions to problems within the industry. It is impossible to address the whole problem without addressing all its facets.

The research is goal-based, so the Flagship researchers need to define and find the skills needed to achieve the goals and work with researchers within CSIRO and from other organisations.

More information: http://www.healthycountry.com.au/SWWesternAus/WaterReuse/index.htm

Contact: Simon Toze, CSIRO Water Flagship; Simon.toze@csiro.au

Case study 5: Fans collaborate to develop online game

In a collaboration across the sectors, Australian-based gaming company Auran Technologies has pioneered the idea of collaboration with game fans to develop its successful online game, Trainz.

Background: Auran Technologies is unique in the gaming industry, being the only long-term Australian-owned company that publishes its own games. Begun from scratch in 1995, it developed its own programming engine and sold the engine and the rights to the Dark Reign game to Actavision. Auran self-publishes Trainz.

Many gaming companies based in Australia are American-owned. Games companies come and go because they lack successful games or funding. Some come up with good ideas but cannot get a publisher, so they close down. People get an idea and go to the larger companies, which take the game and publish it around the world.

Gaming companies have always needed to combine creative business with the mastery of technical aspects of gaming. Including fans as co-creators of the game, in online forums and the development of prototypes, adds a further humanities dimension to the generic cross-sectoral collaboration inherent in the games industry.

While the Australian games industry is going through difficult times, Auran Technologies has managed to maintain its intellectual property and market share by focusing on massive multiplayer online games—the area of growth and innovation globally. Fan-created content, in the form of extensions to gaming software, is on the increase. However, developing relationships with gaming fans and meeting their needs can be difficult for corporations, particularly when the game is under construction.

Auran Technologies has developed techniques to engage its user base in co-creative activities guided by a community liaison manager, and is a leader in social engagement innovation.

Collaboration stage: The collaboration stage is advanced. Auran Technologies has three or four projects ‘on the go’ simultaneously—it takes two years develop a game and have it ready for distribution.

Funding: Sale of Dark Reign game; government grants.

Partners: Auran Technologies collaborated with game fans while developing the train simulation game, Trainz. The game relies heavily on fan-created content for its success.

Outcomes:

- Trainz is up to its fourth release and continues to do very well commercially.
- Auran Technologies is an industry leader in the field of fan collaboration.

Why collaboration: The humanities input in managing the communities of game fans who help to develop games such as Trainz cannot be underestimated; nor can the fans’ input.

More information: http://www.auran.com/

Contact: John Banks; Queensland University of Technology; ja.banks@qut.edu.au

Case study 6: Using virtual space to design better urban environments

Social scientists, architects and engineers from six universities are collaborating on the Suburban Communities project to develop tools to support interactivity within households, community groups and neighbourhoods using information and communication technologies. This project, supported by the Spatial Information Architecture Laboratory, aims to enhance connectedness in residential communities across Australia and New Zealand.

Background: The collaboration was initiated by Professor Mark Burry (design). He was invited by the Royal Melbourne Institute of Technology (RMIT) to become one of 10 innovation professors. The Spatial Information Architecture Laboratory was created out of this program, and now has around 15 researchers and over 30 postgraduates.

The laboratory is a transdisciplinary education and research centre within the School of Architecture and Design at RMIT University. It brings together artists, architects, designers, computer scientists, geospatial scientists, performers, social theorists and philosophers to research strategies for viewing and managing information in a spatial perspective. The laboratory hosts events to promote exchanges between research areas, educational programs and industry.

Two-thirds of the project's researchers have arts/humanities backgrounds, and the remainder come from science and engineering backgrounds.

Collaboration stage: Advanced. The laboratory started in 2001. It has grown to the desired size with streams of researchers who develop their own ideas.

Funding: RMIT funds three salaries, equipment and infrastructure. The funding ratio is 40% university to 60% external grants/competitive funding.

Outcomes: The project researchers have built up a viable laboratory with identified streams. The laboratory has had ARC success. Postgraduates are moving on to research careers or positions in the leading professions.

The laboratory explores the intersection between research, education and industry practice (e.g. manufacturing). It aims to find ways for industry to engage with the university and ways for students to engage with the research and industry sectors.

Why collaborate: The work is transdisciplinary rather than collaborative. Each person involved in a team is an expert in one discipline but knowledgeable in others, to the extent that they can work with others on things that they could not do alone.

More information: http://www.sial.rmit.edu.au

Contact: Mark Burry; (03) 9925 3520; mark.burry@rmit.edu.au

Case study 7: Exploring the ethics of biological research through art

Artists and scientists at SymbioticA—a research laboratory located in the School of Anatomy and Human Biology at the University of Western Australia—are working together to explore scientific and technical knowledge from an artistic and humanistic perspective.

Background: Artist Oran Catts initiated the collaboration in 1996, knowing that the scientist he approached was working with artists. The difficulties for collaborations are the expectations and the changing roles in collaboration. SymbioticA developed a process in which the scientists act as mentors for the artists, until the artists can produce work. The laboratory employs three Canadian researchers (recipients of ARC residency program support); two artists in residence; a part-time researcher; 3–4 full-time researchers (non-permanent); a PhD student; a postgraduate student/researcher; and two researchers in Atlanta. One of the researchers is an anthropologist who studies the way people collaborate. Formal contracts are drawn up between collaborators.

The laboratory enables artists to perform in vitro experiments that explore issues in science and technology that profoundly affect our society, particularly in the life sciences, such as genetic engineering. While immersed in the laboratory environment, artists deal with bioengineering and its controversial ethical implications from a position of knowledge. Both the artists and the scientists gain insights into the ethics and community understanding of the science and the art.

Australian and overseas artists and other professionals in the humanities interested in exploring possible and contestable futures arising from scientific and technological developments can actively participate in research with others at SymbioticA.

Collaboration stage: Advanced. SymbioticA was established in 2000.

Funding: The University of Western Australia provided funding of $150,000, and external research projects bring the funding up to $250,000.

Outcomes:

- SymbioticA has positioned itself internationally in the new arena of art and biology. Artists can apply to work at the laboratory or come to workshops.
- Oron Catts will be travelling to Stanford to advise on how to set up a similar laboratory there.
- SymbioticA has produced 7 major exhibitions, 32 presentations and addresses at conferences, 4 catalogues and 4 workshops.

Why collaboration: Collaboration allows artists to engage in the life sciences without being totally immersed in them. The collaborative members go through 'cross-contamination' (artists 'contaminating' scientists and scientists 'contaminating' artists) to get different points of view. SymbioticA has developed an effective framework for dealing with these conflicting knowledges.

More information: http://www.symbiotica.uwa.edu.au/

Contact: Oron Catts; (08) 6488 7116; sym@symbiotica.uwa.edu.au

Case study 8: Robotic wheelchairs interact with humans

A team of robotics designers and a media artist have developed robotic wheelchairs that interact dynamically with humans. Fish and Bird, the two robots in the exhibit, read and react to human body language by moving about and writing text.

Background: Dr Mari Velonaki was responsible for the original concept and art development in the project. Velonaki contacted Professor Hugh Durrant-Whyte of the Australian Centre for Field Robotics to discuss the concept, and the project developed from there. Other researchers involved in the project include James Hudson, David Rye, Steven Scheding, Stefan Williams and David Wood. There have been many other collaborators involved throughout the project.

Funded by an ARC Linkage grant and the Synapse initiative of the Australia Council for the Arts, the Fish–Bird project has not only received international acclaim for its artistic innovation in public exhibitions, it also offers advances in wheelchair technology and monitoring systems that may be applied in a variety of hospital and aged-care environments.

The project promotes a positive view of wheelchairs in the community by encouraging people to confront their own ideas about the human–machine interface.

Collaboration stage: The collaboration is due for completion in 2006.

Funding: An ARC Linkage grant of $247,000 over three years was matched by in-kind contributions from industry partners.

Partners: Australia Council for the Arts; Artspace Sydney; Australian Network for Art and Technology; Museum of Contemporary Arts, Sydney; Patrick Systems and Technology; and the Australian Centre for Field Robotics at the University of Sydney.

Outcomes: Shown nationally and internationally, the outcome includes significant artistic and robotics research. The collaboration led to further research at the Australian Centre for Field Robotics, such as research into the medical applications of human–machine interactions and robotic wheelchairs.

Why collaboration: Collaborators shared complementary skills and learned more about the human–machine interface. The technical (robotics), social (human–machine), and political issues that the collaborators have explored created a strong knowledge base for the project.

More information: http://www.araa.asn.au/acra/acra2005/papers/rye.pdf and http://www.ozco.gov.au/arts_in_australia/projects/projects_new_media_arts/synapse_fish_bird_-_mari_velonaki/

Contact: Mari Velonaki; m.velonaki@acfr.usyd.edu.au; (02) 9215 9110; 0410 315 751

Case study 9: Better planning for natural disasters

An independent working group of the Prime Minister's Science, Engineering, and Innovation Council (PMSEIC, representing Australian experts in geosciences, meteorology, social sciences, emergency services, community assistance organisations, and other groups) has collaborated to produce an integrated and realistic way forward for tsunami science and preparedness in Australia.

Background: The working group was formed in response to the devastating Boxing Day tsunami of 2004. Its main objective was to complete a comprehensive report and a presentation on tsunami science and preparedness in Australia for the PMSEIC.

The PMSEIC report developed from this work was presented to the Prime Minister at the 14th meeting of the PMSEIC on 2 December 2005. The report provides practical initiatives and recommendations to improve emergency management coordination, encourage scientific collaboration, and raise community awareness.

Collaboration stage: Completed. The working group that prepared the PMSEIC report involved input from people across a broad spectrum, from the sciences and the emergency services to the humanities.

Funding: The project was fully funded by the PMSEIC.

Outcomes: The group's report, an invaluable information source, was well received by the PMSEIC. The report's three major recommendations to the PMSEIC and the Australian Government are to establish:

- a Regional Centre Excellence for Tsunamis
- a sustainable and effective Australian Tsunami Warning System
- an effective pathway to incorporate hazard science into emergency management policy through the Australian Emergency Management Committee.

Why collaboration: Working in collaboration**,** the group developed an effective framework for the collaborative report after several meetings. The diverse group of skilled, passionate and committed people involved in the report made it a success. Out of this collaboration, group members have formed a strong network of contacts for future work together.

More information: http://www.dest.gov.au/sectors/science_innovation/publications_resources/profiles/tsunamis/htm

Contact: Dr Phil McFadden; (02) 6249 7967; phil.mcfadden@ga.gov.au

Case study 10: Text mining software improves national security and defence operations

Leximancer, a recently developed tool for monitoring threats such as terrorist activities, would not have been possible without the skills of physicians, information technologists, psychologists and linguists. Researchers from these groups collaborated on Leximancer, which automatically analyses documents and displays extracted information. The information is presented on a conceptual map that shows the main ideas from the text and how they are related.

Background: Andrew Smith began creating Leximancer in 2000. He joined the University of Queensland's Key Centre for Human Factors and Applied Cognitive Psychology and collaborated with researchers in psychology, communication researchers and others conducting content and textual analysis. In 2002, Smith joined forces with the university's commercial arm, UniQuest, to further the development of the software and take it into the marketplace.

Leximancer has analysed and mapped texts as diverse as Edward Gibbon's *Decline and Fall of the Roman Empire* and the full report of the United States 9/11 Commission. The software is fundamentally changing the exploitation of text and natural language assets in business, government, security, law enforcement, HASS and STEM research, and education.

Collaboration stage: Ongoing. As long as project development for Leximancer continues, so will the collaboration. The collaboration involves researchers and analysts from universities and other organisations who use Leximancer, physicists, psychologists and communication researchers at the Key Centre for Human Factors and Applied Cognitive Psychology.

Funding: COMET Grant; the University of Queensland's Key Centre for Human Factors; Australian Research Council.

Partners: The University of Queensland. Leximancer Pty Ltd invites prospective partner organisations to contact the company.

Outcomes: The ARC supported the development of the software, which has already been sold to the United States Social Security Administration and an Australian Government agency in the defence sector. Professional and academic users can buy software licences for Leximancer. Local police are also using Leximancer to cluster burglary reports.

Why collaboration: Collaboration with software users was necessary to develop the product's usability. Collaboration with UniQuest was essential for the further development and distribution of Leximancer.

More information: http://www.leximancer.com/

Contact: Dr Andrew Smith; (07) 3365 7171; asmith@humanfactors.uq.edu.au

Case study 11: Managing bushfires near home

A major group of researchers is working together to help to protect people whose homes or lives are under threat from bushfire.

Background: Established under the Australian Government's CRC Program, the Bushfire CRC provides research that improves the management of bushfire risk to the community in an economically and ecologically sustainable way.

The Bushfire CRC researchers identify impediments and suggest improvements to the Australasian Fire Authorities Council's 'stay or go' policy. The CRC is also developing recommendations for town planning and building standards in fire-prone areas. This collaborative approach combines the skills of mathematicians, psychologists, geographers, economists, policy analysts, and materials and manufacturing scientists and engineers.

Collaboration stage: Ongoing. Collaboration continues to play a major role at the Bushfire CRC. The CRC lists over 20 core participant organisations and 11 associate participant organisations.

Funding and partners: The Bushfire CRC's seven-year, $100 million research program brings together state fire and land management agencies; eight universities; CSIRO; Australian Government agencies, including the Bureau of Meteorology and Emergency Management Australia; and New Zealand fire and forest research agencies.

Outcomes: Increased bushfire knowledge and safety in the Australian community.

Why collaboration: The collaboration between expert researchers and end users across Australia sets the CRC apart. The research is driven specifically by the needs of the partners who will ultimately implement the research results.

More information: http://www.bushfirecrc.com

Contact: David Bruce; (03) 9412 9606; david.bruce@bushfirecrc.com

Case study 12: Making science and technology relevant to everyday life

With scientific knowledge doubling every seven years, Questacon (the National Science and Technology Centre) provides ways for 'ordinary' people to play a meaningful part in discussions about its impact on their future.

Background: Australian National University physicist Mike Gore and zoologist Chris Bryant started Questacon in 1984. Gore had gone to see the Exploratorium and been inspired, and Bryant encouraged him to set one up in Canberra. Over 20 years later, Questacon has around 210 employees and 65 volunteers from the sciences, technologies, and social sciences and humanities.

Questacon collaborates with state and local science centres to exchange ideas, donate materials, do joint projects, build exhibitions, and tour projects in rural and remote Australia. The centre demonstrates the relevance of science and technology in our everyday lives, and has become Australia's leading interactive science and technology centre and outreach program.

Collaboration stage: Ongoing. Questacon's activities are collaborative by definition, because they combine science and technology with social science and humanities.

Funding: Questacon receives more than $1 million per year, 40% of which comes from outside sources, such as Shell Australia. Some Questacon programs receive enough funding to be provided free to communities. The program Sciencelines, for example, receives enough funding to allow Indigenous communities to take part at no charge.

Partners: Australian Government; the Australian National University's Centre for Public Awareness of Science; Shell Australia.

Outcomes:

- Science and technology projects, demonstration shows and hands-on exhibits that have inspired new generations over the past 20 years.
- A more scientifically literate society.
- Encouragement of scientific engagement at all life stages, from early childhood to retirement.

Why collaboration: Questacon's public outreach programs require the integration of knowledge and skills from various disciplines, such as graphic design, industrial design, education, social science, art, and most sciences (including robotics and astronomy). Students are brought together to get them to understand their own discipline from another point of view and to understand other disciplines.

More information: http://www.questacon.edu.au/index_flash.asp

Contact: Bobby Cerini; bcerini@questacon.edu.au; (02) 6126 2229

Appendix D

Interviews

D1 Summary

The aim of the interview phase of the research was to inform the overall research questions by gathering data from people with complementary, but quite different, perspectives on cross-sectoral collaborative research.

The research consisted of 75 structured face-to-face or telephone interviews with people from three groups, in which we asked participants a series of questions pertinent to their expertise. We interviewed:

- people from 23 national and international organisations and programs that support HASS–STEM collaborations (30 interviews)
- people involved in or initiating cross-sectoral collaboration (39 interviews)
- people researching cross-sectoral collaboration (6 interviews).

One of the main drivers of support for cross-sectoral collaboration was recognition by organisations that dealing effectively with many 'big picture' questions requires cross-sectoral collaboration. Interviewees recognised that many global issues involve complex policies and systems and are, by their nature, cross-sectoral. These include energy, water, greenhouse gases and land use.

Other organisational drivers of cross-sectoral collaboration identified by interviewees are the needs to produce more robust output, to meet the requirements of end users (community, industry and market), to generate greater commitment and involvement by end users, and to generate better end-user engagement and understanding.

Interviewees believed that acknowledging the costs of collaborative work and adequately resourcing collaborations are essential to ensure genuine collaboration.

The structured interviews with cross-sectoral researchers uncovered more similarities than differences between the factors that respondents considered important in cross-sectoral collaboration. Drivers of collaboration included the need to align with the strategic direction of the organisations supporting research and to deal effectively with complex problems that were important to government and industry bodies. Researchers were also driven by a keen sense of social and community responsibility and the desire to contribute to solutions for major social and environmental problems. The researchers believed that cross-disciplinary understandings in their areas of research were often richer than those coming from single disciplines. They believed that cross-sectoral collaboration is affected by the number of partners and the disciplinary areas involved, sectoral interests, the time available to conduct the research, the complexity of the research and the structures supporting the research.

The researchers recognised problems stemming from STEM's recognition of the HASS sector and vice versa. Another challenge was the need to create space for collaboration to develop. Researchers recognised that this took hard work and dedication, but that there were significant rewards.

Lack of institutional support for cross-sectoral collaboration was a major challenge, as it reduced available funding and created a need to show support from organisations in funding applications. Researchers were also concerned that the Research Quality Framework may drive people back to their disciplines and devalue earlier gains from cross-sector collaboration.

The most frequently stressed ingredients for successful cross-sectoral collaborations were the characteristics of the people involved in the projects, building supportive infrastructures for the projects, and having processes in place to assist potential researchers to get it right. Researchers also suggested a number of strategies that would support cross-sectoral collaboration, including special funding, organisational support, increased networks and educational support. Researchers believed governments and other funding bodies need to make an investment in the longer term potential of cross-sectoral collaboration. Organisations need to support the best disciplinary and interdisciplinary research approaches and provide incentives for individuals, groups, and national and public institutions to collaborate.

The development of networks was a recurring theme in research and education across the sectors. An organisational focus on building network capacity that will support the potential of collaborations across the sectors is needed, including educational initiatives for greater porosity across HASS and STEM.

Those researching cross-sectoral collaborative processes were driven either by the strategic direction of their organisations or by their own attraction to collaboration as a research topic. These researchers emphasised that, while collaboration needed organisational support to address common issues or deal with particular problems, the work of individual researchers was also important and should be recognised. Time management was a problem, especially for projects with a limited and very specific timeframe and for the production of outputs in formats acceptable to specific disciplines. Another challenge was some supporting organisations' lack of flexibility and the difficulty they appear to have in sharing power. Differing disciplinary assumptions also need to be clarified in any cross-sectoral collaboration.

These interviewees identified several key ingredients for successful cross-sectoral collaboration, including clarifying roles, responsibilities, goals, expectations and the decision-making processes of the team. While many decisions in collaborations need to be made collectively, team members must also be individually accountable. It was generally agreed that collaborators must be prepared to take risks in the research, but that the risks must be shared by the team.

Interviewees conducting research on cross-sectoral collaboration also made a number of recommendations, including the following:

- help researchers communicate their expertise to others
- use collaboration brokers to facilitate successful partnerships
- engage industry by being clear about what opportunities collaboration can offer
- run education workshops to help collaborators understand collaborative processes
- harness what is happening in regional collaborations in Australia.

D2 What we did and how we did it

We conducted a series of structured face-to-face or telephone interviews with three different groups of people. Participants were asked a series of specific questions pertinent to their expertise (see questions at end of this appendix). These questions were framed around support for and involvement in cross-sector research, the challenges and opportunities of collaborative projects, the indicators and key ingredients to successful collaboration, the barriers, disincentives and things to avoid when doing collaborative projects and finally, the strategies that support collaboration.

We identified participants for this phase of the project using a number of strategies including through web sites, publications or conference presentations of their research, offices of research, suggestions by members of the Reference Committee, people involved in different phases of the project such as the information-gathering survey. The interviews were transcribed and sent to the participants for comment and revision. These revised transcripts were then analysed for themes using the cut and paste function in word.

D3 Who we interviewed

In total, we conducted 75 in-depth structured interviews with three main focuses: organisations supporting collaboration, collaborative researchers and finally, those researching collaboration. We conducted 30 interviews with key individuals, representing 23 national and international organisations and programs supporting collaboration; 39 interviews with people who have initiated or are involved in a cross-sector collaborative initiative; and, finally, six interviews with people who research the collaborative process.

D4 Organisations and programs supporting HASS–STEM collaboration

D4.1 What we did

This phase of the research consisted of a series of structured face-to-face or telephone interviews with people from organisations and programs that support HASS-STEM collaborations. Participants were asked a series of questions examining their support for collaboration; why and how they support collaboration; how projects are evaluated or assessed; factors that indicate project success; the indicators and key ingredients to successful collaboration; their must do or must avoid factors; the barriers and disincentives to collaboration; and, finally, the strategies that support collaboration (see questions at end of this appendix).

D4.2 How we did it

Participants for this phase of the project were identified in different ways. For example, participants found us through web sites and research offices, were suggested by either a member of the reference committee or one of the people interviewed throughout the different phases of the project, or through the information-gathering survey. Interviews were transcribed and sent to the participants for comment and revision. These revised transcripts were then analysed for themes using the cut and paste function in Word.

D4.3 Who we interviewed

For this phase of the project, we interviewed 30 representatives of 23 organisations and programs supporting collaboration. See Table 18.

Table 18: The organisational representatives we interviewed

Name	Organisation
Professor Philip Esler	Arts and Humanities Research Council, UK
Dr Melinda Rackham	Australian Network for Art and Technology
Ms Jan Muir	Australian Research Council
Mr Neil Calder	Stanford University, USA
Mr Frank Pannuci	Australia Council
Dr Elie Faroult	C.E.C. , EU
Dr Louise Robert	Canadian Institutes of Health Research, Canada
Ms Michaela Bauer	Centre for International Health - Curtin University
Dr Carol Nicoll	Centre for International Health - Curtin University
Ms Veronica Bullock	Collections Council of Australia
Dr David Gronbaek	COST, EU
Mr Mark Woffenden	Collaborative Research Council Association
Ms Katrina Nilsson	DANA Centre, UK

Name	Organisation
Dr Andrew Clark	Engineering and Physical Sciences Research Council
Mr Nicolas Guernion	Engineering and Physical Sciences Research Council
Dr Paive McIntosh	European Science Foundation, EU
Mr Claus Nowotny	European Science Foundation, EU
Dr Henk Stronkhorst	European Science Foundation, EU
Mr Andrew Campbell	Land & Water Australia
Dr Tom Ziessen	Meeting of Minds, EU
Dr John Dodgson	National Academies Forum
Ms Katherine Mathieson	National Endowment for Science, Technology and the Arts, UK
Mr Chris Powell	National Endowment for Science, Technology and the Arts, UK
Mr Philip Callan	National Health and Medical Research Council
Dr Steve Thompson	Royal Society of New Zealand, NZ
Professor Peter Fische	Science and Technology Foresight, EU
Dr Werner Wobbe	Science and Technology Foresight, EU
Mr Andrew Donovan	Synapse Art and Science Initiative, Australia Council
Ms Verity Slater	Wellcome Trust, UK
Dr Anthony Woods	Wellcome Trust, UK

D4.4 What we found

The structured interviews with these representatives from organisations that support collaboration indicated that support is provided primarily through funding to support postgraduate and postdoctoral research, for residency programs, and specific events or specific areas of research requiring collaboration. Support is provided from government and the private sector. There is also increasing support for cross-sector research by industries, such as rural research and development organisations and minerals-based organisations.

Organisations supported collaborative conferences, seminars and workshops to bring researchers and practitioners together to discuss the potential for collaboration, such as the Land and Water Australia's (LWA) Integration Symposium of 2004, which gathered leading thinkers in the country around the issues of integration. LWA cross-sector collaboration is also driven by their Social and Institutional Research Program:

We run seminars and workshops. We're playing a leading role in this endeavour; it is pretty slow in rubbing off on other organisations (Andrew Campbell, LWA).

The Australia Council supported Constellations Conference brought together scientists and artists as part of the Synapse initiative. The Academy of Science supported the Expanding Horizons Event, held for the first time this year, which brought together 185 early career researchers from both the HASS and STEM sector to discuss and explore collaboration. The National Academies Forum is the umbrella organisation for the four Learned Academies. Three to four members of each academy meet twice a year and the forum organises at east one activity a year. Last year was the follow up to the tsunami disaster. The forum discussed how STEM and HASS could contribute to the reconstruction of tsunami-devastated areas.

Many EU and UK government-funded programs were devoted to funding networking activities between researchers. Examples are the EU COST program, which provides funding for collaborative research meetings, and the S&T Foresight program, which funds meetings for new areas of research and policy for the EU. The Foresight Unit has 16 people exploring new areas of research and new policies for EU and member states. They support economic competitiveness and other policies supporting advances is the cross-disciplinary work. Wellcome Trust funding supports coordinator of collaboration networks with teaching and research leave to manage these collaborations.

The Australia Research Council supports Research Networks between university-based researchers and teams who are eligible to receive ARC funding assistance, and researchers working in, or supported by, other research bodies and research funding bodies.

The Federal government, including the Australian Research Council (ARC) and the National Health and Medical Research Council (NH&MRC), is the major supporter of research projects and activities involving collaboration across the HASS and STEM sectors. In 2005, 74 projects approved for funding by the ARC included RFCD codes in both HASS and STEM sectors. A number of ARC Centres of Excellence and the Synapse Projects funded jointly by the ARC and the Australia Council involve cross-disciplinary work across these sectors. Synapse has existed since 2003 has three main prongs: short artist residencies, long-term arts-science linkage projects and an on-line database.

Recent analysis by the ARC has indicated that the proportion of research proposals in the major ARC schemes that may be considered cross-disciplinary in scope is increasing, and that their success rate is at least as high as that of single discipline proposals (see http://www.arc.gov.au/pdf/ARC_response_to_Preferred_Model_051005.pdf, pp 4-5).

It is clear that much cutting edge research is likely to cross traditional disciplinary boundaries, including the HASS–STEM boundaries. However, the ARC does not specifically prioritise cross-disciplinarity in its assessment processes. The proposals are assessed for funding in the same way as single-discipline proposals and projects. Assessors may be drawn from a number of different disciplinary backgrounds to assess a proposal which covers multiple fields of expertise. Progress and final reports for both single- and multi-discipline projects are assessed in similar ways.

The NH&MRC provides funding for cross-sector projects. However, there is a formal process of peer review for reviewing collaborative research proposals through grant application. The NH&MRC will seek collaborative research in certain areas and make sure all aspects fit criteria. However, this is a very competitive process.

Funding can also be provided jointly. For example, the residency program managed by the Australian Network for Art and Technology (ANAT) that grew out of the ARC Linkage program and is described as a halfway measure between Australia Council Grants and ARC Linkage Industry Grants. ANAT also supports a Research and Development Laboratory, putting 20 media artists together with textile, jewellers, fashion artists and three-week intensive workshops for potential collaborators.

LWA has a broad mix of disciplines on selection panels for funding and collaborative projects marked highly.

Drivers of support for cross-sector collaboration

One of the main drivers of support for cross-sector collaborations was recognition by organisations that many 'big picture' issues require cross-sector collaboration to deal effectively with them. Interviewees acknowledged that failure in the past to involve cross-sector disciplines in projects has resulted in a failure of these projects to achieve their goals. Organisations also supported collaborative research as a better use of limited resources (to avoid duplication).

…there are huge benefits from bringing the right people together from different agencies. There is no point in agencies reinventing the wheel or finding new people (Philip Callan, NHMRC).

Interviewees recognised that many global issues are complex policy and systems issues and are by their very nature cross-sector. These issues include energy, water, greenhouse gases and land use:

….RSNZ [Royal Society of New Zealand] has supported the creation of a Humanities Research Council in New Zealand. We have run a joint conference with an institute of Social Sciences, plus several workshops. The Social Sciences are an integral part of the Royal Society of New Zealand They are substantial, especially where social and natural scientists have to come together to discuss such topics as genetic modification or sustainability (Steve Thompson, Royal Society of New Zealand).

Many organisations in Australia and overseas believe that cross-sector projects promote innovation. Innovation happens at the interface between sectors, leading to improved outcomes and the development of new approaches and better products, however, organisations must be willing to take risks for the returns that can be gained from collaboration. For example, the UK's National Endowment for Science, Technology and the Arts (NESTA) takes major risks every year, expecting that only half of its projects will turn into enterprises.

About half of what we do are things that will probably turn into enterprises. We support people who have an IP idea. The other half of what we do is that we capacity build for innovation – arts sciences and technology. Our involvement is in innovation in learning and assisting new talent to move outside core discipline. This includes being involved in creative industries. We also use 30 million pounds a year from lottery money (NESTA).

Organisations were increasingly recognising that solving many of our practical problems requires expertise outside one discipline. For example, the capacity of engineering and technology to respond to population growth relies on many disciplines. Hence, according to many of those interviewed, there is a need for integrated knowledge, a whole of government approach, and organisational support and funding for integrated research.

Indigenous science, for example, is an area where one discipline alone cannot address the issue. The need to respond to community needs in relation to science and technology is also a major driver for cross-sector collaboration:

The relationship between the sciences and the social sciences is very important, especially as the community role becomes more important – we are taking more notice of what they are saying. One of our roles is to put across our view of science, technology and engineering to get community support. If you look at scientific activities, e.g. nuclear issue—it has obviously come up in discussion—you have the science and technology input but the social science is just as important—what does the community think, and what is behind their thinking and why do they think this (John Dodgson, Academy of Science).

Other organisational drivers of cross-sector support identified by those interviewed were more robust output, meeting the needs of end-users, generating greater commitment and involvement to the program by end-users, and better end-user (community, industry and market) engagement and understanding. There was a perception of a need to understand community values in relation to science and technology, and a need to understand the language of end-users. Some interviewees from these organisations believed there was a need to recognise more broadly that artistic design and social sciences make the science relevant to community:

Two years ago, we got experts together to look at this idea of convergence – launched this group that finished last year (2004) at a conference with 250 people from Canada and Europe. There was a report from the conference on issues. The main idea was this was not for the progress of technologies, but needed by European citizens to meet their needs in e.g. health, privacy, safety and environment (Elie Faroult, C.E.C.).

Barriers

Interviewees representing major organisations supporting collaboration indicated that the major challenge to cross-sector collaboration was cultural. This indicated a lack of awareness by sectors of the value of the other sector. Researchers lacked motivation to talk outside their discipline and this was attributed to a lack of awareness of opportunities and benefits of cross-sector collaboration. Having a distorted view of the other sector was also a major issue, for example, social science being seen as handmaiden to science. Some pointed to exiting cultural views within science that did not encourage collaboration with social science.

The idea of science being conducted by the lone researcher and recognition and rewards going to individual researchers was also an issue. For some organisations, collaboration across the sectors was not a cultural norm:

There is resistance to incorporating social scientists – this is not seen as incorporating mainstream science. My feeling is that I concur with the overall philosophy of HASS–STEM collaborations—that as we draw information or incorporate this it will be beneficial but it is not a cultural norm (Mark Woofenden, CRC Assocation).

The lack of rewards and recognition for interdisciplinary work was also a major barrier. Rewards for work such as publications were not seen to support interdisciplinary approaches. Recognition was also difficult for early career researchers and some organisational leaders advised their earlier career staff to stay in discipline:

If you've just finished a PhD then it is best to lock yourself in a room and write two prestigious articles a year for the next couple ways. They can rewrite stuff from PhD in all the different journals. There are perverse incentives (Andrew Campbell, LWA).

Interviewees recognised the pressure placed on early career researchers to stay in their discipline and publish in disciplinary journals as there are no recognised interdisciplinary journals:

It is harder to get cross disciplinary research, etc into publication; by definition journals are discipline based and narrow. A good article in something like ECOS is much more useful for society, but generates no brownie points for scientists (Andrew Campbell, LWA).

Researchers were still required to maintain their status in their disciplinary community as there was a lack of academic acceptance of cross-disciplinary work. Cross-sector collaboration requires an element of risk, whereas there were perceptions that the disciplinary establishment argues against risk. It was recognised that there was pressure to stay within disciplinary boundaries:

Difficult for people to step outside their home discipline—if you do you may have to trade quality (Anthony Woods, Wellcome Trust).

While some organisations supported collaboration because it prevented the duplication of resources, there was recognition that **s**ustaining the funding base for collaborative research was difficult. Acknowledging the costs of collaborative work and adequately resourcing it was needed to ensure that genuine collaboration occurred:

There are high transaction costs involved in collaboration—travel, meetings, partnerships agreement – each contract takes negotiation. I employee more staff per R&D money going out [compared to other R&D funders] as most is managed through multi-party collaboration (Andrew Campbell, LWA).

There was often no follow-up funding available after short-term projects were completed. For example, ANAT's open and competitive scheme means that they cannot fund same artist two years in a row. There is no on-going funding to build relationships with science organisations.

Obtaining funding for collaborative research projects was acknowledged to be difficult for many reasons. Some interviewees pointed to discrimination in the peer review process of multi-disciplinary projects. There could be a perceived trade in quality for disciplines in collaborative projects assessed by peer review. Peer review committees often had a lack of understanding of other disciplinary approaches or there was a limit of qualified people to look at cross-sector funding proposals. Outcomes from some disciplines, such as the humanities and social sciences were often harder to measure. Some interviewees indicated that collaborators had to provide defined outcomes at the beginning of a collaboration. The lack of comparative data to look at collaborative projects was provided as a reason for these continuing perceptions.

Another barrier pointed to by these interviewees was the perceived lack of HASS relevance to funders. These views were particularly expressed by HASS interviewees. Humanities and social science researchers were perceived to be hopeless at explaining the impacts of their activities to funding bodies. The creative industries were perceived not to sell the message of their relevance, which created a lack of understanding of their value by revenue people.

People have got the message that the creative industries are important but they are not really sure what to do with them. (Professor Philip Esler, Arts and Humanities Research Council (AHRC))

In addition, social outcomes were perceived to be more difficult to measure and therefore gaining support for collaborations with these outcomes was perceived to be more difficult:

There is potentially an implied inhibitor that the social outcomes are harder to measure than the industry outcomes—less concordant with the CRC Program (Mark Woofenden, CRC Association)

The lack of public awareness, interest or involvement in some science and technology issues also meant a lack of investment in the social sciences and humanities as the human element was not acknowledged:

In other fields where the public has been less involved there has been less willingness to invest resources. For example, the IT area is not a success as it does not have the public acceptance problems. (Peter Fisch, CEC)

Key ingredients

Key ingredients for cross-sector collaboration included involving end-users, focusing on their needs and partnering with industry in collaborations. Employing researchers and managers with experience in both sectors who have skills in managing diverse and complex projects was also believed to be essential.

Many organisational interviews spoke about the need for a shared but flexible approach in collaboration. This included understanding why you need integration and collaboration, incorporating different approaches and working styles of researchers, being clear about expectations and not forcing collaboration but building mutual trust and a shared vision.

They also recognised that that collaborating was only one way of working. Establishing common goals was believed to require a lot of discussion and collaborators needed to bring the views of different disciplines to the forefront and tackle these at the start of the project.

Supporting organisations needed to see value from investing collaborative work. Effective organisational support was described as developing structures that guide and support the collaboration, overcoming organisational power and supporting key leaders in organisations to work together. Communication across the sectors could be achieved by agreeing on a shared language; using boundary spanners; or developing a new language. Direct contact hours between the sectors were essential for good communication to develop.

Recognising collaboration as a means to an end; not an end in itself was also acknowledged as a key ingredient. This included avoiding collaboration for the sake of collaboration but pursuing ideas that pushed the sectors and disciplines. The quality of the research question was also important for collaboration as was working towards a clear understanding of an issue, expressing problem in terms that both sectors can understand.

These organisations believed that supporting work where both sectors are influenced through the collaboration and where both sectors feel they get benefit was key to successful cross-sector collaboration.

Promoting the importance of these types of collaborations was also recognised to be important, particularly on-going promotion of collaboration outcomes when completed. Successful collaborations required adequate funding, with larger grants for established groups. Collaborations needed to working through many bodies to keep collaborative funding for projects going and deal with funding bodies prepared to take risks.

A good relationship between collaborators was also a key ingredient. These relationships could be measure by **e**xisting relationships between the collaborators and collaborators wishing to continue working together once a project had ended.

Key ingredients for funding were:

- meeting the mission of the funders
- milestone delivery to funders
- work peer reviewed by academic community
- clearly described outputs and outcomes from the collaboration
- developing solutions that could not be done individually
- existing track record and being established in the field
- engaging people affected by the work
- demonstrated knowledge or interest in the other sector already
- cash and in-kind contributions from supporting organisations shows commitment
- screening process and contractual agreements

Funding programs required assessors of funding applications that have more than one disciplinary area of expertise.

Recommendations

- Improve DEST recognition of processes for measuring collaborative work and addressing need for social and physical scientists to work together on key problems through policies.
- Set up innovation fund that recognises that creative and financial industries are at the cutting edge of innovation.
- Nurture and promote alternative funding sources for art-science collaborations such as private sector investment and focusing on collaboration for technology transfer.
- Provide funding that gives projects time to establish themselves and funding groups on a longer term basis to undertake collaborative projects on issues of national importance.
- Provide strategies for multi-stakeholder funding of projects.
- Fund meetings and small studies that encourage people to engage in 'foresighting' – requires collaboration e.g. health and biology.
- Support existing programs such as the CSIRO Flagships program and expand the humanities and social science emphasis in the CRC Program.
- Promote successful collaborations for awareness-raising and develop community awareness strategies for collaborative work.
- Provide initiatives that increase awareness of potential benefits of engaging.
- Follow up support structures for collaboration such as the Constellations Conference.
- Provide exposure to multi-disciplinary methods and publications and develop training courses in collaboration around particular issues, for example, environmental science.

D5 Key practitioners of HASS–STEM collaboration

D5.1 What we did

This phase of the research consisted of a series of structured face-to-face or telephone interviews with people involved or initiating cross-sector collaboration. Researchers were asked a series of questions examining their support for the research, their involvement, the challenges and opportunities of collaborative projects, the indicators and key ingredients to successful collaboration, the barriers, disincentives and things to avoid when doing collaborative projects and finally, the strategies that support collaboration (see questions at end of this appendix).

D5.2 How we did it

Participants for this phase of the project were identified through their publications or conference presentations of their research, suggested by either a member of the Reference Committee or one of the people interviewed throughout the different phases of the project, or through the information-gathering survey. Interviews were transcribed and sent to the participants for comment and revision. These revised transcripts were then analysed for themes and data arranged using the cut and paste function in word.

D5.3 Who we interviewed

For this phase of the project, we interviewed 39 experienced people involved in cross-sector collaborations. See Table 19.

Table 19: The key practitioners we interviewed

Name	Organisation
Ms Peta Ashworth	CSIRO
Professor Gabriele Bammer	The Australian National University
Mr Noel Beynon	Land and Water Australia
Dr Chris Blanchard	Charles Sturt University
Professor David Brereton	Centre for Social Responsibility in Mining, Sustainable Minerals Institute
Dr Christine Cargill	Australian National Botanic Gardens (ANBG) Public Art Program
Dr Aaron Corn	University of Sydney
Mr Trevor Dhu	Geosciences Australia
Associate Prof. Di Flemming	School of Design, RMIT
Mr Ted Gardner	Department of Natural Resources, Mines & Water
Mr Gary Garner	Queensland University of Technology
Associate Prof. Ian Gordon	Director, Statistical Consulting Centre, University of Melbourne
Dr Jill Gordon	Medical Humanities Unit, UNSW
Dr Donna Green	CSIRO
Ms Jen Guice	CRC for Water Quality and Treatment
Dr Steve Hatfield Dodds	CSIRO
Professor Colleen Hayward	Rio Tinto
Professor Richard Head	Public Health CSIRO Flagship
Professor Greg Hearn	Institute for Creative Industries and Innovation
Professor Brien Holden	Cooperative Research Centre for Eye Research and Technology
Mr Ashley Jones	The University of Queensland
Professor Yehuda Kalay	Berkley Centre for New Media
Associate Prof Justin Kenardy	Centre Of National Research On Disability and Rehabilitation
Professor Susan Kippax	National Centre for HIV social research, UNSW
Professor Geoff Lawrence	University of Queensland
Professor Leon Mann	University of Melbourne
Professor Iain McCalman	Australian National University
Professor Don McKee	The University of Queensland
Dr Catherine Mobbs	Bureau of Rural Sciences
Dr John Mott	The University of Queensland
Professor Paul Munroe	NANO General Manager
Dr Bronwyn Myers	Charles Darwin University
Ms Petra Skoien	Department of Natural Resources, Mines & Water
Professor Will Steffen	Director, Centre for Resource and Environmental Studies, ANU
Dr Robin Torrence	Australian Museum
Professor James Trevelyan	University of Western Australia
Professor Jannie van Deventer	University of Melbourne
Dr Jeni Warburton	Centre for Ageing

D5.4 What we found

Collaboration drivers

There were a number of drivers to engage in cross-sector collaboration for these researchers. Firstly, the research was driven by the need to align with the strategic direction of the organisations in which they work and secondly, to deal effectively with complex problems of importance to government and industry bodies in an integrated manner, as typified in the quotes below:

Politicians and policy advisors are busy people and do not have time to read separate reports and see how to integrate them. There is a demand for scientists to provide information that is integrated — or at least be aware of it — is increasing.

Where I sit now in Bureau of Rural Sciences — the department where we sit — they drive the extent to which the social sciences program collaborates with other programs. They do this by demanding integrated advice. If you have an area that says, 'it doesn't help us to get separate reports from social and technological—we want an integrated report' — if there is an integrated reporting demand then this will happen.

Researchers were also driven by a keen sense of social and community responsibility. For example, a spokesperson for the Centre for Social Responsibility and Mining said, 'We need to deal with the social issues'. This person had a desire to engage with the social aspects of mining and were given time by their organisation to establish contacts within the mining industry. Other researchers reinforced the need to incorporate the social context of a question, to translate the science to communities using social science skills and involving communities in the issues.

Interdisciplinary research is very good at getting to answers that incorporate the social context of the question. In reality, most of our 'science' questions do to various degrees need to be considered in the broader context, so in some cases it makes a lot of sense first up to use interdisciplinary methods to frame these research questions or broader research agendas.

If you are going to try and solve real world problems and just do it through the eyes of biophysical scientists you miss out on community and stakeholder understanding of the problem; you're missing a vital part of sustainability. Sustainability is about the economy, environment and society, but most of Australian science misses the last component—the social.

Researchers were driven to deal effectively with major social and environmental problems requiring outcome oriented research such as the CSIRO Flagships which require collaboration across the sectors to achieve their objectives.

I strongly support collaborative research as the social is crucial in solving problems like salinity, environment degradation, and biodiversity loss. Many of the causes of bio-physical problems relate to economic settings and social attitudes, which can be overlooked if social scientists are not brought on board.

Researchers were driven by the belief that cross-disciplinary understandings are often richer than those coming from any single discipline as they put together knowledge holistically to deal effectively with problems generating smarter solutions and creative ideas. A holistic understanding of the environment requires holistic approaches, as shown by this researcher:

There is some recognition in theory now that now can't solve anything without an holistic approach to it; e.g. water problems — you know the technology and science but needs to change people culture and behaviour — nothing can be achieved without this. There is a strong recognition on the importance of creativity not confined to either sector — it can manifest itself in all sorts of areas, particularly in humanities and arts. There is recognition in US in business school that there is a need to involve artists and so on and link to scientists for corporate advantage.

Structures that support cross-sector collaboration

Researchers identified various structures that support cross-sector collaboration including the CASR fund for collaboration in education, The Land and Water Australia (LWA) Integration program runs seminars at LWA on topics at the front end of science, working in 'hub' arrangements with other organisations.

In the last six months we've had ten seminars — a bit of a trial — we've pulled in people from all sorts of areas to talk about integration and their topic areas, topics at the front end of science — Steven Hatfield Dodds

—integration within CSIRO; Gabriele Bammer – epidemiology and population health; Prof John Beaton, Academy of Social Sciences they are all working with us in 'hubs' arrangement—trying to bring together the integration concept and putting into practice some of that.

As mentioned above, the CSIRO Integration program (SEI) is an internal network that identifies skills and expertise needed to conduct collaborative research—http://www.csiro.au/integration

Barriers to cross-sector collaboration

Cross-sector collaboration is affected by number of partners, disciplinary areas, sectoral interests, time and duration, complexity, and structure. While there are fundamental principles that go across all collaborations (e.g. trust, relationships), how is achieved the effort required, can be quite different.

Cross-sector researchers acknowledged the existence of very real issues within the HASS and STEM sectors. There are various levels of collaboration between the sectors at the organisational, team and individual levels as well as collaboration between industries and universities. There are very real issues with STEM's recognition of the HASS sector and vice versa. However, this is changing. For example, technology is beginning to recognise the need for community engagement and that HASS can provide the skills to enable this engagement to take place:

Slowly but surely it is becoming obvious to technology people that you can't run technology in a vacuum away from interaction with people and communities. Many examples in the mining industry where you do things from a technical basis and the technology goes wrong and then there is a big back lash from the community. Billion dollar projects have been stopped because of technology problems causing community backlash.

Challenges to cross-sector research take many shapes. One such issue is that each sector approaches problems differently making collaboration challenging. Traditional science has historically also had a low tolerance level for critical social science. This is made more difficult by the perception, and often the reality, of a pecking order or hierarchy between the various disciplines and sectors and between pure versus applied researchers as shown in the following quotes from researchers:

Coming from different paradigms can create difficulties in successful collaborations. A classically-trained western scientist might believe that it is important to be objective and that some of the interdisciplinary ideas that might look at the contextual significance and implications of the research might challenge this in 'objective' scientist research mentality.

We have difficulty finding economists and finance people to work with the team. There are not a lot of good economists around—also a pecking order ranking within sector—a perception that working with social issues is of less value than working with finance – tackling the big issues. Within a sector you don't always get collaboration or sharing – they [researchers] don't get rewards for collaborating that way – their rewards go in a different way – not collaborating across social issues. The issue of implicit ranking of disciplines. [Collaboration is] difficult with a discipline that see themselves further up the pecking order and working with those perceived as down

There is also a big difference between the basic sciences and social sciences and the applied. There is a value judgment that basic is of more value than applied. When you start trying to work across core/basic to applied areas there is that implicit ranking of value 'we are the bench people who do the important stuff and you just go out to apply it'.

This, of course, is not true of all disciplines. Sociology can frame problems in ways that are useful for STEM sector researchers. Some disciplines are close in methodology or overlapping interests; for example, cognitive psychology and health psychology use similar methodologies to neurosciences and medical science. New film and media are close to software engineering. For example the field of archaeology is naturally collaborative as their problems require collaboration across sectors:

Archaeology is uniquely in the HASS sector in Australia…but it [archaeology] is in sciences in the rest of the world. I have worked collaboratively with earth scientists on a number of occasions, and profitably.

Another challenge is the need to create space for cross-sector collaboration. Creating spaces for collaborating across the sectors takes hard work and dedication but encourages permeability across all knowledge generation sources.

Some researchers believed that crossing sectors happens through trust, individual relationships and networks rather than institutional support. This lack of institutional support can make it challenging to find collaborators from different disciplines or sectors to work with on cross-sector projects. Universities, for example, appear rooted in disciplines, making it difficult for interdisciplinary researchers. University department and faculties don't 'own' externally funded people and therefore do not support them. There are few institutional incentives for collaboration with university funding formulae, making cross-sector collaboration difficult and often viewing one sector as a service provider for the other. Institutions are traditionally in competition with one another which also does not facilitate cross-sector collaboration:

There are no incentives to overcome disciplinary boundaries – and you have to do it by own will. I can only do it because I have been doing it for 30 years — and I have done it though establishing trust rather than institutional support.

The third thing is that universities are still, despite their attempts to move on from this, rooted in the disciplines themselves. People who are not strictly historians, anthropologists etc. get trapped in areas where they are neither fish not fowl. They writing exciting research grants but don't win tenure track positions because they might not have the degrees in the right discipline. I think in some ways it is politically dangerous to take this route [collaboration]. Even though CHASS and the AVCC and the upper executive of universities want everyone to engage in post-disciplinary research clusters — in the ranks there is a need to hang on to existing bodies of knowledge in the disciplines.

I think as long as they deliver to both the HASS and the STEM sectors a benefit and that there is an understanding that all components contribute to the goals, then there is not a problem. If you view one component as just a service component for the rest of the project then it will not work.

Many researchers expressed a concern that sufficient funding was unavailable for cross-sector work. They were also concerned by the way funding applications assessors seem to be biased against cross-sector collaboration. They raised the concern that the emphasis on engaging with industry means research that is aimed at engaging with the community is not well-supported:

Within universities there are often — I am not referring to one university but all — funding formulae that make cross discipline collaboration difficult, as different sides or organisations try to get the maximum return.

Funding is major challenge — put in a couple of grants in the environmental area with scientists, but if these are judged by scientists, then they say they are too woolly as they see social science like this. And if judged by people in my own social science area, they are seen as too cold and hard. An example is 'healthy aging' — this is hard to fit into a NHMRC grant even though they say this is important, they still give priority to medical projects. Given the work I put into a grant application, I am not willing to do this anymore unless I see positive outcomes.

In the US there is a lot of money to do this work from a number of difference sources: federal; private industry and philanthropy. The latter hardly exists here — certainly not of the size of (for e.g.) the Ford and Rockefeller Foundations. The availability of this funding adds another dimension to new forms of research — for example research that combines community based research and scientific work through NGOs.

I think it is important to recognise the value of these kinds of collaboration and give them support. I'm greatly concerned that the government is trying to negate their responsibilities of supporting basic research, research and training (and non commercially viable or public good research) and engaging too much with co-investment with industry and commercial partners. This means that a lot of very important research may not get done because it isn't seen as a commercial priority.

At the other end of the scale, you've got a problem with research that needs to get done at the community level. There aren't often the resources or skills that are needed to do this at this level, but interdisciplinary work that focuses on engaging with community organisations that can be very valuable.

Researchers were also concerned that the Research Quality Framework may drive people back to their disciplines and inhibit the gains that have been made towards working collaboratively across sectors.

The Research quality Framework (RQF) — if that comes in I am concerned about how this might impact. I am concerned that this will drive us back to disciplinary boxes because it easier to do this/

Key ingredients

Researchers identified a number of key ingredients to maximise the success of cross-sector collaborations, including appropriate resources and organisational structures and involving community and other end-users in the project. The most important ingredient, however, is the characteristics people on the collaborative team.

Not everyone makes a good collaborator. Cross-sector collaborations happen between individuals, not sectors or organisations. Therefore, according to many of those interviewed, the characteristics of the people involved are the most important ingredient to success. Collaboration often happens organically. Being part of a team that works well together often means working with people you like or respect and trust that are passionate about their research. These people have an ability to share their perspectives to enable the development of common overarching project goals, are open to new ideas and who give up adherence to discipline norms and are willing to take risks.

People who work in successful collaborations, according to those interviewed, take the time to reach agreement beforehand on what they are trying to achieve, that is, establish clear understandings at beginning of project. They are willing to work at establishing good relationships and building the team. It is not critical that all team members are 'boundary spanners', but every team needs someone who is good at crossing boundaries between disciplines to facilitate effective communication. However, every team member needs to exhibit a degree of flexibility:

We need, also, to have one to two scientists on the team who are genuinely interested in working with social scientists. Otherwise, it is often hard for the latter to 'break down barriers'. Having strong rapport with one or two biophysical scientists can bring others along — who may not be so convinced of the virtues of the social scientists. If some of the scientists are sympathetic to social science, then you know you're getting somewhere, because they know that they can't do job without you.

It is always people with passion for the same thing. I think people who are very interested in their fields of research and are interested in broadening them out — people who aren't necessarily in it for their own fame and glory. It is rare for people who get Linkage money who aren't already part of teams who work well together.

We make sure we employ people who are open, like working in teams, curious, are not really precious about their favourite method — because the sort of work we do is very applied. You have to be able to give up a lot of your adherence to the norms of your discipline – to be willing to do what it takes to help the client – to step outside what you are comfortable with. A lot is happening at the boundaries of what is already known.

Being prepared to try anything once and if something doesn't work – so what? It didn't work. I think it needs to be about being adventurous.

Those groups of people have worked best when there have been great skills in working in a group. Great interpersonal skills — this depends on the group — inclusive or exclusive (hierarchy). Also, the willingness of people to reflect on their part in the project. The communication – bringing those [skills] together with some of the other skills.

Being prepared to let things evolve — go in a direction you may not have initially thought of — that is hard but often you get to the best outcomes.

You can be collaborators without having an equal stake.

Must establish clear understandings at the beginning as can easily get misunderstandings. People can not really understand where the other person is coming from — it is the same for working on any collaboration — need to choose partners carefully. People must be willing to listen and learn from each other — true of any collaboration.

Strategies to support collaboration

Researchers interviewed suggested a number of strategies that would support cross-sector collaboration, including funding, organisational support, increased networks and educational support.

Researchers suggested that the ARC review its process for assessing cross-sector project applications and provide mechanisms for priority-based assessment and assessment panels rather than disciplinary based panels. Reduced paperwork and clear principles for the application process would also encourage collaborative efforts. More broadly, researchers believed governments and other funding bodies need to make an investment in the longer term potential of cross-sector collaboration. They suggested investing in new areas of research which provide skills, software and flexible funding for collaboration with a focus on 'possibility creation' as well as problem solving. It was thought that DEST should support cross-sector collaboration in universities through special grants and more generally, have greater recognition of collaborative work and its importance. Funding also needs to target the interfaces between sectors and encourage transdisciplinarity:

I think a pitfall is that the Australia Research Council doesn't have a grass roots mechanism to cope with projects that are cross-sector — there are science panels and a humanities panel. I don't think dissolving them would be a good idea — but we need to look at joint sittings of panels that they are relevant to. Many projects will try to go the humanities route if they are cross-sector — considered to be softer and easier and less open to hard, cold scientific scrutiny which will often fail to recognise research in the humanities as real research That is always the suspicion of the science towards the humanities but both are ways of getting to the truth of creation and the philosophical possibilities of it all.

I think it [the collaboration] has to be clearly defined. It needs to be economically stated that people get fed up with the reams of paper. People will not apply for funding if they have to fill out the 50 pages response template — it is an insult to our academic values. The selection criteria needs to be cleverly designed — intelligent from the beginning — with a promise that the outcome will be exhibited in the public domain — and invested in and built upon.

Create awards or competitions — they come into the domain of the wider community — you get access to creativity in a quickly disseminated way. Make these awards and competitions around collaborations.

[Opportunities] need to be constructed by government — need to be quite specific with opportunities for funding. The opportunities need to come out of future predictions.

Researchers believed organisations need to support both disciplinary and interdisciplinary work and provide incentives for national and public institutions to collaborate. There is a need for institutional rewards for collaboration and for Universities to provide incentives for staff to collaborate, that is, provide rewards for individuals involved in collaboration. Researchers suggested things such as Universities promoting the outcomes of collaboration, celebrating through awards or in conjunction with other institutions develop and run a national collaboration showcase and include collaboration workshops. Researchers believed that existing collaborative structure such as CRCs need continued support:

…see the outcomes of your work. That is a really important thing that will motivate people to continue collaboration. They see that it has gone somewhere and will make a difference — with the clients and with the collaborators — over time we've built up a relationship with people — particularly economists — they start using the concepts and they can almost become your advocates and champions — an interesting development that we've noticed in the past — our potential contribution is acknowledged.

Researchers strongly believed that there needs to be a focus on building network capacity, that is, the design of process that facilitates the possibility of collaboration across sectors. In terms of ways to do this, researchers suggested bringing high intellect members of both sectors together, the creation of collaboration websites, support for initial project meetings and preliminary workshops to explore ideas across the sectors. We should also examine the value of things such as the rise of the Network R&D model in Europe and US that maintains a large and mostly informal network of small research and development suppliers including universities and small independent research companies. There is also a need for independent expertise in what skills are needed that can advice and train potential collaborators:

I'd love to see the Commonwealth set up its collaboration web pages. Every 12 months there could be a national collaboration showcase. We build into the funding the travel for one member of the team to present at the showcase. This needs to be uploaded up on the website — to have templated guidelines and cut all the crap out. I know how important it is to streamline the process.

The minister or the senator should be involved. Then I would like a collaboration of collaborators/collaborations — the representative of each of the collaborative showcases — to pitch their outcomes to each other. You build an innovation cycle, then you get funding out of the government investment.

Building on the theme of networking was the recurring theme of education for potential cross-sector collaborators. Researchers talked about the need to develop skills in education to look at futures, that education and training is vital. Australia needs to provide opportunities for students and researchers whose work is collaboration-based. Researchers believed there we should not downplay the importance of educational initiatives promoting collaboration and the earlier this happens in a students studies their more likely they will be to have collaborative skills. Education needs to occur to create greater porosity across all disciplines at an early stage and we need education initiatives for porosity across HASS and STEM:

It's vital to actually train people academically in interdisciplinary approaches. I don't see this happening in Australia. Without the explicit attention focused on training people to think and operate in this manner, it is an uphill battle. So a must do would be to educate and then engage people actually trained to understand where disciplinary partners are coming from and work out how to harmonise these approaches as well as adding an explicitly interdisciplinary dimension to them. You can't just assume that putting people from different disciplines together on the same project will, necessarily lead to interdisciplinary research.

I haven't got a stake in CRCs and they have their problems, but unless we have something like this that demonstrates commitment to cross disciplinary research, it is unlikely to be fostered in Australia.

We haven't talked about education much. Look at the hierarchy between HASS and STEM — 12 different cluster bands for undergraduate education funding — from expensive to less expensive. Here is a statement of value and of contribution to society. Overriding his hierarchy, however, is the issue of status. In universities there is the hierarchy of the intellect. I see this structure of status sometimes being inverted by the hierarchy of intellect. Take philosophy, for example: having run committees I know the danger of getting a really sharp philosopher who will gut and fillet a comment by someone from the more technical (higher status) disciplines.

Ultimately hierarchies of high intellect will work with others of high intellect — our job is to bring these together rather than leaving them in their enclaves.

D6 Key researchers of HASS–STEM collaboration

D6.1 What we did

This phase of the research consisted of a series of structured face-to-face or telephone interviews with people researching cross-sector collaboration. Researchers were asked a series of questions examining their motivation for the research, the challenges and opportunities in setting up collaborative projects, the indicators and key ingredients to successful collaboration, the barriers, disincentives and things to avoid when doing collaborative projects and finally, the strategies that support collaboration (see questions at end of this appendix).

D6.2 How we did it

Participants for this phase of the project were identified through their publications or conference presentations of their research, suggested by either a member of the reference committee or one of the people interviewed throughout the different phases of the project, or through the information-gathering survey. Interviews were transcribed and sent to the participants for comment and revision. These revised transcripts were then analysed for themes using the cut and paste function in word.

D6.3 Who we interviewed

We interviewed six experienced people researching collaborative processes for this phase of the project. See Table 20.

Table 20: The key researchers we interviewed

Name	Organisation
Professor Ien Ang	University of Western Sydney
Emeritus Professor Val Brown	Australian National University
Dr Linda Candy	University of Sydney
Dr Jill Gordon	Medical Humanities, University of Sydney
Dr Catherine Manathunga	The University of Queensland
Dr Peter Oliver	Queensland Department of Natural Resources, Mines and Water

D6.4 What we found

Collaboration drivers

The drivers to examine cross-sector collaborative processes were two-fold for these researchers. Firstly, the research was driven by the need to align with the strategic direction of their organisation, which was 'to engage with the outside world', and secondly, characteristics of the researchers themselves.

These researchers were currently, or had in the past, engaged in cross-sector collaborations and therefore had experience working in this area. Most of these researchers found collaborating with others a unique and rewarding experience. The knowledge gained from conducting this type of research, a natural desire to collaborate, understanding that cross-sector collaboration can better deal with 'big picture' issues, and reflections of their own experience with collaboration led each of them to wish to understand more about the processes that facilitate or hinder collaboration, as typified by the following quote:

… It gradually dawned on me that the solutions to problems for the forests lay in the socio-political arena. For the next ten years, I applied the systems thinking of ecology to public health issues in a small city. Once again, I found that a better future, for the city or for the environment, required an understanding of the complex patterns connecting the two.

Challenges and tensions

These researchers emphasised that, while cross-sector collaboration needed support to address common issues or deal with particular complex problems, the work of individuals was also important and should not go unrecognised as organisations increasingly embraced collaboration. Individual and single discipline research continues to serve important functions that must be acknowledged and even cross-sector researchers are unable to collaborate continuously during the research process.

I think individual work isn't going to go away and has an important function — sometimes it is much easy to do things on your own — collaboration is important but at the same time there needs to be space and time for individual reflection e.g. writing is not easy together a.. We haven't talked about this systematically — there are lots of conflicts about this — whose name will come first — I don't know how to resolve that — it seems the way is to discuss this in advance.

While supportive of the need for collaboration, all those interviewed recognised the significant tensions and challenges of doing cross-sector work. One tension discussed involved maintaining credibility in your own discipline for career advancement while being involved in cross-sector research.

The management of time was a real issue especially for projects with a limited and very specific time frame. Two challenges specifically in relation to time were mentioned, firstly, moving too quickly in applying for grants without first discussing the shared objectives and deciding on people's role and contribution:

…people want to enter into collaborative projects too quickly — in a hurry — apply for grant — get the grant — then need to work together but haven't really discussed the shared objective and then they get into big conflicts about those things.

A significant issue discussed relates to the need for output, in whatever format is acceptable to specific disciplines and the time needed to accomplish this goal:

… you also need to maintain credibility in your own academic field. That means you need to have a series of successful outcomes that you have to evaluate according to their own context. That is hard because often there is not enough time — one of the big problems — the grants you have are such limited time.

Another challenge faced by those doing cross-sector work was the lack of flexibility in the various supporting organisations and the difficulty they appear to have in sharing power:

One of the challenges for governments and large organisations is that they tend to centralise power and create uniformity of processes. This is not conducive to good partnerships. There is always challenge and tension that organisations could have about these issues. These need to be talked through and exposed. Need to look at how to manage losing power and increasing willingness to take risks within the organisational culture.

Differing disciplinary assumptions also need to be clarified in any cross-sector collaboration:

Accommodating different cognitive strategies: e.g. exploratory vs. goal driven styles need to be made explicit as they will need different resources at different times.

Key Ingredients for successful collaboration

Interviewees identified several key ingredients for successful cross-sector collaboration mostly pertaining to ensuring effective communication in clarifying roles, responsibilities, goals, expectations and the decision-making processes of the team.

Participants in cross-sector projects need to ensure they understand each others 'language' and disciplinary practices. They need to set outcomes that are achievable and acceptable for all disciplines, understand what is a realistic expectation of the project, and set realistic timelines.

Partnership characteristics — people need to have realistic expectations of what could be achieved otherwise there is a problem. When I read material about what should or could be achieved it seems there is sometimes a confusion of capabilities and abilities. A lot is being expected of partnerships!

It is important to develop relationship building skills in team members and/or involve researcher brokers in the team with these skills.

From a natural resource management (NRM) point of view, you need to look at what is important for participants, the broker of the collaboration and what was important for the group. From the broker — need to be a communicator, reflective practitioner, and good at group process works. Broker needs a cross section of these skills. For many NRM groups I saw — tenure and enthusiasm important. This includes the ability to develop and maintain relationships. Some people were great at personal relationships where the collaboration came from.

While many decisions in these collaborations need to be made collectively, team members must also be individually accountable. Collective decisions can be recognised through a shared set of characteristics that one researcher described:

Collective decisions were found to have a consistent set of characteristics. They were future-directed, working towards a shared ideal, rather than tied to repairing past mistakes; equitable: combining individual, community, specialised, organisational and holistic contributions on equal terms; open-ended: providing continual collective learning opportunities that involve all the contributors; a positive sum game: recognising that each collective decision adds value both to the individual contributors and to the whole that is greater than the sum of the parts; and rich with ambiguity and paradox: welcoming these essential elements of change-oriented decisions.

While it was generally agreed that collaborators must be prepared to share and take risks in the research, they must also ensure these risks are shared by the team.

Indicators of success

The main indicators of success emphasised by these researchers were project outcomes that benefited all academic disciplines involved, project collaborators that have a desire to collaborate in the future and collaborations that have assisted end-users:

an outcome that all parties are happy with. That is not always as clear as stated. It is not just one outcome or output—for the academics concerned. They don't just want an applied outcome—they need some more fundamental innovation acknowledged—more broadly in conceptual and theoretical terms—how a project would feed back into the academic disciplines—that is really important—not just applied research but engaged research with different industry partners or people working in science and technology.

Projects that bifurcated or supported new avenues of collaboration were also indicators of a successful collaboration:
…that new projects come out of it—one project not enough to investigate all avenues—need to continue to the next stage.

Recommendations

Interviewees made a number of recommendations to assist cross-sector collaboration including:

- Help researchers communicate their expertise to others.
- Use collaboration brokers to facilitate successful partnerships:
- Government policies, programs – brokerage system is crucial – has to be done by people who are in the field and have a broad understanding of the field—an academic thing A question of understanding the intricacies of academic life. ARC is basically peer review—working well.
- Engage industry by being clear in terms of what collaboration can offer them and being clear about opportunities:
- Industry/business support—I think CHASS want to have meetings with industry and business about this—we have to be realistic—so many issues that they are faced with—for them a small thing—for us—more finding ways to persuade them that we can contribute to the R&D—but then in some cases we might be completely irrelevant anyway—have to be realistic in that sense.
- Run education workshops to assist collaborators to understand collaborative processes.
- Harness what is happening in regional processes in Australia.

D7 CHASS interview questions

D7.1 Organisations and programs supporting collaboration

1. To what extent does your organisation support collaboration between the Humanities, Arts and Social Sciences (HASS) sector and the Science, Technology, Engineering and Medicine (STEM) sector?

Prompts

- level of funding
- number of programs
- personnel involved
- compared to non-collaborative work

2. Why do you support it? (Or why don't you support it to a greater extent?)

3. How do you support?

Prompts

- direct funding
- in-kind support

- providing facilities
- organising/facilitating/supporting conferences/events/workshops

4. How do you evaluate or assess cross-sector proposals, milestone reports, etc?

5. What are the factors you look for to indicate a collaboration has been a success?

6. What do you think are the key ingredients for a successful collaboration?

7. What are the barriers or disincentives for collaboration to work? How might these be overcome?

8. What strategies do you think are important for supporting collaboration?

Prompts

- Government policies, programs
- Industry/business support
- Community leadership/participation

9. Are there any 'must do' or 'must avoid' in setting up and implementing collaborative projects?

10. Any other comments you'd like to make?

D7.2 Individuals involved in or initiating collaboration

1. To what extent do you support collaboration between the Humanities, Arts and Social Sciences (HASS) sector and the Science, Technology, Engineering and Medicine (STEM) sector?

2. To what extent are you involved personally in such collaboration?

3. Why do you support it? (Or why don't you support it to a greater extent?) Why are you involved in such collaboration?

4. What are the challenges in setting up such collaborative projects?

5. What are the opportunities?

6. What are the factors you look for to indicate a collaboration has been a success?

7. What do you think are the key ingredients for a successful collaboration?

8. What are the barriers or disincentives for collaboration to work? How might these be overcome?

9. Are there any 'must do' or 'must avoid' in setting up and implementing collaborative projects?

10. From your involvement in collaborative projects, what are the key 'lessons' you have learnt that you'd seek to implement next time around?

11. What strategies do you think are important for supporting collaboration?

Prompts

a. Government policies, programs

b. Industry/business support

c. Community leadership/participation

12. Any other comments you'd like to make?

D7.3 Researchers of collaboration

1. **What motivated you to research collaboration between the Humanities, Arts and Social Sciences (HASS) sector and the Science, Technology, Engineering and Medicine (STEM) sector?**

2. **Did you find anything surprising?**

3. **What are the challenges in setting up collaborative projects?**

4. **What are the opportunities?**

5. **What are the factors that indicate a collaboration has been a success?**

6. **What do you think are the key ingredients for a successful collaboration?**

7. **What are the barriers or disincentives for collaboration to work? And are there any strategies for overcoming these?**

8. **Are there any 'must do' or 'must avoid' in setting up and implementing collaborative projects?**

9. **What strategies do you think are important for supporting collaboration?**
   Prompts
   a. Government policies, programs
   b. Industry/business support
   c. Community leadership/participation

10. **Any other comments you would like to make?**

Appendix E

Key ingredients survey

E1 Summary

We designed a survey to test the key ingredients for cross-sector collaboration that emerged from the literature review, information-gathering survey, Expanding Horizons event, case studies and interviews. In total, 688 people responded to the survey. Of those, 576 had been involved in either cross-sectoral (410) or within-sector (166) collaborations. We excluded from further analysis 112 respondents had not been involved in a collaborative project.

Approximately two-thirds of respondents involved in cross-sectoral collaboration (249) were from the HASS sector, and one-third (146) were from the STEM sector (within-sector collaborators were not asked this question).

The results of the survey need to be interpreted with caution because the respondents were self-selected, making it difficult to call the survey truly representative of cross-sectoral collaboration. However, the results of the survey supported the results we obtained through case-study and interview research.

The first group of key ingredients questions were demographic, including the presence or absence of a formal collaboration leader; whether the survey respondent was the leader; the career stage of the respondent; the respondent's sector; the number of people in the project; the number of separate disciplines in the project; the stage of the project's life cycle; and the project budget.

A large majority of respondents in both sectors reported that their projects could not have been done without collaboration. Both types of collaboration tended to involve geographically dispersed teams.

The projects described in the survey were at various life-cycle stages, although more advanced projects tended to be more commonly reported for both types of collaboration. On average, more funding sources were reported for cross-sectoral projects (mean = 1.7) than for within-sector projects (mean = 1.3).

The most common outcomes or measures of success identified for both types of projects were knowledge, understanding, improved strategies, publications, education, and guidelines and models. On average, more separate outcomes were reported for cross-sectoral projects (mean = 4.0) than for within-sector projects (mean = 2.9).

Survey respondents who were project leaders tended to report greater levels of project success. All projects that were more advanced in their life cycle tended to be credited with higher levels of success, regardless of type. Projects with larger budgets also gained higher scores for success.

Projects that reported more help from facilitators of collaboration tended to have higher levels of success. The greater the number of team members and disciplines involved in the collaboration, the greater the chance of success—regardless of whether the project was across several sectors or within just one sector.

The most common means of identifying potential collaborators for cross-sectoral projects were existing networks, friendships, and organisational facilitation. Within-sector projects also used existing networks and friendships, but were less likely to use organisational facilitation.

The second group of key ingredients measures were summary scales and their individual items, including the innovativeness of the team; the flexibility of the team structure; communication; team openness; independence; workplace characteristics; challenges to collaboration; facilitators of collaboration; and leadership. The innovativeness of the team and the facilitators of collaboration scales both predicted success, regardless of the type of project.

In cross-sectoral projects, the flexibility of the team structure, communication and facilitators of collaboration were key ingredients for success. Levels of team independence, workplace characteristics, leadership, and the impact of challenges to collaboration did not show any relationship with project success at the overall level, but items within these scales were critical ingredients in the success of cross-sectoral collaborations.

The survey results confirmed many of the items drawn from the other components of this project as being critical ingredients in the success of cross-sectoral projects. The results also shed light on the elements that are common to all collaborations, and those that are unique to cross-sectoral collaborations.

E2 How the survey was designed and administered

To ensure research rigour, we designed a survey to test the key ingredients that emerged from the literature review, information-gathering survey, horizons event, case studies and interviews. The key ingredients identified from the literature and our previous analyses were organised into themes that had emerged from this data. Those themes were identified as innovativeness, communication, team, leadership and workplace characteristics, challenges to collaboration, and facilitators of collaboration.

The previous studies also identified key demographics that potentially were linked to successful collaboration, including the stage of career of project members, size of the project, geographical proximity of team members, stage of the project's life cycle and the project budget. In addition, the survey was designed to test whether there were differences between collaborations within sectors and those across the HASS and STEM sectors.

Once the draft survey was completed it was circulated to members of the reference committee for comment. The final electronic survey was then placed on the CHASS web site and the link emailed to all participants in the previous studies and the extensive networks of the reference committee members.

E3 Who completed the survey?

In total, 688 people responded to the survey. 576 of those respondents had been involved in either cross-sector (n=410) or within-sector (n=166) collaborations. 112 respondents had not been involved in a collaborative project and were excluded from further analysis.

Table 21: The number of respondents who had engaged in collaboration

Type of collaboration	Frequency	Percent
Cross-sector	410	59.6
Within-sector	166	24.1
None*	112	16.3
Total	**688**	**100.0**

*Note: This group of respondents were excluded from all further analysis.

Approximately two-thirds of cross-sector respondents (n=249) were from the HASS sector and one-third (n=146) from the STEM sector. This two-thirds/one-third split was also reflected in the results of the information-gathering survey.

Table 22: The number of respondents who had engaged in collaboration (by sector)

What is your discipline area?	Cross-sector*	
	Count	Percent
Humanities	56	13.6
Arts	43	10.5
Social Science	150	36.5
Total HASS	249	60.6
Science	69	16.8
Technology	14	3.4
Engineering	25	6.1
Medicine	38	9.2
Total STEM	146	35.5
Other	15	3.9
Overall Total	**410**	**100.0**

*Note: Respondents reporting on within-sector collaboration were not presented with this question.

Approximately two-thirds of survey respondents (regardless of type of collaboration) identified themselves as a leader of their project. This indicates that project members are relatively under-represented in the survey sample, and that the majority of ratings of leader characteristics are self-reports, which are liable to be more biased than reports made by non-leaders.

Table 23: The number of respondents who identified themselves as leaders

I am a leader	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent	Count	Percent	Count	Percent
Yes	213	64.2	75	68.2	288	65.2
No	119	35.8	35	31.8	154	34.8
Total	**332**	**100.0**	**110**	**100.0**	**442**	**100.0**

Respondents involved in cross-sector collaboration tended to be more advanced in their careers than those involved in within-sector collaboration.

Table 24: The number of respondents by career stage

At what stage in your career are you?	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent	Count	Percent	Count	Percent
Early (<5 years)	85	20.8	43	26.1	128	22.3
Middle (5-15 years)	111	27.1	57	34.5	168	29.3
Mature (15+ years)	213	52.1	65	39.4	278	48.4
Total	**409**	**100.0**	**165**	**100.0**	**574**	**100.0**

E4 Characteristics of the projects surveyed

The following tables summarise the characteristics of the projects reported by the survey respondents. Cross-sector and within-sector projects are summarised separately, and differences between the two types of collaboration are highlighted. In some instances sample sizes are reduced due to missing data.

The large majority of respondents in both groups reported that their projects could not have been done without collaboration.

Table 25: The number of respondents who thought collaboration was critical for the success of their project

Could this project have been done without collaboration?	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent	Count	Percent	Count	Percent
Yes	39	9.6	22	13.4	61	10.7
No	369	90.4	142	86.6	511	89.3
Total	**408**	**100.0**	**164**	**100.0**	**572**	**100.0**

Social science and science were the two most common disciplines involved in cross-sector projects, while social science and humanities were the most commonly involved in within-sector projects. Engineering was under-represented in both types of collaboration.

Table 26: The disciplines involved in respondents' projects

What disciplines were/are involved in the project?	Type of Collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent*	Count	Percent*	Count	Percent*
Humanities	146	35.6	66	39.8	212	36.8
Arts	115	28.0	36	21.7	151	26.2
Social science	244	59.5	70	42.2	314	54.5
Science	179	43.7	37	22.3	216	37.5
Technology	124	30.2	28	16.9	152	26.4
Engineering	90	22.0	19	11.4	109	18.9
Medicine	133	32.4	32	19.3	165	28.6
Other	95	23.2	28	16.9	123	21.4

*Note: Percentages add up to more than 100 because many projects involve multiple disciplines

On average, more individuals, and separate disciplines, were involved in cross-sector projects than in within-sector projects.

Table 27: The number of people and disciplines involved in respondents' projects

Number involved in the project:	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Mean	Median	Mean	Median	Mean	Median
People	14.0	7.0	8.4	4.0	12.4	6.0
Disciplines	2.8	3.0	2.1	2.0	2.6	2.0

Both types of collaboration tended to involve geographically dispersed teams.

Table 28: The dispersal of team members

In your project, are all your team members co-located or geographically dispersed?	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent	Count	Percent	Count	Percent
Co-located	98	25.5	43	30.3	141	26.8
Dispersed	286	74.5	99	69.7	385	73.2
Total	**384**	**100.0**	**142**	**100.0**	**526**	**100.0**

Cross-sector projects more commonly involved team members from New South Wales, Victoria and Queensland, while within-sector projects more commonly involved team members from New South Wales, Victoria and one or more overseas countries. As would be expected given their lower population levels, Tasmania, South Australia and the Northern Territory were less commonly represented in the sample. On average, more locations were involved in cross-sector projects (mean = 1.7) than in within-sector projects (mean = 1.5).

Table 29: The location of team members

Where are (were) the project team members located?	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent*	Count	Percent*	Count	Percent*
ACT	72	17.6	22	13.3	94	16.3
Northern Territory	21	5.1	4	2.4	25	4.3
New South Wales	150	36.6	60	36.1	210	36.5
Queensland	108	26.3	24	14.5	132	22.9
South Australia	51	12.4	16	9.6	67	11.6
Tasmania	35	8.5	12	7.2	47	8.2
Victoria	137	33.4	43	25.9	180	31.3
Western Australia	51	12.4	23	13.9	74	12.8
One or more countries outside Australia	78	19.0	41	24.7	119	20.7

*Note: Percentages sum to more than 100 because many projects involve multiple locations.

The projects described in the survey represent a wide range of stages within the project life-cycle, although more advanced projects tended to be more commonly reported for both types of collaboration.

Table 30: The stage of respondents' projects

Which of the following best describes the stage of your project in its life cycle?	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent	Count	Percent	Count	Percent
Conceptual stage	25	6.5	11	7.9	36	6.9
Early stage	50	13.1	22	15.8	72	13.8
Middle stage	82	21.5	30	21.6	112	21.5
Outcome stage	132	34.6	34	24.5	166	31.9
Completed	93	24.3	42	30.2	135	25.9
Total	**382**	**100.0**	**139**	**100.0**	**521**	**100.0**

The most common funding sources for cross-sector projects were the Federal Government, universities, and State governments. For within-sector projects, the most common funding sources were the Federal government, universities, and self-funding.

On average, more funding sources were reported by cross-sector projects (mean = 1.7) than within-sector projects (mean = 1.3).

Table 31: The source of funding of respondents' projects

Which of the following best describes your source(s) of funding?	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent*	Count	Percent*	Count	Percent*
State government (e.g. Smart State Grant, state government department, etc)	104	25.4	17	10.2	121	21.0
Federal government (e.g. NHMRC, ARC, DEST, CRC, CSIRO, etc)	213	52.0	72	43.4	285	49.5
University (e.g. University seeding grants, etc)	137	33.4	55	33.1	192	33.3
Not for Profit or non-government sector	46	11.2	7	4.2	53	9.2
Industry (e.g. casino, NRMA, RACV, RTA, Telstra, etc)	76	18.5	15	9.0	91	15.8
Self-funded	50	12.2	22	13.3	72	12.5
Overseas (e.g. UN funding; British National Lottery, etc)	25	6.1	15	9.0	40	6.9
No funding	26	6.3	6	3.6	32	5.6

*Note: Percentages add up to more than 100 because many projects involve multiple funding sources.

Cross-sector projects tended to involve larger budgets than within-sector projects.

Table 32: The budget for respondents' projects

What is/was the budget for your project? (in Australian dollars)	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent	Count	Percent	Count	Percent
under $50K	125	33.0	55	39.3	180	34.7
$50K to $200K	108	28.5	36	25.7	144	27.7
$201K to $1M	98	25.9	37	26.4	135	26.0
Over $1M	48	12.7	12	8.6	60	11.6
Total	**379**	**100.0**	**140**	**100.0**	**519**	**100.0**

The most common research areas for both project types were 'Promoting and maintaining good health', 'Appreciation of cultural and historical heritage', and other uncategorised areas. On average, more research areas were reported by cross-sector projects (mean = 1.7) than within-sector projects (mean = 1.2).

Table 33: The areas addressed by respondents' projects

Which of the following research areas does/did your project address?	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent*	Count	Percent*	Count	Percent*
An environmentally sustainable Australia	83	20.2	16	9.6	99	17.2
Promoting and maintaining good health	133	32.4	35	21.1	168	29.2
Frontier technologies for building or transforming Australian industries	86	21.0	21	12.7	107	18.6
Safeguarding Australia	25	6.1	6	3.6	31	5.4
Appreciation of cultural and historical heritage	95	23.2	32	19.3	127	22.0
An Australian society engaged with Asia	13	3.2	9	5.4	22	3.8
Public participation in decision making	69	16.8	14	8.4	83	14.4
Respect for diverse cultures	60	14.6	25	15.1	85	14.8
Other (please specify)	113	27.6	36	21.7	149	25.9

*Note: Percentages exceed 100 because many projects addressed multiple areas.

The most common outcomes identified for both types of projects were knowledge/understanding, improved strategies, publications, education, and guidelines and models. On average, more separate outcomes were reported by cross-sector projects (mean = 4.0) than within-sector projects (mean = 2.9).

Table 34: The outcomes addresses by respondents' projects

Which of the following outcomes does/did your project address?	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent*	Count	Percent*	Count	Percent*
Knowledge/understanding	319	77.8	112	67.5	431	74.8
Improved strategies	232	56.6	66	39.8	298	51.7
Guidelines and models	164	40.0	40	24.1	204	35.4
Education	173	42.2	43	25.9	216	37.5
Therapies	37	9.0	12	7.2	49	8.5
A new product	57	13.9	21	12.7	78	13.5
Community programs	110	26.8	22	13.3	132	22.9
On-line databases	60	14.6	15	9.0	75	13.0
Relationships	87	21.2	21	12.7	108	18.8
Graduate students	107	26.1	34	20.5	141	24.5
Publications	181	44.1	70	42.2	251	43.6
Artworks or performances	64	15.6	21	12.7	85	14.8
Other (please specify)	40	9.8	10	6.0	50	8.7

*Note: Percentages sum to more than 100 because many projects involved multiple outcomes.

The most common identification methods used for cross-sector projects were existing networks, organisational facilitation, and existing friendships. Within-sector projects similarly used existing networks and friendships, but were less likely to use organisational facilitation. On average, more identification methods were reported by cross-sector projects (mean = 1.7) than within-sector projects (mean = 1.4).

Table 35: How potential collaborators were identified

How did you identify potential collaborative team members?	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent*	Count	Percent*	Count	Percent*
Existing networks	297	72.4	103	62.0	400	69.4
Existing friendships	98	23.9	35	21.1	133	23.1
Serendipity/chance	67	16.3	23	13.9	90	15.6
Conference, seminar, workshop or display	71	17.3	29	17.5	100	17.4
Facilitated by my organisation	106	25.9	26	15.7	132	22.9
Other (please specify)	50	12.2	14	8.4	64	11.1

*Note: Percentages sum to more than 100 because many projects involved multiple methods.

Regardless of type of collaboration, about 80 of respondents reported the existence of one or more formally designated leaders in their project.

Table 36: Types of leaders

Type of leader	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Count	Percent	Count	Percent	Count	Percent
A formal designated leader	153	42.7	53	42.4	206	42.7
Several designated leaders	133	37.2	47	37.6	180	37.3
No formal leadership, but a leader has emerged	46	12.8	10	8.0	56	11.6
No leaders	26	7.3	15	12.0	41	8.5
Total	**358**	**100.0**	**125**	**100.0**	**483**	**100.0**

E5 How the survey was analysed

To facilitate analysis, similar items in the survey were grouped together. Exploratory factor analysis was used to identify groups of items that could be combined to form summary scales. The table below lists the number and characteristics of scales produced within each topic area. Some survey items were not included in the scales, because they did not strongly connect with other items. In creating scales, any negatively worded items were reversed, so that the final scale represented higher levels of the dimension measured.

Key ingredients predicting a successful collaboration

As shown in the table below, 10 summary scales were produced.

Table 37: Summary scales

Topic Area	Items	Factors	Scale label	Example item	Items	Alpha
Innovation	13	2	Innovativeness of team	One of the team can be counted on to find a new use for existing methods or equipment.	8	.60
			Flexibility of team structure	The rules in our team are mostly formal.	3	.51
Communication	7	1	Communication	We openly discuss with each other how to achieve our goals.	6	.72
Team members	10	2	Team openness	Team members are open to new ideas.	7	.74
			Independence	We like to work individually on problems.	3	.50
Leadership	14	1	Leadership	They facilitate participation in decision making within the project team.	11	.86
Workplace characteristics	7	1	Workplace	The organisational structure in my workplace is flexible.	7	.81
Challenges	25	1	Challenges	Managing differences in expectations	22	.88
Facilitators	11	1	Facilitators	Respecting and trusting the members of the team	9	.80
Success	16	1	Success	The value of our project has gained national or international recognition.	13	.85

The topic areas of communication, leadership, workplace characteristics, challenges to collaboration, facilitators of collaboration, and success each produced a single scale. The innovation items produced two scales, labelled 'innovation' and 'structure'. Similarly, the team member items produced two scales, labelled 'team openness' and 'independence'.

Table 38: Success items

Success items
We have assembled an appropriate mix of collaborators that work well together.
The conceptual framework for the project is well understood by project members.
We have gained funding for the project.
The project team members have increased their creativity, inventiveness and innovativeness.
The project team is producing outcomes such as new knowledge, products, services, publications or displays.
We have gained recognition for our work from peers and/or industry.
The value of our project has gained national or international recognition.
We have solved the problem the project was designed to address.
We have presented the outcomes of our work either electronically or face-to-face to relevant bodies.
Our project work has engaged the public.
Our project work has influenced the work of others nationally and/or internationally.
We have developed an extensive network that will help future collaborative projects.
This project's success will lead/has led to future national/international collaborative projects.

The success scale, as seen in table above, was judged to represent an overall index of perceived project success, and was used as a dependent measure in the regression analyses reported in the next sections.

E6 Predictors of success—overall scales

To investigate the overall capacity of the survey items to predict project success, a series of regression analyses were conducted, using two sets of predictors. The first group of predictors were demographic measures, which included the following: presence of a formal leader; whether the survey respondent was the leader; career stage of the respondent; respondent's sector; number of people in the project; number of separate disciplines in the project; the stage of the project's life cycle; and the project budget.

The second group of predictors were the summary scales developed earlier: innovation; structure; communication; team openness; independence; workplace characteristics; challenges to collaboration; facilitators of collaboration; and leadership.

Regressions were conducted separately for cross-sector and within-sector projects, as well as for the total sample. In general, the regressions successfully predicted project success, explaining 42-50 percent of the variance in the success measure.

For cross-sector projects, the findings for specific predictors were as follows:

- Survey respondents who were project leaders tended to report greater levels of project success—this probably reflects a self-reporting bias.
- Projects that were more advanced in their life cycle, and projects that had larger budgets, tended to have higher levels of success.
- Projects that reported higher levels of innovation and structure tended to have higher levels of success.

- Projects that reported higher levels of communication and team openness tended to have higher levels of success.
- Projects that reported more help gained from the facilitators of collaboration tended to have higher levels of success.
- Levels of team independence, workplace characteristics, leadership, and the impact of challenges to collaboration did not show any unique relationship with project success.

For within-sector projects, the findings for specific predictors were as follows:

- Survey respondents who were project leaders tended to report greater levels of project success.
- Projects that involved more individuals, and more separate disciplines, tended to have greater success.
- Projects that were more advanced in their life cycle, and projects that had larger budgets, tended to have higher levels of success.
- Projects that reported higher levels of innovation tended to have higher levels of success.
- Projects that reported more positive workplace characteristics tended to have higher levels of success.
- Projects that reported more help gained from the facilitators of collaboration tended to have higher levels of success.

Note: all individual findings are controlled for the effect of the other predictors.

Table 39: Predictors of success

Predictor	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Formal leader[a]	-.100+	-.072	.094	-.011	-.052	-.051
Respondent is leader[a]	-.143**	-.036	-.191+	-.077	-.155**	-.040
Career stage[b]	-.018	-.043	.118	.018	.013	-.028
Respondent's sector[c]	-.043	-.034	-	-	-	-
Number of people in project[b]	.062	.023	.256*	.156+	.107*	.049
Number of disciplines in project[b]	.077	.097*	-.175+	-.116	.014	.029
Stage in project life cycle[b]	.233**	.260**	.280**	.244**	.249**	.257**
Budgetb	.248**	.231**	.179+	.252**	.232**	.226**
Innovation		.169**		.217+		.169**
Structure		.111*		-.015		.078+
Communication		.130+		.061		.127*
Team Openness		.212**		-.099		.124+
Independence		.072		-.036		.030
Workplace		.047		.155+		.064
Challenges		-.037		-.060		-.030
Facilitators		.155**		.355**		.212**
Leadership		-.021		.028		.002
R2	.203**	.229**	.251**	.250**	.189**	.232**
R2	.203**	.432**	.251**	.501**	.189**	.421**

[a] Coded as 1=Yes and 2=No.

[b] Coded as 1=Low and 2=High, based on a median split.

[c] Coded as 1=HASS and 2=STEM; only reported by cross-sector respondents.

+ p<.10; * p<.05; ** p<.01

E7 Predictors of success—individual Items

To investigate the relationship between individual survey questions and project success, the items within each topic area were used as predictors of the success summary scale. The tables below report the results of these analyses separately for each of the seven topic areas in the survey: communication; team members; leadership; workplace characteristics; challenges to collaboration; and facilitators of collaboration.

The tables report Beta weights, which reflect the unique relationship between each item and project success, and which adjust for the interrelationships between the predictors. Overall success of the prediction is shown by R^2. Results are reported separately for cross-sector collaborations, within-sector collaborations, and for the total sample.

Innovation

As indicated in the table below, innovativeness predicted success for both within and across sector projects. The profiles, however, are quite different, with the only common responses being 'we provide critical input toward a new solution', and 'we are prepared to take risks if they advance the project'.

Table 40: Innovation

Innovation (Beta weights)	Type of collaboration		Total
	Cross-sector	Within-sector	
Innovativeness of the team:			
One of the team can be counted on to find a new use for existing methods or equipment.	.064	.153+	.093*
My colleagues and co-workers stick to their own ideas and methods.	-.126*	.075	-.069
We work on a problem that has caused others great difficulty.	.042	.031	.035
We provide critical input toward a new solution.	.200**	.302**	.222**
We develop contacts with experts outside our immediate team.	.151**	.119	.156**
We are prepared to take risks if they advance the project.	.126*	.167+	.134**
We monitor and pay attention to changes in our working environment.	-.002	-.063	-.010
If my co-workers are asked, they will say we have a sense of humour.	.034	-.053	.018
We have sufficient time to develop our creativity.	.060	.205*	.103*
We have an appropriate physical space dedicated for the project team.	.071	-.028	.053
Flexibility of team structure:			
The rules in our team are mostly formal.	.127*	.015	.088+
The leader is the only one who decides how we spend our budget.	.002	-.172+	-.039
We expect people to follow organisational routine.	-.053	.052	-.013
R2	.244**	.345**	.253**

+ p<.10; * p<.05; ** p<.01

For cross-sector projects, the following innovation items (in order of importance) were related to project success:

- We provide critical input toward a new solution
- We develop contacts with experts outside our immediate team
- The rules in our team are mostly formal
- We are prepared to take risks if they advance the project
- My colleagues and co-workers stick to their own ideas and methods (negatively related).

For within-sector projects, the following innovation items (in order of importance) were related to project success:

- We provide critical input toward a new solution
- We have sufficient time to develop our creativity
- We are prepared to take risks if they advance the project
- The leader is the only one who decides how we spend our budget (negatively related)
- One of the team can be counted on to find a new use for existing methods or equipment.

Communication

As indicated in the table below, communication items predicted success for both within and across-sector projects. However, communication was more important to the success of cross-sector projects. For cross-sector projects, the following communication items (in order of importance) were related to project success:

- We discuss our ideas with potential commercial partners
- We openly discuss with each other how to achieve our goals
- We discuss ideas with project or organisation members
- Our disciplines have their own specific language, which makes it difficult to communicate (negatively related).

Table 41: Communication

Communication (Beta Weights)	Type of collaboration		Total
	Cross-sector	Within-sector	
Some team members facilitate communication across disciplines and/or sectors.	.052	.218*	.094*
We discuss our ideas with potential commercial partners.	.198**	.281**	.224**
We openly discuss with each other how to achieve our goals.	.152*	.145	.144*
We discuss ideas with project or organisation members.	.134*	.059	.121*
In my collaborative team, I am consulted and can participate in decisions that affect me.	.043	-.038	.029
My team has difficulty providing and accepting feedback from each other.	-.006	-.129	-.040
Our disciplines have their own specific language, which makes it difficult to communicate.	-.113*	-.076	-.104*
R2	.187**	.276**	.204**

+ p<.10; * p<.05; ** p<.01

For within-sector projects, the following communication items (in order of importance) were related to project success:

- We discuss our ideas with potential commercial partners.
- Some team members facilitate communication across disciplines and/or sectors.

Team characteristics

As indicated in the table below, there was considerable overlap on the team characteristics' items predicting success for both within and across-sector projects.

For cross-sector projects, the following team member items were related to project success:

- We are enthusiastic about the project/research.
- Team members have clear roles and responsibilities.
- Team members are open to new ideas.
- Some team members let their individual egos or arrogance get in the way (note this is a positive relationship).
- We listen and take the time to understand my ideas.

Table 42: Team members

Team members (Beta Weights)	Type of collaboration		Total
	Cross-sector	Within-sector	
Team member openness:			
Team members are open to new ideas.	.135*	.222+	.148**
We are enthusiastic about the project/research.	.257**	.222*	.232**
We spend time trying to understand the views and practices of each other.	.044	.065	.051
We listen and take the time to understand my ideas.	.108+	-.048	.083
Team members have clear roles and responsibilities.	.184**	.093	.167**
We do not consider each other's skills and expertise as that important.	.000	-.088	-.023
Some team members let their individual egos or arrogance get in the way.	.124*	.010	.098*
Independence:			
We like to work individually on problems.	.075	-.077	.042
Team members prefer to stick with the methods and practices of their discipline.	-.065	-.041	-.053
My team members would like me to work in the same way as them.	.013	.040	.022
R^2	.226**	.193*	.211**

+ p<.10; * p<.05; ** p<.01

For within-sector projects, the following team member items were related to project success:

- We are enthusiastic about the project/research.
- Team members are open to new ideas.

Leader characteristics

Very few of the leadership items predicted success for within and across-sector projects. For both types of collaborations discussing the 'big' picture with the team was important.

For cross-sector respondents who were leaders, the following leadership items were related to project success:

- They are aware of the 'big picture' and discuss this with the team
- They champion the project to decision makers.

For cross-sector respondents who were not leaders, the following leadership items were related to project success:

- They are aware of the 'big picture' and discuss this with the team
- They are not open to feedback (negative relationship).

For within-sector respondents who were leaders, none of the individual leadership items were meaningfully related to success. For within-sector respondents who were not leaders, the overall regression was non-significant, so none of the individual beta weights can be interpreted. For both these analyses, smaller sample size meant limited power to identify actual effects in the data.

Table 43: Leadership

Leadership (Beta Weights)	Type of collaboration				Total	
	Cross-sector		Within-sector			
	Leader N=205	Not Leader N=113	Leader N=70	Not Leader N=32	Leader N=275	Not Leader N=145
They are aware of the ‘big picture’ and discuss this with the team.	.257*	.318*	.025	.379	.199**	.317*
They are a role model for the rest of the team.	-.061	-.118	.036	-.034	-.052	-.127
They make all the decisions alone.	.086	.102	-.220	-.253	.012	.146
They listen to me when I approach them with an issue.	.057	-.072	-.087	-.120	.047	.050
They facilitate participation in decision making within the project team.	.003	-.003	.086	-.219	.017	.046
They give good practical information and advice that helps me cope with my working environment.	.056	.082	.032	-.077	.055	.003
They are not open to feedback.	.045	-.301*	-.101	.698+	.015	-.061
They provide insufficient support.	.137	-.051	-.014	-.692+	.121	-.114
They champion the project to decision makers.	.305*	.112	.162	.526*	.254**	.210*
They tend to ignore administration, funding and reporting bodies as a waste of time.	.002	.011	.092	-.013	.012	.002
They delegate responsibilities appropriately to members of the team.	.132	-.035	-.128	.059	.071	-.039
They work just as hard as other staff in this team.	-.007	-.133	.177	-.236	.043	-.092
They do not have the authority to improve the team working environment.	-.037	-.061	.051	.584*	-.025	.018
They have the resources to improve the team working environment.	.048	.089	.441	.111	.160*	.075
R2	.244**	.221*	.339*	.600	.220**	.171*

+ p<.10; * p<.05; ** p<.01

Workplace characteristics

The workplace characteristics that facilitated the success of cross-sector projects emphasised strategic influence, lack of acknowledgement and flexibility, while for within sector projects strategic influence and involvement in decision making were important.

For cross-sector projects, the following workplace characteristics items were related to project success:

- Our collaborative efforts will influence the strategic directions of my organisation
- We receive less recognition of our professional skills and knowledge from our wider organisation than from other entities (note this is a positive relationship)
- The organisational structure in my workplace is flexible.

For within-sector projects, the following workplace characteristics items were related to project success:

- Our collaborative efforts will influence the strategic directions of my organisation
- In my organisation I am consulted and can participate in decisions that affect me.

Table 44: Workplace characteristics

Workplace characteristics (Beta Weights)	Type of collaboration		Total
	Cross-sector	Within-sector	
The organisational structure in my workplace is flexible.	.119+	-.093	.060
Our collaborative efforts will influence the strategic directions of my organisation.	.181**	.314**	.222**
In my organisation I am consulted and can participate in decisions that affect me.	.028	.233*	.085
People in my organisation collaborate with one another.	.082	-.042	.036
We receive less recognition of our professional skills and knowledge from our wider organisation than from other entities.	.168*	-.011	.115+
We receive insufficient recognition of our achievements from my organisation.	-.098	-.030	-.088
The administrative support in my organisation makes collaborative activities difficult.	.038	.046	.037
R2	.089**	.170**	.095**

+ p<.10; * p<.05; ** p<.01

Challenges to collaboration

Dealing with some challenges related to collaboration were important factors in the success of both cross-sector and within-sector projects.

For cross-sector projects, the following challenges to collaboration (in order of importance) appeared to impair project success (i.e. when these were rated as a greater challenge, projects were less successful):

- unequal power or status between team members
- maintaining commitment within team
- operating outside my comfort zone

For cross sector projects, the following challenges actually seemed to benefit project success (i.e. when these were rated as a greater challenge, projects were more successful):

- managing conflict
- intellectual property issues
- managing conflict
- the reporting requirements of funding bodies

For within-sector projects, the following challenges to collaboration items (in order of importance) appeared to impair project success (i.e. when these were rated as a greater challenge, projects were less successful):

- maintaining commitment within team
- insufficient resources to achieve the project goals

Table 45: Challenges to collaboration

Challenges to collaboration (Beta Weights)	Type of collaboration		Total
	Cross-sector	Within-sector	
Operating outside my comfort zone	-.120+	.058	-.088
Competing priorities of workload and commitments	-.038	.038	.018
Publishing collaborative research results	.007	-.021	.000
Attrition and initiating new members into the team	.079	-.029	.081
Managing conflict	.198**	.154	.159**
Managing differences in expectations	.033	-.046	.032
Identifying common ground	-.039	-.093	-.052
Avoiding burnout	.077	-.009	.052
Maintaining commitment within team	-.162*	-.235+	-.209**
Peer review funding processes	.051	.037	.029
Sharing success	-.028	-.110	-.040
Identifying potential cross-sectorial collaborators	-.077	-.165	-.104+
Understanding the big picture	-.038	.004	-.022
The reporting requirements of funding bodies	.108+	.121	.098+
Intellectual property issues	.172**	.113	.148**
Moulding ideas to fit government priorities	-.018	.153	.012
Job insecurity	.037	-.121	.012
Involving those with a vested interest in the outcomes (end users)	.028	-.024	.006
Collaborating when another approach is possible	-.093	.134	-.040
Time and patience involved in consulting team members	-.038	.065	-.014
No previous experience of a collaborative process	-.073	.145	-.007
Unequal power or status between team members	-.196**	-.067	-.169**
Insufficient resources to achieve the project goals	-.078	-.230+	-.122*
Unequal workload between team members	-.003	-.134	-.030
Geographical distance between team members	.018	.053	.049
R2	.175**	.222	.152**

+ p<.10; * p<.05; ** p<.01

Facilitators of collaboration

There were distinct differences between what facilitated collaboration in cross-sector and within-sector projects.

For cross-sector projects, the following facilitators of collaboration items were related to project success:

- Large project teams
- An expectation of future collaboration with team members
- Experiencing early success in the project's life cycle.

For within-sector projects, the following facilitators of collaboration items were related to project success:

- A common purpose or goals
- Respecting and trusting the members of the team
- Experiencing early success in the project's life cycle.

Table 46: Facilitators of collaboration

Facilitators of Collaboration (Beta Weights)	Type of collaboration		Total
	Cross-sector	Within-sector	
Experiencing early success in the project's life cycle	.120*	.181+	.126**
The right mix of skills and personality	.098	.023	.089+
An expectation of future collaboration with team members	.122*	.107	.124*
Understanding each other's cultural beliefs and practices	-.034	.099	-.004
A common purpose or goals	.097	.516**	.190**
A flat organisational structure with little or limited hierarchy	-.005	-.044	-.013
Respecting and trusting the members of the team	-.009	-.209+	-.054
Individual team members being accountable for their contribution to the project	.087	-.036	.061
Training in how to collaborate with others	.022	.000	.004
Large project teams	.292**	.126	.259**
Mentorship of team members	.023	.033	.038
R2	.265**	.402**	.281***

+ p<.10; * p<.05; ** p<.01

E8 Key ingredients and successful collaboration

The aim of this survey was to test the key ingredients of success in cross-sector collaborative projects derived the literature review, information-gathering survey, horizons event, case studies and interviews.

The first group of key ingredients were demographic measures, which included the following: presence of a formal leader; whether the survey respondent was the leader; career stage of the respondent; respondent's sector; number of people in the project; number of separate disciplines in the project; the stage of the project's life cycle; and the project budget.

Survey respondents who were project leaders tended to report greater levels of project success. All projects that were more advanced in their life cycle, regardless of type, and projects that had larger budgets, tended to have higher levels of success. Projects that reported more help gained from the facilitators of collaboration tended to have higher levels of success.

The greater the number of team members and disciplines involved in the collaboration, the greater the chance of success regardless of whether the project was across sectors or within a sector. On average, more outcomes were reported by cross-sector projects (mean = 4.0) than within-sector projects (mean = 2.9). The most common means of identifying potential collaborators for cross-sector projects were existing networks, organisational facilitation, and existing friendships. Within-sector projects similarly used existing networks and friendships, but were less likely to use organisational facilitation.

The second group of key ingredients were the summary scales and their individual items including: innovativeness of the team; flexibility of team structure; communication; team openness; independence; workplace characteristics; challenges to collaboration; facilitators of collaboration; and leadership. The innovativeness of the team and the facilitators of collaboration scales uniquely predicted success, regardless of the type of project.

In cross-sector projects, the flexibility of the team structure, communication and facilitators of collaboration were key ingredients for success. Levels of team independence, workplace characteristics, leadership, and the impact of challenges to collaboration did not show any unique relationship with project success at the overall level, but dimensions of these scales were unique critical ingredients in the success of cross-sector collaborations.

Projects that experienced higher levels of communication tended to have higher levels of success, regardless of whether they were cross-sector or within-sector projects. Communication, however, was more critical to success in cross-sector collaborations. For cross-sector projects discussing ideas with team members, their respective organisations and potential commercial partners were key factors in success.

Openly discussing how to achieve goals and overcoming and understanding each others discipline specific languages also facilitated success in cross-sector projects. For within-sector projects, discussing ideas with potential commercial partners, and having key team members facilitate communication across disciplines, was critical to success.

Team characteristics factored into two sub-scales—one related to team members' openness and the other related to team members' independence from one another. Levels of team independence, that is, a preference for working on individual problems, sticking with known disciplinary practice and working with people who prefer to work in the same way did not predict success in any type of project.

Projects that experienced higher levels of team openness experienced higher levels of success, regardless of whether they were cross-sector or within-sector projects. However, team openness was more critical to success in cross-sector collaborations.

For all projects, demonstrated enthusiasm for the project and team member's being open to new ideas were common ingredients for success. For cross-sector projects, in addition to the points already mentioned, having clear roles and responsibilities and being prepared to listen and take the time to understand each others ideas were key ingredients to success. The individual egos or arrogance of team members, interestingly, did not detract from success and seemed to enhance team openness and facilitated success in cross-sector collaborations. It seems that 'ego is not a dirty word—at least, not in cross-sector collaborations.

Overall levels of innovativeness (team innovativeness and structural flexibility) predicted success for all types of projects; however, the specific profiles are somewhat different. In both types of projects success was related to providing critical input towards a solution and being prepared to take risks.

For cross-sector projects, developing contacts with experts outside the immediate team, ensuring informality in relation to rules, and being open to the ideas and methods used by different disciplines were important. This stresses the importance of both the innovativeness of the team and the flexibility of its structure. For within-sector projects, having sufficient time to develop creativity, having a say in budget decisions and having at least one team member that could be counted on to find a new use for existing methods or equipment was important, and more about team innovativeness than structural flexibility.

Projects that reported more facilitation of their collaborative efforts tended to have higher levels of success, regardless of the type of project. Facilitators of collaboration were important features in the overall success of both cross-sector and within-sector collaborations, particularly experiencing success early in the project's life cycle.

Again, there were distinct differences between what facilitated collaboration in cross-sector and within-sector projects. For cross-sector projects, having large project teams and an expectation of future collaboration with those team members facilitated success. For within-sector projects, having a common purpose or goal, and respecting and trusting team members were more important.

For both cross-sector and within-sector projects, survey respondents who were project leaders tended to report greater levels of project success. This probably reflects a self-reporting bias. The overall leadership scale did not uniquely predict success for within or across-sector projects. For cross-sector respondents who were leaders, being aware of the 'big picture' and discussing this with the team, and championing the project were key indicators of success. For cross-sector respondents who were not leaders, leaders being aware of the 'big picture' and discussing this with the team and being open to feedback were key ingredients for success.

For within-sector respondents who were leaders, none of the individual leadership items were meaningfully related to success. For within-sector respondents who were not leaders, the overall regression was non-significant, so none of the individual beta weights can be interpreted. For both these analyses, smaller sample size meant limited power to identify actual effects in the data.

The overall workplace characteristics scale did not show any unique relationship to cross-sector project success, but was related to within-sector project success. Some individual workplace items were however, related to success for both cross-sector and within-sector projects. For example, a perception that the projects' collaborative efforts will influence the strategic directions of the organisation was strongly related to success. The workplace characteristics that specifically facilitated the success of cross-sector projects emphasised the need to receive recognition of the project teams' professional skills and knowledge from the wider organisation, and the need for flexible organisational structures. Within sector projects' involvement in organisational decisions that impact on the project was a critical ingredient to success.

The overall challenges to collaboration scale did not uniquely predict levels of success for either type of project. Individually, several of these items were related to project success. For both types of projects, when maintaining commitment to the team was a greater challenge, projects reported lower levels of success. For cross-sector projects, when dealing with unequal power between team members, and operating outside the respondent's comfort zone were greater challenges, projects reported lower levels of success. For within-sector projects, experiencing more challenge from insufficient resources was also associated with less project success. I

Interestingly, some items that we thought would represent challenges to collaboration were not. For example, respondents in cross-sector collaboration who reported experiencing ***more*** challenge from managing conflict, dealing with intellectual property issues and the reporting requirements of funding bodies were actually ***more*** likely to report project success. This latter finding seems to reflect a positive benefit for projects that successfully meet these challenges.

The survey results confirmed many of the items drawn from the components of the project as being critical ingredients in the success of cross-sector projects, and shed light on the elements that are common to all collaborations and those that are unique to cross-sector collaborations.

Appendix F

Expanding Horizons event

F1 Summary

This appendix summarises information provided by 185 respondents at the CHASS Expanding Horizons event, held in Canberra on 28–29 March 2006. An event for early-career researchers, Expanding Horizons brought to Canberra people from all disciplines and from regions and institutions across Australia. A large part of the event was devoted to a discussion of collaboration across the disciplines, in line with the final aim of our project:

to explore other areas of research, education and practice where collaborative approaches would be useful.

We conducted two sessions, involving 20 groups, over the two-day program. Our first aim was to give participants the experience of organising a collaborative project across the humanities, arts and social sciences (HASS), and science, technology, engineering and medicine (STEM) sectors. Our second aim was to gain participants' feedback about their collaborative experience. We used content analysis to identify areas of overlap and difference between the groups.

Of the 20 groups, 18 believed they had created a potentially viable project. According to all of the groups, these projects addressed the current National Research Priorities, with 10 projects addressing multiple priorities. All groups felt that their projects required collaboration across the HASS and STEM sectors. Most groups found that combining people from diverse disciplines, with multiple methods and theories, can produce more holistic approaches to problems and increase the possibility of solutions.

The groups identified many benefits and barriers to cross-sectoral collaboration. Some stated benefits included the introduction of new research tools, such as methodologies or instruments; the discovery of a number of potential funding sources; and a better understanding of cross-sectoral issues. A common barrier to collaboration, according to the groups, was simply the challenge of working with cross-sectoral colleagues. Some challenges occurred within the groups, while others stemmed from a wider context. Participants were encouraged to identify and evaluate their disciplinary assumptions, often uncovering previously unidentified sources of conflict.

The two sessions were evaluated very positively, and what had been intended primarily as a data-gathering exercise became a source of valuable learning for the participants.

When asked about the key lessons of the exercise, participants stated that:

- cross-sectoral collaboration was not only possible but was easier than they had first thought
- although challenging, cross-sectoral collaboration encouraged new thought processes
- shared understandings and a common language could be created in a short time—a sense of humour was a great asset in this process
- collaborative projects can solve world problems
- it was enjoyable to speculate about hypothetical research agendas.

Overall, participants saw cross-sectoral collaboration more positively after the session than before it, and felt that it was beneficial to experience the collaborative process.

F2 What we did and how we did it

We conducted two sessions over the two-day program. Our first aim was to give participants the experience of organising a collaborative project across the HASS and STEM sectors. Our second aim was to gain participants' feedback in relation to their collaborative experience. We used content analysis to identify areas of overlap and difference between the groups.

DAY ONE: Participants were divided into 20 small groups of approximately eight to 10 people. Each group was given the exercise below to complete.

- Identify which National Research Priorities you and your group are most interested in or are applicable to your work:

  1. An Environmentally Sustainable Australia
  2. Promoting and Maintaining Good Health
  3. Frontier Technologies for Building or Transforming Australian Industries
  4. Safeguarding Australia

- In your group of 10, design a potential collaborative research project around one or more of the National Research Priorities that will result in:
  - a commercial product or service &/or
  - be of benefit to a defined sector (community group, not-for-profit sector, general public good, Australia or international community, etc) &/or
  - a new way of doing something eg a new way of teaching physics, gathering or generating knowledge, land care management, water conservation, safeguarding Australia, a new art form, helping people with a medical or health care issue, service delivery, etc

  If participants had difficulty finding a project that addressed the National Research Priorities, they were asked to design a potential collaborative research project around one or more of the following, or to design a project with no parameters:

  1. Appreciation of Cultural and Historical Heritage
  2. An Australian Society Engaged with Asia
  3. Public Participation in Decision-making
  4. Respect for Diverse Cultures

  They were then asked to brainstorm or discuss and record answers to the following questions:

  1. Have you created a potentially viable project?
  2. Did your project address the National Research Priorities (1-4) above?
  3. If your project addressed the National Research Priorities which priorities did it address?
  4. If your project did not address the National Research Priorities, define the area of your project eg. topics 5-8 or your own topic.
  5. What were you hoping to achieve with your designed project?
  6. Could this project be done without collaboration?
  7. What might be the main benefits of using a collaborative approach?

8. What are the major internal challenges, barriers or issues this group might face when collaborating with each other?

9. What would facilitate collaboration within the group?

10. Are there any external factors that would help encourage or discourage collaboration?

11. If this project was to be conducted, where do you imagine the funding would come from?

12. What are your individual, or your group's, key lessons from this exercise?

DAY TWO: Participants were asked to sit with their group of 10. We then fed back to the group in a PowerPoint presentation our summary analysis of their answers to the discussion questions. They were asked to respond to this analysis and, where appropriate, give corrections and suggestions.

F3 What we found

Their projects

Of the 20 groups, 18 believed they had created a potentially viable project. All participants felt that their projects addressed the current national research priorities, with 10 projects addressing multiple priorities. All groups felt that the project they had developed required collaboration across the HASS and STEM sectors.

Table 47: Project titles

National Research Priority	No. of Groups
An Environmentally Sustainable Australia	2
Promoting and Maintaining Good Health	15
Frontier Technologies for Building or Transforming Australian Industries	10
Safeguarding Australia	6
Appreciation of Cultural and Historical Heritage	1
An Australian Society Engaged with Asia	2
Public Participation in Decision-making	2
Respect for Diverse Cultures	1

The benefits of a cross-sector approach

Most groups found that combining people from diverse disciplines with multiple methods and theories can produce more holistic approaches to problems and expand the possibility of solutions. The majority of groups agreed that cross-sector collaboration creates better understanding of the issues and ways of researching, such as new methodologies or instruments. Working across the sectors also forced participants to identify and evaluate their disciplinary assumptions, sometimes uncovering previously unidentified sources of conflict.

Participants identified many benefits of a cross-sector collaborative approach, including the:

- ability to pool resources
- greater availability of funding sources
- creation of common understanding

- potential for greater community and industry engagement and commitment to solving problems
- potential for greater policy outcomes
- increase in social networks
- increase in creativity and the possibility of creative solutions
- unexpected outcomes or research directions
- likelihood of a more robust project

The challenges of a cross-sector approach

Participants found that working with people from different sectors was not without its challenges. Some challenges occurred within the project group, while others stemmed from a wider context. The most frequently mentioned challenges are listed below. Participants identified challenges in relation to the collaborative project team itself such as the:

- geographical separation of team members
- need to clarify roles and responsibilities
- use of discipline-specific jargon
- maintenance of cohesion and focus within the team
- management of increased complexity
- identification and discussion of different approaches and perspectives
- politics of group work
- management of conflict and differing expectations
- importance of learning to understand and listen to group members
- building of respect and trust
- importance of keeping projects moving (accountability)
- management of competing priorities (workload and commitments)
- ability to operate outside comfort zones
- skill of project management
- loss of group members
- management of group dynamics and decision making
- importance of valuing all group members' contributions, regardless of discipline or sector

Participants also identified challenges in relation to the wider context of cross-sector collaboration such as the:

- search for funding
- requirements of funding bodies (for example, lack of a track record and ability to recruit appropriate disciplinary support can negatively affect funding)
- management of public opinion
- gaining of institutional and cross-disciplinary support

- limitations of university structures – income, authorship and IP
- competition within schools and faculties and between universities
- Research Quality Framework
- management of politically sensitive research outcomes
- unequal weighting to disciplinary outputs
- lack of government support
- management of international cultural differences

The facilitators of a cross-sector approach

The groups identified many facilitators of cross-sector collaboration. All were mentioned by at least 2 groups of participants. These are listed below, from the most frequently mentioned to least frequently mentioned:

- having time to develop the project team, clarify its objectives and conduct the project
- funding and other resources
- competent project management
- institutional or disciplinary support that encourages collaboration
- meeting regularly to enable better communication
- listening with an open mind
- equality and respect for the other sector
- good management and project leadership
- creating video conferencing or IT/online forums to aid communication
- understanding common goals
- identifying common interests – having a common purpose
- trusting your collaborators
- creating partnerships and friendships
- intellectual tolerance
- involving those who will benefit from the study
- having guidelines
- small projects that start slowly
- ARC classification boxes that reflect cross-sector research
- a passion for creativity

The barriers to collaboration

Participants identified the following barriers to cross-sector collaboration. All were mentioned by at least 2 groups of participants. These are listed below, from the most frequently mentioned to least frequently mentioned:

- lack of time
- lack of recognition and rewards
- lack of funding
- ignorance and close-mindedness
- barriers between sectors – disciplinary or cultural

- poor use of funds
- lack of understanding of each others field
- inability to identify common grounds
- poor communication
- bureaucratic systems and boundaries
- unequal power in the group
- negative workload issues

The potential funding sources for collaborative projects

Participants identified a number of potential funding sources for cross-sector collaborative projects, including:

- industry (e.g. Microsoft; NRMA; RACV; RTA; car manufacturers; abattoirs; Telstra)
- lottery funds and gaming companies (British National Lottery; Jupiter's Casino)
- NGOs and not for profit organisations
- The European Union
- UN funding
- T3 Future fund
- Federal and state government (NH&MRC; ARC; DEST; CRC; Vic Roads; state education departments)
- university seeding grants

The key lessons of participants

When asked about key lessons gained from their projects, many participants stated that cross-sector collaboration was not only possible but was easier than they had first thought.

Participants found cross-sector collaboration challenged them and encouraged new thought processes. They discovered that they could create shared understandings and a common language in a short time; that a sense of humour was a great asset; that everyone can talk at once and still understand each other but it is really important to listen; and how collaborative projects can solve world problems.

Participants felt it was essential to understand how much each person could contribute to a project and, through these conversations, inspiration led to unexpected directions. The groups learnt that cross-sector collaboration creates complexity, requires negotiation and needs time—enthusiasm and energy come from building on the ideas of others. One group was surprised that creative conflict aided successful collaboration, but accepted that there was a need for open, transparent discussion. Still, the group felt that academic leadership of a project was essential.

The groups also felt that people shouldn't collaborate if another approach is possible, and that small groups are more effective. They found they were good at moulding ideas to fit government priorities, and that the collective wealth of skills and experience in each group was beneficial.

Participants found it enjoyable to speculate about hypothetical research agendas. They viewed collaboration more positively after the session than before it and felt that it was beneficial to experience the collaborative process.

F4 What participants told us in their session evaluations

The two sessions we ran were evaluated very positively, and what had been intended primarily as data gathering for us became a source of valuable learning for participants. The quotes below typify their comments:

Meeting and working with people from other disciplines was the most enlightening experience for me. It opened my eyes to the broadest range of possibilities. I have always worked solo and the thought of working in a cross-disciplinary [way] always posed a problem. The exercise with the group has had a profound effect on me.

I really enjoyed talking with people from the arts, humanities and social sciences. I'm used to collaborating across science disciplines, but don't get so many opportunities to discuss research with people from the HASS sector. I liked the group activity where we were asked to assemble an interdisciplinary research proposal; we were encouraged to think more broadly than usual and let go of our pet research interests.

I found [discussion with people from other disciplines] really valuable. Since the conference I have had contact (via email) with many of the people I met.

I have at least three new ideas percolating - so [discussions with people from other disciplines] was really worthwhile.

I enjoyed discussing issues with people from other disciplines. It certainly challenges one to think outside the comfortable paradigms of one's own discipline. I haven't developed any specific research proposals from these interactions - although who knows what might happen in the future.

Yes, over dinner I started speaking to someone who gave me some great ideas for a piece of funded research I'm about to start…I have since contacted him and aim to maintain contact with him and use his suggestions in my research. If I had just had a written piece on him I probably couldn't have imagined having common ground or a need for his expertise but when I heard about what he was doing then I was able to say I could use that in this and this situation and then we were off. I think opportunities like the dinners and press club lunch when you could talk informally was really useful.

In theory you can't imagine having much in common with other researchers or need for their expertise but in reality when you got talking to people, and opened your mind, you could see so many exciting applications of their research into yours.

Appendix G

Examples of cross-sectoral collaboration

We explored the examples of cross-sectoral collaboration described in this appendix while researching the 12 in-depth case studies described in Appendix C. These examples were not analysed for this report, but they provide useful information that influenced our research. We also interviewed many of the key people involved in these projects.

Example 1: Management of depression in HIV sufferers

Researchers at the National Centre in HIV Social Research have embarked on a project to learn how to better deal with HIV-positive male patients who suffer from depression. The centre's Primary Health Care Project on HIV and Depression is a collaboration between researchers, academics and general practitioners. The three-year project will be conducted in general practice clinics with a high caseload of HIV-positive patients in New South Wales and South Australia.

Background: Professor Susan Kippax, a social researcher at the National Centre in HIV Social Research, initiated the project. Other colleagues leading the research team are Professor Michael Kidd and Professor Deborah Saltman of the University of Sydney's Discipline of General Practice.

Collaboration stage: The project started in April 2006; collaboration is at an early stage.

Funding: NHMRC's General Practice Clinical Research Program.

Partners: Clinical Research Unit for Anxiety and Depression at the University of New South Wales (UNSW); Australian Federation of AIDS Organisations; University of Sydney; National Association of People Living with HIV/AIDS; Australasian Society for HIV Medicine.

Outcomes:

- Increased knowledge about the complex interactions between depression and HIV.
- A web module for patients and general practitioners to access so they can understand and manage depression.

Why collaboration: Collaboration is an essential part of HIV research in Australia.

More information: http://nchsr.arts.unsw.edu.au/research%20projects/phc_hiv_dep.html

Contact: Susan Kippax , s.kippax@unsw.edu.au, (02) 9385 6799

Example 2: Understanding public perspectives on low-emission technologies

CSIRO and the University of Queensland, on behalf of the Centre for Low Emission Technology, are conducting a social outreach project to better understand public attitudes towards low-emission technologies. The project combines the expertise of social scientists, engineers, scientists and technologists.

Background: Dr Anne Littleboy from CSIRO initiated a small pilot project in December 2003. She wanted to tap into the knowledge of social scientists to help assess public attitudes to new technologies. CSIRO supported the project, recognising that it was inefficient to research technologies that the public would reject.

The results of the pilot project were so promising that the whole project was handed over to the Centre for Low Emission Technology, which was able to fund the project in its entirety. Researchers have been able to gauge public opinion through a telephone survey, two focus groups, in-depth interviews and a follow-up survey.

Collaboration stage: Continuing. The project is funded from 2004 to 2006. The current phase of the project began in 2005.

Funding: The Centre for Low Emission Technology is funding the three-year, $700,000 project.

Partners: University of Queensland; CSIRO; Australian Coal Association; Queensland Government; Tarong Energy Corporation Limited; Stanwell Corporation Limited.

Outcomes: By testing public reaction to new technologies, the researchers have found that members of the public are independently making the same decisions as policy makers about emerging technologies. These findings are positive, because they suggest that the public is willing to accept change to be more environmentally friendly.

Documented public attitude and behaviour changes include:

- switching off stand-by lights
- consciously conserving electricity
- running air conditioners at a higher temperature
- recycling more
- thinking twice before driving cars alone
- considering buying ‘green’ vehicles
- attempting to influence the behaviour of others (partners, family members, friends, etc)
- seeking environmental information from the internet and other sources.

Why collaboration: The project could not have been undertaken without cross-sectoral collaboration, as the researchers were required to establish a process for creating dialogue. The STEM scientists did not have the skills to engage the public, and the social scientists had little knowledge of new technologies and their benefits and disadvantages.

More information: http://www.clet.net

Contact: Peta Ashworth, peta.ashworth@csiro.au, 0409 929 981

Example 3: Using art to further technology

Photographic artist Stephanie Valentin’s work with the UNSW’s Nanostructural Analysis Networked Organisation (NANO) has resulted in artistic and technological advances. NANO members collaborated with Valentin to inscribe words on microscopic specimens, producing striking images and at the same time perfecting the use of NANO’s focused ion beam technology.

Background: Valentin approached Professor Paul Munroe of NANO with the idea of collaborating on ‘nanoart’. Munroe told Valentin that NANO’s focused ion beam could etch a word into a grain of rice, and Valentin presented Munroe with tinier pollen grains instead. This led to their first collaboration, which was successfully exhibited in 2003 and published in *Nature*. Valentin’s second collaboration with NANO, titled *Fathom*, used marine organisms for etching and was also critically acclaimed.

Collaboration stage: Beginning in 2002, the first collaborative project between Valentin and NANO led to two exhibitions of Valentin’s work. Although this initial project is complete, the collaborative process is ongoing. Valentin and NANO members have discussed future projects and ideas.

Funding: Valentin, a fine arts PhD student at UNSW, funds her work with PhD income support, photography teaching and artwork sales. NANO is a Major National Research Facility funded and established under DEST, and does not charge Valentin to use its focused ion beam.

Outcomes:

- Valentin's work with NANO has been exhibited at the Stills Gallery and the Brian Moore Gallery in Sydney.
- Knowledge gathered from its work with Valentin has helped NANO to perfect its use of the focused ion beam.

Why collaborate: NANO has benefited from its collaboration with Valentin on several levels. The success of Valentin's 'nanoart' work has led to publicity for the NANO laboratory and its technology. The collaboration has also pushed NANO in new directions. NANO's expertise with the focused ion beam (which was new to the lab when Valentin first approached NANO) owes a lot to the collaboration.

The project encouraged NANO to embark on other projects that it had not previously contemplated. For Valentin, the project has increased her profile and expanded her artistic boundaries.

More information:

- on Valentin: http://www.stillsgallery.com.au/artists/valentin/
- on NANO: http://www.nano.org.au/

Contact: Rosie Hicks, rosie.hicks@emu.usyd.edu.au, (02) 9351 7551

Example 4: Public art at the National Botanic Gardens

A collaborative project at the Australian National Botanic Gardens is part of the gardens' program to encourage artist interaction with botanists and the gardens' plant collections, and to create interpretive art works accessible to the community.

Background: As part of the Australian National Botanic Gardens' Public Art Program, the Australian Network for Art and Technology (ANAT) sponsored new media artist Julie Ryder to collaborate with cryptogamic botanist Christine Cargill on a project to explore the science behind the taxonomy of cryptogams.

Collaboration stage: The four-month project was completed by March 2005. Ryder continues to produce collaborative artwork with Cargill. They exhibited in 2005 and have been invited to exhibit in Shanghai at the Zendai Exhibition of Modern Art.

Funding: ANAT provided a stipend; the Botanic Gardens gave Ryder facilities and resources in kind.

Outcomes:

- Raised public awareness through an artistic perspective of herbariums and cryptogamic plants, and new visitors to the herbarium.
- An opportunity for Cargill to inform people that 'plant museums' exist.
- An increase in artists interested in collaborations with cross-sectoral colleagues: they now know how to gain access to the scientific world.
- Increased awareness that allows the Botanic Gardens to gain further support for its work.
- School group visits to the herbarium.

Why collaborate: The collaboration provided an artistic view, new perspectives and reinterpretations. Ryder brought in ideas that the Botanic Gardens would never have contemplated, such as preserving the newspaper used to press flowers, which was normally thrown away. The collaboration was a success for Ryder, Cargill and the Botanic Gardens.

More information: http://www.anbg.gov.au/anbg/exhibitions/2005-art&briophyte/index.html

Contact: Robin Nielsen, (02) 6250 9500

Example 5: Mediaware

Software developed collaboratively has found a major market in the defence, security and intelligence fields.

Background: Mediaware is widely recognised as the global leader in the development of advanced digital video processing systems and solutions. The company was founded in 1996 by three research scientists from CSIRO who had conducted groundbreaking research in the areas of compressed video (MPEG) and image processing. They left CSIRO to commercialise this technology.

Mediaware is the global leader in digital video intelligence, video surveillance and reconnaissance systems for the defence and intelligence sectors, and the leading supplier of digital video exploitation systems and subsystems to United States military and intelligence organisations. The systems enable analysts, warfighters and law enforcement professionals to rapidly and accurately analyse and exploit real-time video intelligence; warfighters and imagery analysts can now exploit video faster than ever for rapid and accurate decision-making in battlefield environments.

Mediaware supplies its systems directly and through its United States system integrator partners, which include General Dynamics, SAIC, Raytheon, Lockheed Martin, and Northrop Grumman. It is also bidding in several Australian defence projects.

More information: http://www.mediawaresolutions.com

Example 6: *Lord of the Rings* face-mapping now a tool for radiotherapists

Radiotherapists have gone to the movies to solve an old problem: how to keep a patient's head very still during treatment.

Using FastSCAN technology (which was used to create various characters in *The Lord of The Rings* films), it is now possible to digitise a patient's facial features into a computer using a laser scanner. This 3D data is then exported to a computerised milling machine that produces a plaster model of the patient. A clear sheet of rigid and strong plastic is then vacuum-formed over the model, creating a mask that will fit the patient perfectly. The mask can then be attached to the treatment couch, ensuring that the patient stays still.

More information: http://www.health.wa.gov.au/radiationtherapy/scholarships/role.cfm

Example 7: Games for health

The Serious Games Initiative founded Games for Health to develop a community and best practices platform for the many games being built for health-care applications. To date, the project has brought together researchers, medical professionals and game developers to share information about the potential impact of games and game technologies on health care and policy. The goal is to foster and support a community of researchers, developers and users of game technologies to organise and accelerate the adoption of computer games for a variety of challenges.

Games for Health is most interested in answering four interrelated questions:

- can games improve the provision and quality of health care?
- what existing and emerging game technologies (such as multi-user virtual environments) might be particularly useful when applied to health care?
- how can we expand the application of computer-based game technologies to face key challenges in the health-care sector?
- how do we identify and proactively deal with any social, ethical and/or legal issues that might arise through the application of game-based tools to health care?

More information: http://www.gamesforhealth.org

Example 8: Indigenous child health program ensures workforce for the future

Aboriginal child health is affected by asthma, allergies and respiratory diseases, birth defects, cancer and leukaemia, developmental disorders, mental illness and infectious diseases. As part of the Rio Tinto Child Health Partnership, Indigenous communities, the Australian Government, state and territory governments, health and medical practitioners and researchers are working together to prevent child health problems, rather than treating them only when they reach crisis point.

The partnership aims to improve the health and wellbeing of Indigenous mothers and children in Western Australia, Queensland and the Northern Territory to ensure a healthy and viable workforce for the future.

Background: Rio Tinto is a major partner, contributing $1.5 million over seven years to this $5.2 million project. In collaboration with the Telethon Institute for Child Health Research, the project is supporting Indigenous health workers in local areas where Rio Tinto has significant operations, and translating the work of the Telethon Institute into policy, practice and interventions.

Collaboration stage: Underway. The project started in August 2003 and will finish in 2009.

Funding: $5.2 million — from Rio Tinto, the Alcohol Education and Rehabilitation Foundation, and the Australian and Queensland, Western Australian and Northern Territory governments.

Partners: Perth's Telethon Institute for Child Health Research; Rio Tinto (incorporating Argyle Diamonds, Comalco, Rio Tinto Aboriginal Foundation); the Alcohol Education and Rehabilitation Foundation; and the governments listed above.

Outcomes:

- The Western Australian Aboriginal Child Health Survey in the Northern Territory and Queensland was so successful that the Australian Health Ministers' Advisory Council agreed to consider implementing the model nationally.
- Queensland Health has signed community agreements on promoting healthy pregnancy, including foetal alcohol syndrome prevention, with three Indigenous communities.
- Queensland Health is developing a train-the-trainer resource for promoting healthy pregnancy using community-based health interventions, following input from the Queensland trial sites.
- In conjunction with the University of Newcastle, the Northern Territory Department of Health and Community Services commenced a trial of brief intervention counselling with pregnant women via community health nurses.
- Multidisciplinary hospital teams, including Aboriginal health workers, have been implemented in the Northern Territory to work with general practitioners.

Why collaborate:

- To ensure that different stakeholders benefit from each other's information; for example, the state jurisdictions benefit from foetal alcohol syndrome research at the Telethon Institute.
- To ensure that the institute benefits from the contribution to the wellbeing of Indigenous Australians in jurisdictions in which Rio Tinto has significant operations.
- To build strong regional communities, ensuring healthy local workforces in the future.
- To develop collaborations with governments, industry bodies and Indigenous communities.
- To translate Telethon Institute research into health policy, practice and interventions.
- To link with Rio Tinto businesses and other partners to achieve mutual goals.
- To leverage key research outcomes of the partnership on to the national agenda.

More information: http://www.wafuturefund.riotinto.com/news-item-live.asp?newsID=166

Contact: Colleen Hayward, (08) 9489 7758, colleenh@ichr.uwa.edu.au

Example 9: Collaboration leads to sustainable fire management practices in Indonesia

Researchers in Indonesia and northern Australia have collaborated in a Tropical Savannas CRC project on fire management. The project, funded largely by the Australian Centre for International Agricultural Research (ACIAR), reviewed and recommended changes to fire-management policies and regulations across Indonesia and northern Australia.

Collaboration stage: The initial project has been completed, but work continues in 2006.

Funding: Tropical Savannas CRC; ACIAR; AusAID; Charles Darwin University; Bushfires Council; Crawford Fund.

Outcomes:

- Engagement with communities in Indonesia and the Northern Territory using a participatory methodologies, developing and implementing fire-management approaches.
- Increased capacity within government agencies (particularly Indonesia's provincial planning boards), sustainable outcomes and skills transfer.
- Mapping of fire extent, land use and forest resources at sites in East Sumba and Ngada (central Flores).
- Development and extension of partnerships between government and university in the Northern Territory and government agencies, NGOs and universities in Indonesia in the areas of land, resource and fire management, and educational exchanges of materials and staff.
- Review of fire policy and regulations across Indonesia and Northern Australia.

Why collaborate: Collaboration with Indonesian bodies ensures the project's relevance to community needs.

More information: http://savanna.ntu.edu.au

Contact: Bronwyn Myers; 08 8946 6726; bronwyn.myers@cdu.edu.au

Example 10: Social responsibility in mining

The Centre for Social Responsibility in Mining conducts research on social issues relevant to the mining industry and helps build the industry's capacity to manage those issues more effectively.

Background: The centre was established by the University of Queensland in 2001, in response to growing interest in and debate about the role of the mining and minerals industry in contemporary society.

The centre is a run by a multidisciplinary mix of eight people from engineering, business, psychology and anthropology backgrounds. The team collaborates with other centres, such as the Centre for Water in the Mining Industry, and maintains links within and beyond the University of Queensland.

Collaboration stage: Underway. The centre, which began at the end of 2001, aims to become self-funding.

Funding: Set up using seed funding of about $1 million from the Queensland Government through the University of Queensland. Current funders include the ARC and the Australian Coal Association Research Program.

Partners: Anglo Coal Australia Pty Ltd; BHP Billiton; Ensham Resources Pty Limited; Rio Tinto Australia; Placer Dome Australia Ltd; Thiess Pty Ltd; Newmont Australia; Xstrata Copper; Roche Mining.

Outcomes: The Centre for Social Responsibility in Mining has established a good profile in the mining industry. Its projects have had a positive impact on mining in Australia. There are currently eight PhD students associated with the centre.

Activities include:

- developing a map of linkages and an experts directory
- identifying and documenting good practice (for example, the centre has put together a major project on good practice for Aboriginal employment in the mining industry)
- developing tools for mining companies to assess their social impacts
- surveying attitudes towards the mining industry.

Why collaborate: According to the centre's David Brereton:
The diversity of issues that you have to deal with are such that you can't carry all capability in one centre, and you need to make smarter use of resources to collaborate when you need to. We are trying to collaborate on the margins where social science meets science—you get further if you have the capability to do this.

More information: http://www.csrm.uq.edu.au

Contact: David Brereton; d.brereton@smi.uq.edu.au (07) 3346 4043

Example 11: Australian Creative Resources Online

Australian Creative Resources Online (ACRO) is a nationally funded project established in collaboration with Queensland University of Technology, the Australian National University, Avid Australia, and Strong Point. ACRO is an archive of video, music and other creative material built to provide creative raw materials that help stimulate the production of new broadband content.

ACRO is designed to play an important role in the new creative environment offered by broadband technologies. Artists, educators and researchers are becoming more restricted in the material they can use, because of changes to copyright law. ACRO will reverse this trend by providing access to large amounts of high-quality multimedia material.

Background: ACRO director Phil Graham had the original idea. Having come out of the music and talent industry, he was concerned that an enormous amount of produced material was not being used and there was no way to get the material repurposed. ACRO was born out of an understanding that the education sector could use the material in the multimedia curriculum.

Collaboration stage: Advanced. The project started in 2002 and is ongoing.

Funding: ACRO began as an ARC-funded infrastructure project under the Linkage Equipment and Infrastructure Fund. The original grant in 2002 funded the Australian Creative Resources Archive, upon which ACRO is built. The University of Queensland extended the original ARC grant with an infrastructure grant in 2003. This established ACRO. Through various internal and external funding schemes, the university has committed almost $1 million to ACRO.

Partners: ACRO works in collaboration with a number of partner organisations, including the Queensland University of Technology, Creative Commons, AARnet, the Australian National University, Avid Technologies and others listed on the ACRO website.[18]

Outcomes: Ashley Jones of ACRO says:
[The project] has really challenged the way people think about copyright issues. [It has] been recognised as a significant breakthrough as it's not a historical archive, but a creative archive. There's a massive difference. Even though there is historical material, people are meant to be creative and innovative. Having impact for short filmmakers, music, and imaging from our storage. [It has] rattled the cage of the way people think about how your can refocus content.

Why collaborate: ACRO would not survive without its collaborators; as a multimedia project, ACRO is collaborative by definition.

Contact: Ashley Jones; Ashley.jones@uq.edu.au; (07) 3381 1542 or 0412 104 491

18 http://www.acro.edu.au/acroparts.html

Example 12: Australasian Centre on Ageing

The Australasian Centre on Ageing was established in 2001 at the University of Queensland, with assistance from the Vice-Chancellor's strategic funds, the faculties of Social and Behavioural Sciences and Health Sciences, and the Seniors Interests Branch in Queensland's Department of Families. The centre integrates and focuses research expertise in human ageing from across the university, and links it with government and community priorities to form a world-class international centre of research excellence.

The centre's research falls (although not exclusively) within five themes: ageing and society; ageing and place; ageing and the economy; ageing and health; and acute and aged care.

More information: http://www.uq.edu.au/cfha/

Example 13: Natural disaster research at Geoscience Australia

How urban communities respond to earthquakes, cyclones, tsunamis, storms and landslides is being studied in a multidisciplinary project. Economists, engineers, physicists and computational modellers (geophysicists and climate modellers) are working together through Geoscience Australia to define the threats posed to urban communities by natural hazards with rapid onset.

Geoscience Australia's Risk Assessment Methods Project (RAMP) integrates natural hazard research, potential national exposure and socioeconomic vulnerabilities, including energy and power networks, to better predict the likely impacts of events. By accurately modelling likely impacts on urban communities and building those estimates into land-use planning and emergency management, Australia will be better able to prepare for and respond to natural disasters when they occur.

The project will develop fully integrated multi-hazard risk assessment tools, methods and visualisations that will support the longer term Disaster Mitigation Australia Package requirements of state and local governments.

The main research areas for RAMP are:

- national risk model development
- model and method development for the estimation of return periods and likely impacts from rapid-onset natural hazards, including earthquakes, landslides, tsunamis, severe winds and cyclones
- further work on the National Building Exposure Database (a tool to develop nationally consistent estimates of the number, type and value of Australia's buildings and infrastructure)
- impact modelling tools for emergency management.

Previous RAMP outputs include:

- an integrated earthquake risk model
- software supporting spatial representations of fluid dynamic modelling and, in particular, tsunami impact for various locations
- robust techniques for quantifying hazard and risk across a range of natural sudden-impact hazards
- the National Building Exposure Database
- direct and indirect economic modelling techniques to define the impact of natural disasters at regional and national scales.

More information: http://www.ga.gov.au/urban/projects/ramp/index.jsp

Contact: Matt Hayne; (02) 6249 9536; Matt.Hayne@ga.gov.au

Example 14: Conservation biology and law at the University of Wollongong

Formed in 2001, the Institute for Conservation Biology and Law is one of the University of Wollongong's major research strengths. The institute is unique in combining expertise in conservation law and policy with strong research in evolutionary and environmental biology.

Aims of the institute:

- To conduct world-class research concerning the biology and conservation of Australia's native biota.
- To train research students to be highly competent researchers in this area.
- To foster interdisciplinary research and research training, linking science with law, policy and management.
- To interact with other scientists, as well as managers and policy personnel, to achieve effective conservation of the Australian biota.

Partners: NSW Department of Primary Industries; CSIRO; Department of the Environment and Heritage; Australian Museum Evolutionary Biology Unit; Southern Rivers Catchment Management Authority.

More information: http://www.uow.edu.au/science/biol/icb/index.html

Contact: Sharon Robinson; (02) 4221 5753; sharonr@uow.edu.au

Example 15: Social dimensions of alternative urban water supply and usage

Alternative water technologies are a major part of the solution to reduce the demand on potable water from storage dams. The overall concept is called *potable water substitution.* The use of alternative water technologies is as much a social issue as a technological issue, but there has been very little research to investigate how people interact with these forms of technology.

Technological solutions are not people-neutral and can lead to unexpected and perverse social outcomes. There are likely to be important social implications from shifting some of the responsibility for bulk water supplies from centralised water utilities to the home owner.

The study has a learning/communication dimension. One of its aims is to identify opportunities for learning and improving communications with the various actors.

Background: Ted Gardner, Principal Scientist of the Water Cycle Science Group and Dana Thomsen initiated a collaborative research project to understand societal influences on feasibility of decentralised/alternative water supplies.

According to Gardner:
Decentralised/alternative water supply refers to any system or combination of systems which substitute for the mains water supply. Examples include rainwater tanks, on-site treatment plants for treating sewage or grey water. These systems have various functions; for example, rain collected from rainwater tanks may be used for watering the garden, toilet flushing, laundry usage or even the hot water system. Grey water is used mainly for irrigation. The scale can range from the individual household level to community managed local treatment and reticulation systems. 'Greenfield' developments in master planned new urban subdivisions incorporating alternative water supply are the focus of this study.

Collaboration stage: Initial. The team is currently conducting a stakeholder analysis and will be getting a stakeholder group together (over four years). It will study residents living in greenfield developments and how they interact with technology, such as rainwater tanks and water treatment.

Funding: Funding is supplied from special Queensland Treasury funds. The research is supported by the Queensland Department of Natural Resources, Mines and Water.

Partners: Department of Natural Resources, Mines and Water; E-water CRC; Brisbane City Council; Griffith University; Queensland Government.

Outcomes: The major outcome of the study will be to increase and optimise the uptake of alternative water technologies in new urban subdivisions, such as greenfield developments.

Why collaborate:

- At the macro level, the study requires a collaborative approach involving local authorities; state government departments and agencies; urban developers; planners; water technology manufacturers; professional, community interest and environmental groups; and residents of greenfield developments.
- At the micro level, the collaborative research team brings skills from engineering, water cycle science, social science, sociology, psychology and education. Different perspectives and knowledge-sharing shape the direction of the study.

Contact: Ted Gardner; (07) 3896 9488 or 0417 729 181; Ted.gardner@nrm.qld.gov.au

Example 16: Ageing well

Ageing is one of the most significant changes facing Australia, and brings opportunities as well as challenges.

The Research Network in Ageing Well sits squarely in the National Research Priority area, 'Ageing well, ageing productively'. It will generate innovative, multidisciplinary approaches necessary to understand ageing people, relations between age groups, and the economic, social, and policy contexts that shape ageing experiences. It will bring together established and early-career researchers and end users, forming a unique network that generates and implements research agendas, and translates and applies findings to national goals.

The network has been funded through the ARC and the NHMRC by the Australian Government as part of its Research Networks Program.

The Research Network in Ageing Well will work to generate knowledge to underpin the goals articulated in the National Strategy for an Ageing Australia, the PMSEIC report *Promoting healthy ageing in Australia,* the Framework for an Australian Ageing Research Agenda, the Stocktake of Australian Ageing Research and Policy Initiatives, and the national Building Ageing Research Capacities Program.

More information: http://www.ageingwell.edu.au/

Example 17: Strike a chord with Questacon

Music, rhythm and dance are common to every human culture. Music infuses our lives, to soothe or excite our senses and to help us celebrate important cultural and life events. Questacon's Strike a Chord exhibition consists of 22 hands-on exhibits, plus quirky graphic fact panels and a 'tot spot'.

Strike a Chord brings together a broad range of disciplines to explore:

- the physics of sound and musical instruments (acoustics)
- the physiology of hearing and singing
- the psychology and sociology of music
- musical composition.

More information: http://www.questacon.edu.au/html/strikeachord.html

Appendix H

Reference Committee

Name	Organisation
Dr John Beaton	Academy of the Social Sciences in Australia
Professor Tim Brown	Australian Council of Deans of Science
Dr Catherine Brown-Watt	Australia Council for the Arts
Ms Bobby Cerini	Questacon
Ms Oon Ying Chin	Department of Education, Science and Training
Ms Deborah Crossing	Engineering House
Professor Stuart Cunningham	Queensland University of Technology
Mr Toss Gascoigne	Council for the Humanities, Arts and Social Sciences
Professor Malcolm Gillies	Council for the Humanities, Arts and Social Sciences
Associate Professor Jill Gordon	Centre for Medical Humanities
Dr Stefan Hajkowicz	Centre for Sustainable Ecosystems
Ms Naomi Hart	Department of Education, Science and Training
Ms Anne Leitch	Centre for Sustainable Ecosystems
Professor Joseph (Joe) Lo Bianco	University of Melbourne
Ms Anne McConnell	Department of Education, Science and Training
Ms Jenni Metcalfe	Econnect Communication
Ms Jan Muir	Australian Research Council
Dr Robert O'Connor	Consultant and independent scholar
Dr Anne Pisarski	Communication Partners
Dr Melinda Rackham	Australian Network for Art and Technology
Dr Michelle Riedlinger	Econnect Communication
Professor Linda Rosenman	University of Queensland
Associate Professor Kate Stevens	MARCS Auditory Laboratories, University of Western Sydney
Ms Julie Walding	Department of Education, Science and Training

Appendix I

Acknowledgments

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Name	Organisation
Professor Ien Ang	University of Western Sydney
Ms Peta Ashworth	CSIRO
Professor Gabriele Bammer	Australian National University
Dr John Banks	Queensland University of Technology
Ms Michaela Bauer	Curtin University
Mr Noel Beynon	Land & Water Australia
Dr Chris Blanchard	Charles Sturt University
Ms Marie-Pier Boucher	University of Western Australia
Professor David Brereton	Centre for Social Responsibility in Mining
Emeritus Professor Val Brown	Australian National University
Mr David Bruce	Bushfire CRC
Dr Eleanor Bruce	University of Sydney
Associate Professor Sam Bucolo	Australasian CRC for Interaction Design
Ms Veronica Bullock	Collections Council of Australia
Dr Stuart Bunt	University of Western Australia
Dr Andrew Burrow	Spatial Information Architecture Laboratory, RMIT
Ms Jane Burry	Spatial Information Architecture Laboratory, RMIT
Professor Mark Burry	Spatial Information Architecture Laboratory, RMIT
Mr Neil Calder	Stanford University
Mr Philip Callan	National Health and Medical Research Council
Mr Andrew Campbell	Land & Water Australia
Professor Paul Campbell	Royal Children's Hospital
Dr Linda Candy	University of Sydney
Dr Christine Cargill	Australian National Botanical Gardens
Mr Gary Cass	University of Western Australia
Mr Oran Catts	University of Western Australia
Ms Bobby Cerini	Questacon
Dr Subhash Challa	University of Technology, Sydney
Ms Boo Chapple	Spatial Information Architecture Laboratory, RMIT

Name	Organisation
Dr Andrew Clark	Engineering and Physical Sciences Research Council
Ms Jane Coakley	University of Western Australia
Dr Aaron Corn	University of Sydney
Mr Trevor Dhu	Geoscience Australia
Dr John Dodgson	National Academies Forum
Mr Andrew Donovan	Synapse Art and Science Initiative, Australia Council
Mr Graham Edelsten	Auran Technologies
Professor Philip Esler	Arts and Humanities Research Council
Dr Elie Faroult	CEC
Professor Peter Fische	Science and Technology Foresight
Associate Professor Di Flemming	Royal Melbourne Institute of Technology
Mr Brian Fletcher	Questacon
Professor Roland Fletcher	University of Sydney
Ms Miranda Forwood	Australasian CRC for Interaction Design
Professor Cindy Gallois	University of Queensland
Mr Ted Gardner	Queensland Department of Natural Resources, Mines and Water
Mr Gary Garner	Queensland University of Technology
Associate Professor Ian Gordon	University of Melbourne
Dr Jill Gordon	University of Sydney
Dr Donna Green	CSIRO
Dr David Gronbaek	European Cooperation in the Field of Science and Technical Research
Professor Miranda Grounds	University of Western Australia
Mr Nicolas Guernion	Engineering and Physical Sciences Research Council
Ms Jen Guice	CRC for Water Quality and Treatment
Professor John Handmer	Royal Melbourne Institute of Technology
Mr Lawrence Harvey	Spatial Information Architecture Laboratory, RMIT
Dr Steve Hatfield Dodds	CSIRO
Dr Tom Hatton	CSIRO
Associate Professor Colleen Hayward	Rio Tinto Child Health Partnership
Professor Richard Head	CSIRO
Professor Greg Hearn	Institute for Creative Industries and Innovation
Professor Brien Holden	CRC for Eye Research and Technology
Professor Mike Humphreys	University of Queensland
Mr Will Inveen	Questacon
Ms Lindy Johnson	Queensland Department of State Development
Mr Ashley Jones	University of Queensland
Professor Yehuda Kalay	Berkley Center for New Media
Ms Verena Kaminiarz	University of Western Australia
Associate Professor Justin Kenardy	Centre of National Research on Disability and Rehabilitation

Name	Organisation
Associate Professor Roy Kimble	Royal Children's Hospital
Professor Susan Kippax	National Centre for HIV Research, UNSW
Professor Geoff Lawrence	University of Queensland
Mr Justin Leonard	CSIRO
Emeritus Professor Bob Lester	University of Queensland
Mr Michael Lester	Land & Water Australia
Ms Rowena Lindquist	
Mr Andrew Maher	Spatial Information Architecture Laboratory, RMIT
Dr Stephen Malloch	MARCS Auditory Laboratories
Dr Catherine Manathunga	University of Queensland
Professor Leon Mann	University of Melbourne
Mr Alan March	AusAID
Ms Katherine Mathieson	National Endowment for Science, Technology and the Arts
Professor Iain McCalman	Australian National University
Dr Phil McFadden	Geoscience Australia
Dr Paive McIntosh	European Science Foundation
Professor Don McKee	University of Queensland
Mr Joe McLean	UniQuest
Dr Catherine Mobbs	Bureau of Rural Sciences
Mr Gregory More	Spatial Information Architecture Laboratory, RMIT
Dr John Mott	University of Queensland
Dr Bess Moylan	Living with Heritage
Ms Jan Muir	Australian Research Council
Professor Paul Munroe	Nanostructural Analysis Network Organisation
Dr Bronwyn Myers	Charles Darwin University
Ms Blair Nancarrow	CSIRO
Dr Carol Newnham	Royal Children's Hospital
Dr Carol Nicoll	Curtin University
Ms Katrina Nilsson	Dana Centre
Mr Claus Nowotny	European Science Foundation
Dr Peter Oliver	Queensland Department of Natural Resources, Mines and Water
Mr Frank Pannuci	Australia Council
Dr Dan Penny	University of Sydney
Associate Professor Bob Pokrant	Curtin University
Mr Chris Powell	National Endowment for Science, Technology and the Arts
Professor Margot Prior	University of Melbourne
Dr Melinda Rackham	Australian Network for Art and Technology
Ms Leane Regan	CSIRO
Mr Alan Rhodes	Country Fire Authority
Dr Louise Robert	Canadian Institute of Health Research

Name	Organisation
Dr David Rye	Australian Centre for Field Robotics
Mr Rob Sale	Australasian CRC for Interactive Design
Dr Steve Scheding	Australian Centre for Field Robotics
Ms Helen Shoemark	Royal Children's Hospital
Ms Petra Skoien	Queensland Department of Natural Resources, Mines and Water
Ms Verity Slater	Wellcome Trust
Mr Andrew Smith	University of Queensland
Mr Glenn Smith	Australasian CRC for Interactive Design
Mr Graham Smith	Questacon
Professor Will Steffen	Australian National University
Dr Henk Stronkhorst	European Science Foundation
Mr Yamin Tengono	Spatial Information Architecture Laboratory, RMIT
Dr Steve Thompson	Royal Society of New Zealand
Dr Robin Torrence	Australian Museum
Dr Simon Toze	CSIRO
Professor James Trevelyan	University of Western Australia
Professor Jannie van Deventer	University of Melbourne
Dr Mari Velonaki	Australian Centre for Field Robotics
Dr Jeni Warburton	Centre for Ageing
Dr Marcus Watson	University of Queensland
Professor Philip Weinstein	University of Western Australia
Dr Stefan Williams	Australian Centre for Field Robotics
Dr Werner Wobbe	Science and Technology Foresight
Mr Mark Woffenden	CRC Association
Mr David Wood	Australian Centre for Field Robotics
Dr Anthony Woods	Wellcome Trust
Ms Margaret Woods	Spatial Information Architecture Laboratory, RMIT
Dr Tom Ziessen	Dana Centre
Ms Ionat Zurr	University of Western Australia

Appendix J

Research methodology

1 Literature review

The literature review (Appendix A) describes the theories and approaches applied by researchers to understand collaboration between the HASS and STEM sectors, the benefits and outcomes, and the major barriers to collaborating across the sectors. Wherever possible, empirical evidence supports the theoretical research outcomes described. We also include examples of current collaborative practice and describe the important factors.

The literature review provided information on:

- reasons for collaborating across sectors
- benefits and costs of such collaboration
- environments in which collaboration occurs
- factors facilitating collaboration
- barriers and challenges to collaboration.

It includes an overview of social, philosophical, management, educational and leadership research applied to cross-sectoral collaborations and collaboration in general.

The review guided our selection of theories and elements of existing practice, and helped identify factors affecting collaboration positively or negatively. This information formed the theoretical framework for the project.

2 A survey to gather information

A descriptive online information-gathering survey to understand the extent of cross-sectoral collaboration was conducted through the CHASS web site. It used Survey Monkey, a tool for hosting electronic surveys, and the survey was promoted widely on networks around Australia.

Data were interpreted using a combination of descriptive statistics and thematic and Leximancer analyses. Leximancer is a content analysis software package that constructs a thesaurus of the most frequently occurring concepts in the textual data and maps the relational distance between those concepts. Such analysis produces an accurate description of the main themes and concepts in the data and their relationship to each other.

This survey constructed a broad description and understanding of current cross-sectoral collaborations by asking:

- which sectors and types of organisations are collaborating
- the degree of collaboration occurring across sectors
- reasons why people do or do not collaborate
- which disciplines are more likely to collaborate
- funding sources

- where collaboration is happening in Australia
- incentives and ingredients for successful collaboration
- barriers and disincentives to collaboration.

The survey largely consisted of open-ended questions. The interpretation of the 606 responses (see Appendix B for detailed results) was limited by the lack of any easily accessible baseline data for comparison, but the responses provide a broad picture of cross-sectoral collaboration in Australia. They also informed the choice of case studies, and identified key ingredients and barriers that were then further tested.

3 Expanding Horizons

The Expanding Horizons event was held in Canberra in March 2006. CHASS brought 185 early-career researchers from the HASS and STEM sectors together to explore cross-sectoral opportunities and to engage with politicians and other decision makers in Canberra. (See Appendix F for results of a participant survey.)

One part of the two-day event divided participants into 20 groups of about nine people each. The groups were asked to devise a collaborative proposal addressing one of Australia's National Research Priorities. They discussed the process and the outcomes in a subsequent plenary session. We used content analysis to identify areas of overlap and difference between the groups.

The information from this process provided insights into the incentives, barriers and opportunities for early-career researchers to participate in cross-sectoral collaboration.

4 Case studies and examples

The literature review, information-gathering survey and our interaction with the project's Reference Committee helped identify 12 case studies to examine in depth, and a range of examples to illustrate key points.

The 12 case studies were selected to illustrate a range of variables, including different:

- collaborating disciplines across HASS and STEM
- scales of collaboration
- types of collaboration
- stages of collaboration
- management structures
- funding sources for collaboration
- planned and actual outcomes from collaboration.

Appendix C has full details of the case studies and their analysis, and excerpts are incorporated in this report. Case studies were investigated through a combination of in-depth interviews, a desktop review of available documentation (including websites), and focus groups.

Appendix G lists other examples. These were not subject to the same intensive analysis, but did feature interviews with key people.

Data collected from the case studies were analysed in a similar way to the information-gathering survey data, using Leximancer. The case studies yielded information about the benefits and costs of collaboration, the incentives and impediments to collaboration, and the key ingredients for successful collaboration. They suggested possible recommendations for the report.

5 Interviews

We conducted 75 in-depth personal interviews by telephone or face to face. These were with:

- 30 representatives from organisations that support, fund or influence cross-sectoral collaboration in Australia and overseas
- 39 practitioners in collaborative research (excluding people involved in the case studies)
- 6 people who had researched collaboration across the sectors.

These interviews explored the supporting structures, programs and policies for cross-sectoral collaboration, to ensure that the data included the views of leading individuals; and to supplement information from the literature review. Appendix D has full details of the interviews.

6 Survey to test key ingredients

The last phase of the project tested the key ingredients identified from earlier phases, through an electronic survey using Survey Monkey (see Appendix E for survey details and analysis).

The key ingredients were organised according to the main themes emerging from the data. The themes were: innovativeness; communication; team, leadership and workplace characteristics; challenges to collaboration; and facilitators of collaboration.

Earlier phases had also identified potential key factors of successful collaboration, including project members' career stages, the size of the project, the geographical proximity of team members, the stage of the project's life cycle, and the project budget. The survey was designed to examine these factors and test for differences between collaborations within sectors, and for those across the HASS and STEM sectors.

The earlier phases had also identified key factors that were potentially linked to successful collaboration, including project members' career stages, the size of the project, the geographical proximity of team members, the stage of the project's life cycle, and the project budget. We designed the survey to examine these factors, and to test whether there were differences between collaborations within sectors and those across the HASS and STEM sectors.

The final electronic survey was posted on the CHASS website following comments from members of the Reference Committee, and publicised widely across the sector.

To make analysis easier, we grouped similar survey items and used exploratory factor analysis to identify groups of items that could be combined to form summary scales. In creating scales, we reversed negatively-worded items so that the final scale represented higher levels of the dimension measured. Data were subjected to a series of multiple regression analyses.

688 people completed the survey. Almost 60% of responses were from people who had collaborated in cross-sectoral projects, 24% were from people who had collaborated only within their sectors, and 16% were from people who had not collaborated at all (see box for reasons). 60% of the respondents were from the HASS sector, 35.5% were from the STEM sector, and 3.9% were from 'other' disciplines.

Reasons for not participating in cross-sectoral collaboration

n = 688; 61% HASS sector; 34% STEM; 4% 'other' disciplines

60% of respondents had collaborated in cross-sectoral projects. Those who had not collaborated gave the following reasons:

Lack of opportunity	33%
Difficulty making connections	28%
No perceived need	18%
Lack of time	11%
Lack of resources	8%
Lack of experience	3%

Appendix K

Comparison of key elements in different forms of collaboration

The key ingredients survey tested the key ingredients identified through the information-gathering survey, the case studies and the interviews. This survey also compared the importance of key ingredients for cross-sectoral and within-sector collaborations.

While the results of the survey need to be interpreted with caution, they confirmed the key ingredients identified as important for collaborative success.

Regardless of the type of collaboration, predictors of success were the innovativeness of the collaboration team and the presence of 'facilitators' of collaboration.

The innovativeness predictor included the following characteristics (in order of priority):

1. Team members provide critical input to find new solutions.
2. The team develops contacts outside the team.
3. Team members are prepared to take risks to advance the project.
4. There is sufficient time to develop creativity.
5. One of the team is able to find new uses for existing methods and equipment.
6. There are rules within the team that are mostly formal.

The 'facilitators' of collaboration included the following elements (in priority order):

1. a large project team
2. a common goal or purpose
3. early success in the project's life cycle
4. an expectation of future collaboration
5. the right mix of skills and personalities in the team

As can be seen, these match a number of key indicators previously identified.

In cross-sectoral projects, the flexibility of the team structure and communication were also key ingredients for success. These were less important for within-sector projects.

Levels of team independence, workplace characteristics, leadership and the impact of challenges to collaboration did not show any relationship with project success at the overall level, but dimensions of these scales were critical ingredients in the success of cross-sectoral collaborations. This is summarised in Table 2 (ingredients unique to cross-sectoral collaboration are shown in bold).

Table 2 Critical factors for success in cross-sectoral collaborations compared to within-sector collaborations

Factor Importance: – (none); + $P < 0.10$ (some); * $P < 0.05$ (moderate); ** $P < 0.01$ (high)	**Cross-sector**	**Within-sector**
The leader is the one who decides how we spend our money	–	+
One of the team can be counted on to find a new use for existing methods or equipment	–	+
My colleagues and co-workers don't stick to their own ideas and methods	*****	**–**
We provide critical input towards a new solution	**	**
We develop contact with experts outside our team	******	**–**
We have sufficient time to develop our creativity	–	*
We are prepared to take risks if they advance the project	*	+
The rules in our team are mostly formal	*****	**–**
Some team members facilitate communication across disciplines and/or sectors	–	*
We discuss our ideas with commercial partners	**	**
We openly discuss with each other how to achieve goals	*****	**–**
We discuss ideas with project or organisation members	*****	**–**
Our disciplines have their own specific languages, but we can communicate across these	*****	**–**
Team members are open to new ideas	*	+
We are enthusiastic about the project/research	**	*
We listen and take time to understand ideas	+	–
Some team members let their individual egos and arrogance get in the way	*****	**–**
Team members have clear roles and responsibilities	******	**–**
Leaders are aware of the big picture and discuss this with the team	******	**–**
Leaders champion the project to decision makers	**	*
Leaders have the resources to improve the team working environment	–	*
The organisational structure is flexible	**+**	**–**
Collaborative efforts will influence the organisation's strategic directions	**	**
Team members feel they are consulted and can participate in decisions	–	*
The project receives recognition from the wider organisation as well as from other entities	*****	**–**

From Table 2, communication appears to be more critical to success in cross-sectoral collaborations than in within-sector collaborations. For cross-sectoral projects, discussing ideas with team members, their respective organisations and potential commercial partners were key factors in success. Openly discussing how to achieve goals and overcoming and understanding each other's discipline-specific languages also appears to facilitate success in cross-sectoral projects. This backs up the key ingredients identified in Section 5.2.

Appendix L

Abbreviations and acronyms

ACIAR	Australian Centre for International Agricultural Research
ACID	Australasian CRC for Interactive Design
ACRO	Australian Creative Resources Online
ANAT	Australian Network for Art and Technology
ARC	Australian Research Council
CHASS	Council for the Humanities, Arts and Social Sciences
COST	European Cooperation in the Field of Scientific and Technical Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEST	Department of Education, Science and Training
HASS	humanities, arts and social sciences
LWA	Land & Water Australia
NANO	Nanostructural Analysis Networked Organisation
NESTA	National Endowment for Science, Technology and the Arts (United Kingdom)
NGO	non-government organisation
NHMRC	National Health and Medical Research Council
OECD	Organisation for Economic Co-operation and Development
PMSEIC	Prime Minister's Science, Engineering and Innovation Council
R&D	research and development
RAMP	Risk Assessment Methods Project (Geoscience Australia)
RDC	research and development corporation
RMIT	Royal Melbourne Institute of Technology
STEM	science, technology, engineering and medicine
UNSW	University of New South Wales