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Knowledge Society Network: Toward a Dynamic, Sustained Network for Building Knowledge

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Abstract. The Knowledge Society Network (KSN) is a bold design experiment that takes advantage of new knowledge media to maximize society's knowledge resources and the effective and equitable mobilization of knowledge. This exploratory study investigated the relationships between network structures and knowledge advancement in the KSN over four years (2002-2005), from a sociological perspective. Four major sub-network structures for collaboration and knowledge-interaction are described, as reflected in social network analysis of discourse in the KSN. Strengths and weaknesses of work within each sub-network were identified and suggestions for creating a more dynamic, sustained network for knowledge advancement are proposed.

Introduction

Society is being transformed into a "knowledge society" (Drucker, 1986). The advances and ubiquity of communication and Internet technology provide new forms of connectivity for traditionally-dispersed and loosely-bound knowledge workers, transforming the nature and process of knowledge work. As described in a recent UNESCO (2005) report titled *Towards Knowledge Societies*, "The magnitude of technological change, which over recent decades has affected the means of knowledge creation, transmission and processing, have brought a number of experts to hypothesize that we stand on the threshold of a new era of knowledge" (p.47). The Knowledge Society Network (hereafter KSN) is created under such background and is created as a bold design experiment that aims to maximize society's innovative capacity by taking advantage of new knowledge media (Scardamalia, 2003; Scardamalia, Hong, & Zhang, 2006).

Arguably, the main challenge for 21st century education is to initiate students into a knowledge-creating culture. KSN's educational thrust is toward meeting this challenge by immersing even very young students in environments where their main job is knowledge creation (with learning as a by-product). A different but equally challenging effort is bringing knowledge building into the work lives of professional groups (e.g., teachers, bankers, and health care practitioners) who see their job as delivery of quality service rather than advancing the state of the art. Accordingly, much of KSN's work has focused on what it means to create knowledge in these less obvious contexts and how knowledge building can succeed in such contexts, where other sorts of demands are usually paramount. Broadly speaking, the shared goal of KSN participants is to advance knowledge building theory, pedagogy, technology, and practical know-how on enough fronts that it can make a difference to give all citizens a chance to be productive members of a knowledge society.

Characteristics of the KSN

Networks are ubiquitous. What is distinctive about the KSN? The following points offer a partial answer:

(1) Interdisciplinarity. The KSN represents a multidisciplinary mix of the knowledge,

information, and learning sciences. The learning sciences were founded in recent years and were defined from the beginning as an interdiscipline, and they have since expanded to include additional relevant disciplines. Largely through initiative of the U.S. National Science Foundation, neuroscience has come to play an important (in some laboratories, dominant) role in the Science of Learning Centers. Although KSN includes one brain research group doing notable research related to cognitive development and learning, it is distinguished by embracing an emerging discipline relatively neglected in the U.S. initiatives: the "knowledge" sciences. "Knowledge science" originated in the context of artificial intelligence and knowledge engineering and was primarily concerned with knowledge acquisition—gaining usable access to what people know (Gaines & Boose, 1988). Since then, interest has grown in knowledge creation as a theoretical problem (Bereiter, 2002; Dennett, 1995), a cultural imperative (Homer-Dixon, 2000), a practical objective (Nonaka & Takeuchi, 1995; Wickramasinghe, 2006), and a locus of socio-political controversy (Pestre, 2003);

(2) <u>Size and international scope.</u> With approximately 400 active participants, KSN is considerably larger than other research-oriented networks in the field. Moreover, the KSN reflects its worldwide membership in its day-to-day activities, bringing an international perspective from more than 20 nations to bear on core problems;

(3) <u>Inclusion of practitioners.</u> Most research groups can claim to have close working relations with practitioners. Nevertheless, a "conveyor belt" model still characterizes most groups: New knowledge originates with researchers and problems of application are worked out in collaboration with practitioners. By contrast, in KSN teachers and even young students produce research and innovations and present them at scholarly meetings;

(4) <u>Conceptual basis.</u> The core concept that has unified and given direction to work of the KSN is *knowledge building*. The term "knowledge building," which appears in 1,400,000 Web documents, refers to the production and improvement of public knowledge of value to a group (Scardamalia & Bereiter, 2003). The competitive demands of a knowledge-based economy and the complexity of urgent societal problems converge on a need to greatly enhance knowledge building capabilities.

A Dynamic Model of Networked Knowledge-Building

Knowledge building theoretical and technological designs make the KSN possible and distinct from other network designs. In the following section, we describe a dynamic model of networked knowledge building that underlies the design of the KSN. We describe this model by elaborating knowledge-building dynamics at three levels of network complexity (see Table 1 for summarized points at each level).

Table 1. Knowledge-Building Dynamics at Three Levels of Network Complexity

Levels	Individual ideas	Networks of ideas	Network-of-networks
Focus of knowledge building dynamics	Idea-centered knowledge work - Idea generation	Sustained knowledge innovation - Idea improvement	Self-organizing knowledge networks - Collective creation of innovative ideas
Theoretical underpinnings	- Objective epistemology (Ideas as	- Network theory (collaboration vs. knowledge-interaction)	- Self-organization theory

	conceptual artifacts)		
Technological architecture	- Idea-centered design	- Object-oriented design - Within-views designs (for in-depth collaboration) and between-views designs (for in-breadth knowledge-interaction)	- Decentralized governance - Hubs of innovation - A community of communities

Note: The three levels should not be treated as distinct, but should be regarded as a continuum.

1. Idea-centered knowledge work

1.1 Theoretical underpinnings

The idea that conceptual entities belong to the world, not simply to individual minds, draws on Karl Popper's (1972) three-world epistemology. World 1 refers to physical and material reality; World 2 refers to reality as mental states created in the human mind; and World 3 refers to reality constructed by conceptual objects. World 3 is especially important because of humans' exceptional capacity to understand and develop conceptual entities that belong to the world.

Carl Bereiter, Marlene Scardamalia, and colleagues (Bereiter, 2002; Bereiter & Scardamalia, 1996; Scardamalia, 1988) established the concept of "knowledge-building" as a foundational approach to collective knowledge work for the improvement of epistemic artifacts (e.g., ideas, concepts, theories, models, and other knowledge constructions). In its essence, it argues that there is a difference between learning and knowledge-building. Learning is activity directed towards enhancing personal knowledge (Polanyi, 1962; 1967), whereas knowledge building is a social, idea-centered process aimed at continually improving ideas represented as community knowledge (Bereiter, 2002; Bereiter & Scardamalia, 1996; Scardamalia, 1999; Scardamalia, Bereiter, McLean, Swallow, Woodruff, 1989; Scardamalia & Bereiter, 2003; in press). An important distinction between personal and community knowledge is that the former emphasizes a psychological concept of knowledge and thus sees knowledge as possessed within an individual's mind (Hyman, 1999; Popper, 1972). On the contrary, the latter highlights a social concept of knowledge and hence sees knowledge as a conceptual object that has a public life (Bereiter & Scardamalia, 1996; Hyman, 1999; Popper, 1972). A common belief in schools today is to learn first and innovate later; and typically innovation will not happen until students reach the level of graduate study. On the contrary, knowledge building puts innovation in the foreground and suggests that even students at very young age have the capacity to generate and improve ideas; and therefore fostering students' innovative capacity should be regarded as the primary goal at all levels of education.

1.2 Technological design

The theoretical framework of knowledge building underlies the technological design of the Knowledge Forum®, a computer-supported knowledge building environment created in pursuit of sustained knowledge advancement. Knowledge Forum is a second-generation CSILE (Computer-Supported Intentional Learning) product—the original medium designed to support a world-3 conceptualization of knowledge, and thus to give student ideas a public life. As a general introduction, Knowledge Forum represents a multimedia community knowledge space where participants contribute their ideas in the form of *notes*[1] to *views*, which are virtual problem spaces for collaborative inquiry and discourse among community members. The Knowledge Forum environment enables participants to *co-author notes*, *build-on* and *annotate notes* of others, generate *problems* and add *keywords*, and create *rise-above notes* to summarize different *notes* with related ideas.

At its simplest level of network complexity, Knowledge Forum is designed as an environment to foster idea generation. Figure 1 shows some selected interface design features of a knowledge building *note* to illustrate this point.

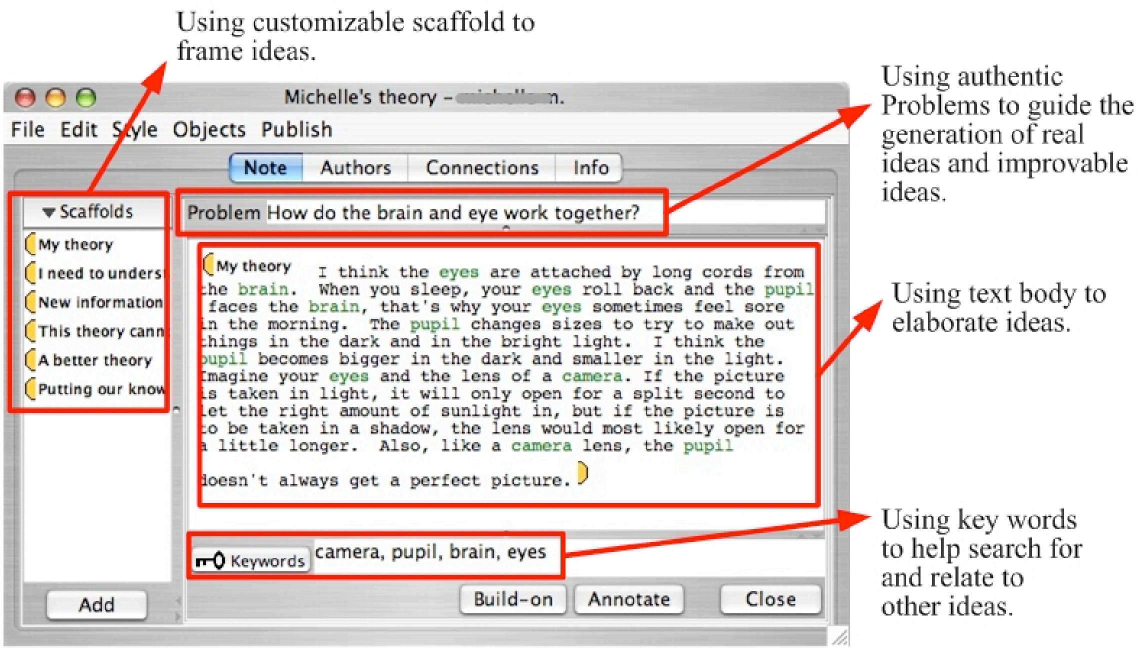


Figure 1. Some Selected Design Features in Relation to Idea Generation

2. Sustained knowledge innovation

2.1 Theoretical underpinnings

According to social network theory (Newman, 2003), the attributes of individual entities are less important than their relationships (or ties) with other individual entities within a network when explaining complex real-world social phenomena. The process of knowledge building is fundamentally social and idea-centered (Scardamalia, 1999). Ideas and knowledge workers who work with these ideas are essentially the individual entities of knowledge building networks. To understanding the complex dynamics of knowledge building, it is thus necessary to understand the relational behaviors between ideas and knowledge workers in the networks to which they belong.

Arguably, ideas can be improved in two dimensions: depth and breadth. From a social perspective, the former is a function of how knowledge workers (epistemic agents) collaborate together in improving ideas, i.e. the intensity of collaboration; whereas the latter is a function of how ideas (conceptual/epistemic artifacts) interact with each other, i.e., the extent of knowledge-interaction between ideas. Building on this definition of idea improvement, below we further elaborate the core of the dynamic model of networked knowledge-building.

[1] Throughout the paper, the terms in *italics* are used to refer to the unique terminology in a Knowledge Forum.

Idea evolution. Figure 2 shows the relationships between collaboration and knowledge-interaction. In it, the X axis represents the intensity of collaboration, which is defined as the number of collaborative ties between any two knowledge workers who work with the same ideas (thus the depth of ideas). The Y axis represents the strength of knowledge-interaction, which is defined as the number of interactions between any two ideas in a given network (thus the breadth of ideas).

A central argument for an idea-centered knowledge-building approach is that ideas, once generated, should have a public life to support the process of continual improvement. But this does not imply that all ideas will be transformed equally. Depending on the dynamics of a network, some ideas may interact, and be elaborated, more than others. Stated differently, once generated, each idea may take a very different evolutionary course.

Figure 2 exemplifies three representative trajectories towards idea improvement. The upper trajectory—idea elaboration—is a course most likely to lead ideas to gain depth due to knowledge workers' collective work (co-elaboration); the bottom trajectory—idea diversification—is a course most likely to lead ideas to gain breadth due to exchange of perspectives between knowledge domains (e.g., fields or disciplines). But it is only the middle trajectory—idea improvement—that represents a course most likely to lead ideas to gain both depth and breadth, and it is posited that this is a course most likely to lead knowledge work into the realm of knowledge innovation.

Idea transformation. Knowledge building can be defined as the production and continual improvement of ideas of value to a community (Scardamalia & Bereiter, 2003), and through this process, ideas evolve. Figure 2 also shows three possible forms that ideas might be evolving into: information, knowledge, and innovation (i.e., more innovative ideas). Although the terms "information" and "knowledge" are often used interchangeably, their concepts are fundamentally different. According to Dretske (1981), Information is "commodity capable of yielding knowledge" (p.44), whereas knowledge is "information-produced (or sustained) belief" (p.86). Based on these definitions, when an idea is simply given to or taken from others (as if it is an article of commerce), without being intellectually challenged and elaborated, it tends to become information. Nevertheless, exchange of ideas between knowledge domains still has its value as it would help increase a knowledge domain's idea diversity. On the other hand, when an idea (e.g., the earth is round) engages intellectual efforts in confirming or falsifying pre-existing beliefs (e.g., the earth is flat), it is more likely to become knowledge. However, if knowledge is practiced within only certain limited domains, without being shared, the possibility of further innovation is limited. As a famous example, for more than half a century two laws, one in chemistry and one in physics, remained relatively disconnected until Albert Einstein's $E = mc^2$,i.e., the Law of Conservation of Mass-Energy, united them: (a) the Law of Conservation of Mass (which was discovered by Antoine Lavoisier; in its most compact form, it states: matter is neither created nor destroyed) and (b) the Law of Conservation of Energy: (which was discovered by Robert Mayer; in its most compact form, it states: energy is neither created nor destroyed[2]). Idea improvement and innovation require both depth and breadth. From a knowledge building perspective, there is no end to this process.

[2] The two laws are being taught separately in Chemistry and in Physics in high school even today.

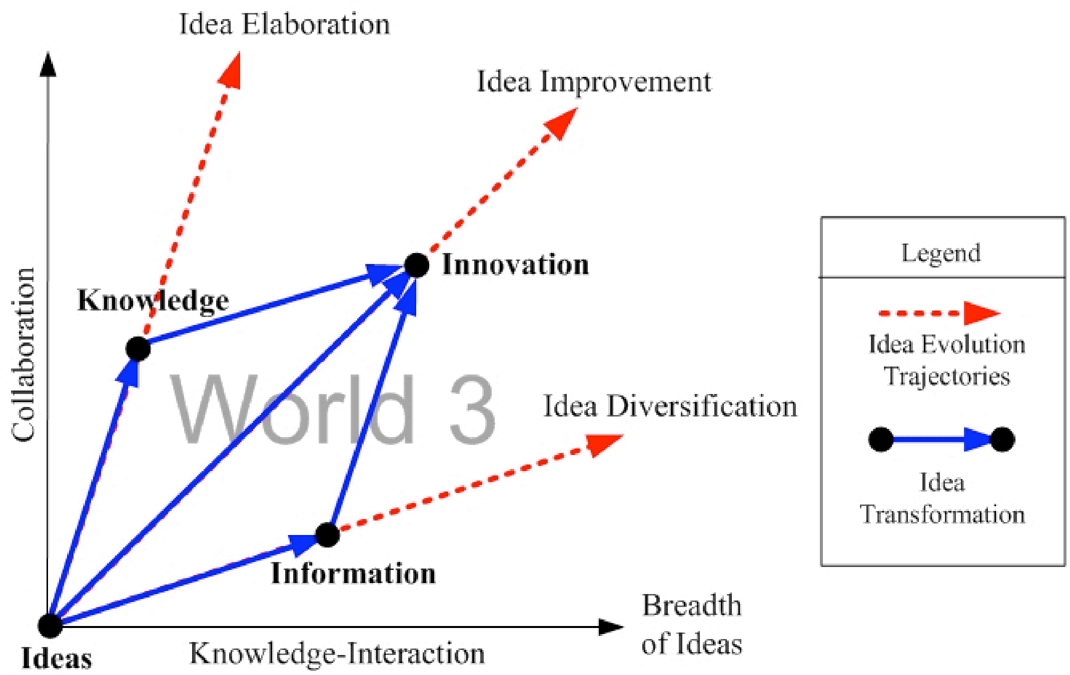


Figure 2. Idea Evolution Trajectories and Idea Transformation

<u>Four network models.</u> As the main interest of this paper is network design, a follow-up question to ask is: What kind of network structure would best foster idea improvement, both in terms of depth and breadth? Figure 3 shows four possible network models based on the degree of collaboration and extent of knowledge-interaction, along a weak - strong continuum. Of the four network models, Quadrant 2 tends to represent a domain-specific knowledge network, due to its strong collaboration but weak knowledge-interaction. Such network structure may enable idea elaboration and within-domain advances, but its innovative capacity will be limited by lack of fresh or diversified perspectives from without (Chubin, 1976; Granovetter, 1983). Unfortunately, in reality, most networks in research, business, and scientific groups are like this (i.e. domain or discipline specific), where innovative ideas are considered as valuable intellectual properties. Sharing is low. They lack the knowledge building principle of symmetry in knowledge advancement. Due to strong knowledge-interaction but weak collaboration, Quadrant 4 tends to represent an information-sharing network. Apparently, the strength of such network lies in its capacity to broaden perspectives by means of idea diversification, but lacks capacity to transform ideas into deep knowledge, again limiting innovation potential (Kline & Rosenberg, 1986). Regrettably, many Internet-based education-oriented networks are created for information sharing, not idea improvement.

In contrast, Quadrant 1 tends to represent a more optimal network for knowledge innovation. With both strong collaboration and strong knowledge-interaction, interactions are more conducive to both idea co-elaboration and diversification. Examples of such network include open source programmers who not only collaborate together across domains (idea co-elaboration) but also share their ideas by exchanging open-source code (idea diversity) (Evans & Wolf, 2005). Quadrant 3 represents an emerging network with relatively weak collaboration and weak knowledge-interaction for enhancing the depth and breadth of ideas. Heuristically, it represents a network with the least capacity for knowledge innovation. In summary, each network model described here could represent a complete, self-sustained network, or it could represent a subnetwork within a larger network. The question to ask next is how to develop more innovative networks.

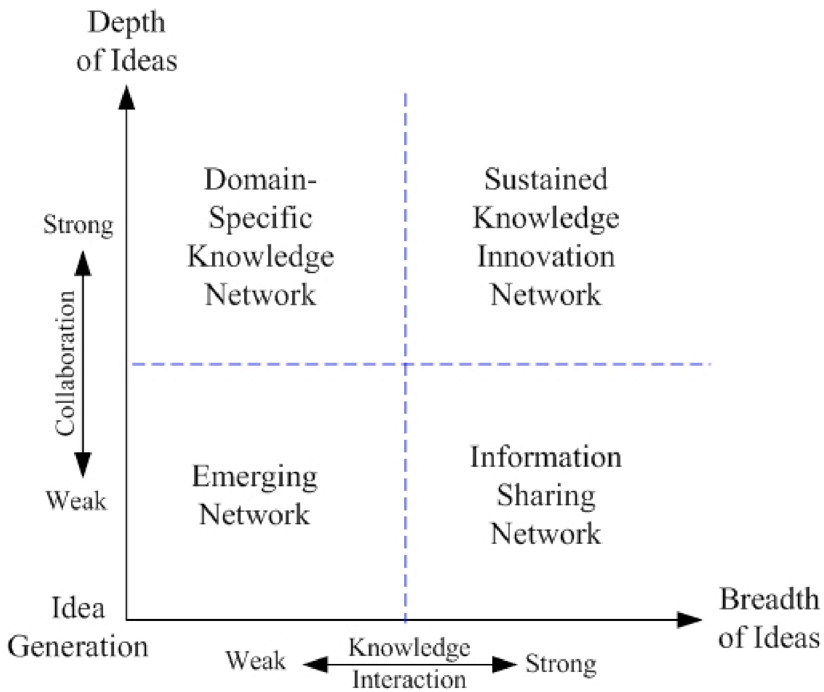


Figure 3. Four Network Models

<u>Four types of network behaviors.</u> The two essential network entities, ideas and knowledge workers support four basic network behaviors: divergent and convergent knowledge-interaction, and sustained and opportunistic collaboration (see Figure 4). Each relational behavior is unique in terms of its purpose, and is defined by the direction of idea transformation and by the type of a network.

First, divergent knowledge-interaction refers to the increasing breadth of ideas by allowing more frequent information flow between knowledge domains (be it conceptual/disciplinary, or physical/work units-based). Second, sustained collaboration refers to greater depth of ideas by engaging knowledge workers in more sustained knowledge inquiry (i.e., working more closely with related ideas) within a knowledge domain. These modes of network behaviors are essential and critical to cultivate the innovative capacity of a networked community. From a cultural perspective, the process is one of initiating a network community into a knowledge-building culture by gradually transforming less innovative ideas into more innovative ideas.

Third, convergent knowledge-interaction refers to the re-configuration of the already diversified ideas by rising above them for further knowledge work and, at the same time, engaging a more focused collaboration among knowledge workers from different knowledge domains. Fourth, opportunistic collaboration refers to the process of adding breadth to ideas already explored in-depth, and moving to a higher plane through recursive processes aimed at idea improvement.

The behaviors are important for transforming domain-specific and information-sharing networks into knowledge-innovation networks. It is important to note that all four network behaviors could occur anytime in a network or subnetwork, but the reason why convergent knowledge-interaction and opportunistic collaboration are not helpful for emerging networks (or sub-networks) is that when ideas are not diversified (no breadth), convergence is not necessary, and when ideas are not elaborated (no depth), opportunistic collaboration may only add superficiality, to ideas (Everitt, 2005).

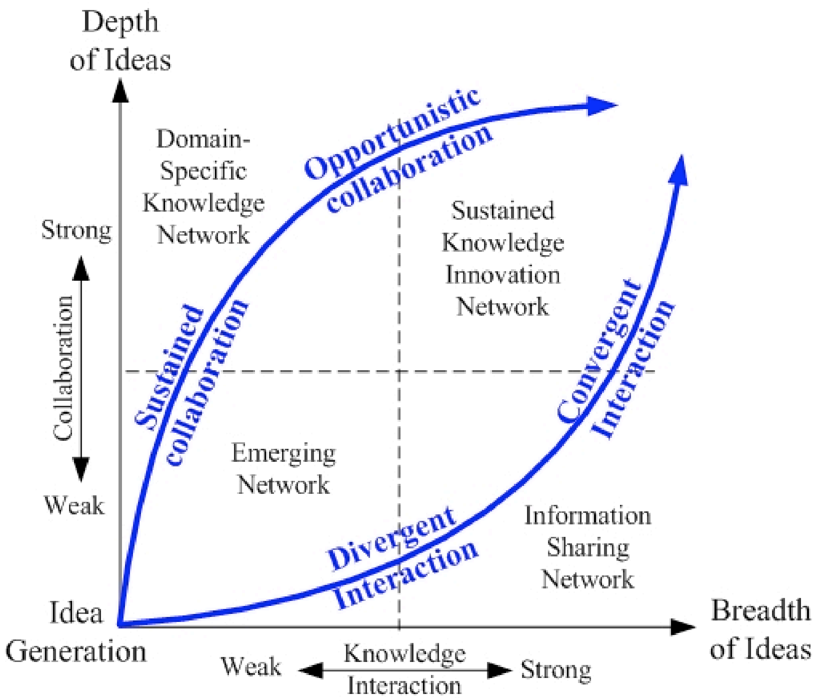


Figure 4. Four types of Network Behaviors

2.2 Technological design

Figure 5 illustrates the interface design of a Knowledge Forum *view*. Technologically, a *view* represents a knowledge domain; the scope of the domain might range from a problem-solving space, to a specific topic of inquiry (e.g., digestive system) or a subject area (e.g., electricity). Conceptually, a Knowledge Forum *view* is also designed to be a knowledge visualization tool for representing higher-order organizations/representations of ideas. Through use of rise-above notes, graphical organizations, etc, users signal the rising status of ideas, as contrasted with the typical nondescript entry of threads, folders, and repositories without means of showing higher-order organizations (Scardamalia, 2003).

Users are also encouraged to work between-*view*s, and to create *views-of-views*, to further help them rise above separate *view*s. At all levels users are encouraged to create meta-perspectives to continually advance ideas and go beyond idea exchange to higher-order integrations. As argued above, most networks out in the world (especially in the Internet) are designed to be either domain-specific knowledge networks or information sharing networks. Unlike these networks, the KSN is designed to support both sustained idea improvement (collaboration) and diversified idea exchange (knowledge-interaction) through an integrated and balanced knowledge-building dynamics.

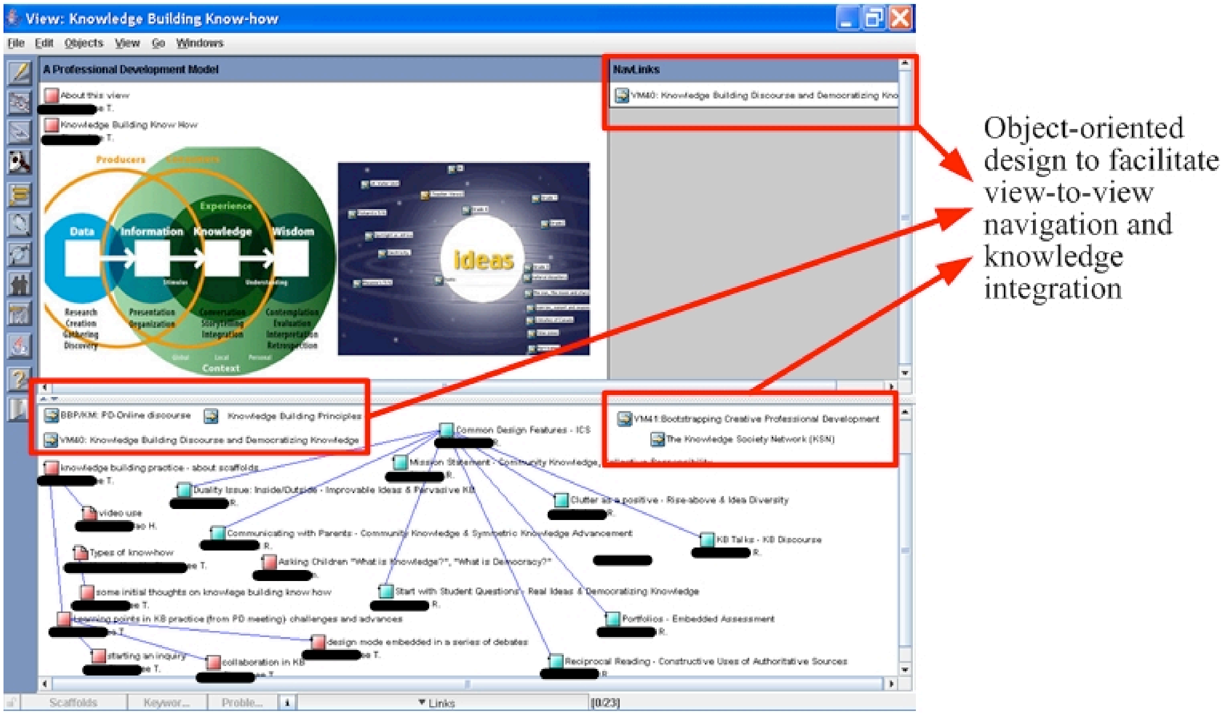


Figure 5. An Example of a Knowledge Forum *View* in the KSN

3. Self-Organizing Knowledge Networks

3.1 Theoretical underpinnings

Technologies are increasingly created by self-organizing knowledge workers (Rycroft, 2003). For example, Linux is developed by an essentially volunteer, self-organizing community of thousands of programmers who collaborate on diversified ideas through constant exchange of open source code (Evans & Wolf, 2005). Internet itself has also been considered as the single largest network system that self-organizes (Fuchs, 2005), and arguably, Internet-based collectives hold promise for increasing society's ingenuity, through less hierarchical and more distributed, opportunistic, and global configurations, with potential for greatly increasing idea productivity (Homer-Dixon, 2006). Accordingly, there is an increasing trend to design self-organizing innovation networks (Rycroft, 2003), whether Internet-based or not.

According to Prehofer and Bettstetter (2005), a system must consist of the following features to be considered self-organizing: (1) It is composed of individual entities and has a certain structure and functionality; (2) it is organized without external, central dedicated control. The individual entities interact directly with each other in a distributed peer-to-peer fashion; (3) the application of simple behavior at the microscopic level leads to sophisticated organization at the macroscopic level; (4) it is characteristic of adaptability with respect to changes in the system.

Building on the arguments laid out in the previous sections, we argue that the KSN is moving towards a self-organizing network system (Figure 6), as corresponding to the above features: (1) The KSN is composed of epistemic agents and ideas as two basic individual entities; (2) at the microscopic level, agents and ideas interact with each other in a distributed fashion (by means of idea elaboration and diversification); (3) the whole network system is governed by four basic network behaviors (sustained and opportunistic collaboration, and divergent and convergent knowledge-interaction); and (4) at the macroscopic level, the KSN is essentially an inclusive network-of-networks with a technologically adaptive functionality and a socially scalable structure that allow the whole network system to continuously grow and adapt to changing needs (see more explanation below).

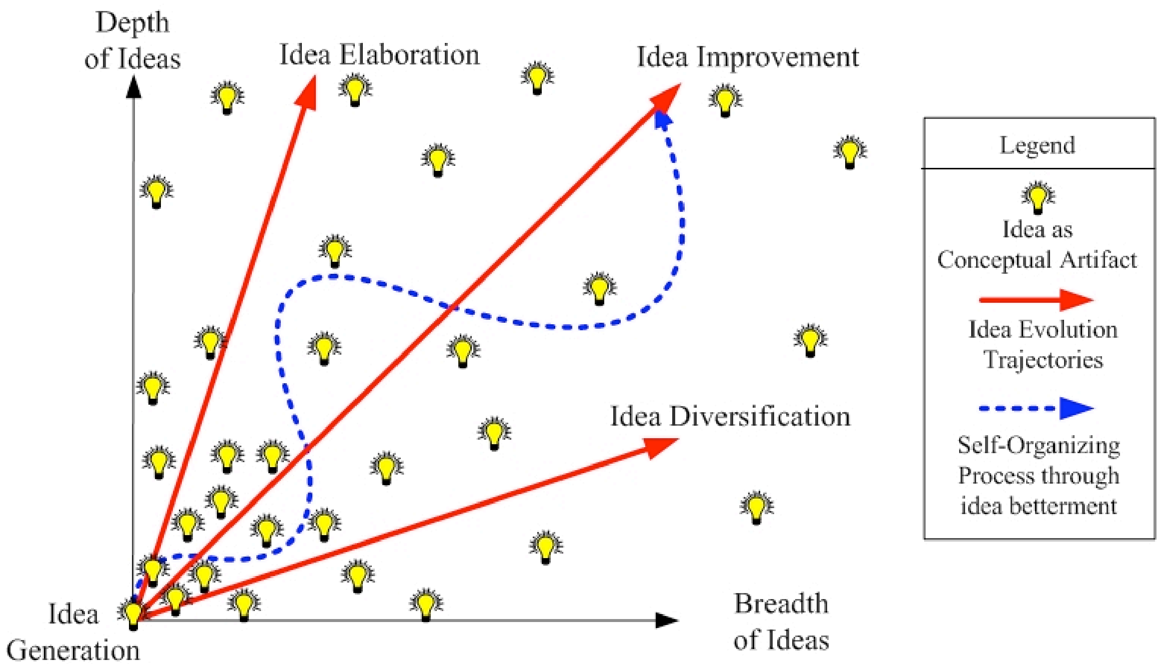


Figure 6. the KSN as a Self-Organizing Network-of-Networks

3.2 Technological design

The shared goal of KSN participants is to advance knowledge building theory, pedagogy, technology, and practical know-how on enough fronts that it can make a difference in society's efforts at sustained idea production and improvement. The KSN does not have a centralized structure; it has a meta-database that serves as a coordinating structure—a hub of innovation to coordinate each sub-group or community. Due to its international scope, a substantial amount of the work of the KSN is still carried out online. From a local perspective, each sub-group or community of the KSN is a single and unique network, but from a global perspective, the KSN is designed to be a knowledge building network-of-networks—or as we prefer, community-of-communities.

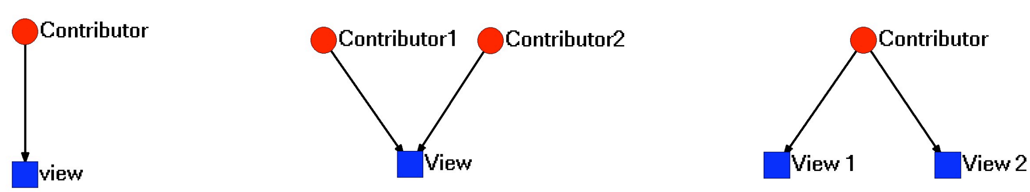
Purpose

This research represents a design experiment with the goal of improving the KSN design through: (1) analyzing network dynamics; (2) identifying strengths and weaknesses; and (3) suggesting design improvement to enhance KSN's capacity for sustained knowledge advancement.

Methods

Participants. Participants in the KSN comprise 353 members from various disciplines (more than 20), sectors (including higher education, health care, community organizations, and businesses) and cultures (nations from Asia, the Americas, and Europe).

Data sources. Knowledge Forum provides the technological infrastructure for the KSN, and the major data source is the discourse of contributors to the KSN. Analyses were designed to capture KSN members' activity, aided by use of an Analytic ToolKit (Burtis, 1998) that underlies Knowledge Forum and provides a rich overview of activity within the database. Relational measures (see below) provide the basis for social network analyses (SNA).
Unit of Analysis. There are three relational measures used for SNA: (1) *Contribution*: represents a basic unit reflecting relations between a contributor and a *view* (Figure 7a), whose intensity is measured by the number of notes. The more notes contributed to a *view*, the stronger the relationship between that contributor and that *view*. (2) *Co-construction:* A unit of co-construction between two contributors exists when two contributors work together in the same *view* (Figure 7b). Intensity of co-construction is measured by observing whether two contributors work in the same *view*(s), and if so, how many of such *view*s. The more *view*s any two contributors work in together, the stronger the intensity of their co-construction. In this particular analysis, contributors are defined as knowledge workers and a *view* is defined in a physical sense as a knowledge domain. (3) *View-connection:* A unit of *view*-connection between two *view*s exists when two *view*s are worked in by the same contributor (Figure 7c). Intensity of *view*-connection is measured by examining whether two *view*s are worked in by the same contributor(s), and if so, by how many of such contributors. The more contributors working in the same two *view*s, the stronger the intensity of *view*-connection between the two *view*s. In this particular analysis, a contributor is defined as a knowledge medium (Stefik, 1986) who communicates between *view*s and a *view* represents collective understanding. The above three types of connectedness provide indication of KSN network dynamics. A software tool called UCINET (Borgatti, Everett & Freeman, 2002) designed for performing SNA was employed for major data analysis in this study.



7a: Contribution 7b: Co-construction 7c: View-connection

Figure 7. Relational Unit of Analysis

Findings and Discussion

Overall growth. Over the past four years, the KSN has grown substantially (see Table 2), and now has 353 active members (till the end of 2005) and 172 views (excluding portfolio views), with each view broadly concerned with issues of knowledge building theory, practice and technology, including issues of professional development and educational reform (see Teo, Zhang, Hong, Gan & Scardamalia, 2006, for an overview of themes). Its growth and sustainability over time suggests the possibility for the KSN to expand its capacity to achieve a higher level of knowledge advancement.

Table 2. Cumulative Growth in KSN (2002-2005)

	Year1	Year2	Year3	Year4(2005)
Number of contributors	10	116	213	274
Number of views	13	55	135	172
Number of readers	47	200	290	353
Number of notes contributed	67	1042	3868	4472
Ratio of contributors over readers*	0.21	0.58	0.73	0.78

* Contributors must be readers but readers are not necessarily contributors.

Collaboration patterns. To understand how members collaborate across years, we used a matrix correlation, to test the association between one relational network as an observed network and another relational network as an expected network (see, Borgatti, Everett & Freeman, 2002, for detailed explanation regarding this method), using "co-construction" as a unit of analysis. The results (Table 3) showed significant positive correlations between the same active members' collaboration in one year and in another. For example, as an effective collaboration pattern, it was found that the same ten active members joining the KSN in Year 1 continue collaborating with one another throughout four years.

Table 3. Associations between the same members' collaboration in different years

	Collaboration in			
	Year 1	Year 2	Year 3	Year 4
Active contributors (N=10) in Year 1				
Collaboration in Year 1	1	.430(*)	.320(*)	.367(*)
Collaboration in Year 2	.	1	.930(**)	.723(**)
Collaboration in Year 3	.	.	1	.791(**)
Collaboration in Year 4	.	.	.	1
Active contributors (N=113) in Year 2				
Collaboration in Year 2	n/a	1	.642(**)	.463(**)
Collaboration in Year 3	n/a	.	1	.730(**)
Collaboration in Year 4	n/a	.	.	1
Active contributors (N=139) in Year 3				
Collaboration in Year 3	n/a	n/a	1	.614(**)
Collaboration in Year 4	n/a	n/a	.	1

*p<.05 **p<.01 (both 2-tailed)

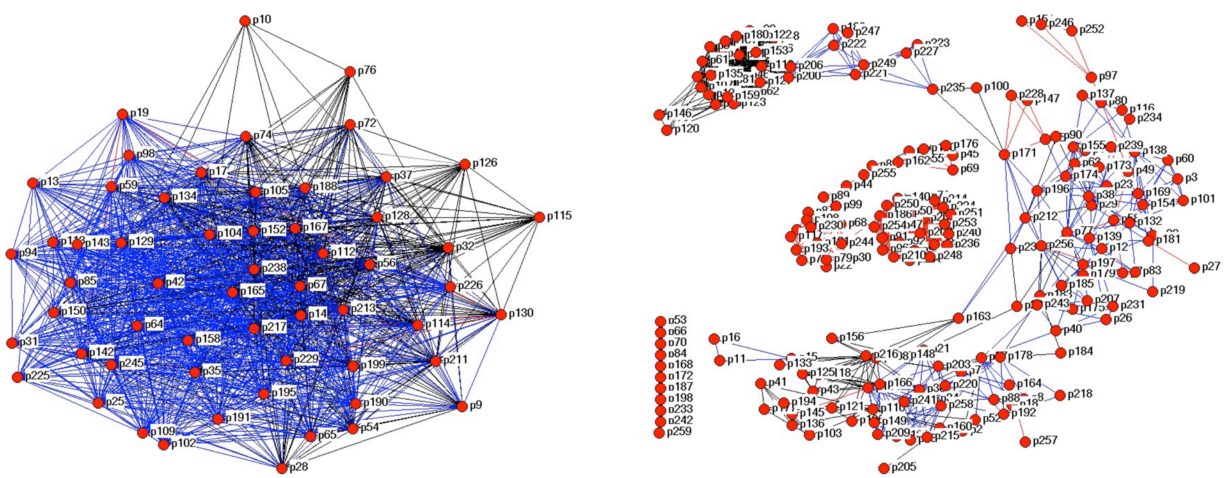
To further explore collaboration patterns, a core/periphery analysis (Borgatti & Everett, 1999) was performed to identify which members belong in the core and which belong in the periphery by fitting a mathematical model to the data network. As a result, it was found that although the core group has fewer members (N=58), its network degree centralization[3] (Freeman, 1979) is significantly much higher than the periphery group (Table 4).

Table 4. Network Degree Centralization

	N	Mean Number of Degree	SD	t test
Core	58	288.86	253.02	7.62***
Periphery	201	35.5	24.66	

***P<.001

Figure 8 shows the visual patterns, in which the core group formed a strong-tie collaboration community (8a), whereas the periphery group formed many weak-tie collaboration communities, clustered by years (8b). A possible aspect for improving the design of the KSN may have to do with rethinking how to enhance collaboration between nested sub-communities in the periphery. In addition, an E-I index analysis[4] (Krackhardt & Stern, 1988) also suggested that there are significantly strong connections between the two groups (Table 5), suggesting an additional strong collaboration pattern in the KSN.



8a: Strong-Tie Pattern in the Core Group 8b: Weak-Tie Pattern in the Periphery Group

Figure 8. Network Patterns of Collaboration in the KSN

Note: In both figures, unit of analysis is "co-construction", in which each red-circled-node represents a contributor and each tie represents at least one view in which two contributors collaborate together. Colors of lines refer to years: year1(green), year2(black), year3(blue), and year4(red). The year 1 ties (green) are too few to be seen in both figures.

Table 5. E-I Index

[3] In SNA, the degree of a contributor is the total number of connections between that contributor and all other contributors in a network; and degree centralization is the mean degree number.

[4] E-I index is the number of ties external to the groups minus the number of ties that are internal to the group divided by the total number of ties.

	total ties	Internal ties	External ties	E-I
Core	5721	2652	3069	.085*
Periphery	5591	2522	3069	

*p<.05

Knowledge-interaction patterns. To understand how one year's knowledge-interaction relates to another year's, a matrix correlation (Borgatti, Everett & Freeman, 2002) was also conducted using "view-connection" as a unit of analysis. The results showed virtually no association between years (Table 6). As elaborated below, views are emergents of the knowledge building process, and not predefined knowledge structures. This may help to account for the lack of statistically significant correlations with respect to knowledge-interaction between years (see more explanations below).

Table 6. Associations between the same views' knowledge-interaction in different years

	Knowledge-interaction in			
	Year 1	Year 2	Year 3	Year 4
Active views (N=12) in Year 1				
Knowledge-interaction in Year 1	1	0.14	0.134	0.16
Knowledge-interaction in Year 2	.	1	0.454*	-0.105
Knowledge-interaction in Year 3	.	.	1	-0.05
Knowledge-interaction in Year 4	.	.	.	1
Active views (N=50) in Year 2				
Knowledge-interaction in Year 2	n/a	1	-0.002	-0.03
Knowledge-interaction in Year 3	n/a	.	1	0.04
Knowledge-interaction in Year 4	n/a	.	.	1
Active views (N=120) in Year 3				
Knowledge-interaction in Year 3	n/a	n/a	1	0.028
Knowledge-interaction in Year 4	n/a	n/a	.	1

*p<.05

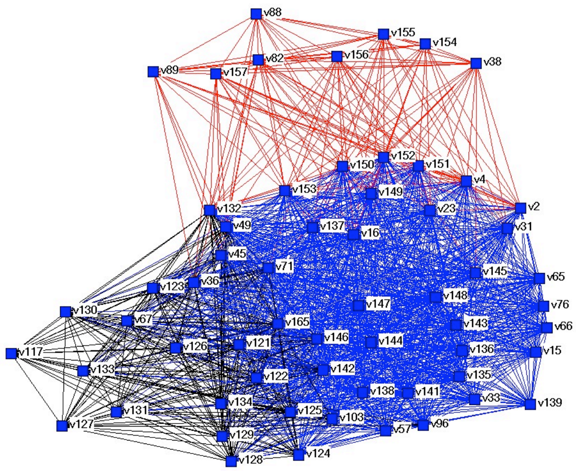
To explore further, the same core/periphery analysis (Borgatti & Everett, 1999) was also performed here. The result showed that although the core group contains fewer views (N=60), its network degree centralization (see Freeman, 1979) is also significantly higher than the periphery group (Table 7).

Table 7. Network Degree Centralization

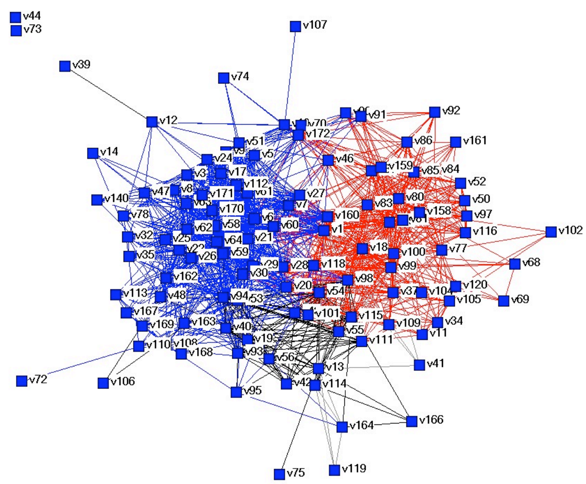
	N	mean number of degree	SD	t test
Core	60	532.52	117.08	19.97***
Periphery	112	171.65	104.85	

***P<.001

Figure 8 shows patterns of similarities in both core/periphery groups. It was found that they both have clear-cut clusters between years (represented by the colors of ties), in which there were very few views being linked together (e.g. there are only five views in the core and six in the periphery linked between year2 and year4). This confirms the above finding that as a pattern of knowledge-interaction, views are emergent from year to year. Improving the KSN may require enhancing knowledge-interaction between divided clusters for networks. At the same time, the E-I index (Krackhardt & Stern, 1988) analysis suggests that there are significantly strong connections between groups (Table 8), suggesting another effective network pattern for knowledge-interaction in the KSN.



9a: Strong-Tie Pattern in the Core Group



9b: Weak-Tie Pattern in the Periphery Group

Figure 9. Network Patterns of Knowledge-Interaction in the KSN

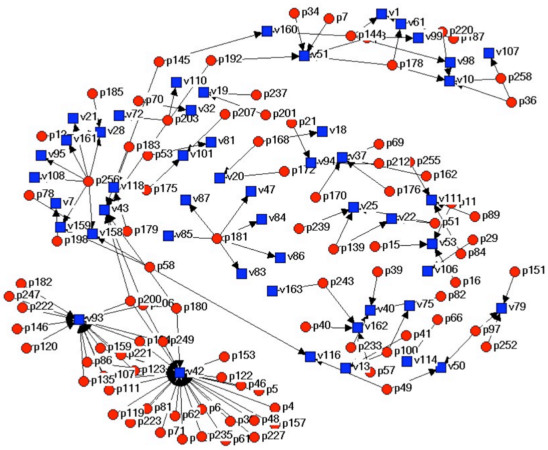
Note: In both figures, unit of analysis is "view-connection", in which each blue-squared-node represents a view and each tie represents at least one contributor (as a knowledge-medium) who connects two views. Colors of ties refer to years: year1(green), year2(black), year3(blue) and year4(red). The year 1 ties (green) are too few to be seen in both figures.

Table 8. E-I Index

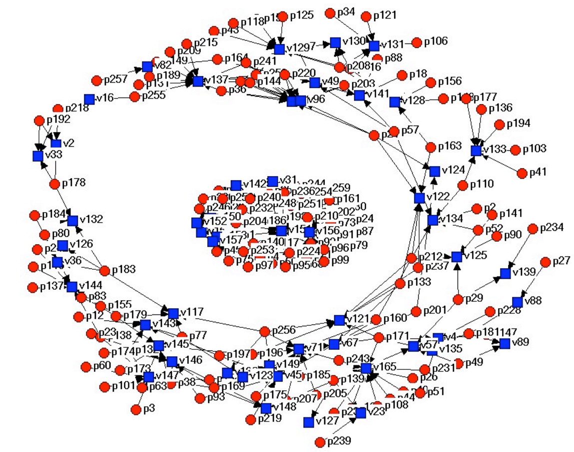
	total ties	Internal ties	External ties	E-I
Core	9118	3540	5578	0.101*
Periphery	11144	5566	5578	

*p<.05

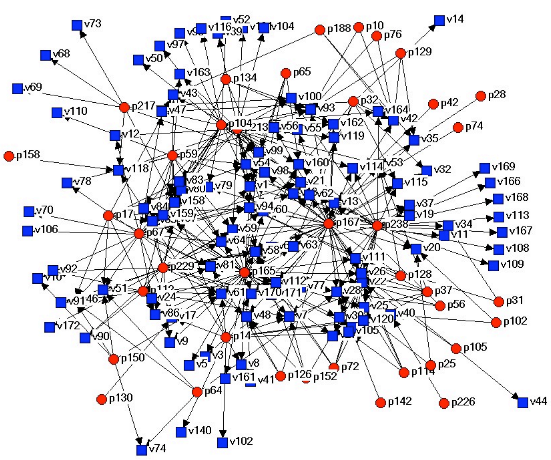
Knowledge-building patterns. To explore these findings in greater depth, the KSN was divided into four subnetworks based on the intensity (strong or weak) of collaboration and knowledge-interaction derived from the above core/periphery analyses, and referred to below as weak collaboration by weak knowledge-interaction (Wc-Wk), weak collaboration by strong knowledge-interaction (Wc-Sk), strong collaboration by weak knowledge-interaction (Sc-Wk), and strong collaboration by strong knowledge-interaction (Sc-Sk), each representing a kind of network dynamics for knowledge-building (Figure 9).



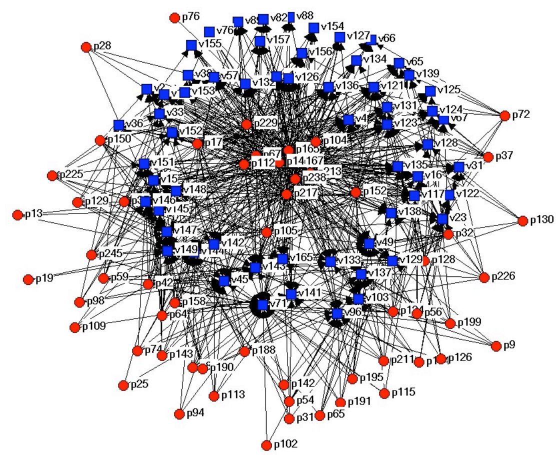
10a: Wc-Wk Subnetwork



10b: Wc-Sk Subnetwork



10c: Sc-Wk Subnetwork



10d: Sc-Sk Subnetwork

Figure 10. Knowledge-building subnetworks
Note: In all figures, unit of analysis is "contribution", in which each red-circled-node represents a contributor; each blue-squared-node represents a view; and each tie represents note contribution by a contributor to a view.

Table 9 summarizes statistics about the four subnetworks. For the Wc-Wk subnetwork, from its lowest numbers of note contribution and ties, and highest numbers of inactive contributors and views, it is clear that its weakness lies in its low participation. On the other hand, for the Sc-Sk subnetwork, it is also clear that it represents a more dynamic network for knowledge-building. For the Wc-Sk and Sc-Wk subnetworks, from their opposing highest vs. lowest numbers of active contributors and opposing lowest vs. highest numbers of active views, it is apparent that there is an imbalance between contributors and views for both subnetworks. Such disequilibrium has caused the Wc-Sk subnetwork to be strong as an information-sharing kind of network but weak as a domain-specific kind of network (due to the highest number of contributors serving as knowledge mediums connecting views); and the Sc-Wk subnetwork to be strong as a more domain-specific kind of network but weak as an information-sharing kind of network (due to the highest number of views contributors co-construct). Given the above analyses, we now shift to the main purpose of this research: How to further improve the network dynamics of the KSN.

Table 9. Comparisons between four knowledge-building sub-networks

Sub-networks	Note Contribution	Ties	Active contributors	Active Views	Inactive Contributors	Inactive Views
1. Wc-Wk	(421)	(136)	93	50	**108**	**62**
2. Wc-Sk	659	241	**141**	(54)	57	6
3. Sc-Wk	1411	346	(39)	**109**	19	3
4. Sc-Sk	**2695**	**775**	57	60	(1)	(0)

Note: Note contribution is the total number of notes contributed to a given subnetwork; Ties are the total connections between contributors and views in a given subnetwork; Active contributors are members who actually contribute notes to a given subnetwork; Active views are views that receive note contribution in a given subnetwork; Inactive contributors and inactive views are the opposite of the active contributors and active views. In each column, the bold number refers to the highest value, while the number in parenthesis refers the lowest value.

Expanding the Possibilities

An important challenge is to establish more direct connections between members and ideas of all subnetworks, as this is likely to enhance knowledge building. For example, literature has suggested that weak ties can lead to strength (Granovetter, 1983), with important new ideas coming from peripheral members; weak-ties in one network may be core members in another network. Also, direct connection may be helpful as an alternative means to enculturating legitimate peripheral participants (Wenger, 1998) into the culture of core members, as strengths and weaknesses of "opposites" can be used to complement each other. The challenge is to create more direct connections..

To address this issue, our research team is currently adding new design features into Knowledge Forum, which include the development of a suite of new assessment tools. One of these new tools is the Social Network Analysis Tool (Figure 11), which enables members to freely explore existing collaboration patterns among members (who links with whom) in the KSN (cf. Hoadley & Pea, 2002; Vivacqua, Moreno & de Souza, 2003; Philip, 2006). Another tool is the Semantic Analysis Tool (Teplovs, 2005; Zolotkova & Teplovs, 2006) (Figure 12), which allows members to explore knowledge-interaction patterns between views (e.g., what ideas relate to what ideas) in the KSN. At an individual level, the tools are designed to extend members' social metacognitive capacity (e.g. knowledge of others' knowledge, see Hong, 2005; Hong & Lin, 2005) to support epistemic agency (Russell, 2002; Scardamalia, 2002) for more effective knowledge building initiated by the members themselves. These new tools should allow members to monitor and reflect more often on who has worked on which ideas (or sets of ideas), so members share a meta-perspective on their work. More effectively distributed knowledge building processes should result (Hewitt & Scardamalia, 1998).

As Scardamalia (2003) suggests, "Networks are ubiquitous, but the social engineering of networks for effective action is in its infancy" (p.63). The importance of this study lies in its possible contribution of new knowledge to our understanding of social processes and of how such process can be enhanced to create a more dynamic, inclusive, and sustained network for knowledge advancement.

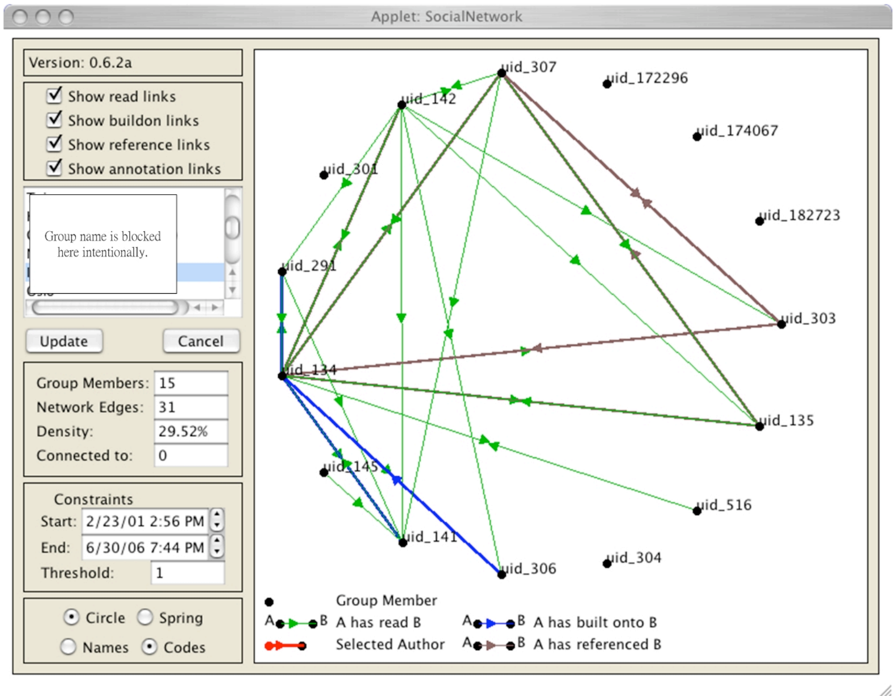


Figure 11. Social Network Analysis Tool

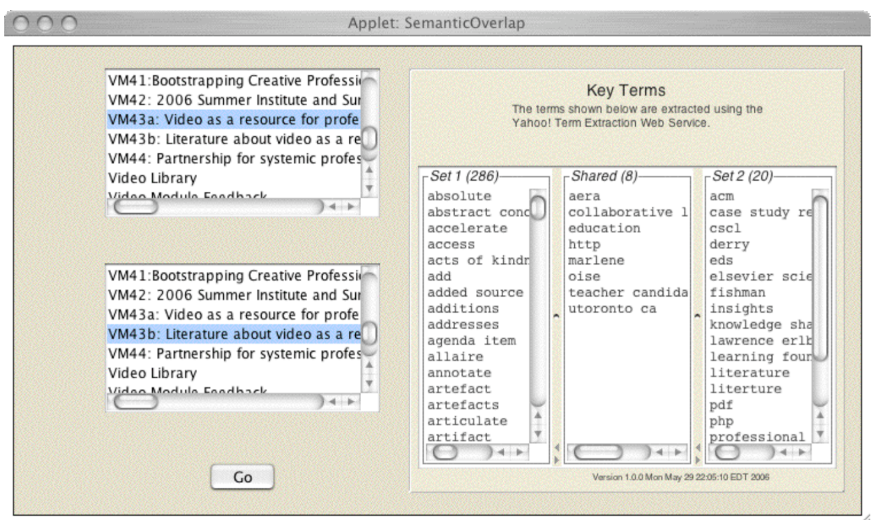


Figure 12. Semantic Analysis Tool

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