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Fusing Systems Thinking with Knowledge Management

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Abstract. This paper introduces the background and purpose of the International Society for Knowledge and Systems Sciences and considers new developments in systems science in the knowledge society. First, in connection with the reason why the name of the society includes knowledge and systems, this paper argues that it is important to support each other for the development of both systems science and knowledge science. Next, this paper introduces three approaches that have tried to combine systems thinking and knowledge management in this academic society. They are Knowledge Systems Engineering, Informed Systems Approach, and Knowledge Construction Systems Methodology. This paper suggests new developments in systems science and engineering that incorporate the concept of knowledge management through explanations of these significances.

Keywords: Systems thinking, knowledge management, knowledge systems, knowledge construction, international academic society

1. Introduction

Systems science has contributed significantly to the construction of modern civilizations after World War II. It initially emphasized the hard technical aspects, but as it began to address environmental or management issues, it started developing soft approaches focusing on the aspect of human relationships.

The most important concept in systems thinking, whether hard or soft, is emergence, which means that a new property appears as a whole through the interaction between elements. But, systematization does not create a desirable emergence automatically. Those involved in the system must also be involved in the emergence. To do so, it is a very natural idea to try to find hints from the knowledge management approach that has emerged in recent years.

It is said that knowledge management began with the computer industry's catchphrase of using computers to organize and effectively utilize knowledge in the enterprise. Despite the difficulty of incorporating procedural knowledge, or know-how, into computers, the main task of knowledge management is to verbalize and systematize such knowledge possessed by veterans. However, knowledge creation aimed at innovation in the current economic environment cannot be achieved only by systematizing veteran know-how.

In business management, veteran know-how must be systematized together with information about finance, technology, human resources, customers, competitors, economic trends, political trends, etc. This is why knowledge management requires systems thinking. Japan Advanced Institute of Science and Technology (JAIST) established the Graduate School of Knowledge Science in 1998 with a focus on knowledge management. The founders of the school saw computer science, management science, and systems science as the foundations of knowledge science.

The International Society for Knowledge and Systems Sciences was established to co-evolve knowledge science and systems science. The first symposium was held at JAIST in 2000, and the international society was established at the fourth symposium in Guangzhou in 2003.

At the annual symposium, researchers in systems science and knowledge science are learning from and teaching each other, contributing to the development of respective fields.

Theories and methodologies combining the concepts of systems thinking and knowledge management have also been proposed in this academic society. This paper introduces three of them.

The first is *Knowledge Systems Engineering* proposed by Zhongtuo Wang of the Dalian University of Technology, one of the leaders in the Chinese systems science community. Just as information engineering is under the umbrella of information science, knowledge engineering should be under the umbrella of knowledge science. However, knowledge engineering has long existed as an academic field to develop artificial intelligence as a member of information science. He defined the knowledge systems engineering as the engineering that builds, maintains, and manages knowledge systems (Wang 2004 2011, Wang and Wu 2015). Since it is difficult to explain all of his vast theories, this paper only presents his basic ideas.

The second is *Informed Systems Approach*, which aims to unify systems science divided into hard and soft. This is a proposal of Andrzej P. Wierzbicki, a prominent Polish systems researcher. He has also contributed to the development of knowledge science at JAIST for several years as a visiting professor. He worked on developing the knowledge creation models at JAIST and also on unifying systems science inspired by knowledge science (Wierzbicki et al. 2006). This paper introduces only the essence of his proposal.

This theory does not aim directly at the fusion of systems thinking and knowledge management, but rather to unify systems science. However, this paper claims that the key to the unification lies in the introduction of knowledge management.

The last is *Knowledge Construction Systems Methodology* by Yoshiteru Nakamori, who participated in the creation of knowledge science at the Graduate School of Knowledge Science of JAIST. Since it is a methodology, it starts with the philosophy and includes the procedures for collecting, organizing, using, and creating knowledge, and the theory of evaluation of knowledge (Nakamori et al. 2011, Nakamori 2013 2019). This paper introduces only the knowledge construction system model, which models the knowledge construction by integrating systems thinking and knowledge management.

This paper is organized as follows. The next section details the reason why we included *knowledge* and *systems* in the name of the academic society. Section 3 provides an overview of the goals and characteristics of knowledge management and systems thinking and discusses the need to complement each other. Section 4 introduces the above three approaches aimed at fusing systems thinking and knowledge management. Finally, Section 5 gives the conclusions of this paper and future perspectives on the International Society for Knowledge and Systems Sciences.

2. Why Knowledge and Systems?

The 20th International Symposium on Knowledge and Systems Sciences was held in Da Nang, Vietnam in November 2019. The background and purpose of this symposium are explained in the following.

Academic fields that emerged before and after World War II, such as systems engineering, operations research, and systems analysis, are called systems approaches. Systems engineering played a key role in the American Apollo program from 1961 to 1972, which sent astronauts to the moon. With this success, it was greatly expected that it would also contribute to solving various complex problems in society.

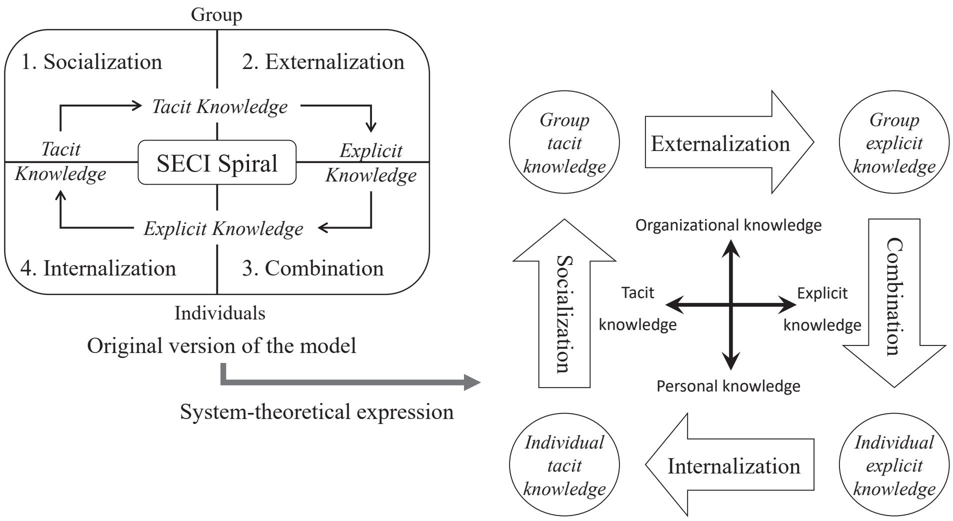

Figure 1 The SECI Model and its Systems Theoretical Expression (Nakamori 2019)

However, as applied to environmental and business management issues, the mathematical model-based approach to problem-solving ran into difficulty. One of the reasons for this is that as the phenomena become complex, solutions based on mathematical models cannot be used directly. Another important reason is that people do not always behave scientifically optimally, even if they know it is good to do so.

With this background, systems science has not only evolved along the dimension of complexity but also refined along the dimension of human relations.

In the UK, the criticism against the systems approaches using mathematical models began in the late 1970s. The most famous one was the soft systems methodology advocated by P.B. Checkland, which has been successfully applied to corporate management (Checkland 1978 1981, Checkland and Scholes 1990). R.L. Flood and M.C. Jackson and others have subsequently developed critical systems thinking (Flood and Jackson 1991, Jackson 1991 2000 2003).

In China, the idea of meta-synthesis was discussed by Zhongtuo Wang, Jifa Gu, and others. Jifa Gu of the Chinese Academy of Sciences proposed the Wuli-Shili-Renli systems approach, which focuses on resources, explores logical solutions, and respects decision-makers (Gu and Zhu 2000, Gu and Tang 2005).

In Japan, Yoshikazu Sawaragi proposed *Shinayakana Systems Approach*. Shinayakana refers to being as sharp as a sword and as flexible as a willow tree. He emphasized the flexible use of solutions based on mathematical models (Nakamori and Sawaragi 1990 1992). A.P. Wierzbicki, impressed by Sawaragi at Kyoto University, asserted the importance of intuition in decision making (Wierzbicki 1997).

These three groups began interacting very naturally and held several workshops in the 1990s, named UK-China-Japan Workshop on Systems Methodology: Possibilities for Cross-Cultural Learning and Integration. They discussed the fusion of the hard and soft approaches and the fusion of Western and Eastern thinking (Gu et al. 2002, Nakamori 2015).

A turning point came in 1998. In April of that year, Japan Advanced Institute of Science and Technology established the world's first Graduate School of Knowledge Science.

The first president Tominaga Keii, who translated the works of Polanyi (1963 1966a, etc), invited Ikujiro Nonaka, one of the authors of the epoch-making book: Knowledge-

Table 1 Comparison between Knowledge Science and Systems Science

	Knowledge science	Systems science
Purpose	Develops knowledge creation techniques aimed at innovation	Develops systems techniques to solve modern complex problems
Means	Optimizes organizational operations through knowledge management	Optimizes organizational operations through systematization
Knowledge	Uses knowledgeable people effectively	Uses systematized knowledge effectively
Subjectivity	Treats subjectivity as directly as possible	Eliminates subjectivity as much as possible
Complement	Must learn systems science for knowledge systematization	Must learn knowledge science for the management of human-centered systems

Creating Company (Nonaka and Takeuchi 1995), as the Dean of the Graduate School. Nakamori got a chance to participate in the project of establishing knowledge science.

The faculty members at this new graduate school were researchers mainly from business science, computer science, and systems science. This suggests that the founders were looking to build knowledge science based on these fields.

There is a famous model that triggered the establishment of the graduate school. That is the organizational knowledge creation model called the SECI model by Nonaka and Takeuchi (1995). The left side of Figure 1 is the original one, while the right side is rewritten according to the tradition of systems science, drawing knowledge by nodes and the knowledge conversion processes by arrows.

Before this model appeared, systems science developed many techniques to help perform the knowledge conversion processes in Figure 1. For instance, there are many problem finding or defining techniques for Socialization, hard and soft modeling techniques for Externalization, integration or optimization techniques for Combination, and quantitative or qualitative system evaluation techniques for Internalization. This fact suggests that knowledge science and systems science can complement each other.

Table 1 compares the knowledge science and systems science to find the possibility of their complementarity.

With the suggestion of Jifa Gu, who joined JAIST in 1999, Nakamori called on researchers who participated in the UK-China-Japan workshop to hold a new symposium. We included knowledge and systems in the name of the symposium with the hope that knowledge science and systems science could learn from each other.

With the above background, we held the first symposium at the Japan Advanced Institute of Science and Technology in September 2000. Table 2 shows the representative systems researchers who participated in this symposium.

Since then, we have been holding this symposium every year. We established the International Society for Knowledge and Systems Sciences at the fourth symposium in November 2003 in Guangzhou, China. In October 2004, we published the first volume of the International Journal of Knowledge and Systems Sciences from the JAIST Press.

3. Knowledge Management and Systems Thinking

Let us think about how to achieve the co-evolution of knowledge science and systems science. To that end, we need to look back

Table 2 Representative Participants in the First Symposium

Name	Affiliation at the time	Remarks
M. C. Jackson	University of Hull, UK	International Society for the Systems Sciences, President 2001
G. Midgley	University of Hull, UK	International Society for the Systems Sciences, President 2013-2014
Z. C. Zhu	University of Hull Business School, UK	JAIST Visiting Professor, 2004-2007
A. P. Wierzbicki	National Institute of Telecommunications, Poland	International Institute for Applied Systems Analysis, Program Leader JAIST Visiting Professor, 2004-2008
M. Makowski	International Institute for Applied Systems Analysis (IIASA), Austria	Participated in the symposium on behalf of IIASA Director
S. W. Chen	Peking University, China National Natural Sciences Foundation	Vice Chair of the People's Congress of China (Minister of Education)
Z. T. Wang	Dalian University of Technology, China	The Chinese Academy of Engineering, Academician
J. F. Gu	Institute of Systems Science, Chinese Academy of Sciences	International Federation for Systems Research, President 2002-2005 JAIST Professor, 1999-2003
S. Y. Wang	Institute of Systems Science, Chinese Academy of Sciences	International Society for Knowledge and Systems Sciences, President 2008-2014
J. Chen	Tsinghua University, China	International Society for Knowledge and Systems Sciences, President 2014-
Y. Sawaragi	Japan Institute of Systems Research Professor Emeritus of Kyoto University	International Federation for Automatic Control, President 1978-1981
K. Kijima	Tokyo Institute of Technology, Japan	International Society for the Systems Sciences, President 2006-2007
Y. Nakamori	Japan Advanced Institute of Science and Technology, Japan	International Society for Knowledge and Systems Sciences, President 2003-2008

on the difficulties that knowledge science and systems science have respectively faced.

3.1 Knowledge Management

Let us start with the background of knowledge science. One of the main themes of knowledge science is knowledge management. Its origin dates back to the 1980s. Computers began to be introduced into companies, and the computer industry advocated knowledge management that comprehensively manages information on business systems and the knowledge and experience of employees.

Knowledge management is a management technique that manages and shares corporate knowledge as an asset throughout the enterprise and uses it to increase productivity and make decisions. In particular, sharing knowledge and know-how cultivated by veteran employees became the main theme of knowledge management.

In the late 1990s, many large companies competed to construct knowledge management computer systems. However, it turned out that building a knowledge management system was difficult. The greatest unavoidable difficulty is to put tacit knowledge into words. This is not surprising since the definition of tacit knowledge is the knowledge that is difficult to express in words. Second, workers who have significant tacit knowledge within the organization are too busy to write it down. Also, they often hesitate to open up their knowledge. Another difficulty is to understand the knowledge of others without sharing experience.

For successful knowledge management, we need to use appropriate techniques in the following three stages. Stage 1: Sharing and visualization of data and information. Stage 2: Conversion of information into knowledge or wisdom. Stage 3: Systematization and utilization of knowledge.

In this paper, the technology that executes these three stages is called *knowledge technology* in a broad sense. The technology to perform Stage 1 originates in information technology, and the technology to perform Stage 3 originates in systems technology. The technology in charge of Stage 2 is *core knowledge technology*. A set of technologies covering the collection and visualization of data and information, the conversion of information into knowledge, and the systematization and utilization of knowledge is called *integrative knowledge technology*.

The School of Knowledge Science at JAIST has conducted research and education as shown in Table 3. It is mainly developing core knowledge technology. Knowledge management in real business operations requires integrative knowledge technology.

3.2 Systems Thinking

Systems science has been regarded as an interdisciplinary science. The reason for claiming that systems science is an interdisciplinary science does not mean that the system models or system methods do not depend on the field. Instead, the reason is that systems thinking is field-independent. The dream of describing all phenomena with the similar system model and processing them with the similar system method has not yet been realized.

One piece of evidence is that systems science, which by definition should be interdisciplinary, is split into two schools. The first school has adopted a hard approach to pursue objectivity in the fields of hard science and technology. The second school has adopted a soft approach that emphasizes the dimension of human relations in management science and social sciences. Despite this split, both employ the systems thinking. That is why they are both called systems science. For more detail, see Wierzbicki et al. (2006).

The most important concept in systems thinking is emergence. The emergence of new properties of a system occurs with an increased level of complexity. Emergent properties are qualitatively different from the properties of any parts of the system. We raise the level of thinking when emergence occurs. Therefore, in systems science, the introduction of a hierarchical structure is the guiding principle of modeling.

Understanding emergent properties requires trained insight and intuition. In other words, it requires a systemic knowledge synthesis ability. Systemic knowledge synthesis is an intuitive approach that uses experience, insight, and wisdom to synthesize knowledge, and the results depend on people.

Polanyi called such ability *tacit integration* (Polanyi 1958 1966b). Tacit integration means the ability to combine several pieces of knowledge, to inductively infer a consistent whole, and to make a comprehensive new meaning. Our acts and methods of knowing are all created by the ability of tacit integration, which is a skill of invention, discovery, and creation.

Humans do not seem to have the ability to understand complex phenomena quickly and analytically. However, humans can intuitively understand complex phenomena as a whole, using knowledge based on experience. People have different perceptions of the same object based on their experiences and knowledge. In other words, the definition of an object depends on the perception of the individual.

Table 3 Knowledge Science Research and Education at JAIST

	Specific initiatives
Methodology	(Systematized problem-solving philosophies, theories, knowledge technologies, evaluation methods) Organizational/personal knowledge management and creation, knowledge systems engineering, knowledge construction systems methodology, etc.
Theory Method Tool	(Knowledge technology: Collection and visualization of data and information; Conversion of information into knowledge; Systematization and utilization of knowledge) • *Research fields originating in management science*: Organizational theory, technology management, service management, innovation management, business ethnography, business model, design thinking, social survey methods, etc. • *Research fields originating in information science*: Artificial intelligence, ontology engineering, ubiquitous computing, human interface, creativity support systems, groupware, sensibility information processing, etc. • *Research fields originating in systems science*: Mathematical modeling and simulation, big data analysis, network analysis, knowledge integration, multiple-criteria decision making, group decision making, systems thinking, etc.
Practice	(Integrative knowledge technology: A set of technologies covering the collection and visualization of data and information, the conversion of information into knowledge, and the systematization and utilization of knowledge) Construction of a company-wide knowledge/information management system, Construction of a local community activation system, etc.
Evaluation	How to justify knowledge that lacks universality, how to verify justified knowledge, etc.

Therefore, a field of study is needed to enhance human intellectual ability. That is the knowledge science, which is sharply opposed to information science that seeks to increase intellectual productivity by enhancing the capabilities of computers.

Organizing information using the computer does not automatically generate knowledge. Knowledge emergence through systematization is a challenge for artificial intelligence, but its success may be dangerous for humans. The emergence of knowledge by human power is desirable for the time being.

In addition to systematization, it is necessary to promote the emergence of knowledge through knowledge management. In other words, it is desirable to introduce the concept of knowledge management into systems thinking.

4. Challenges to Fusing Disciplines

At the International Society for Knowledge and Systems Sciences, we have discussed the integration of hard and soft systems approaches, the fusion of Western and Eastern theories, and the complementarity of systems science and knowledge science. This section reviews the proposals by Z.T. Wang and A.P. Wierzbicki. The former tried to integrate systems engineering and knowledge management (Wang 2004), and the latter proposed a unified theory of systems sciences (Wierzbicki et al. 2006).

After that, this section will introduce the knowledge construction systems methodology that Nakamori developed under the influence of the above. Wierzbicki aimed to unify systems sciences, but Nakamori thinks it would be difficult without incorporating the concept of knowledge management, and one example of

Table 4 Comparisons between Information Systems and Knowledge Systems (Choi and Choi 2007)

	Information systems	Knowledge systems
Management issues	Artificial system as an asset User as a problem	Knowledge as an asset Sharing as a problem
Organizational issues	Engrafting information systems into organizations	Business process to knowledge process
Input-Process-Output based features	Accurate input Efficient process Compatible output	Explicit or tacit input Sense-making process Extensible output
Problem-related feature	Problem-solving	Problem- or opportunity-finding
Organizational learning perspective	Learning bounded to business process	Learning diversified & utilized
Focus of learning (characteristics)	Optimization of what is already learned (preserving and refreshing learning)	New learning & empowerment (innovative)
Locus of value	Business process Efficient design and implementation Reductionism Compatibility/inter-operability	Collaboration Knowledge sharing Utilizing systematic ambiguity Personal expertise

such development is the knowledge construction systems methodology (Nakamori 2013).

4.1 Knowledge Systems Engineering

Wang (2004 2011) proposed a methodology named the knowledge systems engineering for the organization and management of knowledge systems. Its main feature is systematic and integrative thinking for not only knowledge management but also knowledge enabling.

The concept of knowledge management itself is limited. The term management implies control, but knowledge in human brains is inherently uncontrollable. The important thing is to make knowledge enable us to promote the development of human endeavor. So the concept of knowledge enabling or knowledge facilitating is more appropriate for understanding the role of knowledge in real life (see Krogh et al. 2000). The core issue of knowledge management is to place knowledge under guidance to get value from it.

Before explaining what the knowledge systems engineering is, it is necessary to explain what a knowledge system is. A knowledge system is a sort of technology that enables effective and efficient knowledge management. It is different from general information systems. Knowledge systems place more emphasis on coordinating and collaborating on the information to realize collaboration and knowledge sharing by providing a range of knowledge services to their users. The primary goal of knowledge systems is to increase the effectiveness of an organization by using past knowledge to address current activities.

Knowledge systems differ from information systems mainly in that they incorporate or assume communication capabilities within the system. Table 4 shows the differences between information systems and knowledge systems (Choi and Choi 2007).

A knowledge system is not a kind of information technology-based system that has predefined goals and tasks. Instead, it is a complex system consisting of a social system, an information system, and a knowledge content system. The complexity lies in the subjectivity of knowledge in human brains or organizational memory as well as the uncertainty of the environment for knowledge creation.

A knowledge system is also a kind of complex self-organization system, which implies that new knowledge is an emergence of the system. Therefore, we can systematically study such a human-computer system based on systems science theory.

The field of knowledge management has drawn insights, ideas, theories, metaphors, and approaches from diverse disciplines including organizational science and human resource management, computer science and information systems, management science, and psychology and sociology, among others.

Studies can be organized into two different streams. One focuses on information technology and the other focuses on humans. Both streams have the limitations in knowledge management, therefore systematic and integrative thinking for knowledge management is required. Accordingly, a new discipline named the knowledge systems engineering is proposed in terms of the thought of systems engineering.

It integrates the technology-centered and human-centered approaches, integrates the knowledge management and knowledge enabling, and can be acceptable by people both with the science-technology background and with the humanities background.

For knowledge management issues, any single approach such as the information technology-based or human-based will fail to fulfill knowledge tasks. This is because the information technology-based approach focuses mainly on explicit knowledge, on the other hand, the human-based approach focuses on tacit knowledge. However, both explicit and tacit knowledge are vital for knowledge creation and application.

Therefore, we need to rethink how to design and build a coherent model employing systems thinking for knowledge management that can leverage knowledge involving a combination of both explicit and tacit knowledge. The major challenge is to address the tacit dimension of knowledge properly. At the heart of knowledge management are people.

Consequently, traditional technology-push models of knowledge management have to be replaced with new models that reflect the human side of knowledge. This requires a radical shift in emphasis from a focus on know-what to a focus on know-how and know-who. From a complexity perspective, in new knowledge management models, knowledge should be regarded as a living entity rather than managed as a static object or a predetermined process.

The knowledge systems engineering differs from knowledge engineering in artificial intelligence in its area of investigation not only limited to the technological aspect like the existing knowledge engineering. Also from the dimensions of research, it differs from traditional human resource management and information management. For details, see Wang and Wu (2015) that describes the architecture of knowledge systems.

4.2 Informed Systems Approach

This subsection introduces the idea of A.P. Wierzbicki of Poland, a famous researcher in the field of decision analysis, about a new systems science in the knowledge civilization era.

He redefined systems science as the discipline concerned with methods for the *intercultural* and *interdisciplinary* integration of knowledge, including soft intersubjective and hard objective approaches, *open* and, above all, *informed* (Wierzbicki et al. 2006). The keywords in this definition are explained below.

Intercultural integration is not easy because to overcome the incommensurability of cultural perspectives is difficult. We should debate different concepts used by diverse cultures. Interdisciplinary integration has been gradually lost in the division into soft and hard approaches. We should consider this defining feature of systemic analysis. Open means pluralist as stressed by soft systems approaches. We should not exclude any cultural or disciplinary perspectives by design. Informed means pluralist as stressed by hard systems approaches. We should not exclude any perspectives by disciplinary paradigmatic belief.

With the above definition, the principles of transdisciplinary integration become clear as follows. The first thing to understand is the creation of new concepts at a new level with increased complexity in the sense that they are transcendent to concepts at lower levels, that is, the new concepts are independent, irreducible to concepts from different levels. This results in *the principle of cultural sovereignty*. No culture shall be judged when using concepts from a different culture.

When saying culture here, it contains the nuance of academic culture. This principle justifies the disciplinary separation of science into diverse fields. We need a new integration of disciplinary fields. Therefore, this principle must be accompanied by its dialectic antithesis: *the principle of informed responsibility*. No culture is justified in creating a cultural separation of its area. Every culture must be responsible for mutually informing development.

The third principle for synthesizing thesis and antithesis as described above is the basic principle for systems science to be transdisciplinary. That is, the principle of cultural sovereignty and the principle of informed responsibility must be accompanied by *the principle of systemic integration*. Knowledge from diverse cultures might be synthesized by systemic methods, following the principles of open and informed systemic integration.

It is difficult to integrate hard and soft approaches at the level of models or techniques. However, knowledge of problem-solving must be integrated. This paper argues that having the synthesis theory at the level of knowledge gives light to the hope of interdisciplinarity of systems science. To that end, it is necessary to develop the system synthesis principle described above.

Let us consider an example. When we look at the side dishes display at a supermarket, we worry about how to minimize waste loss and opportunity loss.

The soft approach attempts to establish management strategies and forecast demands by interviewing talented managers who have long been engaged in selling cooked dishes. The manager can intuitively predict demand, which has been gradually optimized from many years of practice, and at the worksite, the manager can plan the additional provision of side dishes while watching the sales status. But, the generalization of such management knowledge is difficult because it is usually tacit knowledge dependent on the person in charge.

With hard systems engineering, a mathematical model will be developed that can predict conditional demand, such as weather conditions, based on historical sales data. Then, risk analysis will be done by drawing a waste loss curve and an opportunity loss curve. However, there are uncertainties in forecasts such as typhoon forecasts, daily fluctuations in agricultural yields, and sudden events in the surroundings. The mathematical model is by no means perfect given the fact that raw material orders must be made 10 days in advance.

In today's big data era, sales data and information from the Internet can be used to investigate recent consumption trends. Consumer opinions can be used to modify managers' knowledge as well as adjust demand forecasts based on the mathematical model.

Both the soft approach based on expert knowledge and the hard approach based on mathematical models are systems approaches. Both are approaches that focus on emergent properties due to the interaction between elements.

The same systems technology is not commonly used across fields. However, the systems thinking method is common. For final problem-solving and decision-making, it is necessary to perform synthesis using one as a thesis and the other as an antithesis. To that end, a cross-disciplinary synthesis methodology at the knowledge level is required.

Pluralists advise the selective use of systems methodologies, but decision-making in complex problem situations requires means to integrate different knowledge. One of them is the knowledge construction systems methodology introduced below. This is a methodology taking into account the above three principles of the informed systems approach, with knowledge management at the core (Nakamori 2013).

4.3 Knowledge Construction Systems Methodology

This subsection introduces the knowledge construction systems methodology that combines systems thinking and knowledge management. However, to emphasize the fusion of systems thinking and knowledge management, only the knowledge construction system model, not the whole methodology, is introduced. See Nakamori (2013 2019) for details.

The widely recognized definition of knowledge management is to share knowledge and know-how cultivated by veteran employees and companies. As far as this definition is used, a self-proclaimed knowledge management system using information technology remains at the level of the information management system. The reason is that the documented and formalized knowledge of others is just information to those who receive it.

Knowledge management should include the following three activities. The first is to share scientifically verified objective knowledge, historical or ongoing facts, and formalized meaningful ideas, and get them quickly as needed.

The second is to collect socially embedded data via the Internet, etc. and organize and convert it into information, or to collect knowledge directly from other people and convert it into information, and to make organized information into knowledge by adding significance and availability.

The third includes activities in which the actor creates new ideas by using existing and distributed knowledge, or a group, that includes the actor, creates new ideas by understanding and interacting with their empirical knowledge.

In the knowledge construction system model shown later, the actors' abilities to execute the above three activities are expressed by the following terms. *Intelligence* is the ability to collect and organize existing knowledge. *Involvement* is the ability to collect socially distributed knowledge. *Imagination* is the ability to generate and develop new ideas.

In the model, the knowledge domains in which the above three activities are performed are defined as the *scientific-actual domain*, *social-relational domain*, and *cognitive-mental domain*, respectively. The scientific-actual domain includes rational knowledge that is clear by evidence. The social-relational domain includes social knowledge in society. The cognitive-mental domain includes intuitive knowledge based on individual judgments.

Table 5 shows the data, information, knowledge handled in each domain, and typical knowledge technologies. Table 5 first shows the data, information, and knowledge of the general case since the knowledge construction system model can be used in any scenes of human activity. Below that, as a special case, those that are dealt with in the case of corporate management are shown.

Table 5 Typical Knowledge Technology in Three Knowledge Domains

Knowledge domain	Data, information, knowledge	Knowledge technology
Scientific-actual domain	• *General case*: Science and technology, socio-economic trends, academic evaluation, historical facts, etc. • *Corporate management case*: Product/customer information, sales performance, best practice, etc.	Modeling methods Simulation methods Systems analysis Knowledge management systems Information literacy education
Social-relational domain	• *General case*: Social norms, values, cultures, power relations, reputations, traditions, fashions, episodes, etc. • *Corporate management case*: Product reputation, consumption trends, competitors' information, etc.	Social research methods Big data analysis methods Network analysis methods Marketing methods Business ethnography
Cognitive-mental domain	• *General case*: Judgment criteria, hypotheses, dominant logic, unique concepts, motivations, hopes, etc. • *Corporate management case*: Management strategy, new product ideas, future vision, etc.	Soft systems methodology Knowledge creation models Design thinking Creativity support systems Decision support systems

Now, to make the above knowledge management meaningful, we must pay attention to the following two points. First, the purpose of collecting data and information and converting information into knowledge must be clarified. Otherwise, the search scope and time distribution will not be determined. Second, when the knowledge collected in the three domains is integrated according to the purpose, it is necessary to have a method of integration and a method of evaluating the results.

Therefore, systems thinking for constructing necessary knowledge is required. In the knowledge construction system model, in addition to the three knowledge domains in the knowledge management space, the *initiative-creative domain* is set in the systems thinking space. The initiative-creative domain includes strategic knowledge to collect existing knowledge and construct new knowledge.

The following two abilities are required for actors in this domain. *Intervention* is a strategic planning ability to control the boundary of domains in the knowledge management space. *Integration* is a knowledge construction ability to create a comprehensive whole based on knowledge from three knowledge domains in knowledge management space. The knowledge construction systems methodology considers these two abilities to be creative ability.

To summarize the above, the knowledge construction system model is shown in Figure 2. See Nakamori (2019) on how to integrate knowledge and how to evaluate the integrated knowledge. A knowledge construction diagram is used for the former, and some principles for knowledge justification are applied for the latter.

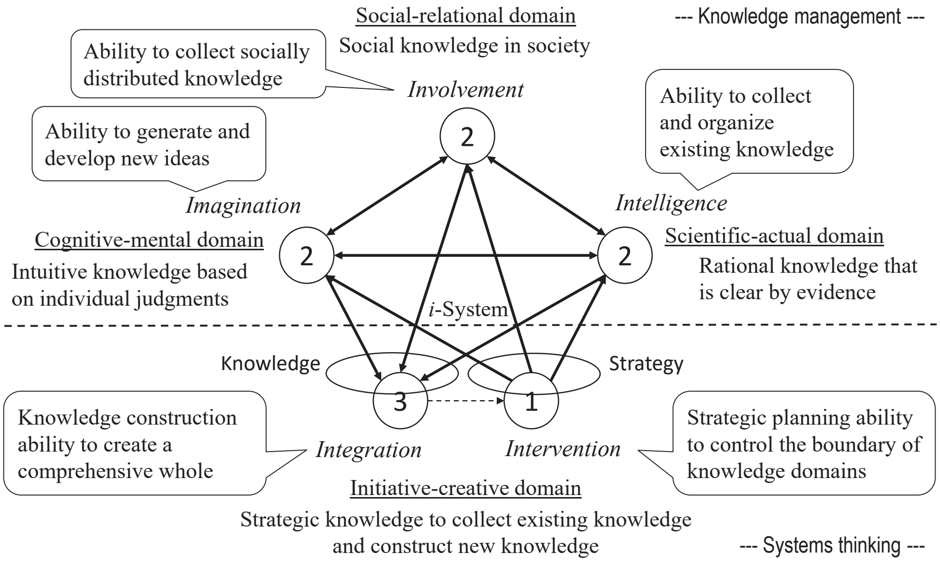

Figure 2 The Knowledge Construction System Model (Nakamori 2019)

5. Conclusions and Perspectives

This paper introduced the background and purpose of the International Society for Knowledge and Systems Sciences and considered new developments in systems science in the knowledge society. In particular, it argued that for the development of systems thinking and knowledge management, it is necessary to complement each other.

It introduced three approaches developed in this academic society aiming to integrate systems thinking and knowledge management. They are the knowledge systems engineering, the informed systems approach, and the knowledge construction systems methodology.

This paper attempted to define knowledge technology. It is a kind of soft technology and supports human creative activities. It is classified into three types according to the roles: Collection and visualization of data and information; conversion of information into knowledge; systematization and utilization of knowledge.

Core knowledge technology is defined as the technology that helps convert information into knowledge. Examples are modeling methods, scenario analysis, computer simulation, creative techniques, hypothesis testing, abduction, causal loop diagrams, design thinking, etc.

In actual company-wide system construction, etc., these combinations are required. Integrative knowledge technology is a set of technologies covering the collection and visualization of data and information, the conversion of information into knowledge, and the systematization and utilization of knowledge.

Figure 3 is an image of converting data and information into knowledge and linking it to innovation. Collecting and using big data alone is not enough to differentiate from competitors and lead to innovation. It is necessary to systematize objective data such as customer information accumulated so far and tacit knowledge such as experience knowledge possessed by employees.

Let us confirm again what knowledge technology is by referring to Figure 3. The technologies that support the execution of the underlined actions in Figure 3 are knowledge technologies in a broad sense. Especially, the technology that converts information into knowledge is called core knowledge technol-

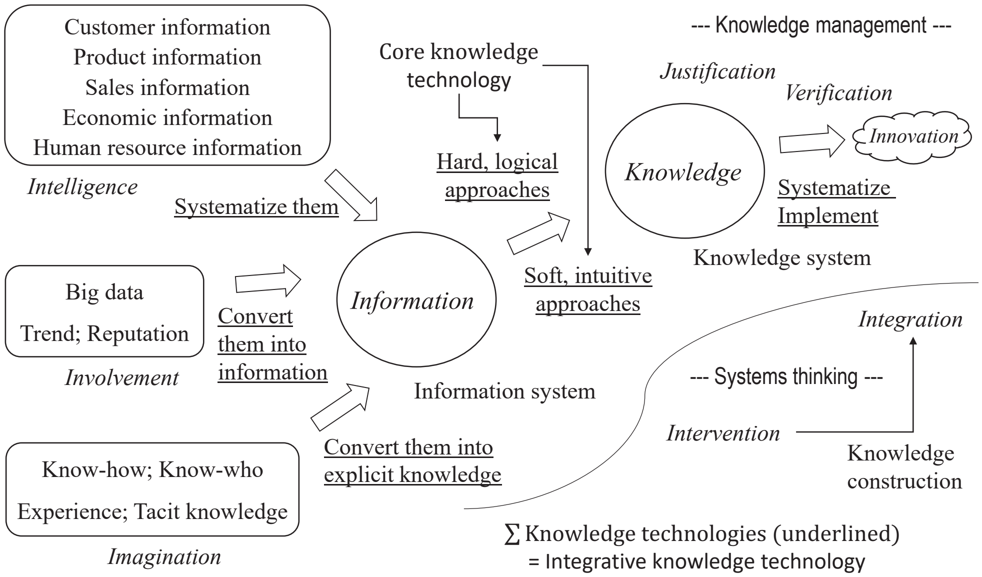

Figure 3 Core and Integrative Knowledge Technologies

ogy, which includes hard, logical approaches and soft, intuitive approaches. The development of these core knowledge technologies is the main theme of knowledge science.

As mentioned above, the entire technology that supports a series of processes to organize data or information, convert it into knowledge, and implement it for innovation is referred to as integrative knowledge technology. Here, it is necessary to fuse systems thinking with knowledge management, which is the theme of this paper.

Finally, the following must be pointed out. We have been aiming for the development of each of the systems science and knowledge science. However, there is also the perspective of building a new academic field that fuses these two fields. The challenge is to define and improve knowledge systems science in response to Wang's knowledge systems engineering.

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