Learners' Roles and Predictable Educational Benefits in Collaborative Learning

An Ontological Approach to Support Design and Analysis of CSCL

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Abstract. To facilitate shared understandings of several models of collaborative learning, and collect rational models of effective collaborative learning, we have been constructing a system of concepts to represent collaborative learning sessions relying on existing learning theories. We call the system of concepts Collaborative Learning Ontology, and have been extracting and representing models inspired by the theories with the ontology. In this paper, as a part of the ontology, we concentrated on clarifying behavior and roles for learners in collaborative learning sessions, conditions to assign appropriate roles for each learner, and predictable educational benefits by playing the roles. The system of concepts and models will be beneficial to both designing appropriate groups for collaborative learning sessions, and interaction analysis among learners to assess educational benefits of the learning session.

1. Introduction

In the last decade, many researchers have contributed to development of the research area "Computer Supported Collaborative Learning" (CSCL) [e.g., 3, 8-15, 19, 24, 26], and advantages of collaborative learning over individual learning have been well known. The collaborative learning, however, is not always effective for every learner in a learning group. Educators sometimes argue that it is essential for collaborative learning and its advantage that learners take turns to play some roles; for example, tutor, tutee, helper, assistant, and so on. Of course, in collaborative learning, the learners not only learn passively, but also interact with others actively, and they share their knowledge and develop their skills through it. Educational benefits that a learner gets through the collaborative learning process depend mainly on interaction among learners, that is, the educational benefits depend on what roles the learner plays in the collaborative learning. Moreover, the relationship between a role in a group and a learner's knowledge and/or cognitive states when the learner begins to play the role is critical. If the learner performs a role which is not appropriate for his/her knowledge and/or cognitive state, his/her efforts would be in vain. So, designers and educators should consider carefully the relationship among learners' states, experiences, and conditions for role assignment; and the synergistic and/or harmful effect of a

combination of more than one role; when they form learning groups and design learning processes. To realize this, we need to organize models and rules for role assignments the designers and educators can refer to, and construct a system of concepts to facilitate shared understanding of them.

Our research objectives include constructing a collaborative learning support system that detects appropriate situation for a learner to join in a collaborative learning session, forms a collaborative learning group appropriate for the situation, and monitors and supports the learning processes dynamically. To fulfill these objectives, we have to consider the following:

1. How to detect appropriate situations to start collaborative learning sessions and to set up learning goals for the group and members of the group,
2. How to form an effective group which ensures educational benefits to each members of the group, and
3. How to analyze interaction among learners and facilitate desired interaction in the learning group.

We have discussed item 1 in our previous papers [8, 9], and have been constructing a support system for analyzing interaction for item 3 [13, 14]. We also have been discussing item 2, especially, concentrated on extracting educational benefits expected to acquire through collaborative learning (i.e., learning goals), and constructing a system to support group formation represented as a combination of the goals [11, 26].

This paper focuses on learners' behavior, roles, conditions to assign appropriate roles for learners, and predictable educational benefits of the roles referring to learning theories, as a remaining part of the item 2. First, we overview our previous work, that is, the system of concepts to represent collaborative learning session: we call it "Collaborative Learning Ontology", especially we describe "Learning Goal Ontology" which is a part of the Collaborative Learning Ontology. Next, we pick up learners' behavior and roles from learning theories. Then, we discuss conditions of role assignments and predictable benefits by playing the roles.

2. Learning Theories and Collaborative Learning Ontology

There are many theories to support the advantage of collaborative learning. For instance, Observational learning [2], Constructivism [20], Self-regulated learning [21], Situated learning [16], Cognitive apprenticeship [5], Distributed cognition [23], Cognitive flexibility theory [25], Sociocultural Theory [28], Zone of proximal development [27, 28], and so on. If learners learn in compliance with strategies based on the theories, we can expect some educational benefits for the learners with the strong support of the theory. So, we have been constructing models referring to these theories. However, there is a lack of common vocabulary to describe the models. Therefore, we have been constructing the "Collaborative Learning Ontology" which is a system of concepts to represent collaborative learning sessions proposed by these learning theories [10, 11, 26]. Here, we focus on the "Learning Goal Ontology". The concept "Learning Goal" is one of the most important concepts for forming a learning group because each learner joins in a collaborative learning session in order to attain a

learning goal. The Ontology will be able to make it easier to form an effective learning setting and to analyze the educational functions of a learning group. [17, 18]

We have extracted common features of phenomena, such as development of learning community, interaction among learners and educational benefits for a learner, from the learning theories. The learning theories account for such phenomena, and a designer or a learner can regard the phenomena as goals. So, we use the term "learning goal" to represent such phenomena. Namely, we call the goal of development of learning community W(L)-goal, the goal of group's activity W(A)-goal, the goal of interaction among learners Y<=I-goal, and the goal of educational benefits for a learner I-goal.

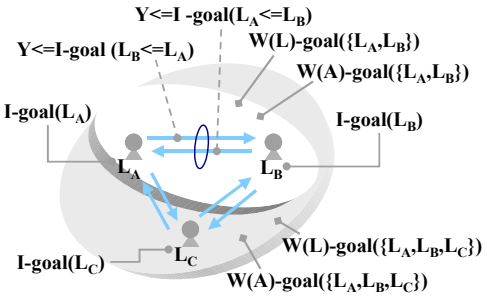

Fig. 1. Learning Goals in a Collaborative Learning Session

Fig.1 represents learning goals in a group where three learners: L_A, L_B and L_C are participating. Learner L_A has an I-goal that is attained through this collaborative learning session and this goal is described in Fig.1 as I-goal (L_A). Both L_B and L_C also have I-goals, and they are represented as I-goal (L_B) and I-goal (L_C) respectively. Y<=I-goal (L_B<=L_A) is a Y<=I-goal between L_A and L_B observed from L_A's viewpoint. In other words, it means the reason why L_A interacts with L_B. Concerning this interaction between L_A and L_B, there is also a Y<=I-goal observed from L_B's viewpoint. That is, it is the reason why L_B interacts with L_A. This Y<=I-goal is represented as Y<=I-goal (L_A<=L_B). Both I-goal (L_A) and Y<=I-goal (L_B<=L_A) are personal goals of L_A. Both W(L)-goal ({L_A, L_B}) and W(A)-goal ({L_A, L_B}) are goals of the learning group ({L_A, L_B}). Similarly, W(L)-goal ({L_A, L_B, L_C}) and W(A)-goal ({L_A, L_B, L_C}) are goals of the learning group ({L_A, L_B, L_C}).

We have identified goals for collaborative learning for each of the four categories with justification based on learning theories. We have identified four kinds of I-goals and three phases for each of them, such as 'acquisition of content-specific knowledge (phase: accretion, tuning, and restructuring)' [22], 'development of cognitive skill (phase: cognitive stage, associative stage, and autonomous stage)' [1, 7], and so on. The learner is expected to achieve these I-goals through interaction with other learners. We have pick up ten kinds of Y<=I-goals, such as 'learning by teaching' [6], 'learning by observation' [2], 'learning by self-expression' [25], and so on. The examples of W(L)-goals are 'knowledge sharing' [23], 'creating a solution' [20], 'spread of skills' [5, 16] and so on. The W(A)-goals mean activities accomplished by learning groups; for example, the learning activity where a new comer to the community learns something by his/her own practice, mentioned in the theory of LPP [16], the learning activity where a knowledgeable learner teaches something to a poor learner, mentioned in the theory of Peer Tutoring [6] (For whole set of the goals, see [10, 11]).

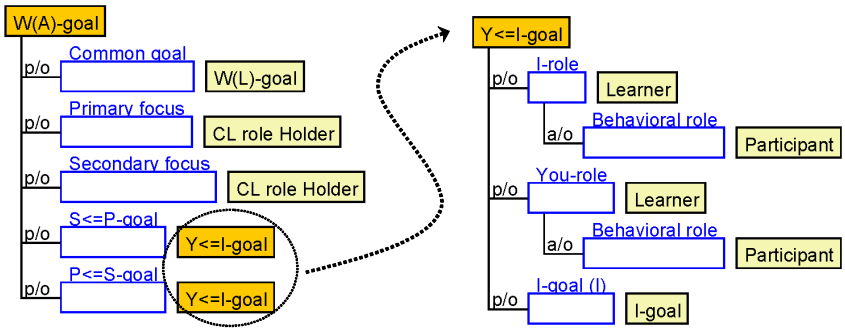

Fig.2. Conceptual Structure of a W(A)-goal and a Y<=I-goal

Each W(A)-goal provides the rationale justified by specific learning theory. That is, the W(A)-goal specifies a rational arrangement of learning goals and a group formation. Fig.2 shows a typical representation for the structure of a W(A)-goal. The W(A)-goal consists of five concepts: Common goal, Primary Focus, Secondary Focus, S<=P-goal, and P<=S-goal. The Common Goal is a goal of the whole group, and the entity of the Common goal refers to the concepts defined as W(L)-goal ontology. Both Primary Focus and Secondary Focus are learners' roles in a learning group. A learning theory generally argues the process that learners, who play a specific role, can obtain educational benefits through interaction with other learners who play other roles. The theories have common characteristics to argue effectiveness of a learning process focusing on a specific role of learners. So, we represent the focus in the theories as Primary Focus and Secondary Focus. S<=P-goal and P<=S-goal are interaction goals between Primary focused learner (P) and Secondary focused learner (S) from P's viewpoint and S's viewpoint, respectively. The entities of these goals refer to the concepts defined as Y<=I-goals. The conditions, which are proper to each W(A)-goal, can be added to the concepts, if necessary. Each of the Y<=I-goals referred to by S<=P-goal and P<=S-goal consists of three concepts as follows:

I-role: a role to attain the Y<=I-goal. A member who plays I-role (I-member) is expected to attain his/her I-goal by attaining the Y<=I-goal.

You-role: a role as a partner for the I-member.

I-goal (I): an I-goal that means what the I-member attains.

We have described detailed discussion of the goals in our previous papers [10, 11, 26]. In the remains of this paper, we concentrate on identifying behavior and roles, clarifying conditions to assign a role for a learner, and connecting the roles with predictable educational benefits.

3. Learners' Roles and Behavior in Collaborative Learning inspired by Learning Theories

Table 1 shows learners' behavior and roles in collaborative learning sessions inspired by the learning theories. There are nine types of behavior and thirteen types of roles.

As we describe in the previous section, we represent each model of learning theory as two roles for learners, interaction goals between the role-holders, and common goal for both role-holders. Learning models which have more than three role-holders can be represented as a composite of models which have two role-holders. So, we represent each model as a simplified two-role model. For example, the model of the theory 'Cognitive Apprenticeship' has Master and Apprentice, and the model of 'Sociocultural Theory' has Client and Diagnoser. It is just the same to any N-tupple relation is composed of binary relations.

The effect of externalization is one of the main advantages of collaborative learning, and the behaviors *presenting* and *tutoring* aim at the effect. The three roles, Problem holder, Panelist, and Client, have the same behavior: *presenting*. The *presenting* is to externalize something in a learner's mind, that is, the learner creates it originally, while the *tutoring* is to externalize what he/she already listened or was taught from others. The behaviors *imitating* and *observing* aim at the effect of modeling other learners, and it regards the other learners as good examples for some behavior. By *observing*, we mean only seeing someone's behavior, and by *imitating*, we mean seeing and doing. The behaviors *advising* and *guiding* aim at developing a learner's cognitive skill such as diagnosing, and it regards the other learners as case-holders. By *advising*, we mean to monitor the other learners, diagnose their problems, and give some advice to them. By *guiding*, we mean that a learner demonstrates something to other learners, observes the other learners do it, and advises on it. The

Table 1. Behavior and Roles of Learners in Collaborative Learning Sessions

Behavior	Definition	Role	Src.
Advising	To diagnose problems and give some advice to other learners	Anchored instructor Diagnoser	[4, 27, 28]
Guiding	To demonstrate something to other learners and then guide the learners' behavior	Master	[5]
Imitating	To imitate other learners' behavior	Apprentice	[5]
Observing	To observe other learners' behavior	Observer	[2]
Passive learning	To be taught something new from other learners	Peer tutee	[6]
Presenting	To explain something in his/her mind to other learners	Problem holder, Panelist, Client	[4, 25, 27, 28]
Problem solving	To solve problems	Peripheral participant, Full participant	[16, 20, 23]
Reviewing	To compare and review other learners' opinions and his/her thinking process	Audience	[25]
Tutoring	To explain something he/she already knows to other learners	Peer tutor	[6]

reviewing expects a learner to reflect his/her thinking process by opinions of other learners, the *problem solving* expects learners to share knowledge and create new ones. The both regard the other learners as stimuli.

4. Who Can Play the Role and Who Is Appropriate?

To design effective learning processes and form appropriate groups for learners, it is important to assign an appropriate role to each learner. As we described, educational benefits depend on how learners interact with each other: what roles they play in collaborative learning. For example, teaching something to other learners is effective for the learner, who already knows it but does not have experience in using the knowledge. Since the learner has to explain it in his/her words in order to teach it to others, he/she is expected to comprehend it more clearly. On the other hand, the same role is not effective for the learner who already understands it well, uses it many times, and teaches it to other learners again and again. In such a case, it is effective not for the learner who teaches it, but only for learners who are taught it. So, to clarify the conditions for role assignments is necessary to support design processes of learning sessions.

Table 2. Roles, Conditions for role assignments, and Predictable educational benefits

Role	Condition	Predictable benefits	Src.
Anchored instructor	* having the target knowledge * knowing how to diagnose others - not having experience in diagnosing others	Acquisition of content specific knowledge (tuning) Development of cognitive skill (associative stage)	[4]
Apprentice	- not having the knowledge how to use the target skill - not having the experience to use the target skill	Development of cognitive and/or metacognitive skill (cognitive stage & associative stage)	[5]
Audience	* having the target knowledge * having experience in using the knowledge * having related knowledge in the domain	Acquisition of content specific knowledge (restructuring)	[25]
Client	* knowing how to use the target metacognitive skill	Development of the meta-cognitive skill (associative stage)	[27, 28]
Diagnoser	* knowing how to use the target cognitive skill	Development of the cognitive skill (associative stage)	[27, 28]

Full participant	* having the target knowledge * having experience in using the knowledge * having related knowledge in the domain * knowing how to use the target cognitive skill * having experience in using the cognitive skill * having how to use target metacognitive skill * having experience in using the metacognitive skill	Acquisition of content specific knowledge (restructuring) Development of the cognitive skill (autonomous stage) Development of meta-cognitive skill (autonomous stage)	[16, 20, 23]
Master	* knowing how to use target cognitive skill * having experience in using the cognitive skill * having how to use target meta-cognitive skill * having experience in using the meta-cognitive skill	Development of cognitive and/or metacognitive skill (autonomous stage)	[5]
Observer	- not having the target knowledge - not having the knowledge how to use the target skill	*depending on what to observe*	[2]
Panelist	* knowing how to use a skill for self-expression * having his/her own opinion - not having experience in using the skill for self-expression	Development of skill for self-expression (associative stage)	[25]
Peer tutee	- not having the target knowledge	Acquisition of content specific knowledge (accretion)	[6]
Peer tutor	* having the target knowledge - not having experience in using the knowledge - misunderstanding the knowledge	Acquisition of content specific knowledge (tuning)	[6]
Peripheral participant	* knowing how to use the target cognitive skill * knowing how to use the target meta-cognitive skill - not having experience in using the cognitive skill - not having experience in using the	Development of cognitive skill (associative stage) Development of meta-cognitive skill (associative stage)	[16]

	metacognitive skill		
Problem (Anchor) holder	* having a problem - having related knowledge to solve the problem	Acquisition of content specific knowledge (tuning)	[4]

Table 2 shows the roles which appear in collaborative learning sessions inspired by the learning theories we have referred to, conditions for each role, and predictable educational benefits by playing each role. This prediction is based on the theories. There are two types of conditions: *necessary conditions* and *desired conditions*. The *necessary conditions* are essential for the role: if a learner does not satisfy the conditions, the learner cannot play the role. On the other hand, the *desired conditions* should be satisfied to enable a learner to get full benefits of the role: if a learner does not satisfy the conditions, the learner can play the role, but educational benefits may not be ensured. In Table 2, the conditions marked with '*' are the *necessary conditions*, and the conditions marked with '-' are the *desired conditions*. For example, any learner can play the role 'Peer tutor' as long as the learner has target knowledge to teach other learners. If the learner misunderstood the knowledge and/or he/she did not have experience in using the knowledge, it is a good opportunity for the learner to play the role 'Peer tutor', because to externalize his/her knowledge in his/her words facilitates re-thinking of the knowledge, and gives an opportunity to notice the misunderstanding [6].

By clarifying the conditions to assign learners some roles like this, it would be possible for designers who are not experts of learning theories and even if computer systems to assign appropriate roles for each learner, to form groups for effective collaborative learning, and to predict educational benefits that each learner will get through the learning session in compliance with learning theories. It will be useful not only to support design processes for collaborative learning sessions, but also to analyze processes for them.

5. Conclusion

We have been constructing a system of concepts to represent collaborative learning sessions. To facilitate shared understandings of several models of collaborative learning, and collect rational models of effective collaborative learning, we have been relying on existing learning theories. We have been extracting models inspired by the theories and constructing Collaborative Learning Ontology. In this paper, we concentrated on clarifying behavior and roles for learners, conditions to assign appropriate roles for each learner, and predictable educational benefits by playing the roles, as a part of the ontology. By specifying these conditions, roles, and predictable educational benefits, we can select easily appropriate roles for each learner, and construct a feasible system to support group formation which searches appropriate learners for each role when a collaborative learning begins [11].

As our next steps, we will consider the possibilities of combination of some roles. We should consider carefully the synergistic and/or harmful effect of a combination of more than one role. Moreover, we plan to extract heuristics to assign roles for

learners. For example, according to the theory 'Peer tutoring', a learner who has a misunderstanding is appropriate for the role 'Peer tutor'. However, there is a risk: if a learner who plays 'Peer tutee' does not know the knowledge, the learner would believe what the peer tutor teaches and the peer tutee would also have the misunderstanding. It is caused by characteristics of the theory: the theory 'Peer tutoring', primary focus is 'Peer tutor' and his/her benefits, and the theory gives little attention to benefits of 'Peer tutee'. We will also describe the risks like this with the theory-based conditions for role assignments. Then, we will consider order of recommendations of roles, and implement the mechanism how to recommend the roles in a collaborative learning support system [14], and supporting environment for instructional design process for CSCL [12]. At this stage, we have been collecting supportive theories for collaborative learning, that is, all theories we referred to describe positive effects of collaborative learning, because we would like to collect effective models of collaborative learning as reference models to design collaborative learning. Of course, collaborative learning also has negative effect, and the negative models are useful to avoid designing such learning sessions. It will also be included in our future work.

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