Information Technology and Knowledge Management

E. Shimemura and Y. Nakamori

Japan Advanced Institute of Science and Technology
1-1 Asahidai, Tatsunokuchi, Ishikawa 923-1292, Japan

Abstract

This paper claims that information technology is and will be quite helpful for knowledge management, however knowledge science cannot be established only by information science. This paper considers the deference between information and knowledge simply, but considers deeply the power or ability to convert from one to another, which is the ability to understand and learn things, or the ability to think and understand things instinctively or automatically. This consideration suggests that what we should do research by the name of knowledge science. This consideration also suggests the basic elements of knowledge science, which are people, information, and system. These are hints to develop a new systems methodology for knowledge creation.

Introduction

Definitions of knowledge range from the practical to the conceptual to the philosophical, and from narrow to broad in scope, which are summarized in [1]. For instance, knowledge is organized information applicable to problem solving [2]; knowledge is information that has been organized and analyzed to make it understandable and applicable to problem solving or decision making [3]; or, knowledge is reasoning about information and data to actively enable performance, problem-solving, decision-making, learning, and teaching [4]. These definitions require clear distinctions between data, information, and knowledge. Several authors try to distinguish them [5][6]. Several authors also define typologies of knowledge, for instance, Nonaka and Takeuchi [7] suggest that the conversion from tacit to explicit knowledge and vice versa is crucial in knowledge creation.

School of Knowledge Science was established in 1998 in Japan Advanced Institute of Science and Technology, which is the first school established in the world that claims knowledge as a target of science. Since knowledge will certainly become a key concept in every field in the 21st century, the school has enlisted researchers from different fields to develop knowledge science that has a trans-disciplinary property in nature. One of the important research topics in the school is to develop

systems methodologies for trans-disciplinary knowledge exchange utilizing information and communication technologies. We will introduce a systems methodology under development, which may contribute to knowledge science.

This paper considers the deference between information and knowledge simply, but considers deeply the power or ability to convert from one to another, which is the ability to understand and learn things, or the ability to think and understand things instinctively or automatically. This consideration suggests that what we should do research by the name of knowledge science. This consideration also suggests the basic elements of knowledge science, which are people, information, and system. These are hints to develop a new systems methodology for knowledge creation [8].

Knowledge Creation

First, let us introduce a popular idea among researchers of knowledge management in Japan: "Knowledge management is not the activity only for resources called knowledge, but the activity to consider how all resources are utilized. You have to make the new structure by repeating new discovery and new creation rather than storing knowledge and considering the combination. Creation can be performed only by people's capability instead of a system." Apparently this expresses the disappointment to the information technology. However, if this is true, systems scientists cannot contribute to knowledge creation theory. Now, let us consider the definition of knowledge creation, especially what creation means, and roles of systems science and technology.

There is a nuance of a completely new thing in the word *creation*. However, it is unreasonable to think that knowledge is created in a situation without prior information, direct, or indirect experience. Here, we define: "Creation is a new combination of materials. Its thinking process is never based on a fantastic leap. It progresses with a certain fixed procedure." This definition gives us relief. However, when this definition is accepted as it is, integration (or synthesizing) and creation will have a quite near meaning. Therefore, we have to include the following meaning in this definition. "New knowledge will be created at a certain stage of an integration or fusion process of different knowledge." But, how? There are mainly two approaches to knowledge management. One relines on people, and the other relies on computer.

People vs. Computer

One of the approaches is given in Nonaka and Takeuchi's famous book: "The Knowledge-Creating Company" published in 1995 [7]. Nonaka assumes that knowledge is created through the interaction between tacit and explicit knowledge, and proposes four modes of knowledge conversion.

* Socialization is a process of sharing experiences and thereby creating tacit knowledge such as shared mental models and technical skills.
* Externalization is a process of articulating tacit knowledge into explicit concepts, taking the shapes of metaphors, analogies, concepts, hypotheses, or models.
* Combination is a process of systemizing concepts into a knowledge system. This mode of knowledge conversion involves combining different bodies of explicit knowledge.
* Internalization is a process of embodying explicit knowledge into tacit knowledge. It is closely related to learning by doing.

This theory is mainly devoted to management of knowledge that workers of an enterprise have individually.

On the other hand, researchers from information science have been trying to establish their own knowledge science using the rapid developing information and communication technology. There is a hierarchy of knowledge science from the viewpoint of information scientists. At the bottom, there is the foundation of information engineering, and at the second level, there are elements of knowledge science, and then these are objects of knowledge science, finally, there are many applications.

Information engineering has been developed as a study of computer hardware and software, and its application, i.e., computer science. Information originally accompanies all the sides of human activities. However, since it is hard for us to feel information directly, unlike substance or energy, its conceptualization was behind. Although the appearance of the computer contributed to its conceptualization greatly, it limited the range of information as the object of technology to the computer and its circumference. It is necessary to expand this range and to bring close to the system of information over life science, social science, and cultural sciences. This approach is quite natural. However, many social scientists do not fully accept this approach.

Information and Knowledge

Let us consider the definitions of information and knowledge, each of which has the following two meanings: Information is:

(A) Knowledge transmitted by character, sign, and voice, etc.

(B) Data arranged to be useful for decision-making.

Knowledge is:

(C) Recognition memorized personally or socially.

(D) Judgment or a system of judgment that has objective validity.

Apparently, there are no clear distinctions between information and knowledge. However, they are different and each of them is converted to the other. What is the energy to bring such transformation? Here, let us call it *intelligence*. Intelligence is:

(E) Ability to understand and learn things.

(F) Ability to think and understand things instinctively or automatically.

People convert data and knowledge into information for some purpose. They create new knowledge based on data and information. These conversion and creation require existing knowledge and some ability called intelligence. We can see that the approach from management science aims at developing the ability (E), while the approach from information science is related to the ability (F). Of course, both are important. However, their integration is difficult.

We should understand the limitation of our ability to objectify the real world, the limitation of our ability to understand indirect observation, and the limitation of our ability to analyze things objectively. The total system is inseparable, but we cannot perceive the inseparable whole. Therefore, we usually cut off weak links and nonlinear features, and consider individual linear subsystems that we can well imagine. Artificial intelligence inevitably inherits this weakness of human beings. Social scientists are never satisfied with such pieces of knowledge. That is why Nonaka theory requires direct experience in the knowledge management and creation process.

From this background, two approaches have been developed separately. One is knowledge management by the persons concerned. The other is knowledge management by information and communication technology. However, there is clearly a limit in the approach to knowledge management from only one discipline. We think it is necessary to develop a systems methodology that uses both approaches systematically.

Knowledge Science

As we have just mentioned, in the context of contemporary knowledge management, there are mainly two approaches to develop intelligence of human beings: one is from management science and the other is from information science. To integrate these approaches and establish a new discipline is a quite natural idea, and then the School of Knowledge Science was established in Japan Advanced Institute of Science and Technology in 1998. Since knowledge will certainly become a

key concept in every field in the 21st century, the school has enlisted researchers from different fields to develop knowledge science that has a trans-disciplinary property in nature.

This is, however, not the first trial in our history, and most of them are not necessarily successful. Something is necessary for the success, which may be the idea of system. Systems science may have an important role for the success of establishing knowledge science. However, there are also two different schools in the field of systems science: hard and soft schools, which roughly correspond to the fields of information science and management science, respectively. Something is necessary more.

One of the difficulties, and also a challenge of knowledge science, is to deal with different kinds of knowledge. The most reliable knowledge source is the scientific investigation that produces public knowledge. This is objective, unique, universal, and repeatable. One the other hand, knowledge obtained in social science includes meanings given by people inevitably, which are wisdom-based knowledge, insight-based knowledge, and experienced-based knowledge. These kinds of knowledge are subjective, vague, ambiguous, and circumstantial. We would like to develop a systems methodology for integration, management and creation of these different types of knowledge. This is a challenge in knowledge science that creates justified true belief.

Methodology for Knowledge Creation

We are developing a systems methodology that uses approaches in social and natural sciences complementarily. This systems methodology itself is a system consisting of five subsystems. The first one is scientific approach that uses physical laws, data analysis, etc. The second is information science, especially a large-scale computer simulation and the networking technology. The third is a method in social science, which is related to forming partnerships among social members. The fourth is knowledge science that integrates, transform, and create knowledge. Finally, systems science is used to manage these different approaches.

The developing system can be called a knowledge-creating system. The system integrates statistical data and individual persons' fragmentary knowledge, and then creates new knowledge nobody had before. Such knowledge must be tacit, otherwise someone including the system had it; this is a contradiction. Therefore, the system should have a process to convert tacit knowledge into explicit knowledge. This means that the members of the project or relevant people constitute a part of the system.

At the subsystem *Intervention*, we consider what kinds of knowledge are necessary to solve the faced problem, and request three subsystems to collect them. Here, knowledge is a problem. At the subsystem *Intelligence*, we collect necessary data and information, analyze them with a scientific attitude, and make a model for simulation or optimization. Here, knowledge is a model. At the subsystem *Imagination*, we simulate complex phenomena based on partial knowledge, using information technology. Here, knowledge is scenarios. At the subsystem *Involvement*, we hear opinions of people by organizing a meeting or questionnaire survey. Here, knowledge is opinions. At the subsystem *Integration*, we evaluate reliability and justifiability of outputs from three subsystems, and integrate them. Here, knowledge is solutions.

We evaluate the knowledge-creating system from the following viewpoint:

* Are the system, actors and contents well defined? Is its foresight power enough?
* Is the totality achieved?
* And, is it actually useful?

An example of complementary use of people and computer is as follows: Suppose now we have a problem of how to activate ecological industry. At *Intelligence*, we will make a model with computer based on ideas of people. At *Imagination*, we carry out computer simulation with assumptions given by people. At *Involvement*, we develop a network with the help of information technology initiated by people. Then, at *Integration*, we will build a strategic scenario-based system by consulting the relevant people.

This methodology is a system because it has the following properties:

* Hierarchical structure.
* Emergent characteristics.
* Function of communication.
* Function of control.

For example, if we consider sustainable development, the role of subsystem *Intelligent* is prediction based on scientific knowledge. To achieve this task, this subsystem asks the lower system to develop a mathematical model, and then the subsystem *Involvement* of this lower system will collect necessary data consulting the relevant people. Them, the next lower system will start collecting numerical data, qualitative data, and scenario data. The subsystem *Imagination* of this layer will ask to collect assumptions and ideas with their possibilities. In such a way, this knowledge-creating system has a hierarchical structure with functions of communication and control. Based on this knowledge with logical thinking and educated intuition, we can produce a systemic knowledge. We can consider that creation of such systemic knowledge or integrated knowledge is a kind of emergency.

The next question: how is the trans-disciplinary knowledge exchange achieved? The subsystem *Intelligence* is mainly based on natural sciences, mathematics, and engineering. The subsystem *Imagination* is mainly related to information science, economics, and statistics. The subsystem *Involvement* is mainly based on management science, social science, and cultural sciences. The other two subsystems *Intervention* and *Integration* are of course related to systems science and knowledge science. Different disciplines are used to determine boundary conditions or to check consistency of knowledge of subsystems. However, this is not performed automatically. This is an interactive system.

Conclusion

One of the important research topics in knowledge science is to develop systems methodologies for trans-disciplinary knowledge exchange utilizing information and communication technologies. By the name of knowledge science, we are developing methodologies and methods related to information environment with which we can convert subjective, implicit or individual ideas into justifiable or hopefully reliable ones. This is not necessarily implies the utilization of information technology only. The methods and ideas in knowledge science should be those that guarantee justifiable trans-disciplinary knowledge exchange. The role of systems science is crucial for development of knowledge science.

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