Building Research Collaboration Networks - An Interpersonal Perspective for Research Capacity Building

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Abstract: *While collaboration is increasingly recognized to be important for research, researchers' collaboration networks are still not adequately recognized as a form of research capacity in the literature. Research is a knowledge creation activity and interpersonal research collaboration networks are important for knowledge cross-fertilization and research productivity. By referring to social network theories, this paper argues that research collaboration networks are a form of research capacity at interpersonal level. It complements capacity building at individual, organizational and inter-organizational levels. However, building research collaborations can be challenging. Three key issues are raised for discussion. First, collaboration networks have nonlinear effect on research productivity. Second, fostering heterophilous communications and maintaining degrees of heterophily can be contradicting and thus challenging. Third, building research collaboration networks proactively requires shift of research management philosophy as well as invention of analytical tools for research management. Debates and solutions with regard to these issues may contribute to the advancement of theory and practice of research management.*

Keywords: *Capacity Building, Research Collaboration, Social Network Theories*

Introduction

The development of social network theories has revealed that social structure of relationships around a person, group, or organization affects beliefs and behaviors (Burt, Kilduff, & Tasselli, 2013). For example, in research on innovation diffusion, Ryan and Gross (1943) find that Iowa farmers' adoption of hybrid-seed corn was mostly influenced by their neighbors, even though the farmers first heard the innovation from commercial salesmen. Godley , Sharkey and Weiss (2013) demonstrate that office location is one of the strongest predictors of grant collaborations amongst neuroscientists within an institute. Rogers (2003) further points out that interpersonal linkages among individuals in a social system can influence the communication flow and promote the adoption and diffusion of innovations in the system.

Increasingly, researchers are working in collaborations to address complex research issues. Higher Education Institutes (HEIs) are giving incentives for their researchers to take part in international collaborative projects. Funding agencies also favors collaborative research because it can draw diverse expertise, promote creativity and innovation and therefore lead to scientific breakthroughs. Social networks have been the subject of both empirical and theoretical studies in the social sciences for at least 50 years but has only been recently applied to research collaborations (Godley, et al., 2013; Woo, Kang, & Martin, 2013).

Implicit in social network theory is the assumption that there are outcomes associated with the connections. It is the thesis of this paper that research collaboration networks derive benefits to higher education institutions (HEIs). This author argues that of two hypothetical institutes (Figure 1), Institute B's intentional connections provide greater opportunity for research collaboration than does Institute A wherein the researchers work in isolation. The author further claims that Institute B has higher research capacity as compared to Institute A.

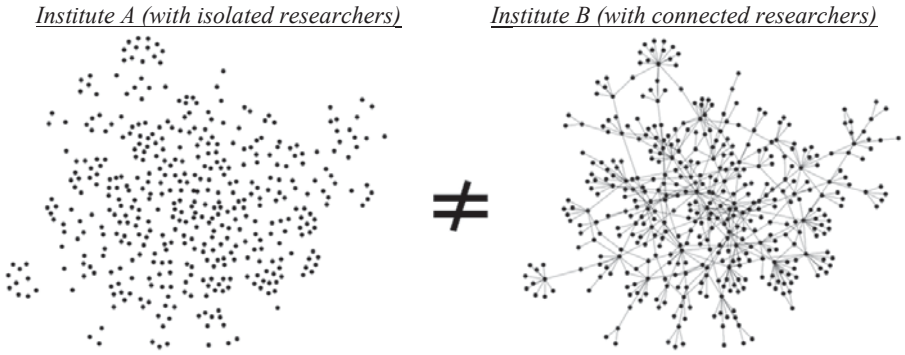

Figure 1. Comparison of Institute A and Institute B

This paper will focus on three important topics. Are social network theories relevant to research management? Can research institutes be informed by social network theories to promote research collaborations? What limitations do social network theories have when applying to research collaborations? In addition, this paper seeks to provide a theoretical framework for the role of research administration and capacity building through social networks. By linking social network theories with research management, the paper hopes to make contribution to the theory and practice of research capacity building.

To anchor this paper theoretically, social network theories are briefly introduced in the next section. The section does not cover technical details of the social network theories and models. More in-depth review of the theories can be found in the literature of Social Network Analysis (SNA) (Woo, et al., 2013).

Social Network Theories

Social network theories form a major paradigm in contemporary sociology. The theories focus on how people, organizations or groups interact with others in social networks (Burt, et al., 2013). In this sociology paradigm, the social relationships are studied in terms of diagrams of social networks which constitute nodes (e.g., people) and ties (e.g., the relationships among people). The diagrams can be used to understand social capitals (Williams & Durrance, 2008), the advantage that an individual, cluster or a network may gain from social interactions as a result of their location in social networks (e.g., who they are connected with). Theories are developed to explain why people interact, how they interact, at what level of closeness and with what kind of outcome.

The study on social network diagrams has led to multiple theories on social networks. For example, when examining the process of job seeking, Granovetter (1973) identifies the strength of weak ties. He finds that job seekers tend to hear of job opportunities from people connected by weak ties (e.g., acquaintance that does not share many common friends, just like people in a social network that has loose connections among members), rather than by strong ties (e.g., close friends who are closely connected among each other, just like people in a social network that has dense and coherent connections among members). The example of weak/strong ties is illuminated in a social network diagram presented in Figure 2. Node E shares a weak tie with Node H and strong ties with Node F and G. Granovetter explains that weak ties can transmit information (such as job opportunity) from distant part of the social system. Thus people that have few weak ties are confined mostly to the local information of their close friends. Empirical studies (Ahuja, 2000; Mehra, Kilduff, & Brass, 2001) have also demonstrated that individuals with weak ties can bridge different clusters in a social network and gain significant advantage.

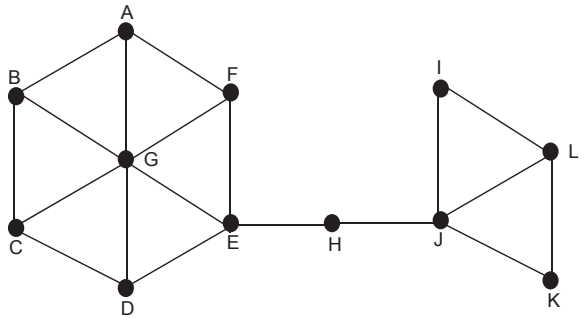

Figure 2. Network 1

Social network theories have their limitations. These theories take a relational approach and emphasize primarily the properties of relations among individuals (Kadushin, 2011). One major critique is their lack of recognition of the properties of these individuals (Martin & Wellman, 2010), for example, individuals' agency and determination in seeking information in social networks. Without denying this limitation, this paper argues that social network theories have potential to inform research management in HEIs.

The rest of the paper is developed into five sections (i.e., Section Two to Section Six). Section Two highlights the importance of collaboration in research. The next section reviews the literature of research capacity building. It argues that research collaboration networks are not adequately recognized as a form of research capacity. The fourth section uses two network diagrams to illustrate that structures of research collaboration networks can have impact on research creativity and productivity at both individual and collective levels. It is then argued that research collaboration networks can make unique contributions to research capacity building. The fifth section refers to social network theories and presents three mechanisms for building research collaboration networks. By making reference to the mechanisms and empirical findings, the last section discusses three challenging issues in building research collaboration networks.

Collaboration is Important for Research

Research collaboration has gain attention in the past few decades (Bammer, 2008; Wray, 2006). The observed growth in co-authorship provides partial evidence for increased collaborations in research (Katz & Martin, 1997; Sooho & Bozeman, 2005).

Bukvova (2010) notes that there is no clear definition on research collaboration in the literature. Many forms of collaboration work, such as casual discussion on a research idea, are hard to be measured as evidence of collaboration. For the purpose of this paper, research collaboration is regarded as joint work between researchers in achieving research objectives. More specifically, the two main forms of research collaboration discussed in this paper are jointly conducting research projects (i.e., joint grantsmanship) and co-authoring publications.

There are at least four reasons for researcher to collaborate: the need to address complex research issues; the need for learning and productivity in research; the need to reduce research cost and the need for intellectual companionship.

First, collaboration is necessary for researchers to address complex research issues that otherwise cannot be addressed by individual researchers. Due to the increased specialization in science, there is a need for individual researchers to keep their own activities focused and specialized (Bukvova, 2010; Katz & Martin, 1997). Such focus and specialization would allow researchers to make significant knowledge advancement in their respective fields (Bukvova, 2010). While it is possible for individual researchers to learn all the knowledge and skills needed to solve a complex research problem, this learning process can be very time-consuming and may prohibit one from being specialized. Thus, researchers, when addressing complex problems, need to pool expertise together and obtain cross-fertilization through interdisciplinary collaborations (Johari, Zaini, & Zain, 2012).

Second, collaboration is important for researchers' sustainable development in knowledge creation. The United Nations Office for Sustainable Development (2012) points out that in a knowledge economy, knowledge and capacity may be replaced or refreshed at a very fast pace. Thus, continuous learning and knowledge transfer are critical for researchers to remain relevant in their respective fields in an ongoing knowledge creation process. Such learning and transfer may bring together researchers with culturally different ideas which create conditions for new knowledge creation. Thus, learning and transfer through collaborations not only lead to research productivity (as indicated by grantsmanship and publications, as a result of knowledge creation), but also help researchers to maintain their ability for sustainable development in a knowledge economy.

Third, collaboration may reduce research costs. Bukvova's (2010) review on research collaboration finds that experimentalists tend to collaborate more than theoreticians. In experimental research, the instrumentations required are getting increasingly complex. Scientific instrumentation costs have jumped considerably with the successive generations of technology. By working together in collaboration, research costs can be shared and research facilities can be better optimized and utilized.

Fourth, collaboration may enable intellectual companionship as well. The goal of research is to expand the boundaries of knowledge. As researchers are specialized and focused, their advancement at the frontier of each research field can be lonely (Bukvova, 2010; Katz & Martin, 1997). An individual may partially overcome this intellectual isolation by collaborating with others and forming working relationships with them.

Since collaboration is important to research, social network theories may have potential in application to research management to promote collaborative relations among researchers. However, the literature review of research management and research capacity building suggests that the literature does not adequately emphasize building research collaboration networks, especially collaboration networks within an institute (but see Godley et. al., 2013).

Research Capacity Building and Research Collaboration Networks

Capacity building is a process in which individuals, groups, and institutions enhance their abilities to mobilize and use resources in order to achieve their objectives on a sustainable basis (Asian Development Bank, 2004). In the context of research capacity, it refers to the ability to conduct research sustainably.

Building research capacity is a key to both the survival of HEIs and their attainment of institutional missions (Hazelkorn, 2005). This is because the funding of HEIs is increasingly tied to the performance (Altbach, 2014; Altbach & Salmi, 2011) measured by research productivity (e.g., scholarly research publications) and impact. The current paper focuses on discussing dimensions of research capacity, rather than their measurements. Commonly accepted indicators (Cooke, 2005), such as publications and grantsmanship are used when discussing research capacity with different dimensions.

The following segments review the literature related to research capacity building. The author suggests that the literature emphasizes research capacity building at individual, organizational and inter-organizational levels. However, the interpersonal collaboration networks within institution are inadequately recognized as a form of research capacity.

Capacity Building at Individual Level

There are widespread concerns among HEIs on research capacity at the individual level. HEIs worry that they have too few researchers who have the knowledge and skill to lead the design, delivery, and dissemination of high quality research (Fowler et al., 2009). HEIs share concern that lacking such would affect their research mission attainment.

To develop the knowledge and skill of researchers, capacity building is usually carried out through professional development (Department for International Development, 2008). For example, the Teaching and Learning Research Programme (TLRP) was funded by the Economic and Social Research Council (ESRC) at the United Kingdom (UK). The programme supported and developed educational researchers across the UK through conference, training, online resources and mentorship. Wilkes, Cummings and McKay (2013) also share that a mentoring approach was

implemented in 2012 in New South Wales (Australia) to assist a group of generalist pediatricians practicing to comply with the demands in research.

Crisp, Swerissen, and Duckett (2000) characterize professional development as a bottom-up organizational approach for capacity building. The underpinning premise is that developing a core of well-trained individuals decreases reliance on external consultants and increases local capacity (Schuetzenmeister, 2010). Such development sustains institute's research efforts.

Capacity Building at Organizational Level

Research capacity can also be defined as organizational enablers, such as pro-research environments. Such enablers make an HEI better able to promote professional development of its researchers, enable research work and enhance research productivity (Cooke, 2005; Fowler, et al., 2009). In the recent research assessment exercises in the UK and Australia, organizational enablers are included as an assessment component (Olson & Merrill, 2011).

Organizational development is a top-down organizational approach for capacity building (Crisp, et al., 2000). The underpining assumption is to remove organizational factors that restrict research and to establish enabling factors that are absent. This involves improving organizational factors, such as research policy, cluture and structure. For example, the North American Primary Care Research Group Committee (2002) focuses on building a research culture to value research and to regard research as an expected and enjoyable activity. The United Nations Development Programme (2008) highlights policy, leadership, strategy and institutional reform as the enablers for research and capacity building. The North American Primary Care Research Group Committee (2002) establishes research centres as the enabling infrastructure for research.

Capacity Building at Inter-Organizational Level

From an HEI's perspective, building inter-organizational linkages deals with the external factors that promote research capacity. Contrasting with the internal factors, such as building individual staff's knowledge and organization's research environment, building inter-organizational linkages concerns with inter-organization collaborations and engagements of stakeholders and society.

The demand for building inter-organizational linkages can be traced to the argument of Network Organization (Borgatti & Foster, 2003) that organizations are embedded in the network of economic and social relations. Thus, organizations must transform themselves into networks. They need to rely on trust and embedded social relationships in order to effectively respond in the ever-changing economic environment. This idea is consistent with social network theories and was operationalized by some institutions for research capacity building. For example, the Welsh Education Research Network (WERN) develops research capacity by building collaborative partnership among all HEIs in Wales (the UK).

Crisp, Swerissen, and Duckett (2000) characterize this approach as the partnership approach and community engagement approach for capacity building. The partnerships approach involves strengthening inter-organizational relations (for example, research partnerships among universities). The community engagement approach aims to transform users of higher education

research innovations (such as industries) from passive recipients to active participants (Finn and Checkoway, 1998). Underpinning this approach is the notion of empowering beneficiaries (Mansuri & Rao, 2004). The empowerment allows an HEI's beneficiaries to be more engaged and aligned for the HEI's institutional mission attainment.

Lack of Capacity Building at Interpersonal Level

Researchers are connected into informal research teams and groups through their research collaboration relations. Rogers, Bozeman and Chompalov (2001) argue that in knowledge economy, such relationships are more important than individuals' attributes. Dulworth (2008) even purports that social networks (e.g., networks of collaboration relations) define who a person is.

Recent work suggests that some factors in collaboration can increase the likelihood of knowledge creation and thus research productivity. Research collaboration networks can play an important role to bridge knowledge flow among researchers in an institute (Easley & Kleinberg, 2010). The number of collaborators is noted as a strong predictor of publication productivity in research (Sooho & Bozeman, 2005). Krebs (2008) finds that one's ability to reach a diverse set of others in the network through very few links is a key to success for both individuals and teams. Dawson, Tan and McWilliam (2011) note that a researcher's ability to access collaboration networks is closely associated with his/her creativity potential. As research is a knowledge creation activity, creativity potential is critical for knowledge creation and research productivity.

However, the literature for research capacity building lacks adequate focus on building interpersonal collaboration networks, especially networks of collaborators within an institute. In many institutes, research participation is often advocated as an approach to increase researcher's knowledge and skill in research (Talajic, 2013). Such participation is different from doing research in collaboration, in which researchers contribute equally as peers and co-learners. Building external linkages is advocated in the literature, but the focus is usually on linkages among organizations. Interpersonal collaboration networks, especially collaborations among researchers within institutions are not adequately recognized in the literature.

To duly recognize how collaboration networks contribute to research capacity, Section Four refers to social network theories and argues that interpersonal research collaboration networks within institutions are also a critical form of research capacity. It can complement capacity building at individual, organizational and inter-organizational levels.

Collaboration Networks are Also a Form of Research Capacity

This section argues that researchers in HEIs may gain advantage in research as a result of their location in collaboration networks. Social network theories have identified that individuals and social groups may gain advantage in information flow due to their locations in social networks. Similarly, it has been theorized that generating new knowledge in research requires knowledge cross-fertilization and conflicting ideas that can be fully utilized in collaborative networks (Haylor, 2012). Thus, interpersonal research collaboration networks may facilitate knowledge flow and

create conditions for research creativity and innovation. However, the literature on the subject of research management lacks empirical studies deciphering how research collaboration networks exert such influence, the discussion in this section is thus primarily focused at a theoretical level based on the understandings established by social network theories.

The section comprises of three segments. The first two segments illustrate how research collaboration networks may facilitate knowledge flow at the individual and collective level. The third segment presents how research collaboration networks may enhance capacity building at individual, organizational and inter-organizational levels.

Collaboration Network May Lead to Individual's Advantage in Knowledge Flow

At an individual level, a researcher may gain advantage in knowledge access and flow over other researchers in the same network. This advantage could arise from his/her position in the network and transcend to the researcher's capacity in research. A social diagram illustrated in Figure 2 may be regarded as a hypothetical research collaboration network (i.e., Network 1). The diagram may be used to illustrate individuals' advantage.

In Network 1, the nodes represent researchers in an institute; the lines represent research collaboration relations among researchers (for example, researchers' involvements in research grants). Researcher C (i.e., node C) is linked with Researcher D, representing that Researcher C and Researcher D work together on a research project, for example Researcher C is the principal investigator (PI) of a project and Researcher D is a co-PI; or vice versa.

In Network 1, Researcher G has more advantage in knowledge access as compared to Researcher K. Researcher G has the largest number of linkages. This suggests that to satisfy the needs for knowledge cross-fertilization (Hanneman & Riddle, 2005), Researcher G has six alternative ways (i.e., through Researchers A-F) to gain access to new knowledge and ideas. In comparison, Researcher K only has two alternative ways (i.e., through Researchers J and L).

Compared to Researcher J, Researcher E is better able to send his/her knowledge-access request to other researchers in the network. Although Researchers E and J both have four connections to other researchers, Researcher E is closely connected to a large cluster (which is comprised of Researchers A-E on the left side of the network in Figure 2). Researcher J is only closely connected to a small cluster (which is comprised of Researchers I-L on the right side of the network). It is much easier for Researcher E to send his/her collaboration request to all other researchers in the network.

Compared to Researcher I, Researcher H has more control over knowledge flow. Researchers H and I both have two connections to other researchers, but Researcher H serves as a bridge that connects two research clusters (on the left and right sides of the Network 1) together. Dawson, Tan and McWilliam (2011) and Katz and Martin (1997) find that researchers holding bridging roles can connect different network clusters. These researchers have access to a greater diversity of knowledge, bring about perspectives from different disciplines or fields, and facilitate knowledge cross-fertilization. They can generate new insights that, when working individually on their own, would not have grasped or grasped so quickly. Thus, Researcher H has easy access to new knowledge and ideas (from both clusters) and he/she has the power to control the knowledge

flow and idea cross-fertilization between the two clusters. This power puts Researcher H in an advantaged position in research collaboration.

One may argue that Researcher E may request to collaborate with Researcher J (or Researcher I) directly without going through Researcher H, the bridge. But this may not be the case for at least two reasons. First, it may be meaningless for Researcher E and Researcher J to collaborate. For example, Researchers E and J may be doing research on science education and social science education respectively. They both join Researcher H's research project that studies the phenomena of conceptual change (in science and social science education). However, it does not make much sense for Researchers E and J to work together directly. Second, there may not be trust between Researchers E and J to collaborate. Researchers have great autonomy and freedom in engaging in research (Zalewska-Kurek, Geurts, & Roosendaal, 2010). They often do not have perfect information in choosing the right collaborator (Coleman, 1988; Govier, 1997). Even if they do, they tend to collaborate with those who they trust, rather than the one who has the right complementary knowledge and skill (Burt, 2003).

Collaboration Network May Lead to Collective Advantage in Knowledge Flow

The overall structure (for example, pattern of the research connections) of a research collaboration network in an institute may also affect the institute's ability and advantage in knowledge flow. This collective advantage can be illustrated in two ways.

First, if a network has few connections, not much power can be exerted by individuals (Kadushin, 2011). Thus the collective advantage in research collaboration is also limited. Highly connected research collaboration network potentially has more power to better facilitate knowledge flow and cross-fertilization. Such a network can better promote creativity and therefore may lead to higher productivity.

Second, even when two networks have the same number of collaboration connections, one network may gain more advantage over the other due to how the connections are structured in each network. The networks illustrated in Figure 2 and Figure 3 (below) are compared to illuminate this argument.

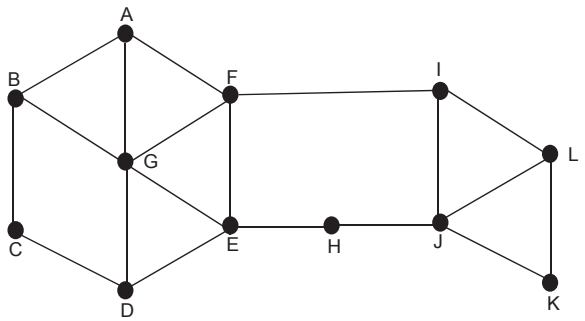

Figure 3. Network 2

Network 1 (illustrated in Figure 2) and Network 2 (illustrated in Figure 3) have the same number of nodes and connections. Network 1 is highly dependent on Researcher H to facilitate knowledge flow between the two clusters (on the left and on the right of the network). This dependency creates a high risk of network disruption for Network 1. In the event that Researcher H (or Researcher E or J) resigns and leaves the institute, knowledge flow between the two clusters will not be possible.

Network 2, on the other hand is less reliant on any particular researcher to bridge the two research clusters. The network has more bridges between the two clusters (for example, from Researcher F to Researcher I, and from Researcher E to Researcher J via Researcher H). In fact, the left and right clusters are less obvious in Network 2. The network may be better regarded as one cluster, instead of two. Network 2 may have more potential to cross-fertilize knowledge and research ideas which may lead to higher research productivity, as compared to Network 1.

The above comparison between Networks 1 and 2 only intuitively demonstrates the existence of collective advantage. In SNA, the collective advantage of a social network can be measured and analyzed mathematically for comparison. Readers may refer to the literature of SNA for such analysis.

Increasing Capacity at Individual, Organizational and Inter-Organizational Levels

If properly engaged, the interpersonal research collaboration networks may also promote capacity building at individual, organizational and inter-organizational levels. First, research collaboration networks allow researchers to utilize relationships to increase their capacity and productivity (Hatala, 2009; Ramanadhan, Kebede, Mantopoulos, & Bradley, 2010). Sooho and Bozeman (2005) study the correlation between collaboration and publication. They find that researchers who spend a higher percentage of time working alone are less likely to be productive in publication.

Hatla (2009) recognizes that an individual researcher's ability to access social network resources could lead to his/her professional success. Hasan and Pousti (2006) argue that even in large highly-structured organizations, collective knowledge-building at small-team level is the predominant source of learning, creativity and innovation. Tacit knowledge, especially new advancements in each discipline may not be necessarily documented in publications. Collaboration networks can foster transferring new knowledge, especially tacit knowledge among researchers (Sluijs-Doyle, 2009). Such knowledge transfer through research collaboration networks could enhance individuals' professional development.

Second, research collaboration networks may also enable organizational development, but Marjanovic, et al. (2013) in a critical evaluation of the existing literature on research capacity building argue that the current focus is on policy-relevant issues at a relatively high-level. There is a need to emphasize how research collaborations influence organizational development. Borgatti and Foster's (2003) summary from the literature of classic social psychology highlights that the amount of interactions, similarity of beliefs and attitude, and affirmative ties are interrelated. As researchers collaborate, they develop common meanings, beliefs, and mutual understandings. This process is called *homophily* (Kadushin, 2011) in the literature on social network theories. *Homophily* is further discussed in the next section as a mechanism for building collaboration

networks. Through the process of *homophily*, collaboration networks among researchers may bring about stronger and more aligned voice from researchers to push the change of institutional rules for research (for example, pushing to reduce bureaucracy in research-related procurement).

Research collaboration networks may also support the development of inter-organizational collaboration and engagement. A further research finding on weak/strong ties is that people who are connected by strong ties are likely to share common friends as well (Granovetter, 1973). This means that researchers in a collaboration network (within an institute) that has dense and coherent connections are likely to share other connections (for example, external collaboration connections) in common. More dense and coherent connections among researchers within an institute also put the institute at a stronger position when negotiating collaboration arrangements with external partners and stakeholders.

With the inclusion of interpersonal research capacity argued in this paper, a more holistic perspective (as illustrated in Figure 4) is that research capacity building constitutes building capacities at individual, interpersonal, organizational and inter-organizational levels. Research capacity at interpersonal level is primarily contributed by research collaboration networks (within an institute).

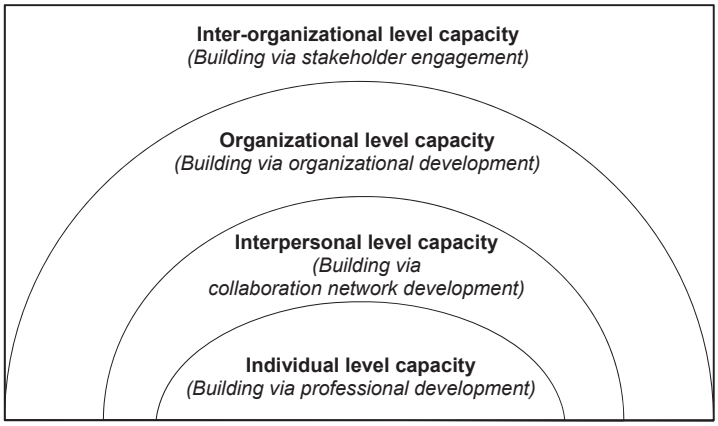

Figure 4. A holistic perspective on research capacity building

However, building research collaboration networks to increase an institute's research capacity is not an easy task. Section Five makes reference to social network theories to present three underpinning mechanisms for building research collaboration networks. The challenges in building research collaboration networks are highlighted in Section Six.

The Mechanisms of Building Collaboration Networks

The formation and development of collaboration networks are organic in nature. Cross, Parker and Sasson (2003) point out that members of a collaboration team must have trust among each

other. Members know that honesty expressed during the team's activity will not be used against them. This explains why most research collaborations are conducted by informal groups. In these groups, researchers are binding together mainly by trust, rather than by institutional arrangements.

To understand how collaboration networks are formed and developed as well as how they contribute to research productivity, *propinquity* and *homophily* are synthesized from social network theories as two key organic mechanisms for building social networks. Research productivity requires knowledge flow and crashing ideas. This makes research collaboration networks unique from normal social networks. This section also discusses why *heterophily* is critical to research capacity and productivity.

Propinquity

The first mechanism is *propinquity* (Kadushin, 2011), which suggests that spatial proximity can lead to social proximity. Individuals are more likely to be friends if they are located geographically close to each other (Kadushin, 2011). Perhaps this is because of the low social transaction cost between individuals who are spatially close.

Propinquity exists in research collaborations. Sooho and Bozeman (2005) study the patterns between collaboration and publication. They find that for researchers who collaborate, more than half of their collaborations are with colleagues in their same institute. Cantner, et al. (2010), Borgatti and Foster (2003) and Katz and Martin (1997) also find that close physical proximity seems to encourage collaborations, perhaps because it tends to generate more informal communications.

Thus, turning physical proximity into social proximity and then to research productivity is important in building research collaboration networks.

Homophily

Homophily (Kadushin, 2011) is the second mechanism. It implies that similarity breeds connection (McPherson, Smith-Lovin, & Cook, 2001): birds of a feather flock together. *Homophily* also suggests that people in the same social group tend to become homophilous over time (Kadushin, 2011).

The exchange of ideas occurs most frequently between individuals who are alike, or homophilous (McPherson, et al., 2001). Individuals enjoy the comfort of interacting with others who are similar. Communication is also more effective when source and receiver are homophilous, for example, when they share common meanings, beliefs, and mutual understandings. Stvilia et al. (2011) observe that collaborations between researchers of different rank are less common. Even such collaborations do happen; they have less impact on research productivity than collaborations between researchers of the same rank.

Homophily also produce homophilous group members over time. Borgatti and Foster (2003) note that amount of interactions, similarity of beliefs and attitude as well as affirmative ties are interrelated. The network organization theory (Sluijs-Doyle, 2009) affirms that networks create group tastes and preferences, and inspire conformity in thought and action among members in the network (Burt, 2003; Coleman, 1988).

Thus *homophily* creates a self-reinforcing positive feedback loop: similarity breeds connection and connection produce more similarities. The self-amplifying feedback loop leads to the establishment and stabilization of a social network in an organic manner from bottom-up.

Homophily exists in research collaborations. Interconnectedness of scientists promotes the diffusion of scientific knowledge and capacity (Wagner & Leydesdorff, 2005). The discussion in Section Four suggests that people do not have perfect information in choosing the right collaborator in research. Even if they do, they tend to collaborate with who they know and trust. Thus, research collaborations also reinforce *homophily* within a collaboration network.

Compared to establishing a new collaboration network, it is more effective to build research collaborations by leveraging on *homophily* in existing networks. Kezar (2014) reviews change in education setups noting that existing social networks are more influential than networks created as part of the change process (Coburn & Russell, 2008; Cole & Weinbaum, 2010). Change is more likely to be successful if it is built upon existing social networks, because trust and *homophily* already exist in these networks (Moolenaar & Sleegers, 2010).

Heterophily

Social network theories suggest that a certain degree of *heterophily* (Kadushin, 2011) is also critical for the success of an organization. This is particularly important for research collaborations because research creativity requires integration of ideas and perspectives from different fields or disciplines, or in another word, *heterophily*.

Heterophily refers to "love of the different". Rogers, Medina, Rivera and Wiley (2005) suggest that diversity of ideas promotes innovations. Granovetter (1973) uses weak ties to illustrate the importance of *heterophily* in communication. Weak ties are those ties 'outside' the core connections that any members of an existing coherent social network has. Granovetter demonstrates that weak ties can serve as bridges, allowing the flow of knowledge and information between two otherwise unconnected networks (e.g., two unconnected groups of friends). While information spreads efficiently among members connected by strong ties, it is usually weak ties that bring in new information (such as clashing ideas) that is crucial for knowledge creation in collaboration. Therefore, a certain degree of *heterophily*, such as weak tie, is necessary for creativity and productivity in research collaborations.

Some Challenges in Building Research Collaboration Networks

While the organic mechanisms appear to be simple, this section highlights some challenging issues in building research collaboration networks. These issues are not meant to be exhaustive. The purpose is to illuminate the complexity in building research collaboration networks and to invite more discussions and dialogs in order to advance the theory and practice of building interpersonal research capacity.

Three issues are selected for discussion in this section. The first issue arises from empirical findings which suggest that collaboration networks have nonlinear effect on research productivity. Therefore designing and maintaining a collaboration network at a sweet spot, where vision is

clear, goals are compelling, people see ways to contribute, progress is tangible, and everyone believes that they can succeed, can be challenging. The second issue is derived from a theoretical argument that *homophily* may have double-edged effect on collaborations. Thus maintaining a good balance between *homophily* and *heteophily* is a challenge. The third issue is on management's role in building collaboration networks. If management is to take a proactive role in building collaboration networks, there is a need to explore analytical tools to inform and support their decision-makings.

Challenge 1: The Nonlinear Effect of Collaboration Networks

The literature on research management suggests that more research collaborations do not always lead to higher research productivity. This is because some factors, such as size of membership and member's social position in a collaboration network have nonlinear effects on research productivity. Thus, there is a need to identify and maintain research collaboration network (in an institute) at certain sweet spot.

Empirical evidence reveals that the size of a collaboration group only has a linear effect on research productivity within certain upper and lower thresholds. Kenna and Berche (2011) examine the data from British and French higher-education research-evaluation exercises. They find that research quality increases with group size, but only up to a limiting threshold referred to as an upper critical mass. Similarly, von Tunzelmann, Ranga, Ben and Geuna (2003) also reveal that growth in productivity declines above a certain group size threshold. O'Leary, Mortensen and Woolley (2011) study multiple team membership and productivity. They note that the variety of teams that an individual works as members reduces productivity, even though such collaborations increase the diversity of information and knowledge that the individual and teams encounter. Martín-Sempere, et al.'s (2002) research on the consolidation of research teams suggests that consolidation could result in a substantial improvement of researchers' capability to establish contacts and collaborations with colleagues. Such consolidation could therefore favor researchers' potential to publish in quality publications. Heinze, Shapira, Rogers and Senker (2009) also identify that for groups in natural science, a size of five to six members seems to be optimal. These findings imply that an optimal group size is desired to enhance productivity in research collaboration.

Member's position in a collaboration network also affects his/her productivity in collaboration. Hansen (2009) finds that there is a difference between those teams that have many direct connections to other project teams and those that use both direct and indirect ties to reach the resources they need. Vardaman et al. (2012) demonstrate that an individual's degree of centrality in a collaboration group is positively and significantly related to his/her productivity. Bukvova's (2010) review show that the collaboration's effect on productivity depends on the type of links collaborative members have. While collaboration with high-productivity scientists tends to increase personal productivity, collaboration with low-productivity scientists generally decreases it. These findings suggest that optimizing an individual's social connections to enhance productivity is a challenge to overcome too.

In summary, the empirical findings suggest that there is a need to maintain research collaboration network at an optimal size and to build critical bridges for knowledge flow among different collaboration clusters. These are to be done carefully with an aim to optimize knowledge flow and productivity in research collaboration. However, what the optimal size is and how to identify a critical bridge to build are challenges to overcome.

Challenge 2: The Double-Edged Effect of Homophily

Homophily (Kadushin, 2011) is a key underpinning mechanism for building social networks. As discussed in Section Five, *homophily* creates a self-reinforcing positive feedback loop that leads to the establishment and stabilization of a social network from bottom-up. However, *homophily* may also produce negative effect on research productivity.

First, *homophily* may generate negative effect on knowledge cross-fertilization. *Heterophily* leads to idea diversity and cross-fertilization and generates new insights (Katz & Martin, 1997; McPherson, et al., 2001). Thus, research creativity requires degrees of *heterophily*. However, *homophily* makes heterophilous communications difficult to take place. Heterophilous communications is less frequent as compared to homophilous communication. Patterns of ties among individuals in a homogenous network constrain the knowledge flow between homophilous individuals in the network and their heterophilous counterparts from a far distance of the network. How to foster more frequent communication between heterophilous individuals is a challenge.

Even when frequent homophilous communication is fostered, *homophily* may also dilute *heterophily* when there is too much heterophilous communication. Rogers, Medina, Rivera and Wiley (2005) suggest that certain degree of *heterophily* is needed to promote innovation and diffusion of innovation. However, *homophily* suggests that heterophilous individuals, when their frequency of communication increases, can be homogenized over time. Identifying an optimal balance between *homophily* and *heterophily* is a challenge.

Even an optimal balance can be identified, maintaining the balance is also a challenge. Bradeley, Hausmann and Nolan (1993) characterize social networks as being less stable and more organic than functional hierarchies. New networks are regularly and instantaneously formed, not from top-down, but from bottom-up influenced by collaborations and day-to-day interactions. The organic nature of collaboration networks makes the control of the network-building process difficult or even not feasible.

Second, group taste and preference produced by *homophily* may sometimes prevent groups from adapting in fast changing research environments. Social interactions among people give members a sense of identity and common purpose through the process of *homophily*. At the same time, the identity and common purpose also constrain the evolution of identity and purpose into the future (Woolcock & Narayan, 2000). This creates 'path dependency' (Holland, 1995) in a complex evolution process: future evolution is both supported and constrained by the current status. Thus, the patterns of ties and network norms created by *homophily* can be both strength and constraint; both promise and obligation.

In summary, the social network theories suggest that maintaining an optimal balance between degrees of homophily and heterophily is a critical challenge to successful innovation and capacity building.

Challenge 3: Management's Role in Building Collaboration Networks

The first two challenges discussed above suggest that building collaboration networks is challenging. A follow-up issue is whether management should play a proactive role in building research collaboration networks. If it does, how can it perform this role?

This paper argues that management should take such a proactive role. Coburn, Choi and Matta (2010) importantly critique the tendency to overly focus on the organic nature of social networks and not look at ways that organization could influence or support the development of networks. Ron Burt (2000) asserts that managing an organization's social capital is becoming one of the core competencies in knowledge-based organizations. Scholars such as Reagans and McEvily (2003), Tilly (2005) and Mansuri and Rao (2004) have also made similar arguments.

More specifically, Castells (2011) argues that management has a role to create goal alignment when building social networks. He argues that once a goal is programmed to a network, the network would have greater capacity to perform efficiently and to reconfigure itself in terms of ties and nodes to achieve its goals (for example, for an institute's mission attainment). Moolenaar and Sleegers (2010) suggest that management can perform this role more successfully if it leverages existing social networks, because trust already exists. Thus, this paper argues that management should take a proactive role to stimulate and influence interactions and development with a commensurate degree of governance in directing research.

It is not possible to prescribe ways in which management foster goal alignment and build collaboration networks. Castells (2011) points out that how different networks are programmed for goal alignment is a process specific to each network. Power relationships at a particular network have to be identified and understood in terms specific to the network. Thus, a useful exploration is to identify tools that can support management in addressing the two issues discussed above.

One possibility is to identify analytical tools to analyze research collaboration networks to inform and guide the building process. IBM (2013) advocates that in knowledge economy, management should use analytics, not instinct. Social Network Analysis (SNA) (Burt, et al., 2013) can be such an analytical tool. SNA is the study of the patterns of social relations by examining how the structure of social relations allocates resources, constrains behavior, and channels social change. It is based on the assumption that the success or failure of societies and organizations often depends on the patterns of their internal social structures (Martin & Wellman, 2010). The tool has been increasingly used to study the structures of social networks. With the theoretical framing established in this paper, another paper is being prepared by the author to highlight how SNA can be used to support the development of research collaboration networks and the building of research capacity.

It is also important to note that while the above three issues have highlighted some common issues across disciplines, there are also discipline-specific variations to be considered in building

research network capacity. For example, Sooho and Bozeman (2005) study the collaboration patterns across disciplines. They find that researchers in computer sciences and electrical engineering tend to have more collaborators whereas researchers in biological and life sciences as well as civil engineering much less. If HEIs adopt the strategies proposed in this paper to build research network capacity, the desired level of collaborations should be calibrated according to the sweet spots in each discipline.

Conclusion and Discussions

In summary, this paper argues that collaboration is important for research and research collaboration networks can contribute to HEI's research capacity and productivity. In the existing literature, research capacity focuses on three dimensions: individual's professional development, organization's policy, culture and structural enablers, and inter-organizational linkages. This paper broadened the perspectives of research capacity by advocating for an additional dimension of research capacity: the interpersonal capacity arising from research collaboration. The argument is significant to the theory and practice of research capacity building.

Research collaboration networks are best developed organically from the bottom-up, rather than superimposed from top-down. However, the literature does not provide an adequate understanding of how to build research collaboration networks to improve research productivity. This paper drew references from social network theories and highlighted *propinquity, homophily* and *heterophily* as three key mechanisms for building research collaboration networks. These mechanisms suggest that similarity and physical proximity breed social connection and at the same time, social connections lead to more similarities. Maintaining degrees of *heterophily* is thus critical for research creativity and productivity. By connecting social network theories with the literatures on research management and research capacity building, this paper suggested a new avenue to advance the theory and practice of research capacity building in specific and research management in general.

However, the practice of building research collaboration networks to improve research productivity can be challenging. Three issues were presented to illuminate the complexity. First, empirical studies suggest that collaboration networks have nonlinear effect on research productivity. More collaboration connections do not always lead to higher research productivity. Being able to develop and maintain collaboration networks at certain sweet spot, or sustainable network of interactions with clearly defined goals, is critical and challenging. Second, heterophilous communication is hard to foster, and too much heterophilous communication may lead to *homophily*. This may negatively affect knowledge cross-fertilization in collaboration. These two issues led to the third issue for discussion: how management can take a proactive role in building and optimizing research collaboration networks. Invention of analytical tools to inform and support research management is necessary.

One way for management to deal with the issues is to engage SNA as a tool to inform and guide the building of research collaboration networks. While SNA can be one possible solution, explorations of possible solutions in breadth and depth are needed. The three issues and the possible solutions are debatable in order to further advance the theory and practice of building collaboration networks.

Readers should also note the limitations of this paper. First, while this paper primarily argues for the importance of relational properties, the properties of individuals should not be neglected. Second, the disciplinary differences is noted in this paper but is not examined further. Nevertheless, by expanding the dimensions of research capacity and by introducing social network theories into research capacity building, this paper contributes to the expansion of the literature of research management and perhaps even the literature of social network theories. It also informs the practice of research management, in particular the practice of building research capacity at interpersonal level.

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Correspondence concerning this article should be addressed to Jun Song HUANG, PhD, Tel: +65-62196177, Email: junsong.huang@nie.edu.sg. The author was the Head of Education Research Administration and Communication at the National Institute of Education Singapore before he obtained a PhD degree in 2014 and pursued his research interests as a research scientist. This paper is the crystallization of his research-management experience in the past ten years. The article is based on presentations at the first international meeting of the National Council of University Research Administrators (NCURA) and the annual congress of the International Networks of Research Management Societies (INORMS) in 2014. The presentations showed how Social Network Analysis (SNA) was used to build research collaboration networks and research capacity in a HEI. The author thanks Associate Professor Victor Chen at the National Institute of Education (Singapore) and the editors of the Journal of Research Administration for their helpful suggestions and constructive critiques.

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