A Collaborative Learning Design Environment to Integrate Practice and Learning based on Collaborative Space Ontology and Patterns

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Abstract. The integration of practice and learning is a key to cultivation of organizational capability for creating or inheriting intellect. In this paper, firstly we address the critical research issues for collaborative space design to integrate practice and learning. Following the discussion, we have built an ontology which specifies the structure of the collaborative learning, described patterns of a collaborative space by reference to the learning theories and developed an intelligent function to support a collaborative space design on ontology-based KM environment, *Kfarm*, as a foundation for supporting collaborative space design.

1 Introduction

Organizational activity studies (e.g. knowledge management study [1,2]) discuss what a good knowledge is and what an ideal process is. For instance, the famous knowledge management model called "SECI model [3]" suggests us an ideal process of organizational knowledge creation and inheritance.

Our long-term objective is to develop a framework, named *Kfarm*[4], which totally supports creating/inheriting organizational intellect (not only knowledge but also skill or competency). For realizing such a rich support framework, we have constructed a basic information model, named "Dual Loop Model (DLM)", following the ontology engineering approach. The ontology engineering approach [5,6] is the way to provide a basis of the information model for system developers, system users, and a system to share concepts and relations of the target world. Concepts and relations in an ontology are well clarified to make both of computers and humans intelligible. We have adopted such an ontology as a core knowledge processing framework for *Kfarm* to support organizational members' intellectual activities.

While building DLM and designing *Kfarm*, as suggested by many KM theories, we have noticed that the integration of practice and learning is a key to cultivate organizational capability for creating or inheriting intellect, and found that the integration can be made reasonably in the case of learning the domain-general competency while doing practical activities with domain-specific intellect. To realize such rational integration, we have made the distinction between the following two types of intellect in DLM.

Intellect of type A: *knowledge or skill required for performing daily jobs.* Intellect which organizational members directly use, create and inherit for performing daily jobs in organizational activities, e.g. domain knowledge to make a plan for performing daily jobs or skill to execute the plan.

Intellect of type B: *competency to create and inherit intellect of type A.* A fundamental and implicit intellect which derives the organizational members' activities to create and inherit intellect of type A, e.g. a competency to create new intellect, competency to lead discussion, or competency to acquire intellect by observing others' behavior.

Our research goal includes to establish a rational design framework of collaborative space to integrate organizational activities to solve practical problem with intellect of type A, and learning intellect of type B to create or inherit intellect of type A. We have discussed a unified model for both type A and type B in our previous paper[4]. This paper focuses on the distinction between these two types. In this paper, firstly we address the critical research issues for collaborative space design to integrate practice and learning. Following the discussion, in Sect. 3, we will describe an intelligent function to support a collaborative space design we have developed.

2 Collaborative learning space design based on ontology

To increase competitive power of an organization, organizational members should have a good *circulation* of the organizational intellect in the DLM. To achieve this we emphasize the need to support organizational members enhancing the *circulation* capability, which means learning an intellect of type B.

As mentioned earlier, intellect of type B mainly includes a competency to create and inherit organizational intellect of type A. This assures us that organizational members should always learn intellect of type B through group practice to create and inherit organizational intellect. Thus, it is important to design an integrated collaborative learning space for learning and practice.

Such collaborative learning space has been designed by an expert designer. However, such a design is often highly abstract and implicit, since intellect of type A and type B have similar characteristic of intellect and could not be clearly distinguished. Additionally, at such a design a designer may be ignorant of whether conflicts between practical goal and learning goal occurred or not.

A key to overcoming such a difficulty is to establish consistent and rational design based on a common conceptual foundation. That is collaborative learning space design based on ontology. Encouraging a designer to be compliant with the ontology, the design intention of collaborative space is expected to be explicit and the designer notices how to avoid and prevent conflicts at the design time.

In this study, consistent and rational design of collaborative learning space is typically achieved in the following three steps: **Step. 1)** Find a right opportunity to initiate collaborative learning in a practical space provided by *Kfarm*. **Step. 2)** Design collaborative learning matching with a state of the practical space. **Step. 3)** Provide an environment for the participants to run the collaborative learning in the physical space such as a classroom or cyber space such as chat or bulletin board.

Step 2 consists of the following three sub-steps: **Step. 2-1) Abstract design:** Design collaborative learning configuration including learning goals, tasks, and participants' roles. **Step. 2-2) Concrete design:** Embody the abstract design by assigning organizational members to the roles, preparing the materials for the task, and so on. **Step. 2-3) Negotiation:** Explain the design rationale to participants.

In this section, we discuss the role of collaborative space ontology and collaborative space patterns in the design process.

2.1 Conflict between learning goal and practical goal

As we have discussed thus far, the goal of this study is to draw up design guideline of building a rationally integrated space for practice and learning. However, the combination is not simple because designers often face the conflict between learning goal and practical goal. Typical examples of the conflicts are shown below:

Conflict at the abstract design: Conflicts concerning goals, tasks, or roles sometimes occur at the abstract design. Assume that a designer wants to set up a collaborative learning for a novice participant to learn how to create a new idea by observing experts' behavior when they are involved in a brain storming session. From a practical viewpoint (to create intellect of type A), all the participants are expected to express their ideas freely. On the other hand, from a learning viewpoint (to learn intellect of type B), the expert participants are expected to explain how they come up with

Table 1. The major concepts in the Collaborative Space Ontology

concept [isa] sub-concepts	Description
goal	desirable change of intellect
organizational goal	desirable change of organizational intellect
practical goal	creation or inheritance organizational intellect of type A (e.g. sharing an idea)
learning goal	learning organizational intellect of type B (e.g. learning creativity)
interaction goal	desirable change from personal intellect to organizational intellect (e.g. publishing an idea)
individual goal	desirable change of personal intellect (e.g. acquiring an idea)
scene	a situation in which participants carry on a work, a job, or a task to achieve the goal
practical scene	a situation in which participants carry on a practical task to improve quality of the task outcome and the task performance
learning scene	a situation in which participants carry on a simplified task comparable to the practical task to scaffold learning the intellect
configuration	interactions among roles of participants to achieve the goal
practical configuration	interactions among roles of participants who have the competency in order to achieve the practical goal with high quality and high performance
learning configuration	interactions designed with learning intention to give high priority to achieve the learning goal
space-time	the when and the where that collaborative activity expected to be carried out. (e.g. a classroom, chat or bulletin board)

their ideas and the novice participants are expected to concentrate on observing experts' behavior. The two different viewpoints may cause a kind of undesirable conflicting feeling of participants.

Conflict at the concrete design: Conflicts often occur when embodying the abstract design. For example, from a practical viewpoint, a competent person is expected to be involved in the collaborative activity to improve the quality of the product and shorten the work time. However, in general, it is always hard to get competent persons involved in others' learning activity.

Ontology and patterns play an important role for a designer to avoid and prevent these conflicts. At consistent and rational design, ontology provides sharable and clearly defined concepts of collaborative learning space, and patterns offer guidelines to build up the integrated space for learning and practice based on the ontology.

2.2 Collaborative Space Ontology

We have built an ontology which specifies the structure of the collaborative learning. In addition, we have described the pattern and its frame which are expected to avoid and prevent the conflict by reference to the learning theories.

In this study, ontology is a fundamental conceptual framework to represent the design rationale or the designer's intention and to maintain the consistency among different viewpoints. A design based on ontology enables a designer to specify design rationale explicitly. The designer may notice hidden relations among different viewpoints. As a result, consistent design free from conflicts would be obtained. Additionally in some learning theory, the ways to avoid and prevent conflict are founded. In order to reuse design experiences, it is important to describe design know-how as patterns and store them. Ontology is also useful to produce consistent patterns because it provides a common vocabulary, data structure, and so on.

Collaborative space ontology is constructed from the effective concepts which are described in the learning theory. We have done comprehensive studies on learning theories to build a "Collaborative Learning Ontology[8]". Following that study we aim at expanding the ontology. The ontology in this paper is constructed from both practical viewpoint and learning viewpoint. Practical viewpoint is creation and inheritance of intellect of type A, and learning viewpoint is learning of intellect of type B.

This ontology inherits the basic concepts relevant to organizational intellect creation and inheritance (e.g. person, intellect, vehicle, and activity). These concepts are defined in DLM. By sharing these concepts a design support system can communicate information about organizational intellect with *Kfarm*.

In order to constitute variety forms of collaborative space at a practical setting or an learning setting, the collaborative space ontology contains the concepts from both practical viewpoint and learning viewpoint; the goals, the task, the scenes, the configurations, the interactions, and so on (Table 1). Our ontology has been defined in an ontology editor of an environment for building/using ontology, Hozo[9], in which concepts are represented as frames with slots and the is-a relations among concepts.

2.3 Collaborative Space Pattern

Collaborative space pattern represents domain-neutral knowledge to prevent the conflict. All the concepts appearing in the patterns are defined in the collaborative space ontology and most of the patterns are supported by learning theories. In that point this pattern and other pattern (e.g. Organizational pattern[10]) differ greatly.

In this section we explain two types of patterns; a learning group configuration pattern to prevent the conflict at the abstract design, and an assignment tuning pattern to resolve the conflict at the concrete design.

The learning group configuration pattern represents an ideal collaborative learning configuration to achieve both the practical goal (to create or inherit intellect) and the learning goal (to learn intellect of type B); they describe rational relations among collaborative learning goals and participants' roles.

For example, the configuration pattern called "Share an idea for practice" (Table 2) has two goals such as a practical goal of sharing a good idea (which is intellect of type A) and a learning goal of developing creativity (which is intellect of type B) through practice. This pattern contains four roles such as a PRESENTER, ADVISER, APPRENTICE, and GUIDE. To achieve the practical goal, a PRESENTER explains her idea, and an ADVISER advises the PRESENTER to refine her idea. Through the interaction between ADVISER and PRESENTER, efficiency and quality of the practice will be improved. To achieve the learning goal, on the other hand, a

Table 2. Learning group configuration patterns

Pattern name	Practical goal / Learning goal	Scene	Configuration			Learning theory
			Roles	Practical interaction		
				Role	Role	
				Learning interaction		
				Role	Role	
Share an idea for practice	Sharing a good idea	practical scene (e.g. create business plan)	・AD. ・P. & G. ・AP.	ADVISER(AD.) refines P.'s idea by advising the P.	PRESENTER(P.) creates a good idea by explaining her idea to the AD.	[11] [12]
	Develop-ing creativ-ity			GUIDE(G.) supports AP. by explaining the thinking process	APPRENTICE(AP) develops creativity by asking G. for advice	[13]
Share an idea by observa-tion	Sharing a good idea	practical scene (e.g. create business plan)	・AD. ・P. ・O.	ADVISER(AD.) refines P.'s idea by advising the P.	PRESENTER(P.) creates a good idea by explaining her idea to the AD.	
	Develop-ing creativ-ity			OBSERVER(O.) develops creativity by observing the interaction between AD. and P.		[14]
Refine intellect through debate	Refining intellect	practical scene (e.g. refine plan)	・R.& D. (all partici-pant assigned as this role)	REFINER(R.) conceptualizes intellect by pointing out implicit part of intellect		[15]
	Develop-ing debate competency			DEBATER(D.) develops debate competency by explaining herself		[16] [17]

PRESENTER also plays the role of a GUIDE of APPRENTICE. A GUIDE supports an APPRENTICE to develop creativity by explaining her thinking process

A tuning pattern represents a pattern to adjust the abstract design to the real organization situation. For example, the tuning pattern named "Relax a role constraint & Add a support role (top of Table 3)" solves the problem that the designer cannot assign an appropriate participant to the expert role. This pattern has two steps to solve the problem; The first step is to relax the constraint of intellectual level required for the PRACTITIONER role; this role holder creates intellect of type A. The second step is to add the SUPPORTER role to compensate a drop of expert's intellectual level caused by the first step. Moreover, the pattern introduces a new learning goal for a PRACTITIONER to develop creativity (intellect of type B) from a SUPPORTER.

Table 3. Tuning patterns

<table>
<tr><th rowspan="3">Pattern name</th><th>Abstract design</th><th rowspan="3">Conflict at concrete design</th><th colspan="2">Tuning</th><th rowspan="3">Learning theory</th></tr>
<tr><th>Role</th><th colspan="2">Tuning steps</th></tr>
<tr><th>Scene</th><th>Tuning merit</th><th>Tuning demerit</th></tr>
<tr><td rowspan="2">Relax a role constraint & Add a support role</td><td>PRACTITONER role constraint: superior intellect</td><td rowspan="2">No candidate assigned to the expert role (hard to get competent parson)</td><td colspan="2">First Step: relax the constraint of intellectual level required for the PRACTITIONER who is expected to create intellect of type A
Second Step: to add the SUPPORTER role</td><td rowspan="2">[13]</td></tr>
<tr><td>practical scene</td><td>Introducing a new learning goal for a PRACTITIONER to learn intellect of type B from a SUPPORTER</td><td>Lower efficiency of the task. Heavy burden to SUPPORTER</td></tr>
<tr><td rowspan="2">Divide a role constraint</td><td>PRACTITONER role constraint: several domain intellect (domain A, domain B)</td><td rowspan="2">No candidate assigned to the expert role (hard to get competent parson)</td><td colspan="2">First Step: divide role constraint of PRACTITIONER into each domain expert constraint (P1, P2)
P1: domain A expert
P2: domain B expert
Second Step: assign appropriate participant to both P1 and P2</td><td rowspan="2">[18]
[19]</td></tr>
<tr><td>practical scene</td><td>Participant a (or b) inherits domain B (or A) intellect and clarifies her thinking process through discussion</td><td>No integration of several viewpoints. Less discussion</td></tr>
<tr><td rowspan="2">Shift a role constraint & Impose stronger constraint</td><td>PRACTITONER role constraint: superior intellect

OBSERVER</td><td rowspan="2">No candidate assigned to the expert role (hard to get competent parson)</td><td colspan="2">First Step: relax the constraint of intellectual level required for the PRACTITIONER who is expected to create intellect of type A
Second Step: impose stronger constraint on the OBSERVER because OBSERVER is well required to have competency of observation and analysis</td><td rowspan="2">[14]</td></tr>
<tr><td>learning scene</td><td>PRACTITIONER gets better understanding and teaching skill by presentation to OBSERVER who develops practical competency.</td><td>Lower efficiency and quality of the task</td></tr>
</table>

3 Design support system for collaborative learning

3.1 Overview of the design support system

Fig. 1 illustrates the support process and the basic components of the system. The support consists of the following which correspond to the three design processes mentioned in the beginning of Sect. 2.

Abstract design support: Provide collaborative space configurations appropriate to the collaborative activity goals specified by designer using the learning group configuration pattern(Fig.1(A)). Designer may select one from the configurations and adjust it to her own design intention. In the case there is no candidate that fits with her design intention, she may design it from scratch.

Concrete design support: Provide the candidate resources suitable for the role in the collaborative space configuration(Fig.1(B1)). The candidates are selected based on the matching between the role definition and the resource property provided by Intellectual Genealogy Graph[7] which affords a good foundation for intelligent support for organizational activities(Fig.1(B2)). In the case that no candidate is found, the tuning patterns will be applied to the conflicts between the required constraint in the abstract configuration and the real situation and then the possible constraint relaxations are recommended(Fig.1(B3)).

Negotiation support: Provide an invitation message for all the participants based on the collaborative space design(Fig.1(C)). The message is automatically generated for each participant to explain the expected behavior in collaborative learning. Designer may modify the message to fit with her design intention. This message plays an especially important role to establish a better common understanding of collaborative learning among the participants.

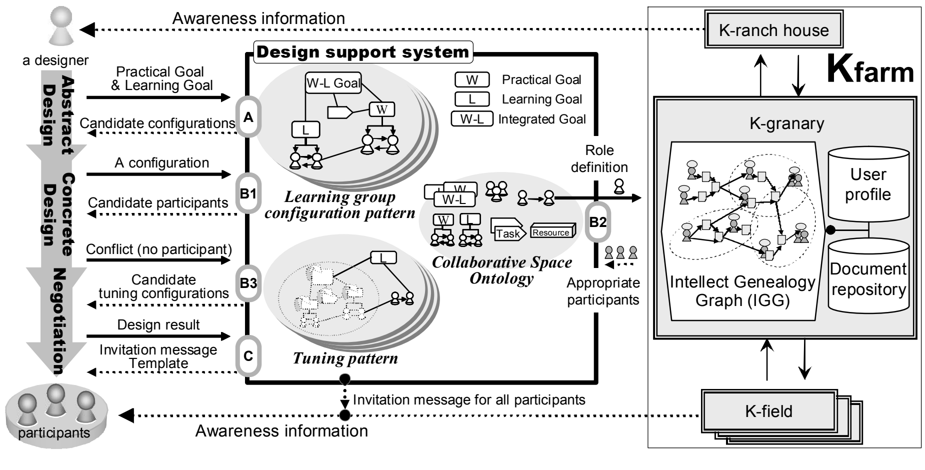

Fig. 1. Overview of the design support system for collaborative learning in *Kfarm*

3.2 An example of the design support

In this section, we will see an illustrative example of support functions along a typical design process.

Assume that an organizational member released an idea memo through K-field to get feedback from other members. While monitoring the status of organizational intellect with K-ranch house, the designer found the memo is important for the development of organizational intellect of type A. The designer tries to refine the idea in a collaborative learning and utilize the space to develop novices' competency of creativity (intellect of type B). Then the designer examines the current status of the intellect on the memo by browsing Intellectual Genealogy Graph through K-ranch house and knows that the current state of the intellect is the "personal idea" that means it is not well refereed in the organization and is not represented in systemic way (i.e., implicit intellect).

The designer selects the practical goal of "Sharing a good idea" and the learning goal of "Developing creativity" from the goals recommended by *Kfarm*(Fig.2(A)). "Sharing a good idea" means to change the intellect status from personal to sympathetic, while "Developing creativity" means internalize the organizational competency of creativity to organizational members.

Kfarm provides the collaborative space configurations suitable for the two goals based on the collaborative group configuration pattern. In this case, *Kfarm* finds two patterns, "Share an idea for practice" and "Share an idea by observation" shown in Table 2. Assume that the designer selects "Share an idea for practice" and use it without any modification.

The next design phase is the concrete design where the designer embodies the abstract design by assigning real resources to the roles appearing in the abstract design(Fig.2(B1). The designer is carrying out the assignment of PRESENTER & GUIDE in the "Share an idea for practice" pattern. This role holder is expected to present her idea nicely and to exemplify her creativity in order for the novices to easily learn the roles of creating idea.

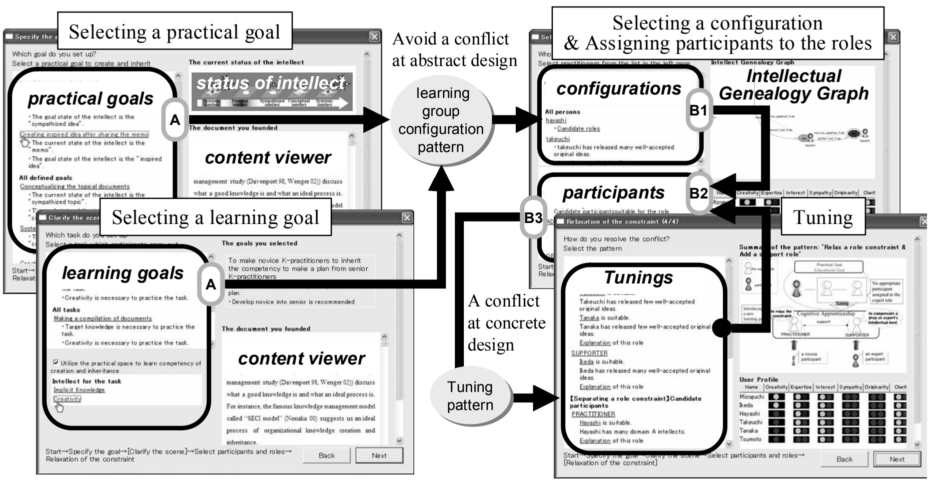

Fig. 2. A screenshot of the design support system

So the designer wants to find a participant who is highly creative (practical viewpoint; intellect creation of type A) and good at assisting others' learning (learning viewpoint; intellect learning of type B). The constraints on the role are specified in the collaborative space ontology and *Kfarm* finds candidates who satisfy the constraints with the aid of IGG in K-granary(Fig.2(B2)). K-granary, for example, interprets "highly creative person" as the person who has released many original ideas that are well accepted as meaningful systemic intellect for the organization.

If the realization of the abstract design is difficult because of conflicts(Fig.2(B3)), *Kfarm* suggests relaxation of the constraint based on the tuning pattern (Table 3). In our case, the pattern; "Relax a role constraint & Add a support role" is applicable. By reducing the intellect level required for the PRESENTER & GUIDE to enable an assignment to the role and at the same time introducing the SUPPORT role to keep the efficiency and the quality from practical viewpoint.

Once the concrete design is completed, *Kfarm* generates an invitation message for each participant.

4 Conclusions

We have discussed issues of design support for collaborative learning based on the collaborative space ontology and patterns, which will be able to make it easier to design an effective collaborative learning in practical environments. With the ontology engineering approach, it is possible to avoid and prevent conflicts in the design process which would have occurred in the design process or design result.

We have been developing a design support system based on the framework, which we call *Kfarm*. The relationship between this system and *Kfarm* enabled to show the candidate of the appropriate participants to the role of the collaborative learning.

We have implemented the prototype of the design support system except some details. It is difficult to make truly convincing evaluation of systems and tools in education because we need considerable long time to properly measure learning effect. Furthermore, in our case, it is also difficult to make comparative evaluation at the conceptual level because, as far as the authors' knowledge, there exists no similar system which supports integration of practice and learning for collaborative space design. However, collaborative space ontology we developed has been designed based on learning theories which are already shown to be valid and useful. For this reason we believe that the system based on the ontology supports the designer to design effective collaborative space. The implemented prototype system has shown the feasibility of our idea which strongly encourages us to go to the full evaluation after the completion of the full-scale implementation of the system.

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