

Learning Goal Ontology Supported by Learning Theories for Opportunistic Group Formation

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Abstract: The most important concept that plays a central role in the decision making process of the negotiation is a collaborative learning goal. At the process of negotiation, each agent considers the personal benefit for its own learner while it considers the social benefit for overall group. To make a negotiation reach an agreement, the compromises between the personal and social aspect is necessary. In this paper, we will focus on the learning goal ontology of collaborative learning and illustrate the basic way of thinking about the negotiation process for the opportunistic group formation.

1. Introduction

The expectation of invaluable pedagogical effects induced by the mutual interaction among learners has been gathering much attention of the researchers in the field of education for a long time. In the research field of computer-based education, CSCL (Computer Supported Collaborative Learning) is a subject of study attracting the interest of many researchers in these years due to the rapid development of computer network, multimedia, and artificial intelligence in education. Our research interest here is to make the educational function of the collaborative learning group clear. In general, each member of a learning group is expected to achieve his/her own personal goal through the interaction while attaining the social goal of whole group. Based on this principle, we can clarify the right situation to shift the learning mode from individual learning to collaborative learning adaptively and also the configuration of the learning group appropriate for the situation. We call the integrated model "Opportunistic Group Formation (OGF)"^[16]. It is important to find a good ontology to represent details of the OGF model so we can obtain maximum social educational utility from collaborative learning, while each learner is allowed to pursue private benefit. The ontology concerning OGF can be divided into two kinds, that is, Negotiation Ontology and Collaborative Learning Ontology. The combination of both ontologies gives us the possibility to scope the shared ontology that should be required. To make a negotiation reach an agreement, it is necessary to answer "What is the most important concept for the "justification" of negotiation?"

In the learning environment based on OGF model, each learner has an agent as his/her tutoring system. The agents sometimes negotiate each other to form an effective learning group. Learning goal¹ plays an important role in the negotiation process, because the negotiation will not lead the agent to an agreement without sharing the same goal. In the OGF negotiation process, it is important to compromise between the personal goal and the social goal. By compromising them, we will get the maximum benefit to learners from forming a group for collaborative learning.

This paper is organized as follows: first we show the overview of our research idea of OGF. Then, we describe the system of concepts concerning OGF, that is, Negotiation Ontology and Collaborative Learning Ontology. Finally, we focus on Learning Goal Ontology in Collaborative Learning Ontology for OGF.

¹ In this paper, we use the term "Learning Goal" in two meanings: (1) A learner's goal which represents what the learner acquires, and (2) An agent's goal to make an effective learning setting for a learner.

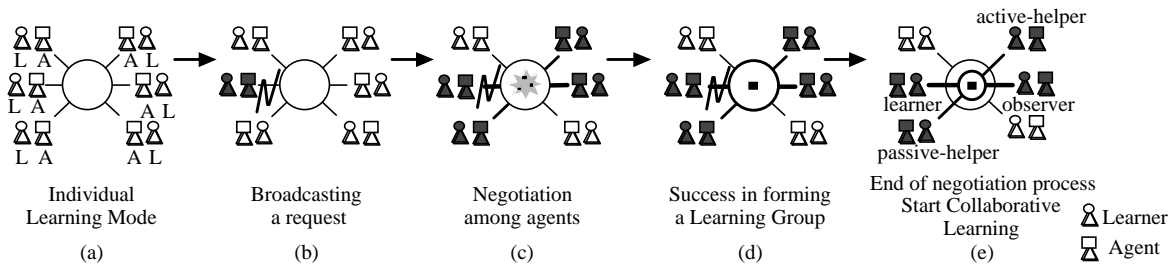


Figure 1. The overview of negotiation process

2. Opportunistic Group Formation

The idea of “Opportunistic Group Formation” can be expressed as follows:

Opportunistic Group Formation is a function to form a collaborative learning group dynamically.

When it detects the situation for a learner to shift from individual learning mode to collaborative learning mode, it forms a learning group each of whose members is assigned a reasonable learning goal and a social role which are consistent with the goal for the whole group.

We will briefly explain the outline of the OGF here. The description of ontologies is described in the next section. Figure 1 shows the overview of the negotiation process.

Basically a learner is in the individual learning mode and studies under a tutoring function of FITS/CL (Figure 1(a)). An agent takes charge of monitoring a learner and tries to get the benefit for its own learner by considering the personal goal. When the agent detects a desired situation for its own learner to switch into collaborative learning mode based on the learner model, the agent will initiate the negotiation process in order to form a learning group. At the same time, the agent establishes a learning goal and a desired role for the learner. This information is broadcasted to other agents as a request for forming a collaborative learning group (Figure 1(b)). It is based on the personal aspect goal. Only the agents that can get the benefit of collaborative learning for their own learners will participate in the negotiation process (Figure 1(c)). Agents are connected each other in order to do the negotiation. In the description of the negotiation process, opinion exchange, persuasion, compromise and criticism action will be selected to use in order to overcome the conflict among agents. The outline of concepts for these actions is shown in Table 1. Each agent considers the personal benefit for its own learner while it considers the social benefit for overall group. Learning goals are concepts that play an important role for executing each action. The most important key to overcome the conflict and reach an agreement of negotiation is to compromise between the personal and social aspect goal on behalf of learners.

When the negotiation completed successfully (Figure 1(d)), each participant in collaborative learning is well informed of the learning goal for a whole group and the role assigned to him/her. Then a new communication channel is opened for the members of the learning group. Participants can freely communicate with each other through the channel by using natural language (Figure 1(e)). The communication is not monitored by agents in any sense. Agents only send some messages via a dialog box in order to give an explanation about how to collaborate in the initial phase and wait until participants achieve the goal. When the achievement of the learning goal is declared by one of the participants, the agents close the channel and ask the participants the outcome of the collaborative learning in order to evaluate their achievement. Each agent updates the learner model based on the evaluation and encourages the learner under its charge to resume his/her learning task in individual learning mode. The communication among agents is done following a protocol based on KQML^[14].

3. Ontology for Opportunistic Group Formation: *Negotiation Ontology and Collaborative Learning Ontology*

Our approach has two objectives: to build a negotiation mechanism and to identify concepts for supporting the negotiation. The former is about the decision making process compromised between the personal and social aspects. The important point to note here is that to make a negotiation reach an agreement, a process model is necessary. We constructed a Negotiation

Process Model represented by transition network^[16]. The Negotiation Process Model is a key to making negotiation successful. The latter is about how to find a good ontology to represent details of the model OGF. In this paper, we will concentrate on the latter.

Negotiation for OGF is based on learning goals, the typical classes of the learning group, roles of members in the learning group and learning scenarios. The fundamental principles that make the negotiation reach an agreement among the agents, are in a shared ontology^[21]. By sharing the ontology, an agent is able to understand other agents' points of view and negotiate with each other.

What is important here is what scope of shared ontology should be required. The sharing of ontology enhances the negotiation in order to reach an agreement. However, it at the same time decreases the independency and generality for each agent's behavior.

The ontology concerning OGF is mainly divided into two types as shown below.

Negotiation Ontology : The system of concepts for modeling the negotiation process such as opinion exchange, persuasion, compromise and agreement (Table 1).

Collaborative Learning Ontology : The system of concepts for modeling the collaborative learning process such as learning goal, learning group type, and learning scenario (Table 2).

When the ontologies are in use, they are arranged into three layers as shown in Figure 2. The top layer is the negotiation level that corresponds to Negotiation Ontology. The negotiation level is the level that represents the important information for negotiation at an abstract level. The bottom layer is the agent level that corresponds to Individual Learning Ontology^[21]. The

Table 1. The outline of Negotiation Ontology

Negotiation message	Short communication words for negotiation process
call-for-participation	Request to other agents in order to form a group formation of collaborative learning for their own learners.
reply	Reply an accept/decline answer after receiving call-for-participation message.
proposal	Submit a (original, opposition, revised, compromise) proposal.
support	Support a proposal submitted by others.
give-opinion	Give (critique/justification) to other's proposal.
interrogate	Ask a question on other's proposal.
open-info	Open local information to public.
persuade	Persuade others to agree the proposal by giving justifications for it.
agree	Agree with a compromise proposal.
Negotiation events	The activities that are happened among agents in negotiation process.
send	The activity of sending a negotiation message from an agent to others.
receive	The activity of receiving a negotiation message from other agents.
reach-agreement	The activity of reaching an agreement under the same appropriate proposal among all the agents which participate in negotiation process.
conflict	The activity of figuring out a disagreement opinion among proposals.
Negotiation process	The process of negotiating among agents in order to reach an agreement of forming a group formation for collaborative learning
devising	The process of forming a proposal and submitting it to other agents.
compromise	The process of forming and exchanging opinion in order to reach an agreement.
persuasion	The process of giving a strongly held opinion of its own learner as a justification
observation	The process of observing and understanding the conflict among proposals in order to control the direction to reach an agreement.
investigation	The process of justifying accept/decline reply and making an opinion as an answer for opposition.
Negotiation objects	The concept that is necessary for negotiation process.
proposal	The design of collaborative group that an agent offer as a proper plan. It includes learning goal, role, topic, and learning scenario.
justification	The opinion that is used to support a proposal. It shows why the proposal is appropriate for collaborative learning.
conflict	The state of difference between part of opinion in proposals.
criticism	The opposed judgement and evaluation in detail for proposal.
Collaborative learning task concepts	The agent level concepts of collaborative learning task that are used in negotiation process.

Table 2. The outline of Collaborative Learning Ontology

Trigger	The detection of an opportunity for a learner to shift from individual learning mode to collaborative learning mode.
Impasse	When a learner has some difficulty on a learning process, the impasse trigger is detected. If the trigger is worth to initiate collaborative learning, the agent detected it submits a request to public.
Review	When a learner complete a given task, the review trigger is detected, If review of the task is worth to be carried out as a collaborative activity, the request for group formation is submitted to public.
Program	The trigger is prescribed by teaching materials authors in advance. For example, the author may describe the necessity of group learning by an experiment for a topic. In such a case, the program trigger will be detected when a certain number of learners successfully acquire prerequisite knowledge for the experiment
Learning goal	Goal for learner from collaborative learning viewpoint.
I-goal	The learning goal that represents what a learner acquires.
$Y \leq I$ -goal	The learning goal that represents the means to attain I-goal.
W-goal	The learning goal that expresses the situation setting up to attain $Y \leq I$ -goals.
Learning group	The collection of learners that are located together in order to carry out its own goal.
Group type	The type of group classified by the interaction among the members of the learning group.
Role	The character of learner which is defined by agent in order to carry out learning goal.
Learner	A Learner acquires knowledge to dissolve the impasse from Helpers
Helper	A Helper mainly helps a learner to attain his/her goal. The learning goal of the Helper is to gain the educational benefit of "learning by teaching".
Presenter	A Presenter performs his/her own understanding of a topic. The learning goal of the presentation is to gain the educational benefit of "reflection".
Observer	An Observer learns from collaborative activity of others learners. The learning goal of the observer is to gain the educational benefit of "learning by observing"
Participant	A Participant gives some comments observing collaborative activity of other learners. The learning goal of the participant is to promote his own understanding
Debater	A debater discusses with others learners who have different level of understanding of the topic. The learning goal of the debater is to gain the educational benefit of "learning by discussion".
Learning scenario	The outline of subject of learning and learning material that are used in collaborative learning.
topic	The subject of learning such as concept, rule and deep knowledge in collaborative learning
card	The teaching material that is prepared for collaborative environment as a set of hypertext card.

agent level is the level that represents the important information for executing educational task object at an abstract level. The intermediate layer corresponds to Collaborative Learning Ontology. At the intermediate layer, only important abstracts for negotiation from agent level remain as the necessary scope of information at an abstract level.

Three different abstract levels of ontology provide us with the following benefits.

To facilitate a negotiation process; agents only need to negotiate at an abstract level.

To encapsulate the implementation differences; agents can participate in the negotiation process to form a collaborative learning group in spite of that they are implemented in different ways.

As an example, we describe teaching materials in two levels, the agent level and the intermediate level. Each agent has a concrete structure of teaching materials, such as the representation of media and the content of problem. In Figure 2, the agent level shows these representations. If the agents are implemented in different ways, each agent's concrete structure of teaching materials may be also different from others in its representation. In this case, it is hard to negotiate a teaching material for collaborative learning among the agents. The agents need to share a common structure of teaching materials abstracted from the concrete structure of teaching materials in the agent level in order to negotiate with each other. The common structure of teaching materials is a part of Collaborative Learning

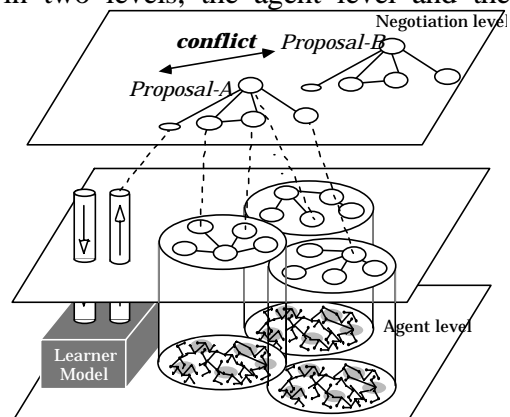


Figure 2. The architecture of ontology in Opportunistic Group Formation

Ontology, and it shows only the information required for negotiation process, such as a subject of learning and a unit of the subject (*i.e.*, "learning topic" in Collaborative Learning Ontology). In Figure 2, the intermediate layer shows these representations. As the Figure 2 indicates, the details of the construction method or representation method of a learner model are neglected, only the competence of the model, which is represented in the learner model, will appear in the negotiation field.

4. Learning Goal Ontology

In the negotiation process among agents, multiple group formations can be proposed. Each proposal is required to have justification associated with it. The learning goal is the most important concept for the "justification" of negotiation. In this section we describe the Learning Goal Ontology that is a part of Collaborative Learning Ontology.

There are many theories to support the advantage of collaborative learning. For instance, Sociocultural Theory^[28], Zone of proximal development^[28], Constructivism^[3,8], Self-regulated learning^[10,24], Situated cognition^[18], Cognitive apprenticeship^[19], Cognitive flexibility theory^[25,26], Observational learning^[1], Distributed cognition^[25], and so on. These theories are derived from a wide research area including pedagogy, sociology and psychology. We can expect different effects through collaborative learning process based on these theories. There are many kinds of learning goals dependent on collaborative learning situations.

In this paper, we classify learning goals achieved through collaborative learning process into the three kinds: I-goal, Y<=I-goal, and W-goal. I-goal, which is described as G:I, represents what a learner acquires through the collaborative learning process. Y<=I-goal, which is described as G:Y<=I, represents the means to attain I-goals. Both I-goals and Y<=I-goals are personal goals. W-goal expresses the situation setting up to attain Y<=I-goals and we describe the goal as G:W. W-goals are social goal as a whole group.

Figure 3 represents the structure of learning goals as an example where three learners: L_A , L_B and L_C exist. Learner L_A has an I-goal to attain through this collaborative learning process and this goal is described in the Figure 3 as G: I(L_A). Both L_B and L_C have I-goals, and they are represented by G: I(L_B) and G: I(L_C) respectively. G: Y(L_B)<=I(L_A) is a Y<=I-goal between L_A and L_B observed from L_A 's viewpoint: the reason why L_A interacts with L_B . Concerning this interaction between L_A and L_B , there is a Y<=I-goal observed from L_B 's viewpoint, too: the reason why L_B interacts with L_A . This Y<=I-goal is represented as G: Y(L_A)<=I(L_B). Both G: I(L_A) and G: Y(L_B)<=I(L_A) are personal goals of L_A . G: W(L_A, L_B) is a W-goal of the learning group (L_A and L_B). G: W(L_A, L_B, L_C) is a W-goal of the learning group (L_A , L_B and L_C).

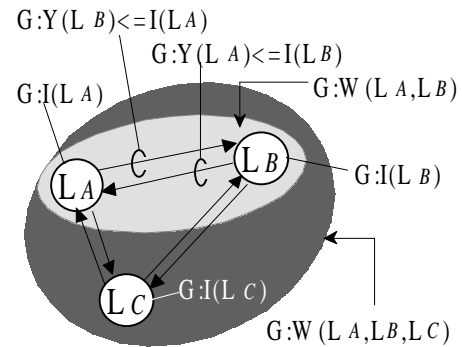


Figure 3. Collaborative Learning Goal Ontology

Table 3 I-goals

I-goal	Definition	Sources
Acquisition of new knowledge	To acquire new knowledge concerning the target domain	
Modification of misconception	To modify misconception already acquired	
In-depth understanding	To acquire deeper knowledge and internalize it	
Knowledge (re) construction	To clarify the relations among knowledge and (re-) construct knowledge structure.	[2,3]
Acquisition of new learning strategy	To acquire new learning strategies	[11]
Development of cognitive skills	To develop cognitive skills such as to monitor another learner and to be in partnership with the others.	[22,23]
Development of skill for self-expression	To develop the skill to externalize self thinking and communicate with another learner	[4]
Development of Self-regulation skill	To develop metacognitive skill to observe self-thinking process and self-ability, to diagnose them and to regulate or control self-activity.	[6,10, 24]

Table 4 Y<=I-goals

Y<=I-goal	Definition	Sources
Learning by observation	Learning indirectly by observing another learner's learning process	[1]
Learning by self-expression	Learning by expressing self-thinking process, such as self-explanation and presentation.	[4]
Learning by criticizing or advising	Learning by criticizing or advising another learner's learning process or opinion through the process to compare, diagnose, and evaluate them	[15]
Learning by teaching	Learning by teaching to another learner	[4,13]
Learning by being taught	Learning directly by being taught by another learner	[13]
Learning by participating	Learning by participating in more advanced learners' group as an apprentice.	[19]
Learning by discussion	Learning by discussion with another learner.	[7]

Table 5. W-goals

W-goal	Definition	Sources
Setting up the situation for Peer Tutoring	Setting up the situation to teach each other.	[5,9]
Setting up the situation for Observational Learning	Setting up the learning situation to share other learners' learning processes	[1]
Setting up the situation for dividing a cognitive or metacognitive function between learners	Setting up the learning situation to divide cognitive or metacognitive function between learners based on Sociocultural Theory	[28]
Setting up the situation for Situated Learning	Setting up the situation, <i>the community of practice</i> , for learning by cognitive apprenticeship	[19]
Setting up the situation for sharing multiple perspectives	Setting up the learning situation to evoke a learner's reflective thinking based on Cognitive Flexibility theory.	[12,25, 26]

4.1 Classification of Goals for Collaborative Learning

In this section, we identify goals for collaborative learning for each of the three categories: I-goal, Y<=I-goal, and W-goal. Then, we show some examples of Opportunistic Group Formation to describe the relations among these three kinds of goals.

Table 3 shows the I-goals. The learner is expected to achieve these I-goals through interaction with another learner. Table 4 shows the Y<=I-goals. For example, to achieve an I-goal "acquisition of new knowledge", some learners could take the Y<=I-goal "learning by being taught". Some learners could take the Y<=I-goal "learning by participating" in a more advanced group as an apprentice. Table 5 shows the W-goals. Each W-goal can be expressed by a set of I-goals and Y<=I-goals.

With these goals, the agent, who initiates a negotiation process to set up a desired learning situation for a learner, can identify members of a group to start an effective collaborative learning session by setting up an I-goal for the learner. Moreover, we can predicate educational benefits gained through the collaborative learning session from the configuration of the learning group.

4.2 Examples of Group Formation based on Learning Theories

As an example, here we describe a group formation for developing a learner- L_A 's Self-regulation skill by Situated Learning. Namely, $G:I(L_A)$ is "development of Self-regulation skill", and $G:W$ is "setting up the situation for Situated Learning". Figure 4 shows an example of group formation for this case. First, the *Community of Practice* is formed for Situated Learning (*i.e.*, L_A , L_C , and L_D). The members of the community are selected according to the Zone of proximal development theory. Namely, both of L_C and L_D are more advanced learners than L_A . Both of $G:Y(L_C) \leq I(L_D)$ and $G:Y(L_D) \leq I(L_C)$ are "learning by discussion", and both of $G:Y(L_C) \leq I(L_A)$ and $G:Y(L_D) \leq I(L_A)$ are "learning by participating". It seems hard to develop the self-regulation skill in the usual learning setting, because the skill is one of the metacognitive skills that are invisible internal processes. The learner- L_B participates the collaborative learning session as a helper for L_A to help L_A to achieve the goal. In this setting, the function of self-regulation skill is carried out as an interpersonal function between L_A and L_B .

$G:I(L_B)$ is also "development of Self-regulation skill". $G:Y(L_B) \leq I(L_A)$ is "learning by self-expression", $G:Y(L_A) \leq I(L_B)$ is "learning by criticizing or advising", and $G:W(L_A, L_B)$ is

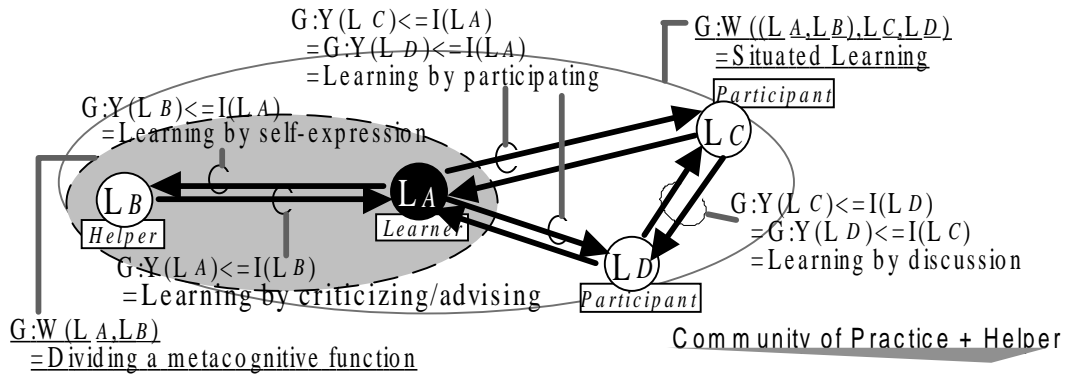


Figure 4. "Community of Practice + Helper" -type learning group

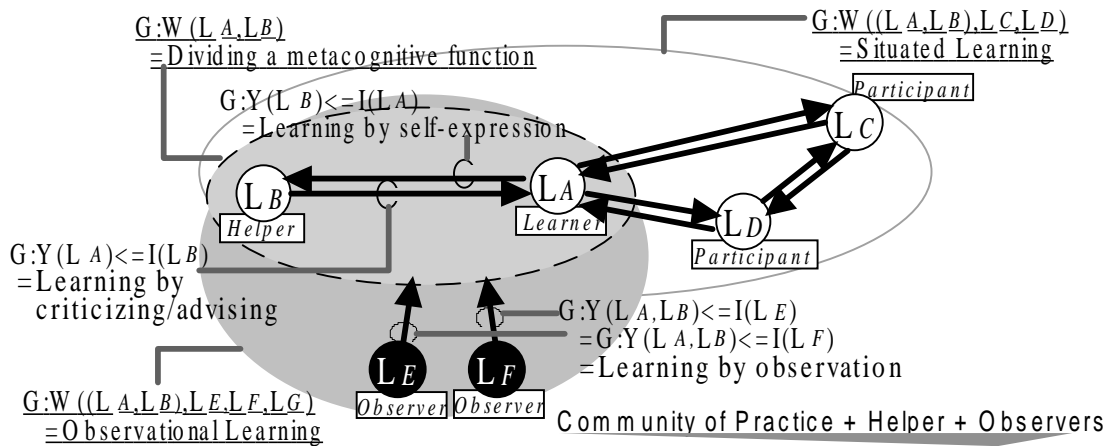


Figure 5. Observational learning as an additional factor

"setting up the situation for dividing a cognitive or metacognitive function" based on Sociocultural theory. It is expected for L_A and L_B to develop their self-regulation skill through the experience to carry out a part of the metacognitive function. According to Vygotsky's Sociocultural theory of learning, individual cognitive (or metacognitive) gain occurs first through interpersonal (interaction with social environment) then intrapersonal (internalization). We expect that the experience will encourage internalization of the function. Moreover, the effect of "learning by participating" is expected for L_A by participating in the learning situation for situated learning with L_C and L_D (i.e., *the Community of Practice*).

In the usual learning setting, other learners can not observe a process of using self-regulation skill, because the process is an intrapersonal process. By dividing the function between two learners, the other learners can observe it; the process comes to be visible. So, we can expect the effect of observational learning by sharing this learning session between L_A and L_B . Figure 5 shows an example to add the situation of observational learning to "*the Community of Practice + Helper*"-type learning session as Figure 4. In this case, L_A learns the self-regulation skill through "Situated Learning" and "dividing a metacognitive function", L_B learns the skill through only "dividing a metacognitive function", and L_E and L_F learn the skill through "observational learning".

5. Conclusion

We have discussed Learning Goal ontology which plays a central role in the decision making process of the negotiation for Opportunistic Group Formation. By considering the personal and social goals, we have identified three kinds of collaborative learning goals: I-goal, $Y \leq I$ -goal and W-goal. An example of group formation for collaborative learning session based on the collaborative learning goals has been given. In this paper, we expected that to investigate the collaborative learning goal and to form the learning group help the learners to receive the maximum of educational benefits. Collaborative Learning Goal Ontology helps form an

effective collaborative group, evaluate a learning group, analyze protocol during group learning process, and so on. At this stage, we have just identified learning goal ontology. Future work includes elaboration of the ontology and description of the relationship between three kinds of learning goals. In addition, from the agents' viewpoint, since the collaborative learning session is a blackbox, the gap of a learner's understanding between the agents and the learners that occurred during learning process in collaborative learning can not be avoided. How the ontology helps us to minimize the gap of learner's understanding is what we are considering.

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