The Notion and Characters of Knowledge Networks†

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Abstract: This paper first focuses on the review of the literature of knowledge networks based on a recent analysis. Then we analyze the connotation and extension of the notion of knowledge network put forward by different field researchers, and we bring forward its notion alongside different aspects of information science. Finally, we provide further discussion and analysis about the character of knowledge networks.

1. Introduction

The knowledge network is becoming more and more important in knowledge management. As Hogberg (1998) pointed out, "To survive in the future, corporations will need a knowledge network that captures and stores all the knowledge, innovations and new ideas that are created, and distributes that knowledge to the right people, so that it can be reused and create more value." For the sake of future survival, enterprises need knowledge networks to obtain and store all established knowledge and new notions and to transfer this knowledge to appropriate people in order to reuse the knowledge and create greater value.

This new notion of knowledge networks can be compared with the concept of knowledge management popular in the mid-1990s, when the organizational concept of the time was "organization as computer." At that time the concept of knowledge management was to create and maintain a substantive data warehouse for catching and organizing special knowledge. As the Internet and the World Wide Web developed rapidly, these notions have become out-dated. The current organizational concept evolved from the idea of the "network organization." There is a book on trade, which even used "That Is Network, flathead" as a title of one section. From a substantive data warehouse to knowledge network, redefinition of the concepts has indicated that intelligence, rather than individual data, is considered as the all and the one (Contractor 2002). These knowledge networks include collective skills to help organizational members produce products and services. Therefore, challenges have been re-conceptualized so that we should understand psychological, social and transmitting mechanisms which bring, maintain, dis-

assemble, and recompose the relationship between knowledge networks.

Recent literature has indicated that the knowledge network has become an effective practical tool for organizations. Besides, creating a knowledge network has become an essential method to implement knowledge management in enterprises. Organizational members must cooperate with each other and be devoted to systematical knowledge work in order to gain their ends. Therefore, a network's function of collaboration has been introduced into knowledge activities. Hence the concept of knowledge network has been born. It is "Net-volution" that gives birth to the knowledge network beyond doubt.

In a knowledge network, the node is knowledge itself. The relationship between knowledge is revealed in a knowledge network. Its structure and hierarchy is very important for every discipline. Knowledge networks are different from online communities, which are a form of knowledge carriers. The nodes of online communities are people who have in common some field. In online communities, knowledge is shared among people.

1.1 The status quo of knowledge networks

We used "knowledge network" as title keywords to search in Elsevier, ProQuest, China Journal Full-text Database (CJFD), VIP Database of Chinese Scientific and Technical Periodicals, ProQuest Digital Dissertations (PQDD), Chinese Dissertation Database Full-text(CDDB FT), Chinese Doctoral Dissertation & Master's Theses Full-text Database (CDMD), and CALIS Dissertation Database. The results of searching are in Table 1.

There is only one paper related to knowledge networks in two searched overseas dissertations, namely "A rhetorical analysis of university Web sites in the knowledge network"(Dutkiewicz, Kerith A.). There are two papers correlative with knowledge networks in four searched domestic dissertations (Wang Lu 1999; and Zhao Xia 2000).

The results of literature search in domestic and overseas periodicals above show that the number of overseas papers on knowledge networks is 70 while the number of domestic papers on the topic is 60, slightly less. It indicates that both domestic and overseas researchers have begun to pay attention to knowledge networks. The results indicate that study of knowledge networks began in the middle 1990s. Scholars have different points of view on the connotation and extension of the notion of knowledge network. It is reported that the notion of knowledge network was advanced in Swedish industry (Beckmann 1995), which focused the study on actual construction and analyzed large numbers of modes of economy and market structure of knowledge networks. NSF (the National Science Foundation) in a paper on knowledge networks in 1998 referred to a social network that can make use of knowledge and information.

At present the latest trend of overseas study on knowledge networks is to introduce the notion into the field of the science of management. And the overseas scholars have done some research on elements, characters, types, construction, and effect on knowledge economy of knowledge networks. Some web sites on K-NET began to appear. Besides, Talisayon (2002) introduced several kinds of communities of knowledge networks on the basis of organizational knowledge sharing, such as communities of practice, S&T communities, *Online Science and Technology Communities*, the online corporate university, and so forth. And there is also an introduction on R&D programs for expanding the domain of knowledge networks funded 6.2 million dollars by NSF in 1998. The aim of the program is to found a scientific basis for a new level for communication of knowledge and information among individuals, organizations, and society.

The results of domestic literature searching on knowledge networks show that the earliest paper on knowledge networks is Guo Qixu's "Knowledge network: distribution of books on Tu Fu in Chinese Library Classification" in *Fujian Journal of Library Science* in 1989. It was field of library-and-information science that introduced knowledge networks first. In 1990, Liu Zhihui advanced that a machine-readable

	Elsevier	ProQuest	CJFD	VIP Database	PQDD	CDDB FT	CDMD	CALIS Dissertation
Number of papers	70	70	62	61	2	4	5	0

Table 1. *Distribution of Papers on knowledge network*

warehouse of knowledge networks could be built using hypertext technology. And it was thought that hypertext as a special knowledge network was useful for studying the theory of a knowledge gene. In 1994, three scholars in education advanced teaching methodology on the basis of the notion of knowledge networks. Once advanced, the methodology became popular among teachers and students. The knowledge network methodology of teaching and learning means that teachers of different subjects make relationships between learned knowledge and form a map of knowledge networks by teaching students relevancy. Students can amalgamate learned knowledge to form an entity instead of facing fragmentary knowledge by building a map of a knowledge network, which can help students memorize by relevancy to strengthen their memories.

The field of artificial intelligence began to pay attention to knowledge networks in 1996. There are some early papers (Yong and Mingzhong 1996; Bo and Zhongkuang 1997; and Bo, Zhongkuang, and Liping 1998). In Guanglong (1999) the notion of knowledge networks was used in economy and science of management. Zuorong (1999), Hongwen and Ruihua (1999), and Jifeng, Zongxian, and Fangli (2001) analyzed the notion of learning, organizational learning, knowledge, organizational knowledge, knowledge management, generalizing the types of knowledge, the modes of knowledge sharing, the aims of knowledge management, and advancing the building of knowledge management networks.

There are nearly 40 out of more than 60 papers on research and practice of knowledge networks used in teaching and learning Chinese, math, foreign languages, physics, chemistry, biology, history, geography, and politics. The others are about description, introduction of knowledge networks and applications in artificial intelligence and economy management. Some papers were theoretical; Zheng, Cuifang, Lu, and Yan (2001), and Lu, Zheng, Yan, Cuifang, and Tie (2002) analyzed the dynamic processes of complicated systems and the efficiency of knowledge output of organizational knowledge network investments. Dan, Zhuchao, and Zhiping (2002) proposed essential elements, constructing principles and methods for knowledge networks. More recently Ye Peng and Fan Xiaozhong (2004) contrasted analysis of semantic repository research to advance a new semantic knowledge network on the basis of the theory of ontology, composed of Chinese information repositories and scattered neuronal networks, known as self-learning neuronal semantic knowledge networks. Zhang Lini (2004) introduced *Know-Net*, which has innovatively integrated the "process" and "product" approaches, developed by a European Consortium of leading edge KM consultants. Sheng Xiaoping (2004) discussed the frame of knowledge management based on knowledge networks. Most domestic and overseas studies knowledge networks focus on description, introduction, analysis of the types, modes, and construction of knowledge networks based on knowledge management and knowledge sharing.

2. The notion of knowledge networks

Rongying and Junping (2007) described the evolution of the notion of knowledge networks and an analysis of the status quo of domestic and overseas study indicates that the connotation and extension of the notion are different to people of different times, from different fields, and with different majors. Gagné , a modern cognitive psychologist, describes knowledge networks as follows: the connections between declarative knowledge and procedural knowledge are embedded in production of propositional networks which compose knowledge networks together. A knowledge network is considered as a storage mode for two kinds of knowledge in the human brain. Knowledge network was defined through describing composition and function of knowledge network.

From the point of view of resources, Latour (1987) suggested an 'inter-linked' web of 'knots and nodes' rich with 'concentration of resources' scattered over the domain (or field) of the network, which defines both the domain or the field in terms of their content. A knowledge network is considered as a knowledge base storing all parts of complicated special technology, experience and knowledge. Both internal and external personnel can use this knowledge base. Therefore, a knowledge network forms as follows:

1. The knots and nodes load knowledge resources.
2. The knots and nodes develop cross-cutting ties and linkages if need be (Podolny et al. 1996).
3. The ties enrich and reinforce knowledge resources in each other. These ties strengthen ,extend, and deepen each function.

There are two thoughts about knowledge networks in the field of science of management. First, for Beckmann (1995), a knowledge network was considered as the organization and activity of production and diffusion of scientific knowledge. As the con-

sumption of knowledge can take place in any form of economic activities, usage of knowledge (namely the consumption of knowledge) was not considered. And Beckmann restricted the notion of a knowledge network to the purely academic without considering production and diffusion of knowledge through industry. The second thought came from Kobayashi (1995), who studied the effect of knowledge spillover on market structure, optimal policy of every node, production technique of knowledge, and availability of knowledge.

In Allee's (1997) opinion, a knowledge network is an association of internal communities or people with a common interest. The "community" may be a group of occupational peers who share their experience or technical knowledge. Allee emphasized that a knowledge network had fluidity, with people conforming to accomplish a task and then disbanding and reforming. NSF (1999) defined knowledge network as a social network which can provide use of knowledge and information. The notion of a knowledge network is that of an agglomerate collectivity of compound sets composed of academic experts, information, and knowledge. And it is used for analyzing some special issues. A knowledge network focuses on entities of knowledge crossing time and space. A knowledge network can be defined as cooperation of individuals for producing , sharing, and using a common *knowledge warehouse*.

Some recent conferences have indicated humanistic issues of knowledge networks. It was debated that to conceive of a knowledge network was to redefine the relationship between knowledge networks and people as knowledge networks had existed before the Internet. Similarly, Hameri and Nordberg (1998) described the need for High Energy physicists to exchange files using the World Wide Web. And they asserted that this new tool was nothing but a set of applications of current technology, web tools and protocols, file formats and desktop computers. Accordingly, even though knowledge networks cannot be the embodiment of the development of new technology, it can certainly promote knowledge sharing by synthesizing current technology and systems.

Liu Hui (1999) thought that organizations and their environments formed an environmental knowledge network supported by the combination of supply chain, industry chain, and knowledge chain. Coates (1999) thought that knowledge management should not be restricted to management of an organization's internal knowledge resources but management of knowledge resources needed in organizational operation of each interest group, which should be amalgamated into knowledge networks. For Coates a knowledge network is a Web structure composed of cells or subsystems for sharing and supplying knowledge. From the knowledge supply chain point of view, Jiang Zhaohua (2004) analyzed the mechanism of industrial clusters and advanced a structure of knowledge networks based on the knowledge supply chain as a function of web innovation capacity. From the regional economy point of view, a knowledge network is the framework of regional innovation systems. Enterprises, universities, agencies, and governments are nodes of regional knowledge web structure. These nodes have diversity, alternating, nonlinear, strong coupling relationships and form an organic whole-a regional innovation system. From another point of view, the interaction between each industry which composes a regional economy system also forms some kind of knowledge network and becomes its nodes. From the subject group point of view, a knowledge network is an organic system comprising specific subjects. As sharing and exchange of knowledge are needed, knowledge networks formed to promote knowledge sharing and exchange and to reduce knowledge transaction cost. With the function of market mechanisms, enterprises in a knowledge network can bargain with the suppliers who own knowledge they need to reach--a *win-win* proposition. Knowledge transactions in knowledge networks are not always *cash and carry*. As knowledge is both explicit and tacit, even some knowledge transfer with transaction characteristics must be realized through professional training. In this process, primarily tacit knowledge works. In the knowledge network of an industrial cluster, lots of knowledge supply chains interact. One enterprise may be in several knowledge supply chains—enterprises, institutions, scientific agencies, government, and so forth.

Moreover, the definition of knowledge network from overseas scholars on knowledge management is that knowledge network is people, resources, and the relationship between them for accumulating and using knowledge. The usage of new knowledge is promoted by means of knowledge creation, and knowledge transfer. This definition is mainly for knowledge creation, knowledge use, and knowledge transmittal inside and outside enterprises.

Some scholars pointed out that the knowledge systems of enterprises did not exist as simple linear knowledge chains, but rather as networks of topological structure including two sides: 1) a network

formed as a result of interaction (e.g. causality, or logical relationship) between knowledge itself; or 2) a network between knowledge carriers (e.g., a network where the nodes are people who grasp special knowledge or carriers that stored some kind of knowledge). In such networks, the nodes are chained through some relationship (e.g. a business process, an information process). The difference and similarity of the nodes are the basis of existence of the network. The nodes may be connected in some task or in some subject necessary to accomplish some task. And they may part when the connection disappears.

Accordingly, there are many opinions on the notion of knowledge networks. We think that the notion of knowledge networks can be described both qualitatively and quantitatively. The description above can be considered a qualitative description of knowledge networks. From the quantitative (and knowledge organization) point of view, it can be abstracted as follows: a knowledge network is a knowledge system composed of knowledge nodes and knowledge associations. The magnitude and manner of forming systems can be different. Like knowledge, the carriers can be human brains and organizations or other entities. The notion can be described concretely as follows: a knowledge network is a network in which knowledge elements, knowledge nodes, knowledge units or knowledge warehouses act as nodes, and relationships between knowledge acts as borders or linkages. In this paper, a knowledge network is an aggregation of knowledge nodes and knowledge borders. And the function of knowledge borders is to transfer knowledge. The function of knowledge nodes concludes knowledge acquisition, processing, reproduction, and actualization. So the notion of a knowledge network may be described as a network which can access, transfer, process, reproduce, and deal with knowledge. This notion emphasizes the functions of a knowledge network.

Furthermore, the netlike characteristic of knowledge can be deduced as follows: a knowledge network is an aggregate of spatial knowledge structures. A knowledge network is an aggregate composed of numerous knowledge nodes and knowledge relations. A knowledge gene is made up of notions or matters, such as knowledge elements, knowledge points, or knowledge units from different manners of cognition. Knowledge relations can be divided into knowledge interrelation and knowledge extra-relation. Knowledge interrelation constitutes individual knowledge and links relations of connotation. Knowledge extra-relation is an extension relation among knowledge individuals and also is linkages of relationships to form knowledge networks.

3. The goal of knowledge networks

The goal of a knowledge network is to promote communication across disciplines, languages, and cultures; to enhance processes and integration of different knowledge sources; to promote efficient work of teams, organizations, or communities across regions and across time; to understand ethical, legal and social implications of this kind of new linkage; and to make it possible for all citizens to find all human knowledge, be it from traditional institutions, or digital collections. A knowledge network is intended to connect technology and humans in order to form efficient combinations of intellectual structure and client capital.

3.1 Knowledge networks in a broad sense

In the broadest sense, a knowledge network might be said to be based on networks of human brain cells. Knowledge networks also might exist in varying media., such as papers, films, disks, CD, and so on. And knowledge networks might integrate the two. So, knowledge networks in the broad sense have two types of structure: subjective knowledge networks (or tacit knowledge networks) composed of subjective or tacit knowledge; and mixed knowledge networks composed of subjective (tacit) knowledge and objective (explicit) knowledge. Therefore, a knowledge network in the broad sense is as follows: a social network between knowledge actors, in order to allow the creation and transfer of knowledge on an individual, group, or organization level. "People cooperate and communicate information through knowledge networks" in order to "transmit … knowledge between individuals and organizations." It is an interactive mechanism for knowledge and perception. The relations between network members can be autonomic or reciprocal, and they may be steady in order to provide interdependence. Who is being quoted here?

Thus a knowledge network includes:

- A knowledge network is a social network or a citation-based knowledge network. In this network, everyone has equal opportunity to attain and choose knowledge and information.
- A knowledge network is a network of communication or information. It is a knowledge ocean

which includes knowledge in different languages, from different disciplines.
- A knowledge network emphasizes strong technical support for knowledge process and integration. Not only are information technology and network technology needed, but also technology for knowledge organization, knowledge reorganization, and knowledge discovery are also important. Knowledge integration and management is the basis of knowledge process and its efficient use can be promoted.
- There will be issues of information ethics, information security, and intellectual property during construction of knowledge networks. These should be solved first in order to promote widespread knowledge in society.
- A knowledge network focuses on attaining knowledge integration and information flows from different levels and activities between human, organizations, and communities.
- There is a close relationship between the human mind and knowledge in the process of construction of a knowledge network. Humans are the power source of knowledge creation and knowledge sharing. It is humans that want to find answers and hunt for and to create new knowledge.
- A knowledge network is a network architecture of knowledge communication and knowledge accommodation, composed of several units (or subsystems).

Knowledge is a kind of resource. Organizations are capable of absorbing and sharing this kind of resource dynamically through information technology and knowledge management systems. In addition, knowledge networks are social networks. The networks need to absorb, create, transmit, exchange, and communicate knowledge. They are deeply rooted in the networks of society, economy, contracts, and administration relationship. In knowledge networks based in organizations, the nodes can be integration of individuals, groups, departments, agents, and so on. Specifically, the nodes can also be inanimate, such as knowledge warehouses, web sites, content and guiding databases, virtual figures, and Webbots.

The social structure of knowledge networks provides guidance in the cognition structures of the network. The linkage mechanism of knowledge networks describes "who-knows-what" while the linkage mechanism of cognitional knowledge networks provides the guide of "who-know s 'who-knows-what.'" The linkage mechanisms of network transmission include: searching information from people and nonliving agents, and distributing information to others; credit and authorization relations, formal affiliations, vicinity, and some relationships that follow information technology structure, such as Intranets and Extranets.

3.2 Knowledge networks in the narrow sense

Knowledge networks in the narrow sense are existent knowledge networks based on documents, which are carriers such as paper, films, disks, CD, and so on. The knowledge network is recorded on these carriers. Knowledge networks also can be called called objective or explicit. From the point of view of knowledge organization, knowledge nodes are not only the notions of knowledge, but also the connotations and extensions of the notions of knowledge, as well as concrete instances of knowledge and data. A typical knowledge network should be based on existing classifications and the subjects they contain. Knowledge resources are organized into corresponding nodes according to their content and categories and are assisted by other kinds of knowledge linkages. The abstract notion network "Classification + Thesaurus" can thus be stated as an orderly, organized, and interactional knowledge structure "Classification + Thesaurus + Knowledge resources + Cited linkages" so that there are rich relationships among previously isolated literatures that can be revealed through classification, knowledge notion networks, and cited linkages. When users are searching or browsing, what they get is not just a literature but also its position and importance in the whole knowledge system. If a literature is considered as a knowledge point, what users see is not only this point but also the entire structural network that places each point in relation to the whole. Such a network is both a framework of knowledge resources and a set of concrete entities of knowledge and data for browsing and searching and information.

4 Characteristics of knowledge networks

In a broad sense the borderline of knowledge networks is blurred. Some scholars consider networks to be a third kind of organization form aside from Pyramids and flat organizations. Therefore knowledge networks, in a broad sense, have the following characteristics:

– Creating and disseminating new knowledge to promote innovation;
– Providing obvious, identifiable and direct interest for network users;
– Formally organized and explicit management structure;
– Ability to cooperate based on value standards;
– Perfect communication mechanism;
– Sustainable development crossing departments.

Knowledge networks in the narrow sense are aggregates of knowledge resources distributed in LANs or WANs. A form of digital resource management, its essential structure and running mechanism is supported by digital technology whose core technology is network technology. All kinds of digital resources are considered as core in knowledge resource systems. Users can access knowledge resources through networks online. Knowledge and information can be updated in real time and shared.

Compared with documents, digital publications are cheap, easy to use, without monopoly or spoilage during reading. The number of digital publications has increased steadily in recent years. And information in networks is becoming richer and richer, which in turn has enriched knowledge and information resources of knowledge networks. It is forecasted that 90% of books will be sold in digital form by 2018. Digital publication has become a trend. More and more books, newspapers and periodicals have been circulated in presswork and digital edition or in Internet directly so that scanning and transformation between texts and graphs are unnecessary. The period of publication is greatly shortened. Digital printing can provide readers with newly, faster, richer knowledge and information. It also provides conditions and convenience for development of knowledge network.

Based on the digitization of knowledge resources, knowledge networks connect knowledge resources and countless computers all over the world through computer network systems and high-speed digital communication networks. Therefore knowledge networks assist communication of knowledge and information to break through the restrictions of time and space including national boundaries and linguisticl restrictions. As access and transfer of knowledge are networked, thousands of readers can go into a virtual "knowledge ocean" at any moment everywhere. More and more formerly-closed libraries have been opened to the public. Knowledge networks have become knowledge resources which can be used by everyone.

What knowledge networks provide has been changing from literature to knowledge. All kinds of knowledge carriers and knowledge sources including books, periodicals, photos, audio-visual resources , databases, web pages, multi-media are organized and linked. The service is provided to users in a dynamic distributed way. At the same time, knowledge discovery and organization technology including automatic indexing, metadata, knowledge search, and cross-database searching have become key technologies.

With digitization and networks as a stable base, knowledge and information resources on networks can be attained by network users by a simple mouse-click. Users do not need to visit a library for a book. Sharing resources crossing regions and national boundaries. Knowledge resources can be used together across regions, industries, and disciplines. The service has been changed from fixed in time to all weather. People can access knowledge resources on networks freely, easily and expediently so that knowledge is shared by all people and society. These characteristics demand an eminent service platform for readers and a highly efficient, simple, and practical mode of knowledge service.

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