UNDERSTANDING INNOVATION AND KNOWLEDGE MANAGEMENT IN DYNAMIC NETWORKS

Submission for:
TENTH INTERNATIONAL CONFERENCE ON HRD RESEARCH AND PRACTICE ACROSS EUROPE 2009

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Stream: Business Strategy, Organisational Learning & Knowledge Management
Keywords: Knowledge Management, Social Network, Innovation, Learning, Social Network Analysis
Submission Type: Full Refereed Paper

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Introduction

Today's organisations operate in an environment that is fast paced, continuously changing and uncertain due to global competition, growth in mergers, acquisitions and alliances and advances in technology and telecommunication (Dowling & Welch, 2004). With such an environment, the competitiveness and sustainability of a modern organisation depends on its ability to behave in an entrepreneurial manner and innovate successfully. It is increasingly accepted (Blunkett, 2000; Gratton, 2000; Iles, 1996) that knowledge, skills and competencies are the key drivers of innovation and thus the source of competitive advantage. It is argued that the real reason for companies' existence is now about turning knowledge into value (McKenzie & van Winkelen, 2004). Access to the latest information (including information from external sources) can provide critical competitive edge for organisations' innovation efforts (Harris, 1999; Gunasekaran, 1999; Sveiby, 1997). Thus knowledge is a key resource that must be managed if innovative efforts are to succeed and businesses are to remain competitive in global markets.

One useful view of innovation is that it is the combined activity of generating creative ideas (i.e. new knowledge) and the subsequent successful exploitation of these for benefit (Roberts, 1988; von Stamm, 2003; O'Sullivan and Dooley, 2008). Creativity results in the development of new knowledge and learning. *Knowledge* can be defined as *information* acquired through implicit or explicit *learning* means and in the process combined with experience, context, interpretation and reflection (Davenport & Prusak, 1998). In a similar vein, Sadler-Smith (2006; p.183) recognised the relationship between knowledge and learning and stated that "the root of knowledge creation is learning". Sadler-Smith (2006) also emphasises that while learning occurs first at the individual level (Sadler-Smith, 2006), the knowledge of the group is greater than the sum of the individual members' knowledge (Senge, 1990). Camagni (1995, p.203) defined this collective learning as the 'dynamic and cumulative process of production of knowledge, which is due to interaction mechanisms typical of an area characterized by a strong sense of belonging and relational synergies'. The learning component of 'collective learning' emphasises the production of knowledge whereas the collective component emphasises the social interaction mechanisms of a collective (Gubbins & MacCurtain, 2008). This illuminates the importance of the "collective" or social interaction for knowledge sharing and learning. Collectives or social networks are found to promote organisational (Floyd & Woolridge, 1999) and collective learning and are a significant source of knowledge which subsequently leads to innovation (Tsai, 2001). Despite the fact that managing an organisation's knowledge assets within networks and converting it into commercially successful products and services through effective collaboration is a critical component of competitive success, it is noted that the process is intricate, complex and difficult to manage (Cormican & O'Sullivan, 2003; Jaffe, 1989; Balconi et al., 2004). Thus, further exploration of how collaborative social networks facilitate knowledge management for innovation is fruitful.

The paper aims to introduce social network analysis as a useful and effective tool for organisations and managers to use to analyse their knowledge management for

innovation efforts. Social network analysis (SNA) facilitates analysis of relationships among actors in a network. It describes a number of social network factors that are useful in analysing overall network structures and identifying the impact they have on knowledge management for innovation efforts. A case study of a knowledge network within the life sciences sector is utilised to conduct an initial exploration of how knowledge is managed through social networks for innovation. The paper will explore key stages of a knowledge management for innovation process from the social network perspective.

Organisational Changes with a Knowledge Management for Innovation Focus: Moves towards Social Network Strategies

For an organisation to successfully innovate i.e. to optimize the way new knowledge is developed and existing knowledge is exploited, it needs to facilitate the dynamic capabilities required for converting the knowledge available from the insights and competences of individual people (the source of new knowledge) into appropriate structures, processes, products and systems that allow the value, in this case innovation, to be exploited (McKenzie & van Winkelen, 2004). Current perspectives of the innovation process view it as an interactive and networked system that spans organisational boundaries to draw on knowledge, experience and capabilities from diverse sources to achieve development objectives (Rothwell, 1992; Tidd et al, 2005). Consequently the locus of innovation and knowledge management is moving from stable, physically collocated functions to dynamic, competency-based, business networks (Voss, 2003; Walters, and Buchanan, 2001; Wright, and Burns, 1998). Networks link organisations, customers and suppliers to create adaptive collaborative value creating networks capable of exploiting emerging opportunities (Cormican & O'Sullivan, 2003; Venkatraman and Henderson, 1998). Moves in this direction include organisations moving from functionally based formal structures to matrix, team-based and networked structures (Morton et al., 2006). Such organizations are 'highly adaptive entities that transcend traditional boundaries as they develop deep and collaborative relationship internally as well as with customers, suppliers, alliance partners and increasingly competitors' (Neilson et al., 2004). It is argued that these relationship-driven organizations are more successful than their non relationship-driven counterparts (Morton et al., 2006).

Organisational knowledge management (KM) initiatives have shifted from a strategy of capturing data and making information explicit in portals and databases to one of promoting tacit knowledge sharing among people (Cross, Parker, Prusak, & Borgatti, 2001; Davenport & Prusak, 1998). Initial knowledge management initiatives were mostly information technology(IT)-based, including repositories that captured critical documents such as lessons learned and best practice. However, many of these early initiatives failed for reasons such as out-of-date documents stored in the knowledge repositories, stored documents not fitting to the employee work process and needs, and the organisations culture, rewards and incentives operating in a manner that discouraged document sharing (Douglas, 2002). While IT certainly has been (and will remain) a critical component of an organisation's knowledge management systems, KM initiatives

also need to focus on the strategic, process, and people components to achieve successful outcomes (Davenport, DeLong & Beers, 1998).

The social network perspective is an appropriate lens through which to examine the interactions among employees (both within and outside the firm) that enable work to be accomplished (Cross & Parker, 2004), or in this case, that enable learning, knowledge access, transfer, absorption and accumulation for the purposes of innovation. It enables exploration of how collaborative social networks facilitate knowledge management for innovation is fruitful. A social network perspective permits conceptualizing the whole, rather than the parts (Storberg & Gubbins, 2006). A social network is a set of people or groups, called 'actors', with some pattern of interaction or 'ties' between them. These patterns can typically be represented as graphs or diagrams illustrating the dynamics of the various connections and relationships within the group (the group being that selected for exploration).

Understanding Knowledge Management Phases of the Innovation Process through the Social Network Perspective

Innovation is about creating new possibilities through combining different knowledge sets. Such knowledge may be from the insights and competences of individual people (the source of new knowledge), found in experience or could be from a process of search- such as research into technologies, markets, competitor actions etc. This knowledge could be codified in such a way that others can access it, discuss it, transfer it etc. or it can be in tacit form, know about but not actually put into words or formulae. A key contribution to our understanding of the kinds of knowledge involved in different kinds of innovation is that innovation rarely involves dealing with a single technology or market but rather a bundle of knowledge which is brought together into a configuration. Successful innovation management is about getting hold of and using knowledge about components but also about how these can be put together- the architecture of an innovation (Tidd et al., 2005). Tranfield et al. (2006) outline the phases of the innovation process and extrapolate the knowledge routines necessary to support each of the innovation phases- discovery, realisation and nurture. Taking the network perspective of innovation necessitates understanding where and how knowledge management routines impact the innovation process and what characteristics of social networks influence knowledge management and how. Table 1 highlights the overlap that exists between innovation, knowledge and social networks; it examines the phases of the innovation process, the knowledge routines evident in each phase, the application of the social network to these routines and examples of social network analysis determinants that can facilitate analysis of the social network for its value to each phase. For example, the discovery phase of innovation relates to searching and scanning the environment to pick up and process signals about potential innovations. Thus potential knowledge sources are scanned for items of interest. The larger the social network the more knowledge sources will be scanned and the likelihood of finding valuable items of interest for innovation is higher. To this end if a social network analysis is interested in determining such factors as the size and diversity of the network and the knowledge of those in the network.

Table 1: Innovation Phases, Knowledge Management Routines Within & Social Networks in Use

Innovation Phase	Description	Knowledge Management Routines	Social Networks Application	Example Social Network Analysis Determinants
Discovery	Searching & scanning the environments to pick up & process signals about potential innovation, such as needs, opportunities arising from research, regulatory pressures, or the behaviour of components.	*Search:* The passive & active means by which potential knowledge sources are scanned for items of interest	Casting a broad search net through the available social networks. The larger the network, the wider the search net will be cast.	• Determine extent to which people are aware of others expertise. • Determine the ease with which a person can gain access to another with required knowledge. • Determine the extent to which an individual is willing to support knowledge transfer. • Determine the likelihood that knowledge shared can be combined. • Determine the channels by which knowledge is exchanged • Determine the level of structural holes and ongoing efforts to close them • Determine the actors position in the broader network
		Capture: The means by which knowledge search outcomes are internalised within the organisation	Access to a greater pool of diverse competencies of relevance to the knowledge accessed will enhance the absorptive capacity of the network & thus its ability to capture & articulate the knowledge	
		Articulate: The means by which captured knowledge is given clear expression		
Realisation	How the organisation can successfully implement the innovation. It involves selecting from the potential innovations those which the organisation will commit resources.	*Contextualise:* The means by which articulated knowledge is placed in particular organisational contexts	Selection decisions on which potential innovations to pursue are based on available knowledge & expertise so having access to a greater network of expertise, knowledge and diverse perspectives to enlighten the selection process improves the selection decisions.	• Determine the types of knowledge being transferred. • Determine the social resources of network nodes • Determine network diversity • Determine the cognitive distance between individuals. • Determine peoples' perception of trust in others to evaluate selections
		Apply: The means by which contextualised knowledge is applied to organisational challenges		
Nurturing	This is the phase of nurturing the chosen option through providing resources, developing the means for exploration.	*Evaluate:* The means by which the efficacy of knowledge applications is assessed	The opening of this phase of the innovation process to input from knowledge sources available throughout the immediate and external social networks of the organisation enhances the expertise & knowledge available, increases the creative capability to solve problems encountered and ensures that relevant stakeholder requirements are incorporated into the design & development activities. Potential errors are minimised by collective knowledge sharing, collaborative routines have the potential to develop technologically superior innovations & reduce the cost & time of development.	• Determine the routines and protocols surrounding knowledge exchange practice. • Determine the 'real value' of knowledge transferred. • Determine the extent of reciprocity. • Determine the evolutionary path of the network.
		Support: The means by which knowledge applications are sustained over time		
		Re-Innovate: The means by which knowledge & experience are reapplied elsewhere within the organisation		

Adapted from Tranfield et al., (2006)

The first phase of any innovation process relates to discovery and involves searching the external environment to identify potential shifts and unfulfilled needs that provide the opportunity for potential innovations. The knowledge inputs for this phase of the innovation process necessitate the organisation spreading as wide a net as possible to capture information from relevant knowledge sources. Opportunities can originate from knowledge sources such as existing customers, suppliers, lead-users, government legislation, developments in technology and related industries, competitor action or even communities of practice. The broadness of the domain makes it impossible for any one individual (or even organisation) to adequately search all potential sources. Consequently, the models of the innovation process are evolving from linear, self contained processes to one which embraces the power of networks. The use of social networks to search for and access knowledge regarding emergent shifts in the external environment improves the organisations searching ability to identify appropriate opportunities for innovation. The social network literatures provide insight and empirical evidence which informs practice on how best to search for and access valuable knowledge through social networks. For example, Granovetter (1973) proposes through his weak tie theory that weak tie relationships, defined as not emotionally intense, infrequent, and restricted to one narrow type of relationship (Granovetter, 1972), enable a focal individual to contact another who resides in a different social circle and hence access non-redundant knowledge. Burt (1992) proposes, through his structural hole theory, that boundary spanners, defined as those actors in a network who connect otherwise unconnected actors, gain access to novel knowledge in a timely fashion, as well as bargaining power. Once the *search* process is complete, the more effectively an organisation can *capture* and *articulate* the knowledge from these networks, the richer the opportunities they have to feed their innovation efforts. In order for meaningful knowledge transfer and learning to occur, the social networking process requires direct and intense interaction between individuals with relevant knowledge and expertise, within the structure of the network (Hansen, 1999) so that knowledge can be internalised in the organisation and given expression in a form understood by those tasked with exploring its innovative potential. The requirement for intense interaction emphasises the importance of the strength of the relationships and the requirement for individuals with relevant competencies emphasises the need to investigate the absorptive capacity of the network.

The second phase of the innovation process relates to *realisation.* This involves firstly screening and selecting appropriate actions to be progressed along the innovation process. Not all opportunities identified are equally attractive. The organisation must decide which concepts from the search phase should be progressed and which abandoned. This is often the most subjective and uncertain phase of the innovation process as the organisation endeavours to estimate the future value of the concept, their ability to develop and exploit it and the alignment of the concept with the organisation's strategic direction. Selection decisions are based on available knowledge and expertise so the adoption of a team-based, consensus approach to decisions is facilitated by having access to a greater network of expertise, knowledge and diverse perspectives to enlighten the selection process. An organisation must strive to identify and access all pertinent information and absorb this knowledge to enhance their decisions. Better

informed decisions regarding the approval of concepts will enhance the likely success of the innovative actions pursued.

The third phase of the innovation process relates to nurturing the innovative actions approved from the realisation phase. The challenge of this phase is to transform the concept into a reality and align it with the needs of the market. This phase integrates technology and market information together with the organisations internal capability to develop the prospective innovation. The further along this phase an action is then the more difficult it is to change the design. Consequently organisations need to access information to ensure the design and subsequent development is correct. The use of concurrent engineering and co-design teams are common in this phase of the process to enhance the knowledge flows and eventual output. Concurrent engineering brings together all relevant stakeholders (e.g. design, manufacturing, logistics, sales, etc.) to collaborate on the development of the action; co-design engages suppliers and other independent organisations to work together on the design of the future innovation. The opening of this phase of the innovation process to input from knowledge sources external to the organisation enhances the expertise and knowledge available, increases the creative capability to solve problems encountered and ensure that relevant stakeholder requirements are incorporated into the design and development activity. Since potential errors are minimised by collective knowledge sharing, such collaborative routines have the potential not only to develop technologically superior innovations but also to reduce the cost and time of development. Such leveraging and integration of necessary resources from the social networks facilitates successful exploitation of the 'new' knowledge opportunity.

The exploitation of value from the developed actions is the primary objective of this phase of the process. The concepts identified in the realisation phase of the innovation process are pursued to increase revenues, expand markets, reduce costs or enhance the organisations competitive advantage in some tangible way. Many organisations succeed in making substantial technological breakthroughs during the nurture phase, only to be unable to secure benefit from the development. The ability to commercialise developed actions is essential to the long term sustainability of any organisation. Knowledge inputs for this phase of the process relate to how an organisation can ensure the market adopts the innovation and what mechanisms can be used to protect intellectual property from competitors. Organisations must be careful when securing intellectual property that the associated secrecy does not adversely affect the necessary knowledge flows to the innovation process or encourage behaviour by individuals within the network that undermines knowledge exchange for mutual benefit.

The Implications of Specific Social Network Characteristics for Knowledge Management for Innovation

This network perspective of innovation views the process as a continuous and cross-functional process involving and integrating a growing number of different resources inside and outside the organisation's boundaries (Boer et al, 1999). Networks create value by synthesising information and knowledge, exploiting expertise and pooling resources across traditional boundaries in order to create new knowledge and achieve

innovations outside of individual capabilities and the resource bases of individual organisations (Prasad and Akhilesh, 2002; Johnson et al, 2001; Ratcheva and Vyakarnam, 2001; Pawar and Sharifi, 2000). Increasingly more innovation is occurring through collaborative networks, whether these are research and development teams within the boundaries of a sole organisation or traversing multiple organisational boundaries. Powell (1998) observes *"When uncertainty is high, organisations interact more, not less, with external parties in order to access both knowledge and resources. Hence, the locus of innovation is found in networks of learning, rather than in individual firms."* Thus, in order to effectively manage the innovation process, one must understand the structure and function of the network contributing to the generation of innovations. Social networks have the potential to facilitate the creation of new knowledge (Kogut and Zander, 1992; Trott 2008) and the synergistic benefits of these social networks depends upon "how effectively linkages… are actually managed" (Gupta and Govindarajan, 1986: 696). Understanding the implications and influence of specific network characteristics is key to facilitating such effective management. Social network characteristics which can be evaluated include; centrality and relative position of an node (actor, individual, organisation, etc.) within the network, the strength of the ties between nodes, the nodes absorptive capacity and network cohesiveness (Hatala, 2006; Tsai, 2001; White, 1997).

Centrality refers to the position of a node within a network. Local centrality deals with the number of direct ties with all the nodes in the network. A high local centrality number represents a more centralised location of the node. This suggests that information can flow easily around the network through these nodes. Global centrality relates to the connections between nodes via paths. Global centrality measures highlight nodes which are not highly connected but provide links from one set of nodes to the other (Cross & Parker, 2004). From a knowledge exchange and innovation perspective, different network positions represent different opportunities for an individual or organisation to access knowledge within the network, with the nodes occupying more central positions being better able to access desired knowledge and resources as inputs to their innovation effort (Tsai, 2001). The positional advantage of centrality also allows the organisation to access information that can facilitate development and exploitation of ideas (Ibarra, 1993) more effectively than those nodes at the periphery of the network. Tsai (2001) finds that that "a units innovative capability is significantly increased by its centrality in the intra-organisational network, which provides opportunity for shared learning, knowledge transfer and information exchange" (p1002). Similarly their timely access to information and structural power increases their bargaining position and improves the possibility of higher benefit from alliances than less central firms (Gilsing et al 2008). Central organisations become better informed about what is going on in the network, which increases the possibility for the central organisation to initiate the formation of new alliances and innovative projects (Gnyawali and Madhavan, 2001). When examining the impact network centrality has on innovation, research has highlighted that although centrality is a strong determinant with respect to administrative innovation, it is not as significant with respect to technical innovation (Ibarra, 1993). One possible reason for the reduced significance of centrality with respect to technical innovation may relate to the group involved being smaller and more specific in expertise, resulting in stronger ties between nodes. (Ibarra, 1993).

The strength of the ties within the network also influences the knowledge exchange between nodes and the innovative capability of the network. Hansen (1999) identified that weak ties are more likely to facilitate access to non-redundant information by comparison to strong ties due to the ability of weak ties to reach outside a nodes immediate social circle. However, it is strong ties that are most likely to facilitate transfer of such information, particularly where that information is complex, due the relationships characterised as strong ties being more likely to be closer and more reciprocal. Levin (1999) found that weak ties characterised as *trusted* weak ties are the most effective network configuration for access to and transfer of valuable knowledge due to their ability to reach beyond a nodes immediate social circle for novel knowledge and the existence of sufficient trust that the knowledge can be transferred. An individual is more likely to exert greater effort to transfer knowledge to a close personal contact than one they do not know or have no reason to trust (Reagan and McEvily, 2003). Strong ties as opposed to weak ties are more effective in facilitating the transfer of both tacit and explicit knowledge across gaps in the network (Hansen, 1999). Tacit knowledge transfers across organisational boundaries more slowly than codified knowledge (Zander and Kogut, 1995) and given the cost in terms of time and resources necessary to develop strong ties, it is more efficient to use strong ties to transfer tacit knowledge and weak ties to transfer codified knowledge (Reagan and McEvily, 2003).

In the medium to long-term, even diverse networks will become denser as partners learn from each other and the absorptive capacity to 'accept' the transferred information increases across the network nodes (Gilsing et al 2008). The relative density of a network through direct and indirect ties influences innovative capability with regard to assessing the reliability of sources of novel knowledge as well as understanding and evaluating these sources (Gilsing et al 2008). Dense networks may be highly effective in exploiting innovation and getting work done due to high levels of trust and understanding between participants, but they can also lead to a form of 'group think' that prevents the network from exploring new areas (Gilsing et al, 2008). Over time, dense networks allow certain organizational nodes build reputation effects over other network nodes to influence interaction behaviour. This can offer opportunities for sub-groups within the network to constrain behaviour that will maximise benefit to the sub-group rather than the larger network (Coleman, 1988; Kraatz, 1998). Such behaviour by 'powerful' nodes can lead to a desire for the other network members to conform rather than be cognitively distant to other network members (Gilsing et al, 2008) and thus reduce the exploratory capability of the network.

The balance between cohesion and division has varying implications. When discussing interactive learning within clusters, Bathelt at al (2004) highlight that knowledge exchange within 'local' networks can be informal and serendipitous in nature due to low geographic and cognitive distance within the community. However as networks becomes more distant and 'global' in terms of geographic and cognitive distance then increased formalisation of linkages and investment is required to support their operations. The effectiveness of interaction will be influenced by the absorptive capacity of each of the network nodes, the cognitive distance between partners and their mutual trust and collective understanding of purpose (Balconi et al., 2002; Hussler and Ronde, 2002).

Similarity between nodes is found to be attractive and distance in knowledge and cognition (cognitive distance) constitutes a liability for inter-organisational learning at the exploitation phase of the innovation process. In contrast at the exploration phase, partner similarity in unattractive where as cognitive distance forms an important asset (Gilsing et al 2008). Cognitive distance across the network nurtures a culture where partner organisations challenge their existing models and assumptions and generate new knowledge. This new knowledge arises through emergent learning within the process of practical thinking (Scriberner, 1986; Brown and Duguid, 1991; Gibbons et al., 1994; Swan and Newell et al, 1999). When network interactions confront uncertainties and unknowns, new understandings are realised through reflection and abstraction (Von Glasersfeld, 1995). This is the basis for creativity and knowledge creation that offers the potential for future innovation.

Structural holes within a network offer significant potential for individuals who occupy the hole (Burt, 1992). These individuals are referred to as "knowledge brokers" (Hargadon, 2003) or "boundary spanners" (Donaldson and O'Toole, 2007). Their ability to span structural holes is often due to the fact they hold requisite wisdom within a discipline and can provide 'weak' ties across groupings that nurture the flow of knowledge both within the network and between the network and the larger external environment (Granovetter, 1985). As explicit knowledge is codified, it can be transferred more readily across structural holes. However tacit knowledge is more likely to transfer across structural holes only where the knowledge brokering individual has strong ties across the hole or else has a diverse and expansive network (Reagan and McEvily, 2003). Knowledge brokers are valuable in that they initiate learning activities between organizations, establish new linkages for enriching knowledge and connect the innovation activity with wider scientific and institutional networks (Powell et al, 1996; Murray, 2002). Knowledge brokers not only increase the connection between groups within the network that enables knowledge exchange but also connects the existing network with other organisational groupings in the larger external environment, that allows the network develop and evolve. The ongoing development of linkages with 'new' organisations prevents the network from becoming cognitively similar and ensures the network knowledge creation efforts maintain relevance by introducing increased diversity from external sources. However, it has been found that the benefits to be gained from structural holes are short-term and boundary spanners need to act quickly to obtain these advantages (Soda, Usai and Zaheer, 2004).

Social network analysis as a Knowledge Management for Innovation Tool

Successful knowledge management for innovation requires an understanding of the characteristics of a given knowledge network so as to determine how it can be more effectively managed for improved knowledge creation and innovation. For example, new-product development or process improvement initiatives can be assessed in terms of how the team is integrating its expertise and the effectiveness of this integration for innovation. Social network analysis (SNA) utilised such measures as outlined previously, facilitates analysis of relationships among actors in a network. Social network analysis methodologies describe a number of social network factors that are useful in analysing

overall social network structures and identifying the positive and/or negative impact on knowledge management for innovation efforts. By exploring an innovation driven social network in this way, one can identify strategies for managing knowledge, developing the network and improving its performance.

Methodology

The case study detailed below is one of a number of university-industry collaborations studied through longitudinal research by the researchers. The methodology adopted as part of this study consists of a series of semi-structured qualitative interviews over the life of the network to assess the networks evolution, understand the structures, routines and practices of the network and identify the factors influencing positive network behaviour. The interviews are conducted with key members of the collaborations management team who can provide both strategic and operational level insights into the network functions. Interviews were conducted every eighteen months. This case study was chosen for analysis as it is the longest established of the networks under study and was created by multiple organizations to advance their scientific understanding and generate knowledge that they could exploit for potential innovations. The study of this network began in 2003. The interview transcripts were analysed using a number of social network analysis determinants, such as those presented in table 1, as themes. This analysis provided initial exploratory evidence of the influence of specific social network characteristics on the university-industry collaboration efforts for knowledge sharing and innovation.

Case Study: Knowledge Creation Network

This university-industry network was established in 1998 and consists of a consortium of pharmaceutical companies collaborating with the University's internationally renowned research centre. The consortium was established to progress advancements in fundamental research of cell signalling which had become a crucial building block for the future drug development process following the mapping of the genome. Prior to the network formation, the lead academic had, over a number of decades, established a world-class university research centre in this scientific area. In the mid nineties, industry recognised their competence gap and were approaching the university centre to collaborate on contract research in this scientific area. Through negotiation, a suitable model emerged where all partners contribute equal funding to the collaboration organisation for an initial 4 year period; 60% directed towards basic research open to the network members and the remaining 40% for a limited amount of testing services on a confidential basis. This cumulated in 1998, with formal letters of contract being signed by participating organisations establishing their commitment and expected deliverables from the network.

The network is centred at the university site, with key individuals from the industry partners coming together once every three months to review the scientific research ongoing in the laboratories, offer their collective scientific advice to the principal investigators and ultimately gain insights into new 'leads' emerging from the research breakthroughs. When industry partners view developments at their quarterly meetings,

they are able to absorb and codify this information to take back to their own organisations. They can then reflect on this information. The quarterly meetings are followed by informal dinner events that allowed industry partners network together in a social environment and reduce the barriers between the various organisational representatives. The scientific 'leads' are normally pursued on an individual basis by the Pharma organizations. Where successful advancements result from the 'leads', the resulting compounds are then returned to the university test centre for confidential screening and validation. The university partner's knowledge capability benefits from access to the scientific experience of the industrial peers, the reservoir of knowledge within the industrial partners compound libraries and the development capability of industry to validate emerging models and discoveries speedily. Likewise, the industry partners knowledge capability benefits from access to the scientific expertise of the university's research scientists, the rich tacit knowledge and process capability of the research centre and the enhanced scanning capability for novel leads that may 'populate their product development pipeline' for the future.

On forming the university-industry network for the first time, the partners needed time to 'form and norm' (Tuckman, 1977). Much of the early interaction was spent establishing structures and control systems for managing the interaction of partners within the network. Early interaction between the collaboration was in line with those outlined in the contract and very transactional in nature. The university laboratories were required by the industrial partners to comply with certain industrial standards (scientific and intellectual property protection) as a threshold for 'real' knowledge exchange and collaboration to take place. Over time, both university and industrial partners have developed higher levels of confidence in the researchers collaborating in the network and in the science each was undertaking. As a consequence, all are now more open and willing to access information coming from the university and also contribute knowledge, equipment and compounds to advance the network's research output.

The majority of network knowledge exchange occurs through interpersonal interaction between industry and university researchers. These interactions occur formally at the quarterly research review meetings but industry can also place a researcher into the university laboratory for two months per annum to learn process practices and gather tacit knowledge that is not easily coded for transfer. Through interaction, peers share ideas, transfer skills and challenge scientific uncertainties and unknowns to develop new understandings through reflection and abstraction. Another important knowledge transfer occurs at the level of the lead academic; he oversees both the discovery research aspect of the network and the testing centre for the industrial compounds from the industry partners. As a consequence of this dual function, he is able to validate previous discoveries from his research labs and influence the future discovery research trajectory of the university's labs in order to ensure the continued value of the centre's research to both existing industrial partners and potential new entrants to the network.

All network partner participants involved in the collaboration have a strong research science background and view each other as peers. This factor proves very important since research science is by its nature highly specialised and jargon laden which can represent a significant barrier to knowledge exchange. Since the network members have

similar academic backgrounds and research focus, this provides a common foundation allowing individuals interact easily and communicate both technically explicit and tacit knowledge more efficiently. The network is in its third cycle of four years and consequently relationships and mutual understanding between the various partners has deepened over this time. A number of personal contacts have developed between principal investigators undertaking research within the university labs and researchers within the industrial partners. As both share common scientific interests, they frequently interact via telephone and email to discuss scientific challenges and exchange advice. The ability of network members to absorb and challenge transferred knowledge is fundamental to the advancement of 'new' knowledge in the form of scientific discoveries. Once the knowledge of discoveries is absorbed into the independent organisations participating in the network, its further development is normally advanced by individual partners, using unique R&D capabilities. However, there have been occasions where industry partners not interested in particular discoveries by the university lab have assisted the university in patenting them, perhaps to prevent competitors outside the network from accessing it, but also to strengthen the reputation and commercial outputs of the university research centre. The collaboration to date has been mutually beneficial for all network partners and plans are underway for the consortium to embark on another 4-year cycle.

Analysis

In order to effectively explore the social network traits of this knowledge creation for innovation network and their implications, the case is analysed using the SNA determinants identified in table 1. This analysis, together with the specific social network indicators used for assessing the level of each social network determinant is presented in table 2.

Table 2: Social Network Analysis of case

Innovation Phase	SNA Determinants	Case Evidence
Discovery	Determine extent to which people are aware of others expertise.	Quarterly meetings act as a catalyst where industrial partners representatives to identify and nurture linkages between the Principal Investigators and appropriate scientists in their organisation. Lead academic also promoted benefits of his network externally through is work on industry advisory boards to attract new industrial partners. *Indicator: Strong ties between lead academic and industrial representative; weak ties between industrial representatives.*
	Determine the ease with which a person can gain access to another with required knowledge.	Network established as a hub and spoke model where majority of interaction occurs through the university at the centre of the network. As a consequence of continued interaction at quarterly meetings, the industrial representatives have behaved as knowledge brokers and informal linkages between certain industrial partners have developed in recent years as a consequence of research synergies. *Indicator: Central position of university in the network ensures highly access between university and individual industrial partners; access constrained between industrial partners but improving as network cohesion increases*.
	Determine the extent to which an individual is willing to support knowledge transfer.	In the early years of collaboration, knowledge transfer was primarily unidirectional from the university but now evidence of higher levels of collective knowledge sharing to advance the scientific projects of the university. *Indicator: Increasing levels of knowledge transfer between partners due to increased trust and realisation of actual benefits of collaboration.*
	Determine the likelihood that knowledge shared can be combined.	Given the specific nature of the network's scientific research, all participants are share common ontology and cognitive capacity to interpret and abstract the knowledge transferred. *Indicator: High level of absorptive capacity within network from outset due to strong scientific capability of partners participating in the network.*
	Determine the channels by which knowledge is exchanged	Knowledge is exchanged formally at the quarterly presentations of university findings. More tacit knowledge is transferred through secondment of industrial personnel into the university. As familiarity has increased within the network, more informal communications (via telephone and email) between specific individuals across the network have developed. *Indicator: Increasing strong and weak ties developing between network members and evidence of multiple channels for achieving knowledge transfer.*
Realisation	Determine the types of knowledge transferred	Both tacit and explicit knowledge transfer occurs between the university and industrial partners through the quarterly meetings and employee secondments. As social networks develop through this interaction, deeper ties develop to allow transfer of tacit knowledge across structural holes. *Indicator: Both tacit and explicit knowledge being transferred between partners.*
	Determine the sources of 'valuable' knowledge	As university holds central position in the network, it uses its position power to manage network interaction and ensure all partners are contributing to an acceptable level. Certain industrial partners have surpassed their contractual obligations in order to increase the innovation capability of the network. *Indicator: Knowledge brokers regularly traverse structural holes of network to enhance its scientific capability.*

	Determine who acquires information from whom and how frequently.	The network provides advice and insights to the multiple research projects ongoing within the university hub. The flow of information is strongly influenced by the specific project and its scientific challenges. *Indicator: High frequency of both formal and informal information transfer from all partners.*
	Determine the cognitive distance between individuals.	Although all individuals engaged in the network are research scientists who strive for knowledge creation and are capable of absorbing knowledge transferred, there is significant cognitive distance between the industrial and academic communities. This distance facilitates innovation by maintaining a constant balance between discovery and commercial forces. *Indicator: High cognitive distance between partners signified by diverse views and opinions regarding path forward.*
	Determine the level of structural holes and ongoing efforts to close them.	The network objective is the advancement of cell signalling science through combining collective partner capability for discovery. Gaps exist in both the state of the art understanding and in partner knowledge. By identifying these gaps, combining collective knowledge and utilising the research capability of the network, these gaps are being filled. The lead academic and industrial representatives act as knowledge brokers in connecting the knowledge holders together, whether this is internal or external of the network. This has resulted in new industrial partners joining the existing consortium. *Indicator: Knowledge brokers establishing new relationships and growing the network with suitably knowledgeable partners.*
Nurturing	Determine the routines and protocols surrounding knowledge exchange practice.	Through a process of trial and error over the past decade, the consortium has developed a set of structures and processes that facilitate the long-term sustainability of the network. These routines include management structures regarding the responsibilities of network members, procedures regarding entry and exit into the network, sanction and reward procedures and agreements regarding intellectual property ownership and opportunity exploitation. *Indicator: Common agreement among partners regarding routines of practice.*
	Determine the 'real value' of knowledge transferred.	The network has been in existence since 1998, with a number of its discoveries resulting in patents and forming the basis for product developments in the industrial partners pipeline. The networks operations made have also resulted in advancement of the state of the art, with these contributions being documented in journal publications. The knowledge store of each of the partners has also been increased which increases both their and the networks innovative capability. *Indicator: Quantifiable number of patents, product/process developments and publications. Qualitatively, perception of increases knowledge store among partners.*
	Determine peoples' perception of trust in others.	As the network has evolved over time, so have the relations between partners. This has resulted in new ties developing that have enhanced the cohesion within the group. Certain industrial partners have surpassed their contractual obligations in order to increase the innovation capability of the network. Also some of the initial structures developed to prevent knowledge spill-over between partners have become obsolete as greater trust develops. *Indicator: Increase in number of strong ties evident between network members.*
	Determine the extent mutual benefit occurs as a consequence of knowledge exchange.	The network has gone through three cycles of renewal where all partners were able to exit the consortium if desired. However network members continued in their support of the network and increased their organisations contribution to the sustainability of the network. This is evidence that all partners view engagement in the network as beneficial and do not feel they are being exploited by other network members. *Indicators: Strong cohesion in network, duration of the network operations and stability of the network membership.*

	Determine the sustainability of the network	The network evolution is guided by the lead academic, with the support of the industrial partners. This helps maintain the balance between discovery and commercial forces and ensure relevance of the networks scientific output going forward. The lead academic also traverses organisational boundaries to attract new partners into the network that can contribute synergistic knowledge to advance scientific discoveries. *Indicator: Strong cohesion in network, duration of the network operations and attractiveness of the network to new membership.*

Conclusions

When increasing environmental uncertainty, organisations are interacting more with external parties, including other organisations and educational institutions in order to access both knowledge and resources to facilitate innovation. It is acknowledged that the key to survival is to recognise that the locus of innovation is found in networks of learning, knowledge sharing and innovation rather than working in isolation. Thus, in order to effectively manage the innovation process, one must understand the structure and function of the network contributing to the generation of innovations. Previous research identifies the benefits of social networks for the creation of new knowledge (Kogut and Zander, 1992; Trott 2008) and the implications of specific social network characteristics such as centrality, density, cohesion, strength of relationships and existence of relationships, on knowledge management for innovation efforts. Thus, understanding the implications and influence of specific network characteristics is key to facilitating effective management of knowledge sharing and innovation processes.

This paper provides indicators as to how an innovation process contains a knowledge management cycle which is influenced by social network characteristics. It provides determinants as to how one could explore such knowledge sharing for innovation networks to ascertain the strengths and opportunities for developing the network to improve access to, transfer of, absorption of and ultimately innovation benefits that can be garnered from the knowledge resources of the network. It provides some initial insights into such a network through a qualitative exploration of the network characteristics as defined and illustrated through interviews with the network members.

To further this research the next phase of this study involves a quantitative exploration of the social network and statistical analysis of these characteristics to determine the influence on innovation efforts.

Selected References

Balconi M., Breschi S., Lissoni F. (2004), "Networks of inventors and the role of academia: an exploration of Italian patent data" , *Research Policy* , vol. 33, no.1,pp. 127 - 145.

Brown, J.S. and Duguid, P. (1991). *Organizational learning and communities-of-practice: toward a unified view of working, learning, and innovating:* Organization Science; Feb, Vol. 2 Issue 1, p40-57.

Coleman, J.S. (1988). Social capital in the creation of human capital. American Journal of Sociology. 94, pp95-120

Cormican. K and O'Sullivan, D. (2003), "A Scorecard for Supporting Enterprise Knowledge Management"*., International Journal for Information and Knowledge Management*, vol. 2, no. 3, pp 191-201.

Davenport, T.H. and Prusak, L. (1998), "W*orking Knowledge: How Organisations Manage What They Know",* Harvard Business Press, Boston.

Donaldson B. and O'Toole, T. (2007). *Strategic Market Relationships: From Strategy to Implementation***,** John Wiley & Sons.

Dooley L and O'Sullivan D, (2008), *Applying Innovation*; Sage Publications

Gibbons, M. Limogues, C., Nowotny, H. Schwartzman, S. Scott, P. and Trow, M. (1994). *The New Production of Knowledge*, Sage Publishing (London).

Gilsing V., Nooteboom, B., Vanhaverbeke, W. Duysters, G and van den Oord, A. (2008). Network embeddedness and the exploration of novel technologies: Technological distance, betweenness centrality and density. Research Policy, 37. pp 1717-1731.

Granovetter, M.S. (1985). *Economic action and social structure: problem of embeddedness*, American Journal of Sociology 91, pp. 481-510.

Gnyawali, D.R. and Madhavan, R. (2001) Cooperative networks and competitive dynamics: A structural embeddedness perspective. Academy of Management Review, 26, pp431-445.

Hansen, M. T. (1999), "The Search-Transfer Problem: The Role of Weak Ties in Sharing Knowledge across Organization Subunits", *Administrative Science Quarterly, vol. 44, no. 1, pp. 82-111.*

Hargadon, A.B. (2002). *Knowledge brokering: A network perspective on learning and innovation*, Research in Organisational Behavior, B. Straw and R. Kramer (Eds), JAI Press, 21: pp. 41-85

Harris, J.R. and McKay, J.C. (1996), "Optimising product development through pipeline management" In *The PDMA Handbook of New Product Development.* (Ed,

Hussler C. and Ronde P., (2002). *Proximity and academic knowledge spillovers: New evidence from the networks of inventors of a French university*. EUNIP Conference 2002, Turku, Finland; Dec 5-7

Ibarra, H. (1993). Network centrality, power and innovation involvements: Determinants of technical and administrative roles. Academy of Management Journal. Vol 36, No. 3. pp 471-501

Jaffe A. B., (1989), "Real effects of academic research", *American Economic Review*, vol. 79, pp 697-970.

Knock, N., McQueen, R., and Corner, J. (1997), "The Nature of data, information and knowledge exchanges in business processes: Implications for process improvement", *The Learning Organization,* vol. 4, no. 2, pp 70-80.

Kraatz, M.S. (1998). Learning by association? Inter-organizational networks and adaption to environmental change. Academy of Management Journal, 41: 621-643.

Morton, S.C., Dainty, A.R.J., Burns, N.D., Brookes, N.J. & Backhouse, C.J. (2006), "Managing relationships to improve performance: a case study in the global aerospace industry", *International Journal of Production Research*, vol. 44, no. 16, pp. 3227-3241.

Murray, F. (2002). *Innovation as co-evolution of scientific and technological networks: exploring tissue engineering*, Research Policy, Dec., Vol. 31 Issue 8/9, pp.1389-1404

Neilson, G., Gulati, R. & Kletter, D. (2004), "Organizing for success in the 21st century", Booz Allen Hamilton-Kellogg School of Management, Fortune 1000 survey findings. Available at: http://www.boozallen.com/bahng/SilverDemo.

O'Sullivan D. and Dooley, L., (2008) Applying Innovation; Sage Publications (USA)

Powell, W.W. (1998). *Learning from Collaboration: Knowledge and Networks in the Biotechnology and Pharmaceutical Industries*. California Management Review, 40(3), pp. 228-240

Powell, W., Koput, K.W. and Smith-Doerr, L. (1996). *Inter-organizational collaboration and the locus of innovation: Networks of learning in biotechnology*, Administrative Science Quarterly, 41, pp. 116-145.

Reagans, R. and McEvily, B. (2003). Network structure and knowledge transfer: The effects of cohesion and range. Administrative Science Quarterly, 48: 240-267

Roberts, E.M, (1988). Managing invention and innovation. Research-Technology Management, 31(1), 11-29.

Rosenau, M.D., Griffin, A., Castellion, G.A. and Anschuetz, N.F.) John Wiley and Sons, New York.

Rothwell, P.A. (1992), "Successful industrial innovation: critical factors for the 1990s", *R&D Management*, vol. 22, no. 3, pp.221–240.

Storberg-Walker, J. & Gubbins, C. (2007), "Social Networks as a Conceptual and Empirical Tool to Understand and "Do" HRD", *Advances in Developing Human Resources*, vo. 9, no. 3.

Sveiby, K.E. (1997), *The New Organizational Wealth: Managing and Measuring Knowledge Based Assets,* Berrett-Koehler, San Fransisco.

Swan, J. and Newell, S., (1999), "Central Agencies in the Diffusion and Design of Technology A Comparison of the UK and Sweden", *Organization Studies*, vol. 20, no.6, pp. 905-931

Teece, D. J. (2007). Explicating dynamic capabilities: the nature and micro-foundations of (sustainable) enterprise performance. *Strategic Management Journal,* 28, 3 pp. 1319- 1350.

Tidd, J., Bessant, J. and Pavitt, K. (2005), *Managing Innovation: Integrating Technological, Market and Organisational Change,* John Wiley & Sons, Chichester.

Trott, P., (2005) Innovation Management and New Product Development. 3rd ed: Prentice-Hall

Tsai, W. (2001). Knowledge transfer in intraorganisational networks: Effects of network position and absorptive capacity on business unit innovation and performance. Academy of Management Journal, Vol. 44, No. 5., pp996-1004

Von Glasersfeld, E. (1995). *Radical Constructivism: A Way of Learning*. Routledge Publishing.

Von Stamm, B., (2003) Managing Innovation, Design and Creativity: Wiley

Voss, C. A. (2003), "Rethinking paradigms of service", *International Journal of Operations and Production Management*, vol. 23, no. 1, pp 88-104.

Wright, D.T. and Burns, N.D., (1998), "New organisation structures for global business: an empirical study", *International Journal of Operations and Production Management*, vol. 18, no. 9, pp 896- 923.

Walters, D. and Buchanan, J., (2001), "The new economy, new opportunities and new Structures", *Management Decision*, vol. 39, no.10, pp 818-834.

Zander, U. and Kogut, B. (1995) Knowledge and the speed of transfer and imitation of organisational capabilities: An empirical test. Organizational Science. 6: pp76-92

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