Evolution of collaborative academic networks

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Abstract
To a substantial degree intellectual innovation occurs as a result of collaboration in interconnected research relationships. The production of knowledge is a social process involving interactions among people and organisations with different backgrounds, resources, predispositions and insights. The members of such a community interact and develop and exchange new knowledge and through these processes shape their community over time. In the last 20 years there has been an increasing amount of collaboration in research and research into collaboration. The ways that research can be fostered includes collaboration internationally (Hakala et al. 2002), across sectors, between university and industry (Anonymous 2004), between science and technology, across scientific disciplines (Forman and Markus 2005), and at individual and institutional levels.

Much work has been done on the link between research productivity and research collaboration showing that more prolific researchers collaborate more frequently and researchers at all levels of productivity tend to collaborate more with highly productive researchers. Other studies have focused on patterns of spatial proximity and scientific interaction at regional and country levels (Andersson and Persson 1993). Additionally there have been studies that have considered the nature of the social networks that collaboration engenders including the social networks of scientists and more specifically the collaborative network of the IMP group. Work on the nature, role and impact of collaboration contributes to a growing literature in areas that examines the nature and characteristics of complex adaptive systems in which network structures play a fundamental role.

In this empirical paper we examine the emergence of collaborative structures in academic networks using a large time-series database of collaboration patterns in academic communities. We are particularly interested both in isolating the types of collaborative structures and how they evolve and in considering the implications of these patterns for the productive output of the collaborative network. The data is supplemented by stories of collaboration narrated by key actors within collaborative groups. These stories illuminate the structural evidence in often-surprising ways, hinting at the wide variety of ‘roles’ and ‘relationships’ that may coexist within even a single collaborative grouping. The paper concludes with a discussion of the implications of this work for the production of knowledge in academic communities and beyond, as well as more general discussion of the implication for innovation. Specifically, the ideas of network competence developed by Ritter et al (2002) and others are considered.

Keywords: Collaboration, Production of Knowledge, Evolution, Social Network Analysis, Narrative

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Introduction

The IMP group has a long time recognition of importance of innovation in relationship and network development. To a substantial degree intellectual innovation occurs as a result of collaboration in interconnected networks. The production of knowledge is a social process involving interactions among people and organisations with different backgrounds, resources, predispositions and insights. This is particularly effective over time where continuing networks of relationships are formed, the members of such a community interact and develop and exchange new knowledge and through these processes evolve their community. Central players in such networks are often academic institutions and their members who work together to develop new insights and technologies, often in conjunction with industry (Grimes and Collins 2003; Reback et al. 2002).

In the last 20 years there has been an increasing amount of collaboration in research and research into collaboration. Emerging from this is an understanding of the value of collaboration in research networks. There is a multi-way link between research productivity and research collaboration with more prolific researchers collaborating more frequently and researchers at all levels of productivity tending to collaborate more with highly productive researchers (Newman 2001). The ways that innovation can be fostered via research collaboration internationally (Hakala et al. 2002), across sectors, between university and industry (Food Manufacturer Anonymous 2004), between science and technology , across scientific disciplines (Forman and Markus 2005), and at individual and institutional levels have been considered. This research is of particular value as it highlights both anecdotally and empirically the considerable value to business and the

wider community that that emerges from collaboration among researchers and between researchers and industry and gives some insights as to how this process occurs.

Other studies have considered the drivers of collaboration, considering patterns of spatial proximity and scientific interaction at regional and country levels (Andersson and Persson 1993) and the patterns of interactions contained within industry subgroups (Webster and Morrison 2004). Additionally there have been studies that have considered the nature of the social networks that collaboration engenders (Forman and Markus 2005) including the collaborative network of the IMP group (Henneberg et al. 2007; Morlacchi et al. 2005). These studies highlight the deep processes that characterize collaborative networks and give insights into managing and being managed within collaborative groups (Wilkinson and Young 2002).

In this paper we examine the emergence of collaborative structures in academic networks as a device for considering the nature of collaborative networks more generally. The paper is organized as follows. We consider the types of collaborative structures, their substance, how they evolve and the implications of these patterns for the productive output of the collaborative network. This approach is illustrated by presenting the "network pictures" generated by the social network analysis of a large database containing information about research inputs and outputs over a five year period in an Australian University. We focus on two Faculties, examination and comparing the collaborations structures within them and then exploring the emergence of collaboration and the dynamic aspects of these collaboration using narrative based approaches. We conclude the paper with a discussion of the evolution of collaborative work.

Collaborative groups and Collaboration in groups

There is considerable interest in the study of collaboration across a wide range of social sciences as collaboration aids in the development of self as well as in the achievement of tasks. For many years, theories of collaboration tended to focus on the characteristics of individuals and their contributions to a group's functioning. More recently, groups and grouping have become the focus with the more emergent, socially constructed, properties of the interaction of greater interest than the individual capabilities and contributions (Dillenbourg et al 1996).

Work on collaborative groupings tends to adopt a broad view of collaboration. While the social sciences differentiate processes of socially connected working with collaboration, these categories are not consistent. For example, "collaboration" and "cooperation" are sometimes differentiated. Cooperation is said to involve the division of labour among participants, where each individual is responsible for a portion of the work and collaboration involves the people working together in a coordinated way to solve the problem (Roschelle and Teasley 1995) Others do not differentiate these and consider both of these as forms of cooperation (Asch 1952) or even as a partial definition of cooperation/collaboration which also includes additional aspects of social bonding (Argyle 1990). For the purposes of this research we adopt the stance of much of the research on collaborative groups which is inclusive, including as many forms of connection as the research context allows. Collaboration is envisaged as input-oriented (Collentine 1998), output-oriented (Connick and Innes 2003), the process of working together (Roschelle & Teasley 1995), a state of mind (Lee 1996) and as is the case here, most often as a combination of these factors.

There is considerable empirical work that has looked at the value of group collaboration. Work in cognitive/developmental psychology has determined there is enhanced value in collaboration when there is heterogeneity of knowledge and skills (e.g. Durfee et al. 1989). Particular benefits emerge from the generation of communication, which is facilitated in collaborative groups (Blaye et al. 1991) and which emerges through time (Dillenbough et al 1996). The communication that collaborative groups generate and facilitate in turn creates a range of further benefits (Blaye, et al 1991). This includes the enhancement of productivity, including research productivity emerging from the processes of collaborative groups (Newman 2001).

Social networks have been the subject of both empirical and theoretical study in the social sciences for at least 50 years (Wasserman and Faust 2005; Watts 2004), partly because of inherent interest in the patterns of human interaction, but also because their structure has important implications for the spread of information and the development of knowledge (Newman 2001). Work on the nature, role and impact of collaboration contributes to a growing literature in areas that examines the nature and characteristics of complex adaptive systems in which network structures play a fundamental role (Barabási et al. 2002; Easton et al. 1998; Wilkinson and Young 2005). Work has considered both acquainted and unacquainted individuals linked both

directly and indirectly in various ways (e.g. friendships, film actors and of course Milgram's famous study) and has looked at their connections in a range of scales from small friendship groups to the societal level (Amaral et al. 2005; Milgram 1967; Watts and Strongatz 1998). Collaboration has been considered in studies of business networks - small and large, domestic (Kraut et al. 1998; Webster and Morrison 2004) and international (Welch et al. 1996).

Academic collaboration has similarly been studied in a range of scales and contexts. Small work groups and individual collaborations have been studied to provide insight into the deeper processes of collaboration, finding that even closely connected individuals can have stresses placed on their collaboration from the wider institutions in which they work (Forman and Markus 2005). Small communities (a few hundred) of researchers linked by a common paradigm/ideological stance have been explored for insight into the concentrations of connections and evolution. The studies of the IMP work found that country of origin was a significant indicator of direct collaboration (i.e. co-authorship) for most researchers (Morlacchi et al 2005) and that the network was growing more slowly than comparable networks - perhaps in part due to this (Henneberg et al 2007). In a large scale study of the collaboration (co-authorship) patterns in the world wide biomedical and computer science research communities, Newman (2001) found that scientific communities constitute 'small world' networks where the average distance between collaborating scientists is small but varies logarithmically with community size. Only five or six steps are necessary to get from one member of a community to another in most instances. This "smallness" is thought to be critical to social cohesion and collaborative development (Barabási 2003) and has been found by other authors in their studies of networks of various sizes (e.g. Morlacchi et al 2005) in their study of IMP collaboration.

In line with other work, Newman (2001) also found that the networks are highly clustered, i.e. two scientists are much more likely to collaborate if they have a third common collaborator than are two scientists who are not so connected. It is argued that this may indicate that the process of scientists introducing their collaborators to one another is an important one in the development of scientific communities. Comparison of patterns of collaboration across disciplines shows differences with some disciplines displaying a markedly greater amount of clustering and the concentration (very high levels publication by a relative small number of scientists).

Collaborative academic work seems on the surface to be ordered when considered at larger scales and in aggregate. We see this order in the flow of research papers and grants produced over time by research communities, but when examined below the surface there is considerable anecdotal evidence to indicate that these collaborations are messy and complex. They contain a range of different kind of interactions that are influenced by a range of factors that emerge within and beyond the network. To illustrate this and highlight the need for multi-method research to examine these activities, we continue with two stories of collaboration that illustrate some of the issues and problems associated making sense of collaboration, before exploring the patterns of order and emergence observed from a larger empirical perspective . (This approach is advocated as effective for exploring the deeper processes of collaboration (e.g. Forman and Markus 2005).

A tale of two collaborations

1. "Collaboration" research group:

This group came together to study collaboration networks. This group included of two of the authors (an IT Professor (ITP) and Marketing Professor (MP)). They were brought together by a Adjunct Marketing Professor (AMP) who had worked with both of them on fledgling research, within research centres, etc., but where no formal collaboration output (publications, grants, joint supervision) had occurred. The group recruited additional members - the Research Data Manager (RDM) from the university research office and several associates from various parts of the university to contribute. The proposed project was funded and over the next two years evolved with original "match-maker" (AMP) dropping out, the research officer (RDM) playing a background role and a colleague and collaborator of the marketing professor (CCMP) and student of the IT professor (SITP) joining the group. The associates never became actively involved as there was no obvious role for them as the research evolved. The research involved developing expertise in social network analysis and management of the large data base and explaining and interpreting the findings that emerged. This work was shared among the research group. MP and CCMP each participated in two substantial social network analysis programs and SITP in one. CCMP and SITP developed the expertise to analyse and then analysed the large data base provided by RDM under the tutelage of ITP. The insights emerging from those social networks allowed a number of key player/archetypes to be identified by CCMP

and ITP. Depth interviews were then undertaken by MP with these key personnel, as well as with the Associate Dean-Research for each faculty. Publications (including this paper) and reports are now emerging from this group, a further grant application(s), a book and development of computer software to evaluate collaboration and identify potential collaboration "hot spots" is planned. This is seen as an unambiguously successful collaboration - while not all of the participants remain in the group, an effective core group was formed which is linked to wider networks of MP and ITP and has led to the development of collaboration capabilities and network links for CCMP.

2. Knowledge in the Enterprise Research Group

The group commenced as a result of an email asking for interest in doing research in knowledge formation and management. Two of the authors were members. One responded to the call as she thought she and the other author would be interested in working together in the area. The initial group consisted of two academics (including the author who responded to the email) from different discipline areas in Business, two academics from information management from within library science (in humanities), a complexity researcher from IT and two software engineers from a very large cross-institutional software engineering research centre (SERC). The group had no clear direction, only common interests and for the first six months met bi-weekly to discuss each others' work and the theories that informed that work. During this period membership evolved, with one library scientist dropping out, the complexity researcher taking an industry job and an IT/management postdoc and another of the authors joining the group. The group eventually started work on two projects – an observation study of a very small engineering company and then a larger quasi-government job-providing network. The contacts for these were provided by one of the software engineers, most of the fieldwork was undertaken by the IT/management postdoc with assistance from several of the other remaining academics. Support was provided by the SERC in the form of in-kind resources, mostly the release of the two engineers to work with the group and by a small competitive grant from the applied for by all the academics to fund the second research project and facilitate building a stronger research link to the job providing organisation. The first project did not progress, the second one continued with depth interviews conducted with selected members of the network and observation undertaken at several workplaces mostly by the postdoc (by her preference) though with others participating and an email survey was done of the entire network (by the two members who are also co-authors of this paper). While data collection was underway the SERC was disbanded and the software engineers departed. The research group now had only four members (the other library scientist had gone on sabbatical at the beginning of the second project and did not subsequently participate) and drifted apart no longer meeting regularly. The two authors wrote two papers with all four members included as authors and then went on (due to lack of involvement of the other two) to advise them the collaboration was over. These two went on to co-author several more papers from the data collected. This concluded their participation in that project; however they continue their collaboration together and are working together on several other projects. The other two former members (who met through the knowledge group – in contrast to the two authors who already knew each other) continued with the project and developed a larger collaboration along similar lines to the original group's interests. However they did not invite their former collaborators to join nor did they advise them they were forming another collaborative group based on the work of the original. They acquired funding and are working on the funded project. While there was no overt acrimony in the group it was not "successful" in terms of continuing cohesion, but it has generated a continuing collaborations and strengthened the pre-existing collaboration of the authors. Therefore it is not straightforwardly a successful collaboration nor is it necessarily unsuccessful. The original group disappeared but the project generated further research projects for one sub-group and strengthened the collaborative link of the other sub-group.

These case histories generate a number of questions that are examined further in this paper:

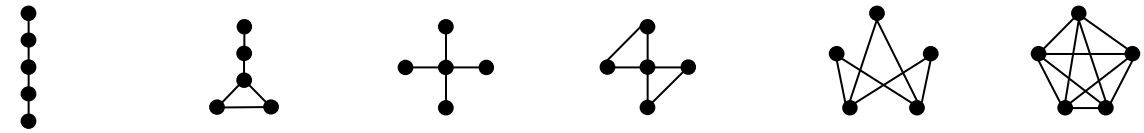
- What patterns of collaboration do we see in academic networks?
- Do the patterns of collaboration observed vary in systematic ways?
- Do the pattern of collaborations observed impact on the effectiveness of collaboration (or vice versa)?
- In what ways can the lessons of academic (social) networks be applied to business networks?

Graph theory has been used to consider the configurations of connections and the implications of those configurations. This paper first reviews the basics of graph theory as it applies to networks, then analyses an extended collaboration network using social network analysis techniques and concludes with interpretation of the structures emerging using follow-up qualitative research.

Network structures

It is possible to construct graphs illustrating collaborations of varying complexity. First, as discussed above academic collaboration is a small world phenomenon. Such phenomena are characterised by short distances between actors (by this we mean relatively few degrees of separation) (see for example Morlacchi et al. 2005 who discussed this in an IMP group context). Small world phenomenon are also characterised by connected graphs compromising sometimes surprising few edges (Watts 2004). Consider a simple world of five potential collaborators. The "structure" of collaboration might is potentially quite different from actor-to-actor. Figure 1 illustrates some of the many (but finite) possible connections between the five individuals.

Figure 1: Possible structures of collaboration with n=5 nodes



Actors can be minimally connected (Figure 1a) or fully connected (Figure 1f), or they can taken any number of intermediate forms (Figure 1b-e). We argue that it is these intermediate forms that are most likely in academic networks. On the other hand, the extreme forms are probably fairly unlikely. However, they serve a useful starting point for a discussion of the likely properties of academic networks which are more and less connected.

We expect that as collaborative structures become increasingly more connected it is likely different types of benefits accrue to the individuals involved and to the institution in which they work. In minimally connected chains we expect that knowledge transfer across the institutional units/sub-units would be more prevalent, along the lines of Granovetter (1982). However, these types of chains are likely to be more vulnerable to disruption (when for example an individual leaves the institution). In contrast more densely connected clusters are more likely to form cohesive communities of practice, which are able to sustain the departure of individuals from the institution. Although clusters a likely to be fairly robust their shorter “distance” means they will have fairly limited role in cross-institutional knowledge transfer. For individuals the costs and benefits accrue differently. Collaborative relationships are expensive to maintain so as an individual works with more others, the costs of maintaining these relationships become an increasing burden for the individual. Of course the real cost to individuals will depend on the substance of the ties between individuals (i.e. the nature of the collaborative work).

The substance of the ties will also have implications for the productivity of the cluster and its reproducibility. In the context of academic work, individuals collaborate on grants, publications (of various forms), in teaching, and on committees. The particular work that ties individuals will inevitably shape the experience for these individuals. For example, in clusters where connections represent links based on a single project, such as a grant application, the success or not of that application is likely to impact on subsequent future collaborative work (i.e. publications). Thus it is meaningless to consider the structures that exist in academic networks without considering their substance.

We note that the structures shown in Figure 1 are static; they represent possible forms at a given point in time. A thorough analysis must consider the temporal properties of the network. This is less readily observed in structural maps. Discourse perspectives and narrative analysis offers an avenue to explore the issues of emergence and dynamics.

Describing networks of academic work

Research networks are usually investigated through diffusion of ideas using ‘co-citation analysis.’ Links are inferred through the way authors refer to each others research and publications (e.g. Morlacchi et al. 2005; Newman 2001). We believe various types of links among researchers such as professor-student, common institution, propinquity, research interests and methods used more directly reflects the nature and structure of research communities. So here we adopt a different approach based on social network methods where we

focus on the people relationships inside a university network. The university of interest is a relatively young institution (less than 30 years old) but with a strongly emerging research profile. We used a range of information sources to construct a network link database, including book, journal and conference publications co-authorship records, co-investigator details on grant applications and grants achieved as well as records co-supervision of higher research degree students. This data was extracted from a number of different databases for all staff employed at the university (i.e. both academic and research staff) for a period of 5 years (2001-2005 inclusive). Details on the nature of links were retained in the database (i.e. journal co-authorship, co-supervision etc). We also included actor attributes such as academic department, research centre membership, as well as level of academic appointment. Table 1 provides a summary of the information available in the database.

Table 1: Node and Edge Data
Node Data

ID	Unique identifier for each Node (person)	Abraham_15965
UTSref	Node membership of organisation	Internal, External, Student
Fullname	Full name of each node (person)	Mr Morris Abraham
Unit	Primary institutional unit of which the node is a member	e.g. accounting, marketing, management, nursing, engineering etc.
FOBmembership	Node membership of Faculty (all nodes were classified according to their status within the faculty of interest)	FOB, External, Institutional-Staff, Institutional-Student
Status	Node seniority	0=external; 1=Professor, 2=A/Professor; 3=Doctor; 4=No research qualifications

Edge Data*

CREF	Unique identifier for each collaborative outcome	2002000854
CPUBCAT_CODE	Type of collaborative outcome	A1=Book; B1=Book Chapter; C1=Journal; E1=Conference; ND=Grant, S=Supervision etc.

* Note following the conventions of graph theory we describe the connection between two nodes (actors) as an edge, this is done to ovoid any ambiguity in relation to the terms ties and links where we follow the IMP networks usage conventions.

The final database included 3327 different actors, 28 academic departments and research centres, 6609 edges and 3000 unique collaborative outcomes. The dataset, though focusing on the staff of a single institution, also includes some information about the links to external actors. Given the size of the database (over 22,680 individual records) we have extracted a smaller set of records to use here. This smaller set includes all edges where at least one node is (i) a member of the Faculty of Business (comprising five academic departments, one semi-autonomous research centre and 13 research centres/groups were staff were also members of academic departments) or (ii) a member of the Faculty of Information Technology (comprising 3 discipline groups and 6 research centres/groups). In this small dataset we have only included publication data (i.e. co-authorships). Grant and supervision data has been excluded as it is beyond the scope of this paper to consider different research indicators and the relationships between them.

The Faculties of Business and Information Technology were selected as the focus of this research as they were markedly different is size, structure and in the nature of the collaborative work in which members

participated. The Faculty of Business is a significantly larger divisional unit, itself made up of five academic departments, some of which were larger than the combined size of all discipline groups in the Faculty of Information Technology. The Faculty of Business also comprised a number of large research centres as well as numerous smaller research groups. In contrast the Faculty of Information Technology has a smaller number of research centres and groups. Finally, while publications are important collaborative outcomes in both faculties, conference publications are more important in the fast moving Information Technology areas, while in Business collaboration on journal publications is more relevant.

The database was analysed using UCINET - Netdraw (Anonymous 2002) to produce network diagrams for each Faculty (Business and Information Technology). Diagrams were prepared that showed the collaboration between staff in the respective Faculties and all their collaborative partners (whether employed at the University or external to it). Network diagrams were also prepared to show (i) the development of the network through time, and (ii) the contributions of each collaborative output (i.e. journals, conferences, books etc.). Each of these diagrams was inspected by members of the research team for evidence of different network structures (as discussed above). This scrutiny suggested a number of likely candidate nodes for closer consideration. Egonet diagrams (network diagrams showing the ego and all alters and all connections between them) were also produced.

Diagrams of structure can only show part of the story. They assist in capturing images of collaboration where individuals work together for a common goal (i.e. a publication) and to some extent the outcomes of joint tasks, but the do not reveal the motivations for this collaborative work nor do they provide insight regarding the type of affective collaboration discussed above. To capture these deeper structures we turned to the stories of individuals. Depth interviews were then conducted with a selected group of key researchers. The interviews lasted between 1-1.5 hours and were wide ranging. We also conducted interviews with the ten Associate Deans Research (the person responsible for the development and management of research endeavours in the Faculty) in the University. The interviews lasted between .5-1.5 hours and included discussion of research management and policy and the role of collaboration within these. For nine of the ten, their own research collaboration was discussed. We also note that although we had prepared a fairly detailed interview protal this was hardly necessary. Participants were most forthcoming and directed the interviews towards areas of the greatest relevance to them. Interviews cover details of their collaborative work and the meaning of collaboration to them. Participants recounted stories about the major collaborative works and how the collaborative relationships developed. This data was analysed thematically for the broad issues regarding collaboration, and for particular indicative examples. Further, more detailed narrative analysis will be undertaken subsequently.

Figure 2: Co-publication data for the Faculties of Business (2a, 2b) and Information Technology (2c, 2d)

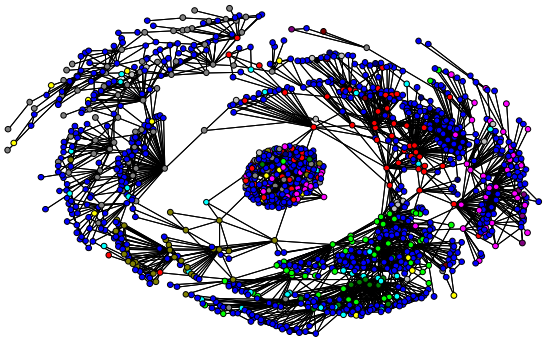


Figure 2a: FOB and externals

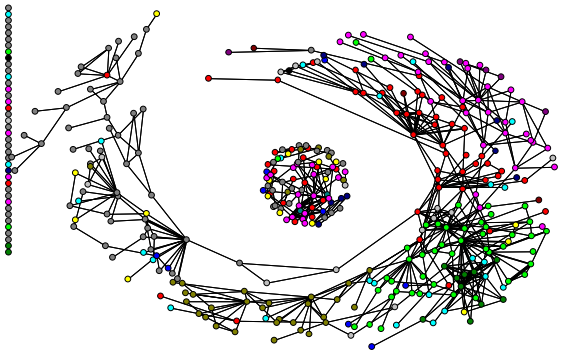


Figure 2b: FOB excludes externals

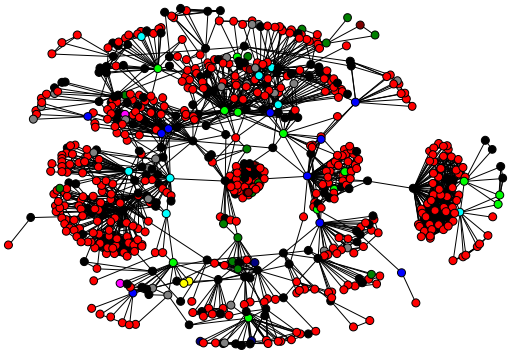


Figure 2c: FIT and externals

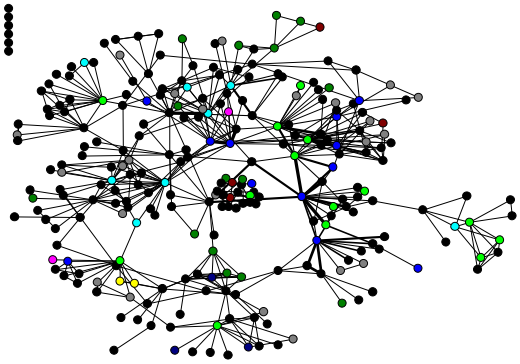


Figure 2d: FIT excludes externals

* Colour versions of these diagrams showing school, and academic unit membership are available from the corresponding author

Figures 2a and 2c show the network diagram for the focal Faculties (Business [FOB] and Information Technology [FIT]). Each dot represents a researcher, the colour of the dot indicates which Faculty they are in and whether external (in 2a and 2c). The edges (lines) between the researchers' shows they have published together and thicknesses of line indicates the amount of co-publication over a five year period. Isolates (those who do not publish with others) are removed and sole authored publications are not depicted. Figures 2b and 2d show the same networks with the external (authors from outside the University) removed.

There are clear differences between the FOB and FIT. First, though smaller there are more collaborative ties between members of different discipline groups in the FIT, and indeed the rest of the University. Relative to its size there is a considerable proportion of academic work conducted with researchers in other faculties, notably Business, Science, Engineering, Humanities and Design. Staff in the FOB also work collaboratively with those in other Faculties, but tend to be somewhat more isolated from each other, both within the Faculty and the University. For example, there is a distinct cluster of individuals working tourism and leisure domains which is completely isolated from the rest of the FOB, and indeed the Quantitative Finance Group (to the left of Figure 2b) is only connected by a single edge from outside the Faculty of Business. These isolated configurations are not present in the FIT.

It is also illuminating to move the focus to individual researchers in the two Faculties. Figure 3 sets out the "ego-networks" for four key researchers, two in each Faculty.

Figure 3: Ego-networks for selected individuals

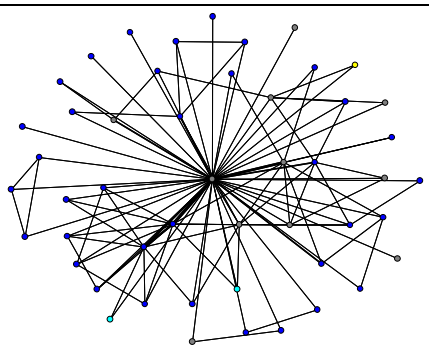


Figure 3a: Star (R1 from FOB)

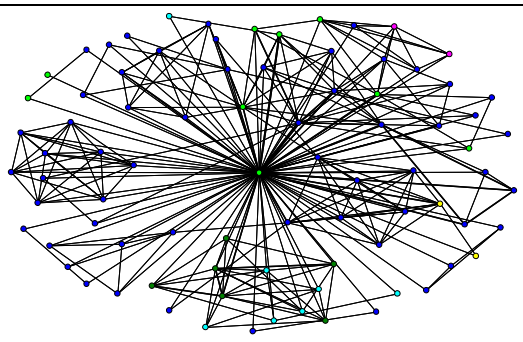
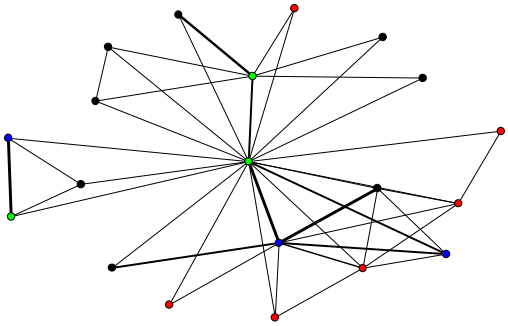


Figure 3b: Mature-Focused (R2 from FOB)



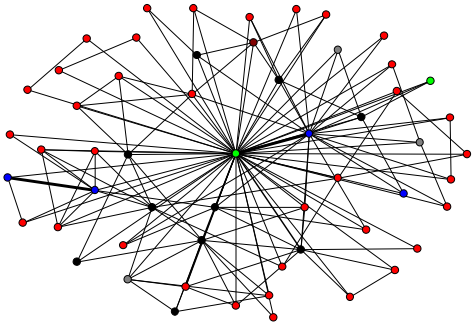


Figure 3b: Developing-Diffuse (R3 from FIT)	Figure 3d: Mature-Diffuse (R4 from FIT)

Figure 3a shows a researcher who collaborates extensively and works on a continuing basis with four main researchers (although there are a number of other co-authors shown). Only a few the collaborators collaborate with each other, and those that do, do not publish a lot with each other (most of the interconnections are via co-publications with the focal researcher). Figure 3b depicts a researcher with a much larger collaborative network and one where there is more collaboration within groups of the collaborators. Some of the edges between collaborators are quite strong indicating that they collaborate independently of the focal academic. However the four to five groups of connected collaborators are fairly separate from each other. This indicates a researcher who has a number of fairly separate streams of research in areas that are not closely related. Figure 3c depicts a researcher with a relatively small network where everyone collaborates with at least one other person in the network beside the focal researcher and where the amount of inter-group collaboration is fairly consistent. Figure 3d shows a researcher with a large network that, while far from fully connected (where every member collaborates with every other), is quite connected. There is a fairly even amount of publication with co-researchers rather than strong links with a few and weak links with the remainder. Many people in the network are connected to a number of others and quite a few of those links are strong.

Depicting individuals research output in this way and comparing the depictions allows us to “visualise” and analyse collaboration in interesting ways. Theories of network functioning give us indicators of the probable productivity and innovativeness of the various configurations which could then be checked against secondary data. Here for example we might surmise that the researcher of 3d is more network-oriented than the others and the network of collaborators is leveraged to provide continuing cross-disciplinary insights. In contrast 3b could indicate the collaboration network of someone who provides insight to various groups and to whom insight flows but where the focal academic acts as a gate keeper of that information rather than (meta) insight emerging in a collaborative way. Again this could be checked using existing research output data and/or considered in conjunction with accounts from the researcher – as is done in the following section.

The deeper properties of collaboration

While the network maps and Ego-network diagrams allow effective visualization of broad patterns of collaboration, they have limited value in helping us to understand how particular collaborations impact on patterns, why particular patterns emerge and how those patterns contribute to the research effectiveness. These questions are addressed by matching the insights of the depth interviews with key researchers and Associate Deans-Research (ADRs) to the observed patterns within the maps. Based on the authors’ knowledge of these networks’ members and their research, we identified patterns in the maps and their correspondence to the configurations identified by graph theory. The patterns of collaboration of interest are "Stars," (where the researcher collaborates with non collaborating others) "Clusters," (where there are one or two connected groups of collaborator amongst a number of non collaborating others), "Diffuse," (where collaboration is spread fairly evenly through the network but the density of connections with network is not high) and "Complete" (where there is a fairly even dispersed pattern of collaboration with a fairly high level of connection through the network). Key researchers were identified and interviewed. They were asked to discuss their collaborative history and views on the value of collaboration generally and their own collaboration in particular. Researchers thought to have a range of patterns of collaboration were interviewed.

Four "key researchers" in the Information Technology Faculty and four in the Faculty of Business were interviewed. All were senior researchers (Professors and Associate Professors), all were part of research centres with a portfolio of collaborative relations within and beyond their centres. All had varying amounts and kinds of direct and indirect collaboration as evidenced by their somewhat differently structured ego nets (Figure 3) and the content of the interviews. Their views of their own collaboration are discussed below followed by consideration of the ways in which these different ego net structures do and do not reflect the informants' accounts of their collaboration.

From all key researcher informants there was recognition of the importance of collaboration and enjoyment of at least some of their collaborative links. Most indicated a desire to do a substantial amount of work collaboratively, i.e. jointly. One informant described himself as a "lone wolf" but he was in the minority with the other's celebrating and usually preferring joint activity. However interviews with ADRs indicated that this preference is not universal. In some discipline areas (humanities, social sciences, culture studies, etc.) there is

much more limited joint research and publication and collaboration takes different forms (e.g. edited collections of papers). However this analysis focuses on two disciplines where collaboration is encouraged and where concrete value is perceived.

Despite some general consensus as to the value and pleasure of collaborations, there was a lack of convergence in these informants' discussions about the nature of collaboration and in particular the nature of their own. There is a wide range of only partially overlapping views as to the nature of collaboration, the way that collaboration is approached and the benefits that are perceived to flow to these researchers from their collaborations. In discussing collaboration some informants focussed on the building of a research group and/or centre and a critical mass of researchers who worked collectively. Often those with whom they directly co-researched were not considered in these discussions. Others talked only of collaborative research activity in terms of co-publication - this was particularly the case for those who do less empirical work. Collaborative grant-getting was also referred to but was less prominent in discussions than were research groups or a body of co-publications. We surmise that the body of research that these researchers had completed and the longevity of their careers was sufficiently large for individual papers and even grants to be relatively insignificant to them and/or grant-getting is not seen as a research activity but rather is perceived as a means to facilitating research activity.

While literature of relationships identifies the need to build up relationship through time, including in collaborative ventures (Reback et al. 2002), not all informants identified this as an issue, instead most were prepared to leap before they looked in starting new research links. However levels of activity in terms of commitment and risk were differentiated by a few of the key researchers. These indicated that they would likely form collaborations easily when writing a paper or undertaking a small project but would be less likely do so in a high risk venture like a large multi-year grant and joint supervision. This identifies the issues of risk and trust as important in some but not all collaborative contexts.

Despite the importance attached to directionality and balance in collaboration (e.g. Dabos and Rousseau 2004), there was no clear differentiation by informants between being approached and approaching researchers. More generally how the collaboration commenced was not perceived as a contributing factor to its productivity or quality. Most of those interviewed indicated there were more instances of the approaches from others as mechanism of collaboration initiation rather than their approaches to others. However this is not surprising as all interviewed are well established in their fields and presumably many researchers would perceive value in collaboration with them and act to establish research links.

Despite the recognition of the growing importance of interdisciplinary collaboration (e.g. Forman and Markus 2005), it was not much discussed by key researchers though it was widely discussed by Associate Deans (who all are or have been active researchers themselves). These ADRs recognised the strategic value of this cross disciplinary research (i.e. it is attractive to funding bodies and governments) but also recognised its administrative difficulties (e.g. who gets the credit and the money) and the likely lack of cohesion (e.g. people end up dividing up the money with each working on parts of the projects and no real interaction/cross fertilisation occurring). However there was also recognition by some ADRs that it was these difficulties that created the opportunities for major breakthroughs.

One key researcher interviewed did recognise that his research was "interdisciplinary" in that it applied certain research tools in a wide range of contexts but this did not create issues as the juxtaposition of the cultures of method and a specific discipline area were not grounds for conflict. In the main though the key researchers worked with a reliable core of researchers where interdisciplinary conflicts had been resolved or had never existed. No one indicated that joint publication was discouraged (in fact a number of ADRs indicated that there was a certain suspicion towards those who did not publish with others) and this applied whether the joint publications were internal to the Faculty or University or beyond. There was the occasional reference to problems of finding appropriate outlets for cross-disciplinary research and problems of getting recognition for publication outside of one's own discipline, however in contrast to accounts in the literature (e.g. Forman and Markus 2005); this was not a major issue for any of the researchers interviewed. More problematic were grant applications and research supervision where institutional problems associated with sharing of resources often existed.

It was difficult to get informants to consider the specifics of the researching process. For most researchers this process was not problematic, they indicated that work was easily coordinated and needed little articulation.

There was no need for the negotiation that is reported within the collaboration literature (e.g. Ede and Lunsford 1983) to manage the process of doing research and/or co-writing. In the main when interpersonal dynamics were considered it was in a negative sense and it was to do lack of responsiveness and failure to meet deadlines by their collaborators. (This was the most frequently mentioned reason for collaboration failure.) This is not the active conflict that is highlighted in the literature, the tension that this produces and the active process of ongoing conflict resolution are seen as critical in co-producing interesting research within interesting collaborations (John-Steiner et al, 1998).

The only obvious driver of a key researcher's pattern of collaboration was personal preference for particular collaborators. This is in line with the body of literature that highlights the centrality of interpersonal dynamics in collaboration (Creamer 2004; John-Steiner 2000) and with theories of social psychology that highlight the centrality of enjoyment in cooperation (Argyle 1991). Words such as "comfortable" and "familiar" were frequently used to describe long term research collaboration. Biological predisposition to continuing collaboration - specifically females' greater capabilities to manage and sustain relationships and collections of relationships - was mentioned by two of the three female informants as critical. However a number of researchers did highlight that even "good" collaborations ended - most often when research interests diverged. This was less likely within a cohesive group such as strong research centre. Then the collaboration was seen as continuing even if co-authoring and common grant activity ended.

Reciprocity emerged a number of times as a driver of research—that is, a group's body of research drove one researcher to work on behalf of other(s) on a particular paper or part of a project with the assumption that this would be reciprocated—however this was mentioned only by a subset of those interviewed. More commonly mentioned was longevity and common development paths (i.e. evolving in similar directions as researchers) or recurring convergence of research interests after periods of diverging—as drivers of longer term association.

Most key researchers' descriptions of their preferred patterns of collaboration were in lines with their stories of collaboration but this was not always the case. For example a researcher with a "complete," network, i.e. a very connected, network might be expected to describe a strong preference for a collaboration community that included linking collaborators with one another. However, instead this researcher's description was of continuing collaboration with a very small number of people, less intense collaboration with one or two more and ambivalence about the broader patterns of his collaborative network. In other instances key researchers' network maps were in line with their descriptions of their collaborations. One spoke at length about the importance of the direct and indirect effects of the collaborative network (the only researcher to do so) and this was reflected in his highly connected patterns of co-publication data. This was also the case when patterns were less connected. Another researcher describes forming collaborations that are entirely reactive. Many collaborations (all external to the university) are formed when he is approached by people at international conferences who are familiar with his work and he is asked to collaborate with them. These are largely independent events so it is scarcely surprising that the collaborations are independent of one another (it should be noted that these external individuals could be collaborating with one another independently of this researcher but our data would not pick this up).

In the main, the descriptions of collaboration capture different information than do the egonet diagrams. Unprompted, researchers do not comment on the connections between their collaborators nor do they appear to have strong feelings about whether these collaborators do or do not work together independently of one another. The strength of the collaboration is partially reflected in the number of publications but this is only discussed by a few of the key researchers (the number of one's own publications is discussed by some ADRs though, perhaps because they are more directly concerned with the various measures of research output and quality). Instead the interviews with key researchers contain stories of the intellectual enjoyment of working with others and the opportunities for challenge, stimulation, travel and new research opportunities that come from collaboration. Emerging from the interviews are important clues for interpreting the collaborative maps but comparison of the maps and interviews also highlight the need for caution in interpreting the interviews.

The maps assist in differentiating interviews and highlight the need to consider the context of the interviewed as well as their narrative in interpreting their discourse. For example, in line with previous findings as to discipline differences in collaboration (Newman 2001), this research shows that the discipline in which research is conducted is an important influence upon the way research is evaluated. In the two Faculties we have focused upon, key researchers assess collaboration similarly though the maps show difference. For example, as already indicated the maps highlight differences in levels of collaboration. However the language

the researchers use is virtually the same - what Business researchers describe as "extensive" collaboration in their interviews is quite modest compared to what IT researchers also describe as "extensive." This no doubt reflects the different research environments of these two Faculties; the language of those interviewed provides only subtle clues to these differences.

Conclusion, Implications and Future Research

The results presented highlight the value of using multi-methods in researching collaborative networks. The big picture is represented, including aspects of the collaborative structure that informants do not consider to be important and/or of which they are not aware. However some of the detail lost in those pictures is retained through the stories told and the additional dimensions of the collaboration (that are important to the informant) that are described. The strength of the collaboration is represented temporally, contextually and quantitatively in the maps and considerable synergy is gained by coupling this with other dimensions of collaboration that discussions and descriptions of collaboration by those mapped can provide.

The investigation of collaborative networks has important implications for the facilitation of research and business. In their case study Grimes and Collins (Grimes and Collins 2003) highlight the use of collaborative research networks in building knowledge and technology and through this enhancing economic growth. There are many other stories of successful collaborations incorporating researchers and their institutions and these often provide continuing benefits. This is further confirmed by the more macro-level research that confirms the positive relationship between research productivity and collaboration.

This work takes a different approach. Instead of focus on the confirmation of the value of collaboration or on the role of collaboration in facilitating innovation, we focus on understanding the deeper processes of collaboration as a window to judging its effectiveness and couple this with descriptive pictures of the scale and scope of collaboration. It is surprising that while there has been research that does look at collaboration in each of these ways; we have been unable to locate any work that combines different research perspectives to do so. While our focus is on academic collaboration we believe that the study of the deeper processes that drive the developing of new knowledge will provide insights in other contexts. Academics and academic institutions are (or should be) important parts of technology development networks and the way their sub-nets operate as well as the way those nets participate in wider collaborative networks are important research issues.

The findings that have been represented indicate that the diversity of what constitutes collaborations. Future research will explore these avenues further. We intend to more deeply explore the meanings contained within the narratives to see if this gives further insight when positioned against the social network analysis. Additional social network analysis to flesh out the network pictures will also be undertaken. Both other parts of the university and other aspects of collaboration will be mapped. We anticipate that the latter will be particularly fruitful. As reported there are a number of indications in the interviews that other indicators of research collaboration such as common research centre membership, co-supervision of research students, grant applications are likely to give better insight into configurations of continuing collaboration. This and the ways in which these might be productively combined and compared will be another focus of future research. Further on we intend to apply these insights to networks in a business marketing context. As already indicated the social networks of business networks have the potential to provide insights into domains that have not yet been much considered. Work that advances this capability and in addition contributes to the understanding of collaboration has much to offer to these future enquiries.

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