Original Paper

Kfarm: An Ontology-aware Support Environment for Learning-Oriented Knowledge Management

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It is important for running an organization to support learning for knowledge acquisition and creation and to encourage spread and inheritance of new knowledge on the proper understanding of relations between individuals and organizations. This paper presents ontology-based framework of information systems for knowledge management focused on a learning system in organization. Major characteristics of this framework are derived from "Ontology" which is used as an index of knowledge and "Dual loop model" which represents the flow of knowledge in an organization. Since these two things enable the framework to grasp the meaning of knowledge and the progress of organizational learning, it can provides appropriate support for knowledge management Then we will introduce a system as concrete examples, namely a learning-oriented knowledge management support environment: *Kfarm* and explain how it works in cooperation with a learning contents design environment: *i*Designer.

Keywords: Learning Contents, Learning Organization, Knowledge Management, and Ontology

1. Introduction

Recently, knowledge sharing, inheritance and creation in an organization have drawn attention under the slogan 'knowledge management [1][2].' In this study, we aim to develop an information system for knowledge management that takes 'learning' as its principal axis. Based on the proper understanding of the relations between individual learning and organizational learning, it supports knowledge acquisition and creation and encourages spreading and inheriting of new knowledge. We call it 'learning-oriented knowledge management'.

To realize this idea, it is necessary to clarify relation between individual learning, which includes acquisition and use of knowledge and externalization of its product, and organizational learning, which is aggregation of individual learning. We mainly focus on the two points shown below:

- A model which expresses contents of knowledge learned in an organization
- A computer-aided model which support for individual and organizational learning activity

Ontology and 'Dual loop model', which we propose in this paper, act as the basis of these points.

Ontology is a system of vocabulary/concepts to describe contents of knowledge to be acquired or created by members of organization. Contents description based on ontology is the basis of the contents-oriented knowledge management, to clarify 'who has what knowledge', 'who wants to know what knowledge'.

The dual loop model is a reference model of the information system design. This model reflects the key idea of our approach inspired by the theories of Senge's 'Learning Organization' [3] and Nonaka's 'Organizational Knowledge Creation' [2]. This is the basis of expressing 'behavior' in knowledge management, to clarify 'who must be informed of what knowledge in which situation'. It is on the line of "Knowledge Awareness" proposed by Ogata [4].

In this paper, we introduce the dual loop model and describe the role of ontology in the learning-oriented knowledge management. We also introduce a system, namely a learning-oriented knowledge management environment: *Kfarm* and explain how it works in cooperation with a learning contents design environment: *i*Designer [5]. as an implementation of our idea.

2. Correlation between organizations and individuals in the knowledge creation process

In this chapter, we propose a model based on which computers support the creation and inheritance of organizational intellect.

2.1 Intellect

The terms 'knowledge,' 'intellect,' and so on are used with various meanings, so there appear to be no definite meanings for them [6]. Though it is difficult to define them strictly in a consistent manner, to show subjects of this study, we will take some exemplary definitions from the literature.

Brown and Duguid [7] argue convincingly that knowledge is more than just information because it

- usually entails a 'knower',
- appears harder to detach than information, and
- is something what we digest rather than merely hold.

Tobin draws distinctions between data, information, knowledge, and wisdom [8].

1. *Data*:
2. *Information*: = *Data*+ relevance + purpose
3. *Knowledge*: = *Information* + application
4. *Wisdom*: = *Knowledge* + intuition + experience

In this research, the term 'intellect' is used to express

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our idea similar to Brown and Duguid's argument about 'knowledge' and Tobin's 'wisdom'. Having an intellect means not only merely knowing something, but also digesting it through creation or practical use. It also means that the intellect cannot be separated from a person because it includes skill and competency. This is the major reason why we introduce the term "intellect." We aim to support creation and inheritance of organizational intellect by managing information concerned with intellect.

2.2 A dynamic theory of organizational knowledge creation

2.2.1 SECI model

Nonaka and Takeuchi proposed that the knowledge of an organization is created by two different types of mutual conversions of knowledge, which are 'explicit knowledge' and 'tacit knowledge', and by individual interactions that have having different knowledge contents[(2)]. Explicit knowledge is formal knowledge that can be packaged as information. It can be found in the documents in an organization: reports, articles, manuals, etc. Tacit knowledge is personal knowledge embedded in individual experience and is typically shared and exchanged through direct, face-to-face contact. They modeled a knowledge creation process in an organization as a SECI model in which knowledge creation in an organization was taken as explicit knowledge and tacit knowledge and was a composite of the following four modes:

- 'socialization' which shares tacit knowledge through shared experience
- 'externalization' which creates explicit knowledge from shared tacit knowledge (expressed by languages)
- 'combination' which creates systemic explicit knowledge with the combination of existing and new explicit knowledge
- 'internalization' which acquires tacit knowledge through experience based on systemic explicit knowledge

This model is constructed as a spiral process, starting at an individual level, expanding by shared degrees to organizational knowledge. Additionally, the more sophisticated and enriched knowledge from the sharing process goes back to individuals. In the spiral, the individual knowledge becomes more enriched and leads to new knowledge creation.

2.2.2 Middle Up-Down Management

Nonaka and Takeuchi proposed "Middle up-down management", which is a form of an organization that promotes a knowledge creation process [(2) (9)]. As shown in figure 1, knowledge leader and knowledge practitioners, from a knowledge creating viewpoint layers, correspond to with top (executives), and middle (middle management), and lower (employees) from organizational viewpoint layers.

"Knowledge practitioner" corresponds to the employees and plays the role of generating creative power. Typical activities of the knowledge practitioner are given below:

- Acquiring intellect from inside and outside of the organization.
- Creating new intellect.

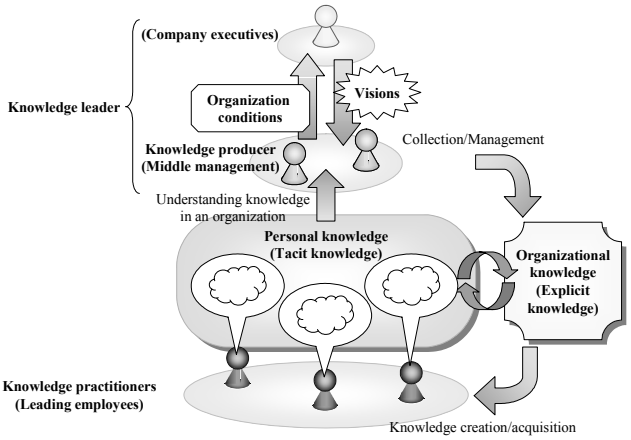

Figure 1 Middle up-down management

- Distributing one's own intellect through the organization.

On the other hand, a "Knowledge leader" corresponds to top and middle managements and is expected to give direction to the knowledge practitioner s. Especially, middle management is referred to as "knowledge producer" and plays the role of coordinating between the top's visions and the knowledge practitioner s' practical activities. Typical activities of the knowledge producer are given below:

- Proper understanding of organizational conditions.
- Assimilating new intellect with the organizational intellect.
- Distributing organizational intellect based on their vision/strategy.

2.3 Dual loop model

Our goal is to present a framework of information systems that supports all the activities from the practical ones in an organization to ones oriented to knowledge creation and skill/competency development. In this research, based on the two ideas set out in previous section, some activities related to the formation of organizational intellect are explained from both viewpoints of the 'individual' as the substantial actor in an organization and the 'organization' as the aggregation of the individuals. The two viewpoints are modeled as two separated loops of activities with explicit interactions between them. The whole model called "Dual Loop Model" is illustrated in figure 2. It works as the reference model for designing a learning-oriented knowledge management support environment. *Kfarm* that we will see in the next chapter is one of the implement of the idea. The dual loop model is constructed from an individual's intellect conversion process (figure 2 (A), personal loop) and organizational intellect conversion process (figure 2 (B), Organizational loop), and it represents the flow of intellect between them. Intellect creation activities in this dual loop model are explained herein and functions supporting each activity are detailed in the next chapter.

We sometimes use terms introduced by Nonaka differently from his use. In order to avoid possible confusion, we used italic font when the terms are used in the same way as

Nonaka's.

2.3.1 Personal loop

The personal loop is a loop of individual activities related to intellect. As shown in figure 2 (A), it consists of four processes: internalization, amplification, externalization and combination. This loop has a learning mode, in which an individual acquires intellect from his/her surroundings, and a creative mode, in which he/she creates original intellect. A typical activity in the learning mode is one in which the members acquire intellect of which the significance is approved in an organization. Systems supporting the leaning and the creation modes can be considered the learning support and creative thinking support systems, respectively. A possible common basic requirement for supporting these two modes is:

- Easy access to useful intellect for intellect acquisition and creation activities.

This is closely equivalent to the considerations in the study of Ogata et al's knowledge awareness support [4], Takeda et al's kMedia [10], and Ohira et al's L-EVIDII [11]. These researches aim to support individual activities in a community. In our research, in addition, we aim to support making harmony between the individual activities and organizational activities which give direction to the individual activities based on a vision and strategy of the organization. We will describe the organizational activities in 2.3.2 and 2.4. We develop this idea in a framework that promotes the 'appropriate creation/distribution' of intellect in an organization based on knowledge management theory.

Basic requirements for each mode of the personal loop are:

- for the learning mode, preparing and implementing a rational learning process for an organization.
- for the creative mode, supporting communication of intellect, e.g. acquiring knowledge and imparting it to others, as the basis of individual amplifying process.

In figure 2, nodes from 1 to 7 represent the events of the individual activities. Typical starting events for the learning and creative modes assumed in the dual loop model are nodes 5 and 7, respectively in figure 2. Node 5 represents an event in which 'significant intellect in an organization' should be acquired, and node 7 is an externally-triggered event that represents a start of the creation of original intellect. These are defined in connection with a user's activity conditions and an organization's loop events.

2.3.2 Organizational loop

An Organizational loop is an abstract model, reflecting members' activities in personal loops in an organization as intellect inheriting and creating activities from an organizational viewpoint. The typical activities include acquisition and creation of intellect inside and outside an organization. The loop consists of four processes: internalization, socialization, externalization and combination. In figure 2, nodes 8, 11 and 12 represent the events that trigger off individual activities performed in the personal loop process. For example, node 8 represents such an event as 'intellect distributed by individuals', node 4 represents 'obtaining intellect from

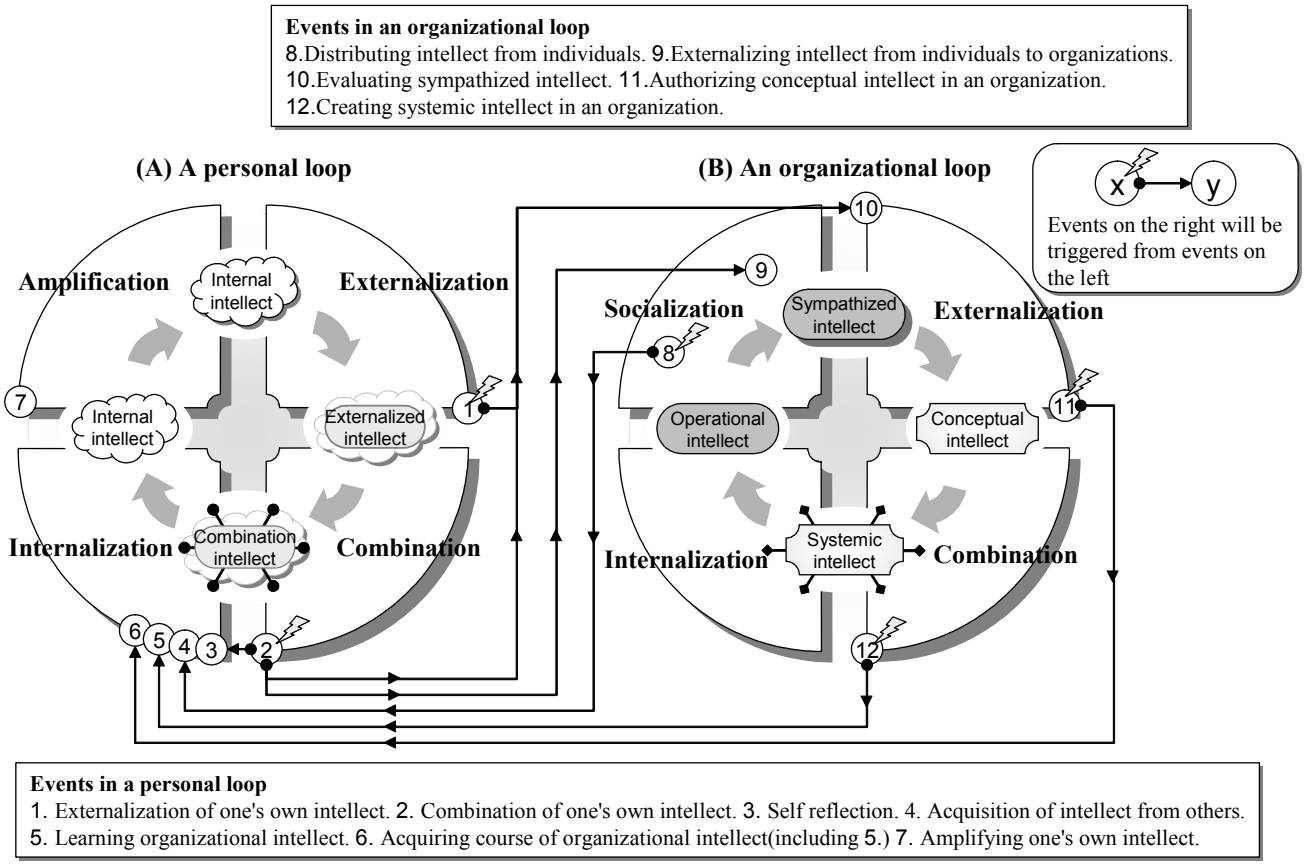

Figure 2 Dual loop model (partly simplified)

others'. The arrow from node 8 to node 4 shows a causal link between the two events.

Furthermore, this dual loop model can explain learning conditions in an organization. For example, an organization that frequently has events in the socialization process (at the top left) and rarely has events in the combination process (at the bottom right) mean that even though an individual actively carries out intellect acquisition and creating activities, they are not likely to be recognized as 'organizational intellect'. Lack of activities of individuals and the organization can be identified as the causes. Further, when an organization has events only in the internalization process in the Organizational loop (at the bottom left), it can be seen that a tendency of the organization leans to knowledge acquisition activity in practice. Thus, the dual loop model is also useful as a reference for analyzing the proper process of intellect acquisition, passing down and creation in an organization.

2.4 Support for creation and inheritance of organizational intellect

In an organizational loop, a typical example of highly creative organizational behavior is that 'members have appropriate intellect, exchange the intellect and create innovative ideas. At the same time, the organization immediately adopts the ideas and clarifies the value of the idea from organizational viewpoint. To develop such an intellect creation process, information technology is thought to be able to support the maintenance of the creation process.

In this paper, we refer to Knowledge practitioner and Knowledge producer as "K-practitioner" and "K-producer", respectively. In the following, K-practitioners and K-producers are related to the dual loop model, and necessary support in *Kfarm* is discussed.

2.4.1 Support for K-practitioners

K-practitioners acquire intellect in the socialization and internalization process of the Organizational loop, and create innovative ideas based on the acquired intellect. Socialization can be regarded as intellect communication among K-practitioners, and can be supported by the information communication technology improve accessibility of other's intellect in organizations. Internalization, however, is regarded as inheritance of systemic intellect that is *explicit knowledge* externalized and combined in an organization. This systemic intellect has *tacit knowledge* behind it, and depending on the *explicit knowledge*, it needs inherited intellect (*explicit knowledge and tacit knowledge*) that is meaningful for the organization.

The inheritance process of intellect process may include both on the job learning process and an intentionally planned learning process in an educational context. In *Kfarm*, we plan to respond to the former with promotion support tools for spontaneous intellect communication, and to the latter with learning support systems that support the progress of intellect acquisition in the personal loop. Especially for the learning support system, rationality in the organizational perspective of the provided learning process becomes important. From this viewpoint, we will have been developing design support tools for learning contents connecting with management of organizational intellect, and learning scheduling functions connecting with understanding of organization members' intellectual state (personal profile).

2.4.2 Support for K-producers

On the basis of the organizational vision, K-producers, in the externalization and combination processes in the Organizational loop, are expected to certify what created intellect from the organization's activities is highly useful, to certify the value of the intellect from organizational viewpoint, and then they are also expected to encourage intellect creation by distributing that intellect to individuals.

To support this, *Kfarm* has following function:

- Notification to K-producers of events that have occurred in the personal loop.
- The visualization functions of the intellectual state of an organization.
- Knowledge systematization support systems including OntologyEditor [12].

3. Ontology-aware support environment for management of organizational intellect

In this chapter, as an embodiment of ideas set out thus far, we introduce the knowledge management support environment that has been developing in this study; *Kfarm*. We have been designing and developing *Kfarm* centered on documents and folder handling, in which users can participate in organizational learning in an easy way that has no major differences to that in an ordinary computer environment.

3.1 Documents as representation of intellect

In *Kfarm*, intellect is represented in documents. The documents mediate intellect among people in an organization. As mentioned before, we assume that intellect can only exist in a person's mind and a document is not necessarily a complete representation of the intellect. Here lists major objects handled in *Kfarm*.

Document: a representation of intellect.

Folder: a document's storage. Indexes explaining contents are attached.

Term index: describes contents of documents and folders in terms designed for easy use by K-practitioners.

Conceptual index: conceptually describes contents of documents and folders and is converted from the term index based on ontology.

Ontology: a system of concepts representing a state of being – a conceptual index. It includes mapping with terms.

Since directly referencing the conceptual definition of ontology would cause unnecessary work for users, *Kfarm* provides simple indexing scheme to K-practitioners. Documents managed in *Kfarm* are categorized, from the viewpoint of the dual loop model, as the following intellect types:

- Personal intellect document: documents before publication.
- Sympathized intellect document: published to organizations. Sympathy with the contents advances in the process of document distribution and referencing.
- Conceptual intellect document: documents with term indexes such that their efficiency in an organization's activities is recognized by K-producers.
- Systemic intellect document: documents with conceptual indexes attached by K-producers.

These intellect types are used by *Kfarm* to understand and support events, and are not presented to K-practitioners. Figure 3 shows a typical state transition process of these documents. Individual and sympathized intellect documents correspond to personal subjective intellect, and to *tacit knowledge*. Also, learning contents are treated as a kind of systemic intellect document.

3.2 A role of ontology

When designing *Kfarm*, we closely looked at the following two points:

- Support designing according to the process described in the dual loop model.
- Detect meaningful events to understand the progress of the process.

Ontology is the basis for realizing this function [13]. In this study, we define the concept and vocabulary for expressing intellect contents as organizational ontology, and as the basic information for sharing and managing intellect in an organization. Ontology in *Kfarm* works as meta-information that defines basic concept to describe content of intellect in an organization. A support system based on intellect contents becomes possible by using organizational ontology in an organization. In *Kfarm* only K-producers are privileged in managing ontology, and they provide editing tools such as OntologyEditor [12].

3.3 Implementation of *Kfarm*

Kfarm is a system referencing the organization structure of the middle up-down management in figure 1, and aims to share and manage documents based on ontology. Figure 4 shows a system structure. *Kfarm* is distributed system and consists of a server: K-granary, at least one K-producer environment: K-ranch house and some K-practitioner environments: K-field. In K-granary (figure 4 (B)), it supervises stored documents in the personal folders of each K-practitioner and in the organizational folders shared with the whole organization according to the term trees and ontology. It controls their upgrading and referencing conditions. Based on information from this server, K-practitioners and K-producers carry out document management in each of the environments (figure 4 (A), (C)). Figure 5 shows the interfaces of each environment. Although five buttons correspond to functions 5 and 6 in figure 5 are provided only to K-producers, K-practitioners will be provided similar interfaces except for those five. In this section, we describe user's tasks in K-field and K-ranch house with related event in the dual loop model (DLM) and support function of *Kfarm*.

3.3.1 K-field

K-practitioners participate in organizational learning through either their own documents or documents obtained from outside. K-practitioners' basic tasks and their support functions are as follows:

Sorting: select a term from the term trees (figure 5 (c)) and put a term index on a folder. Store documents in the indexed folder. The documents have the same indexes as the folder and are converted to conceptual indexes in *Kfarm* (e.g. function 1).
Event in DLM: Event 2. Combination of self intellect.
Support: providing terms based on ontology, making clear term descriptions.

Distribution: distribute one's documents with term indexes to interested people (e.g. function 3-2).
Event in DLM: Event 8. Distributing intellect from individuals.
Support: intellect awareness support.

Reference: search and reference documents and bulletins of others and organizations based on terms (e.g. function 2, 3).
Event in DLM: Event 4. Intellect acquisition from others.
Support: visualize know-who/know-what information.

Learning: search learning contents that fit one's situation and learn (e.g. function 3).

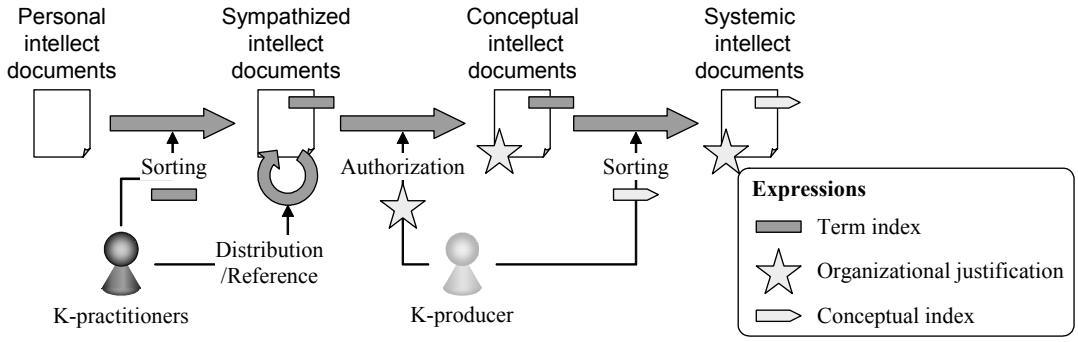

Figure 3 Processes change documents conditions

Event in DLM: Event 5. Learning organizational intellect.

Support: search based on ontology.

3.3.2 K-ranch house

K-producers lead organizational learning, based on the organization's visions, by adopting created intellect and concepts in an organization. Therefore, all behavior/events in a K-field will be informed to K-producers. This information will give K-producers more opportunities to collect new concepts of K-practitioners. K-producers' basic tasks are as follows:

Understanding circumstances: make folders for K-practitioners, understand document exchange events (e.g. function 6).

Event in DLM: Event 10. Evaluating sympathized intellect.

Support: informing distributing events, visualizing intellect exchange.

Editing: make systemic intellect documents as bulletins in order to make clear the direction of an organization (e.g. function 5-1).

Event in DLM: Event 10. Evaluating sympathized intellect.

Support: functions for making bulletins.

Authorization: authorize the useful documents from sympathized intellect documents in organizational activities and use them as conceptual intellect documents (e.g. function 5-2).

Event in DLM: Event 11. Authorizing conceptual intellect in an organization.

Support: inform distributing events, visualizing intellect exchange.

Sorting: sorting of conceptual intellect documents, set up conceptual indexes as official meanings in an organization, and use as systemic intellect documents (e.g. function 5-2).

Event in DLM: Event 12. Creating systemic intellect in an organization.

Support: organizational shared folders, knowledge systematization support functions.

Distributions: distribute K-practitioners systemic intellect documents according to the situation of an organization (e.g. function 3-2).

Event in DLM: Link between event 12 and 5.

Support: visualizing know-who.

Searching learning contents: search learning contents and target people that match the situations of an organization, and distribute (e.g. function3).

Event in DLM: Preparation of link between event 12 and 5.

Support: visualizing organization conditions, searching based on ontology.

4. Learning contents for a learning organization

Learning contents can be seen as systemic intellect documents concerned with both *explicit knowledge* and *tacit knowledge* that members use to carry out activities required in an organization. In general, documents have structures based on the purpose of their use, and the structure of the learning contents can be considered to express 'proper procedures for acquiring systemic intellect'. Conventional organizational learning contents are mostly made from organizational intellect. However, in order to support inheritance and creation of an organizational intellect including *tacit knowledge* in the dynamic intellect creation process, it is necessary to systematize learning contents by taking whole processes of the dual loop model into consideration.

By placing learning contents under the management of *Kfarm*, we aim to support a learning mode in personal loops, which are the basis of intellect creation and organizational activities, to ensure proper progress. Learning contents are

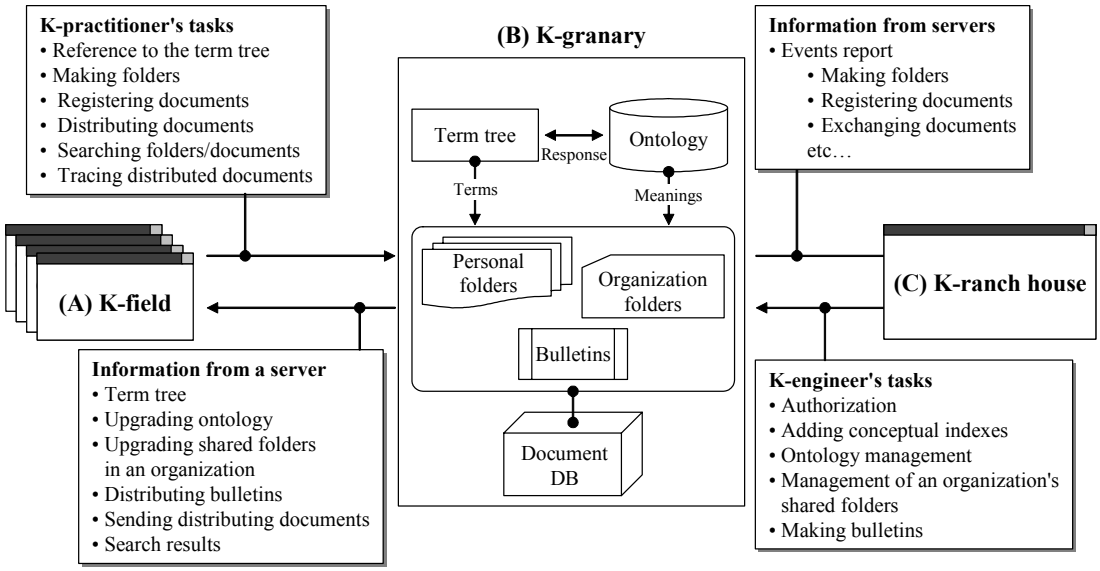

Figure 4 Construction of *Kfarm*

the documents created to be used in the learning mode in the personal loop. The following points are important to realize the support:

- Management of learning contents connected with management of organizational intellect.
- Guaranteeing learning content quality.

*i*Designer [5], which is a designing and developing support tool for learning contents, has been developed based on the above two points. Here we explain how *i*Designer and *Kfarm* work together, and consider the learning contents for a learning organization.

4.1 Learning contents

As mentioned in chapter 3, learning contents are documents structured from the viewpoint of learning. Basic concepts about learning contents are:

- **Control structure of learning contents**: a structure of learning items with their educational intention, equivalent to a courseware.
- **Learning item network**: the conceptual map of learning items. It is equivalent to systemic intellect, structured by links from an educational viewpoint, for example prerequisite link and generalized link.
- **Learning goals**: description of goals intended in the learning contents, for example acquiring knowledge or skills and developing competency. They are also used as the conceptual indexes of systemic intellect included in the contents.
- **Design patterns**: knowledge about sequencing learning items based on pedagogical heuristics.

Learning item network and learning goals act as contact point and play an important role in organizational learning management. From these, it will be possible for *Kfarm* to provide search functions for learning contents that fit for the purposes of organizational learning. As shown in figure 5, learning contents are provided for K-practitioners through a workspace window of *Kfarm*

4.2 Designing learning contents and development support tools

The ontology-aware authoring tool [14] that we have developed is a support environment for designing and developing rational educational learning contents based on the concepts described above. There are two task descriptions in this

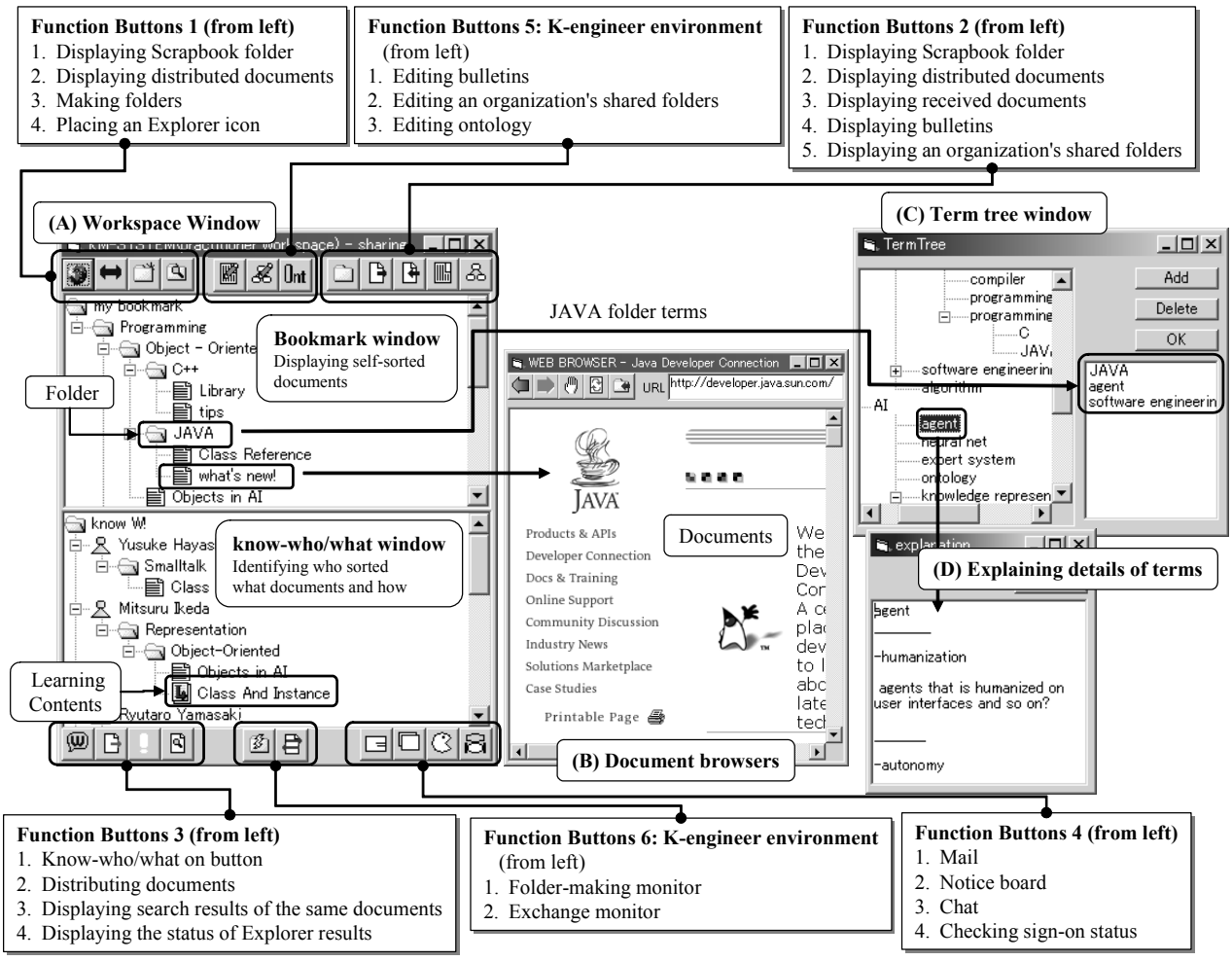

Figure 5 User interface in *Kfarm*

support environment:

- **Structuring task**: To connect the ontology that is a system of target concepts with a learning item that is an educational concept, and to create a learning item network.
- **Sequencing task**: Referencing the learning item network, to sequence learning objects and to create learning content structures.

In systematizing tasks, we provide support functions that compile systemic intellect into learning contents, providing design patterns appropriate for the context of the task progress. At this point, a connection point between the organizational ontology in *Kfarm* and the learning item network of *i*Designer is the basis of guaranteeing rationality for individual learning in an organization, i.e. the learning mode in the personal loop.

In the development of an ontology-aware design tool *i*Designer, which has preceded *Kfarm*, these functions are realized to support the improvement of learning content quality:

- **Providing descriptive vocabularies, concepts and design principles**: It makes clear the design principle of the learning contents, and provides the framework for modeling learning contents.
- **Giving suggestions for design**: It provides design guidelines for authors about learning contents design based on pedagogical heuristics [15].
- **Verifying the consistency of the model**: It is done based on the semantic constraint on the concept and relation defined in the learning contents ontology.
- **Simulation at a conceptual-level**: It simulates how the model works according to the semantic constraint to verify the adequacy of the learning contents [16].
- **Version maintenance**: By maintaining versions of the models according to the semantic constraint on the concept and relation, influences of change in the domain ontology and learning contents models are presented to authors [15].

5. Concluding remarks

Organizational learning can be taken as an aggregation of individual learning, and it is necessary that an individual's intellect increase for an organization to increase its intellect. To realize this, it is also necessary to increase an individual's intellect that matches the value of the idea from organizational viewpoint. By meeting those two requirements, it is thought that beneficial intellect for an organization will be created and the identity of the organization will be established.

In this paper, where an individual's learning becomes the basis of organizational learning, we have suggested *Kfarm* as an architecture for IT systems, which supports giving direction based on organizational visions by K-producers and the cooperating of intellect creation by K-practitioners. *Kfarm* can monitor learning processes in an organization and can provide adequate support based on the correspondence between user operations and events on the dual loop model.

*i*Designer we have already developed can be generalized as a general-purpose learning content design support environment, and its deeper cooperation with *Kfarm* can be a future subject. For example, it will be possible to better fulfill learning support in an organization's activities by connecting user models in *Kfarm* with learner models obtained with the use of learning contents.

We have completed the implementation of *Kfarm* which has all the function described in chapter 3 and have verified them. Furthermore, we are considering introducing collaborative learning into the framework of learning support in an organization [17]. Broadly speaking, it is considered that *Kfarm* itself is a space for less-regulated collaborative learning because it allows learner-directed communication. However, some processes of a dual loop model can be better achieved by rather regulated collaborative learning. For example, collaborative learning thorough a goal-oriented discussion by a group of intentionally selected experts is appropriate at the final stage of creating a new intellect. To cope with such cases, we have been developing a function to support arrangement of regulated collaborative learning.

Acknowledgement

We would like to thank the editors and anonymous reviewers for their insightful comments and suggestions.

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