



# Can knowledge be more accessible in a virtual network?: Collective dynamics of knowledge transfer in a virtual knowledge organization network



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## ABSTRACT

Virtual knowledge organizations (VKOs) produce and embrace priceless, and often, unique knowledge assets within the boundary of each virtual community. An important question is how do we maximize the benefits from these valuable assets at the entire VKO network level? Relying on the graph theory, this study is to investigate how the structure of virtual knowledge networks formed by knowledge agents and knowledge profile of each VKO influence the dynamics of knowledge transfer in a virtual knowledge organization network (VKON). We develop a network model through which knowledge will be efficiently disseminated when knowledge agents are uniformly distributed across the network. Using this model's intrinsic capability to assess global effects of local transformations in a network, we found that VKON complexity, a measure for efficiency of knowledge transfer, is optimized when a new knowledge agent is placed between two communities with the minimum knowledge transfer capacity. The results of this study will help understand the inter-community knowledge transfer dynamics in virtual knowledge community networks.

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## 1. Introduction

As business becomes knowledge dependent, organizational productivity often relies upon in-depth knowledge of business processes, technologies, and transfer knowledge across the organizational boundary [68]. Because organizations may not always have all necessary knowledge within their organizational boundaries, many have implemented inter-organizational knowledge networks as a mechanism to obtain knowledge [35,46]. Virtual knowledge organizations (VKOs) provide an efficient mechanism to search for and access knowledge in needs and facilitate the knowledge transfer process [33,43].

A VKO can be viewed as a virtual organization in which knowledge users co-create and share knowledge [39,44]. An important feature of VKOs is to bring knowledge seekers and providers into one virtual space that is equipped with knowledge databases over networks. Being free from the constraints of hierarchy and rules of real-world organizations, people benefit from this virtual organization by gaining access to new knowledge, expertise, and ideas, all of which may not be available within the organizational boundary [77]. Our notion of VKO focuses on a knowledge-centric virtual community where a group of knowledge workers with common topics, interests, problems, experiences and practices co-create and share valuable knowledge. A unique characteristic of VKOs, which differentiates them from real-world

organizations, is that knowledge processed through VKOs becomes explicit in the way of knowledge digitalization, and turns into common assets benefiting all participating groups [40].

This paper develops on the network and organizational perspective, which defines VKO network (VKON) as networked organizations transmitting knowledge through the network. A VKON can be viewed as a market mechanism that provides knowledge resources to problems and solutions in a decentralized manner [31]. An example of VKON is "Network of Networks (N2)" (<http://n2canada.ca/>), a Canadian national initiative that integrates 29 existing virtual organizations to enhance Canada's disease research capability and capacity.<sup>2</sup> The Network of Networks (N2) was initiated because researchers from diverse knowledge domains confront challenges in carrying out a joint research project that requires integrating knowledge from foreign domain. They need a networked system establishing a common knowledge base and integrating knowledge from various fields. In N2, a number of members who join multiple VKOs play the role of knowledge agents transferring and distributing knowledge across domains. Similarly, in an effort to facilitate knowledge creation process between academia and industry, European academic and business organizations from nine nations

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<sup>2</sup> N2 consists of 29 virtual organizations (websites) including C17 Research Network, Consortium of Canadian Centres for Clinical Cognitive Research (C5R), Alberta Clinical Cancer Research Unit (ACCRU), Canadian HIV Trials Network, Ontario Institute for Cancer Research (OICR) among others, most of whose websites are equipped with knowledge sharing functions.

designed a VKON, European Corporate Academies Transnational Best Practice Network (ECUANET).

During the last two decades, many of research and development organizations that engaged in innovative tasks have begun a rapid transformation toward using virtual organization networks [39]. They, however, have learned that acquiring knowledge from external sources is not a simple task, and that there are challenges in making newly acquired knowledge useful. While the evolution of individual VKOs leads to knowledge specialization by developing local knowledge and coding schemes, it also hinders the acquisition and interpretation of knowledge transferred from other VKOs [20]. In addition, developing an effective channel to transmit knowledge kept in one VKO to another is not an easy task. Then, how can we create a VKO network that would effectively facilitate the knowledge transfer process among VKOs?

We suggest two efficient mechanisms to cope with the challenges of cross-VKO knowledge transfer; acquiring inter-VKO common knowledge, and forming the network based on knowledge transfer agents (knowledge agents hereafter). The current study addresses two important questions; how do we efficiently distribute and acquire necessary knowledge across the network? and how do we maximize the collateral benefits from the valuable knowledge through the entire VKON? Using a mathematical modeling approach, this study attempts to answer these questions based upon the theories of common knowledge and knowledge agent. We posit that the common knowledge between VKOs and the topological properties of a VKON characterized by distribution of knowledge agents are associated with superior knowledge transfer capacity.

The capacity of knowledge network is measured by network complexity, which is a generalization of the number of spanning trees in a graph. This notion of network efficiency has been well addressed in the quantification of flow of information by Stephenson and Zelen [65]. We view a VKON as an organic social network consisting of two outstanding entities: 1) a group of VKOs in which private and common knowledge are created and 2) cross-VKO knowledge agents connecting two VKOs by involving in and transferring knowledge between the two.<sup>3</sup> We argue that the distribution of the agents is an imperative determinant of knowledge transfer capacity and accessibility of knowledge in a VKON. We investigate how a network structure formed by knowledge agents connecting multiple VKOs along with the knowledge profile of each VKO influences the dynamics of knowledge transfer in a VKON. Our objective is to assess the effects of a knowledge network structure formed by the distribution of knowledge agents and common knowledge on knowledge transfer.

The strategy of this paper is to examine interactions between two VKOs, and to illustrate how they affect knowledge diffusion, cohesion of knowledge network, and structural issues of the entire knowledge network. Our VKON model seeks to advance an understanding of knowledge transfer in virtual organization networks in two ways. First, while extant research on knowledge transfers tends to focus on sharing activities within the boundary of a VKO, we consider the dynamics of knowledge transfer at a network level. Second, one common assumption of the studies in this area is knowledge transfer based on direct communication. This study further considered knowledge transfer through indirect communication which is a common practice in VKON.

The knowledge transfer capacity of a VKON is measured by network complexity and common knowledge accumulated in each VKO. The mathematical approach in this study has been adopted in various areas including electrical engineering and biomedical sciences where the original motivation was to address the issues of non-social networks.

We next review relevant literature, focusing on the theory of common knowledge and the knowledge agent. We, then, develop a mathematical model of VKON using information centrality in Section 3.

Section 4 shows an optimal condition for knowledge dissemination in a VKON and Section 5 discusses the effect of merging two VKOs on knowledge transfer in the VKON. Section 6 suggests a way to maximize knowledge transfer capacity in a VKON and Section 7 assesses the amount of knowledge transfer between two VKOs through direct and indirect communication channels. Section 8 examines the effects of common knowledge on the dynamics of knowledge transfer in a VKON. Finally, we summarize and discuss the results and conclude with contributions, implications and limitations of this research in Section 9. Detailed mathematical proofs and leads are provided in the Appendix A.

## 2. The role of common knowledge and knowledge agent

A VKON can be viewed as a network that consists of multiple VKOs. Thanks to the frictionless nature of VKOs [9], they proficiently operate on relational structures or networks [46]. Recently, researchers have paid attention to various phenomena of VKOs due to their tremendous potential for knowledge creation and transfer [2,3,28,39,77]. Given the importance and potential of knowledge transfer, researchers have investigated various phenomena within the boundary of a VKO. Particularly in research and development organizations, the importance of inter-organizational knowledge transfer has been highlighted due to the emerging need of cross-disciplinary research.

While firms acquire valuable knowledge assets through network, there are substantial barriers to knowledge transfer between organizations [30,76]. The identified barriers include 1) lack of absorptive capacity of the recipient entities, 2) lack of credibility on the part of the source of knowledge, 3) disconcerted relationships between the sourcing and recipient entities, and 4) causal ambiguity caused by the complexity of knowledge [66,75]. The barriers can be overcome by increasing common knowledge between the source and recipient organizations [12,17] and by acquiring capable knowledge agents [71,78].

## 3. Common knowledge

Knowledge is socially embedded and highly context-specific, and these characteristics make it difficult to transfer knowledge [8,51]. von Hippel [75] argued that knowledge transfer becomes costly particularly when the recipient organizations need to obtain pre-required knowledge and skills to be able to use the newly acquired knowledge. As a more concrete example, a group of web designers who launch a web development project using web development software will not be aided to a great extent simply by adopting the software program unless they have already obtained the pre-required knowledge related to the web server and the fundamental operating systems. Similarly, the cost of knowledge transfer would be lowered when the software vendor provides training and technical support to the web designers who have common fundamental knowledge. In other words, when both knowledge sourcing and seeking entities share a set of necessary common knowledge, transferring knowledge would be less costly and the transfer process would be more efficient. The cost of transfer can be substantially lowered by common knowledge particularly when knowledge transfer takes place in an “explicit” form [50].

Social scientists have been emphasizing the important roles of *common knowledge* in knowledge transfer [17,28,45,51,70]. It is because common knowledge 1) facilitates the knowledge transfer processes by increasing similarity of knowledge profiles of the two VKOs, and 2) allows knowledge sourcing and seeking parties to share rules in the form of practices. Zhao and Anand [84] further suggest that the similarity of structural and cultural attributes of the knowledge between the two entities, which becomes an important component of common knowledge, is the vehicle acquiring and assimilating newly transferred knowledge. The depth and breadth of common knowledge, therefore, may indicate the functional and technical expertise integrated across organizational boundaries. This notion of common knowledge has

<sup>3</sup> A ternary or higher degree relationship can break down into binary ones.

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