# A THEORETICAL APPROACH AND PROBLEM DEFINITION TO KNOWLEDGE MANAGEMENT IN THE FIELD OF ADVANCED NUCLEAR REACTOR DEVELOPMENT

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**Abstract.** Preliminary definitions of knowledge, information and data are presented due to a theoretical model of cognition relating to human understanding on the basis of cognitive psychology and artificial intelligence. Due to the definitions, a meaning and role of knowledge management are discussed for explicit, implicit and real-tacit knowledge that are classified from the viewpoint of practice. On the basis of the definitions and consideration on the characteristics in the developmental field of fast breeder reactors (FBRs), preliminary guidelines are obtained as the first step for planning a long-term strategy of the knowledge management in this field. For the FBR development toward the commercialization, that is expected to take long time around 100 years, it is of importance to take note of management for transferring human comprehension to developed technologies from experts to laymen and novices in various special fields as well as in different generations of the related experts such as designers, technicians and engineers. Furthermore, the knowledge management should be planned not only as a developmental tool for the technical experts but also as a communication tool between the experts and the stakeholders such as the public and utilities who are related to acceptance and decision for reactor construction that is expected to be made at intervals of a few ten years over different generations during the term of the development toward the commercialization.

## 1. Introduction

The development of FBR takes long time beyond the working lifetime of the related experts, who gain high expertise through the related engineering and technical experience. To continue the development toward the commercial utilization of FBR, a new systematic base is currently required to manage the expertise obtained by the experts over the change of generation, leading to requirement for management of technical knowledge in this field.

Since 1990s knowledge was paid attention in the field of commercial business and then social scientists pointed out the importance of knowledge as an asset as well as capital funds for business companies [1][2][3][4], due to the background of the significant progress of information technologies since 1980s, that spread widely so far in the world. This lead to the so-called knowledge management conducted in the business field [5] [6]. Nowadays the knowledge management seems to be important not only in the business field but also in other fields, even in the nuclear field as well [7].

However a wide range of meaning of knowledge itself leads to a wide range of knowledge management activities. To plan the new systematic base on the basis of the characteristics in the nuclear developmental field, it might be required initially to clarify what knowledge is and then what knowledge management is in the field of FBR development.

From the point of view mentioned above, basic consideration is made at first on definition of knowledge itself due to a model of cognition relating to human understanding and then on a meaning and role of the knowledge management in the nuclear developmental field, leading to problem definition to be solved for a long term strategy of the knowledge management as the first step for planning in this paper.

## 2. Basic consideration due to a theoretical model

In a wide sense, the meaning of knowledge includes not only knowledge of expertise in the field of science and technology but also cognitively higher-located knowledge such as belief, trust, passion and ethics that influence human understanding, thinking and behavior. In this paper, however, the meaning of knowledge is limited to the knowledge of expertise in the science and technology field. Furthermore, the meaning of knowledge is used in the narrower sense, distinguished from information and data, to clarify the meaning and role of the knowledge management in the field of FBR development. In the following, knowledge, information and data are defined due to a model of cognition relating to human understanding.

### 2.1. A model of cognition relating to understanding

Fundamental characteristics of human cognition such as remembering, understanding and thinking are being studied in the field of cognitive psychology. In the early time of the studies, memory stored in a brain was classified into short-term and long-term memory.

The long-term memory is further classified to semantic and episodic memory. The episodic memory is described by the conceptual models of schema that was initially proposed by Bartlett [8] and of script proposed by Schank et al [9], related to human understanding of daily-life experience. From the studies of artificial intelligence, the conceptual model of frame was proposed by Minsky [10] for memory structure related to human comprehension. On the other hand, the short-term memory was studied in the early time, but the concept was later abandoned [11] and replaced with the concept of working memory [12].

Johnson-Laird described by using the concept of mental models that human comprehension was based on a mental model as a working model relating to the working memory [13]. Furthermore, he said that the mental model was a mental representation of knowledge as long-term or short-term memory [14].

Due to consideration of cognitive structure in creative thinking and of philosophical ontology as well as facts coming from brain science, Fukuzawa pointed out the important role of cognitive abstraction influencing the formation of a mental model for understanding in a brain [15]. The abstraction is one of the important cognitive functions of a brain, described by adoption of a part of characteristic stimuli with rejection of the other part of stimuli coming from the outside of a body through the five sense organs, especially through the sense of sight or hearing. In fact, most of external stimuli coming through the five sense organs are abandoned and not used for formation of a mental model for understanding in a brain [15]. Due to a difference in a way to adopt external stimuli depending on personal attention as well as bias or belief on the basis of knowledge in a brain, the mental model for understanding formed in a brain is often different from those of others, leading to different comprehension to the same external thing between people. As an example for such a case, Fukuzawa showed the case of scientific discoveries due to the history of science, pointing out the importance of the philosophy of science as a way of thinking that controlled the abstraction and hence the formation of a mental model for understanding [16]. In fact, scientific discoveries are often attained by correction of misunderstanding shared in people to the same external thing. Furthermore, as an instance of different comprehension to the same external thing, he showed the case of different understanding by silent majorities to the same nuclear technology in different European countries, describing common factors that influenced the abstraction and hence the formation of the mental models for understanding [17].

Due to the mention above, the following model might be proposed as a preliminary model of cognition relating to understanding.

A mental model for understanding is formed in a brain as working memory by using representations adopted due to the cognitive abstraction of stimuli coming through the five sense organs from the outside of a body as well as by using representative knowledge coming from long-term memory, resulting in comprehension to an external thing. The mental model for understanding formed in a brain is not necessarily always the same as in other brains, depending on different personal characteristics such as attention, bias or belief on the basis of knowledge stored in their brains, leading to different comprehension to the same external thing.

### 2.2. Definition of knowledge, information and data

On the basis of the model of cognition relating to understanding, knowledge, information and data are preliminarily defined as follows;

Knowledge: representative mental models stored in a brain as long-term memory, necessary for human understanding and thinking to external things.

Information: representative mental models formed in a brain as working memory by abstraction of stimuli coming from the outside of a body through the five sense organs as well as by using long-term memory stored in the brain, used for understanding and thinking.

Data: external symbols existing outside a body, not yet used for understanding and thinking as working memory in a brain but possible to be used by receipt of stimuli coming through the five sense organs when necessary.

The knowledge and information are long-term and working memory in a brain, used for understanding and thinking that base human judgment and behavior. The concept of data is due to exclusion of meaning of human personality from information.

### 2.3. Meaning and role of management relating to knowledge, information and data

Due to the definitions, the following might be said as a meaning and role of their management.

Data management is to manage computer hardware and software for storage and retrieval of data defined as external symbols. The data management is useful to support information management in the form of informational data as well as knowledge management in the form of knowledge data, if they are related to information technologies. Due to the definitions mentioned in 2.2., the informational data is described as external symbols possible to be used in a brain as information, while the knowledge data as external symbols possible to be stored in a brain as knowledge. The informational data as well as the knowledge data are often in the form of a document.

Information management is to manage a systematic framework for experts in a limited special field, who have stores of related knowledge in their brains and then know how to treat informational data. The information management, often based on the data management, is capable to contribute the promotion of efficiency for expert work in a limited special field. However, if the experts disappear in their special field, the stores of informational data become meaningless.

Knowledge management is to manage a systematic framework for laymen and novices in a special field to promote and support their comprehension to the related informational and knowledge data. The laymen and novices are the people who have no storage of related knowledge in their brains as long-term memory relating to a certain special field and hence have no idea about how to use the related knowledge data. Therefore, the knowledge management, that is able to be based on the data management, should be planned to be focused on and characterized by the aspect to promote and support human comprehension to

the related informational and knowledge data. Since different understanding to the same external thing often occurs due to different mental models depending on personal knowledge bases as mentioned in Section 2.1., it is of importance to manage the comprehension in the knowledge management. From this sense, the knowledge management is capable to contribute comprehension-sharing as well as communication between experts and laymen or novices in a certain special field.

Usually, knowledge is classified into two types; explicit and tacit knowledge. The explicit knowledge is expressed by a language and hence it is declarative knowledge. The tacit knowledge is undeclared knowledge, as it is said “we know more than we know that we know [18]”. In the field of the artificial intelligence, knowledge is classified to declarative and procedural knowledge. From the viewpoint of practice, the tacit knowledge is further divided into two types in this paper; pseudo-tacit knowledge and real-tacit knowledge. The pseudo-tacit knowledge is the implicit knowledge that is practically possible to be converted to the explicit knowledge but not yet done [7]. The real-tacit knowledge is practically unable to be converted to the explicit knowledge and is used with unconsciousness. Then the following might be said for each kind of knowledge.

Explicit-knowledge management is to manage a systematic framework for laymen and novices to promote and support their comprehension to explicit-knowledge data with the form of documents. In the creative field such as technical development, the explicit-knowledge management is capable to induce creativity due to comprehension-sharing between different experts in different special fields. The explicit-knowledge management is also capable to work as an educational tool to transfer knowledge data from experts to novices as well as a communication tool between experts and laymen, since the management aims at promotion and support of common comprehension.

Implicit-knowledge management is to manage a systematic framework to convert implicit knowledge to explicit-knowledge data with the form of documents.

Real-tacit-knowledge management is to manage a systematic framework to transfer comprehension of real-tacit knowledge from person to person with unconsciousness. Though the real-tacit knowledge cannot be treated as knowledge data due to its definition, it is possible to handle the real-tacit knowledge as the form of the same comprehension coming from the same experience. The real-tacit-knowledge management is capable to contribute sharing and transferring the real-tacit knowledge from person to person through the same experience, that plays an important role often in the field of industrial operation and manufacture.

## 3. Problem definition to knowledge management

### 3.1. Characteristics in FBR development

The development of FBR in Japan was started in 1970 at the O-arai Engineering Center of the Power Reactor and Nuclear Fuel Development Corporation (PNC) that was later reformed to the Japan Nuclear Cycle Development Institute (JNC) in 1998 and afterward unified with the Japan Atomic Energy Research Institute (JAERI) to the current organization of the Japan Atomic Energy Agency (JAEA) in 2005. During the developmental term in Japan so far, the experimental reactor Joyo that was constructed at the O-arai Engineering Center in the Ibaraki prefecture in Japan reached its initial criticality in 1977 and the prototype reactor Monju that was constructed in the Fukui prefecture reached its initial criticality in 1994.

Now the development is being performed to introduce FBR and its fuel cycle into the commercial market from 2050 onward on the basis of the decision by the Japan Atomic Energy Commission about the basic principle for the nuclear energy policy and promote

research, development and utilization of nuclear science and engineering [19]. By the continuous development toward the commercial utilization, the demonstration reactor as the next step is expected to start its operation in 2025 and the commercial reactor as the further step in about 2045, due to the report of “Policy on Research and Development of FBR Cycle” decided by the Government in 2006 [20].

The time from the commencement of the development to the commercial utilization of FBR is expected to be 80 years in Japan and also more than 100 years if the initial criticality of the Clementine in the United States in 1946 is taken into account. The time difference of the initial criticality between the experimental reactor Joyo and the prototype reactor Monju was 17 years, while the difference between the prototype reactor and the next-step demonstration reactor is expected to be about 30 years. The experience gained by the research and development work for the experimental reactor Joyo as well as its design and operation work was available for the prototype reactor Monju due to the personnel management of the experts such as engineers, designers and operators within the same generation, since the time difference of 17 years was within their working lifetime. However, this is not the case of the next-step demonstration reactor and also not the case of the further-step commercial reactor. The development of FBR is characterized by the long duration from the commencement to the commercial utilization around 100 years over the change of generation of the related experts.

In addition, it is said from the developmental experience so far that the FBR technology includes various special fields such as physics, chemistry, mechanics etc. and also that construction and operation of FBR need synthesis of various developed technologies, coming from inherent characteristics of technology itself that might differ from discovery in science [16]. Then the development of FBR is also characterized by integrated technologies covering a wide range of various special fields.

### 3.2. Problem definition to knowledge management

The development of FBR is characterized by the long duration over the change of generation and also by the wide range of related special fields, as mentioned above. Then, technical knowledge data increasing with progress of the development should be shared between different experts in different special fields and also in different generations. This means that developed knowledge data should be transferred from experts to laymen and novices in the FBR development field. Therefore, the concept of the information management is insufficient and then the concept of the knowledge management to handle human comprehension is required for transferring the knowledge data in the field of FBR development. Furthermore, since the technology is essentially characterized by synthesis of related knowledge data, that might be different from discovery in science, the concept of the information management is also insufficient and then the concept of the knowledge management is needed in this field.

From this sense, the concept of the explicit-knowledge management is required to treat comprehension to the FBR technology with a synthesis of knowledge data obtained with progress of the development. The implicit-knowledge management is also needed to convert the implicit knowledge to the explicit-knowledge data that should be used for the explicit-knowledge management. To plan the explicit-knowledge management, consideration will be required about how to treat the human comprehension to the synthesis of the developed technologies. For the purpose, further consideration would be required on the basis of the preliminary model of cognition presented in this paper. To plan the implicit-knowledge management, consideration will be needed about a way to convert the implicit knowledge to the explicit-knowledge data with a form of documents. For the purpose, the study in the field of cognitive psychology would also be needed to develop the method.

For the real-tacit-knowledge management, it is required to consider about a way to transfer the tacit knowledge that is obtained in experts with unconsciousness. As such a way, the same experience for common comprehension would be an appropriate way to transfer the real-tacit knowledge from person to person. The experimental reactor Joyo and the prototype reactor Monju as well as their related facilities are the good tools suitable for transferring the common comprehension of the real-tacit knowledge relating to operation and maintenance from experts to novices in the FBR development field.

Furthermore, during the long term of the development around 100 years, the construction of FBR is expected to be made at intervals of about 20 or 30 years. This means that decision for the construction should be made at the intervals by utilities to use the developed technologies as well as acceptance by the public around the related site. The development of FBR cannot be advanced without the decision and acceptance by the stakeholders. Hence, the knowledge management is required not only as the developmental tool for the experts but also as the communication tool of common comprehension for the stakeholders over the change of generation toward the commercial utilization of FBR.

## 4. Concluding remarks

From the consideration on human comprehension on the basis of the cognitive model, the preliminary definitions are presented for knowledge, information and data in this paper. On the basis of the definitions and the consideration on the characteristics in the FBR development, the following remarks are obtained as preliminary guidelines for planning the knowledge management in the FBR development field.

For the FBR development toward the commercialization, the knowledge management to promote and support human comprehension to developed technologies is required rather than the information management. The aspect of transferring the human comprehension over the change of generation in the knowledge management is of importance to fulfill the developmental goal of FBR.

For planning the explicit-knowledge management, it is required to consider the systematic base for sharing common comprehension to developed technologies in the form of documents as knowledge data between experts in different special fields and also in different generations. Furthermore, it is needed as the implicit-knowledge management to develop a method to convert undeclared knowledge to declarative-knowledge data. For these purposes, it might be important to further elaborate the model of cognition for understanding preliminarily presented in this paper on the basis of the progress of the cognitive psychology.

For the real-tacit-knowledge management, common comprehension should be transferred from person to person through the same experience that would be an appropriate way to transfer real-tacit knowledge with unconsciousness. Joyo and Monju as well as their related facilities are the good tools suitable for transferring the common comprehension relating to the operation and maintenance.

The comprehension-sharing of the FBR technology due to the knowledge management is important not only for the experts in the technical field but also the related stakeholders such as the public and the utilities who are related to the acceptance and decision for the reactor construction that is expected to be made at intervals of a few ten years over the change of generation toward the commercial utilization of FBR. In this sense, the knowledge management in the field of FBR development should be planned not only as the developmental tool for the technical experts but also as the communication tool between the experts and the stakeholders over the change of generation.

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