What Learning Patterns are Effective for a Learner's Growth?

An ontological support for designing collaborative learning

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Abstract. The aim of our research includes constructing a guideline to help users select a form of learning appropriate for learning goals and learning tasks. To fulfill the aim we propose Learner's Growth Model (GM) and two types of augmented GM: Form-augmented GM and Task-augmented GM. In this paper we describe these three types of models and a mechanism to generate learning pattern recommendations based on the models. At present, we prepare eighteen types of Form-augmented GM and each Form-augmented GM is inspired by Learning Theories. The validities of these Form-augmented GMs are supported by the learning theories. Concerning Task-augmented GM, we have eight types, and their validities are supported by the data collecting from CSCL researches.

Introduction

The aim of our research includes constructing a guideline to help users select a form of learning appropriate for learning goals and learning tasks. There are different forms of learning: for example, drill-based individual learning, inquiry learning, peer tutoring, knowledge sharing through discussion, and so on. Every learning goal has suitable forms of learning and learning tasks for achieving it. To prepare the guideline, we need a model of a learner's growing process, and should clarify what forms of learning and what kind of tasks are effective to promote each process.

Although there are many research findings which concern development process of a person, forms of learning, and learning tasks, little finding is applied to design actual learning process. It is hard to understand the research findings for people who are not experts of the research area, and of course it is too complex and ambiguous to be dealt by computers. One of major causes of the problem system designers or teachers face is the lack of shared understanding of collaborative learning (CL). It is difficult to understand what design rationale of CSCL (Computer Supported Collaborative Learning) environment is. We do not have even common vocabulary to describe what CL is, because the concepts of CL grow up in different research areas: pedagogy, sociology, psychology, and so on.

As a solution to these problems, we have been adopting Ontological engineering technique [14] to establish shared understanding about the model of CL session [8, 9, 10]. The goal of our research is to enrich CL Ontology which represents CL process and works as common vocabulary. We are aiming at supporting design and analysis of CL process by representing and storing models of CL with the ontology. So far, we have extracted concepts to represent CL process and clarify learning goals which are attained in CL. Using the ontology, we have constructed models of group formations and interaction patterns inspired by learning theories [10, 11]. In this paper, we propose Learner's Growth Model (GM) which is a simplified model to represent a learner's knowledge acquisition process and skill development process based on the Learning Goal Ontology, and clarify relationship between learning forms and Learner's GM. Moreover, we classify characteristics of learning tasks in CL, and show relationships between the characteristics of the tasks and Learner's GM.

1. Support for Designing Learning Scenarios

Figure 1 shows an overview of the mechanism to recommend users learning patterns. The intended users are people who design learning scenarios, like educational practitioners and educational system designers. First, the user inputs the characteristics of the task that he/she intends learners to accomplish. Then, the system shows educational benefits which are expected learners to gain by accomplishing the task referred to the Task-augmented Growth Model. The expected benefits are reified as state transitions on the learner's growth model that we propose later. The user can select a goal state for the intended learners from the states which are activated in the model. Then, the system activates some states which can be initial states for the goal state, and the user selects an initial state for the learners. After that, the system shows possible state transitions from the initial state to the goal state as learning pattern recommendations, and by clicking a link between states in the learning pattern, the user can identify what learning forms, what group formation, and what roles are effective to the transition referred to the Form-augmented Growth Model. Moreover, if the user selects one learning pattern, the system also shows additional educational benefits expected to the learners to gain through the learning pattern.

To realize the mechanism, we need to construct three types of models: Learner's Growth Model (Learner's GM), Growth Model augmented by Learning Forms (Form-augmented GM), and Growth Model augmented by Learning Tasks (Task-augmented GM). The Learner's GM is a simplified model to represent a learner's knowledge acquisition process and skill development process as a state transition network. The Form-augmented GM represents relationship between a learner's growth process and learning forms, and is reified as possible transitions on the learner's GM. On the other hand, the Task-augmented GM represents relationship between a learner's growth process and characteristics of learning tasks, and is also reified as possible transitions on the learner's GM. Next section, we describe the learner's GM which is a base of this system.

2. Learner's Growth Model

2.1 Learning Goal Ontology

Up to the present, through a survey of a variety of studies on CL we have built CL

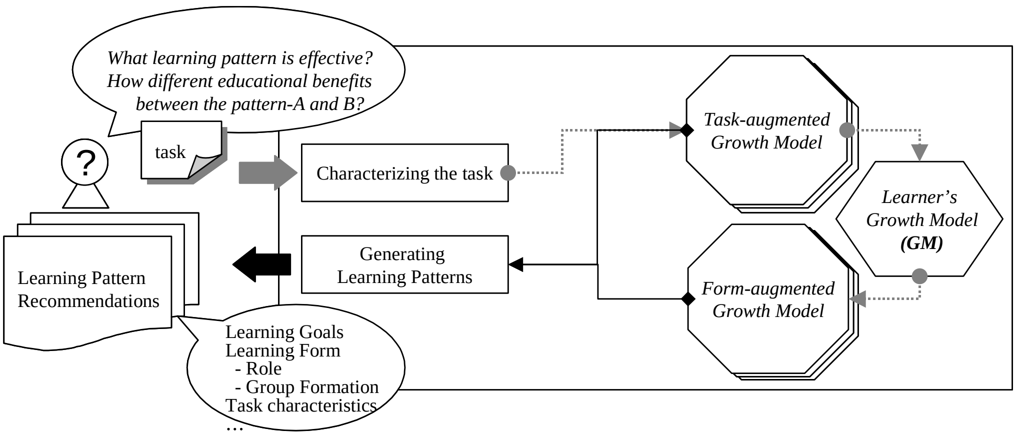

Figure 1. Overview of the mechanism to recommend learning patterns

Table 1. I-goals

I-goal	Definition	Sources
Acquisition of Content-Specific Knowledge	To add new knowledge concerning the target domain to existing schemata, to understand it, and then to consider relationship among knowledge, and (re) construct knowledge structure.	[2, 3, 4, 6, 15, 16]
Accretion		
Tuning		
Restructuring		
Development of Cognitive Skill	To get knowledge concerning cognitive skills such as diagnosing and monitoring, to practice them, and then to refine them.	[16, 18, 23]
Cognitive stage		
Associative stage		
Autonomous stage		
Development of Metacognitive Skill	To get knowledge concerning metacognitive skills for observing self-thinking process, diagnosing it and regulating or controlling of self-activity, to practice them, and then to refine them.	[16, 19, 23]
Cognitive stage		
Associative stage		
Autonomous stage		
Development of Skill for Self-Expression	To get knowledge concerning the skills for externalizing self-thinking process and presenting the learner's self-perspectives, to practice them, and then to refine them.	[3, 21]
Cognitive stage		
Associative stage		
Autonomous stage		

Ontology and formulated CSCL models in terms of the ontology[8, 9, 10]. Ontology is a set of definitions of concepts and relationships to be modeled [14]. In Learning Goal Ontology, which is a part of CL Ontology, we have clarified learning goals which are expected learners to attain during learning session. There are four types of learning goals: learning goals for the whole group (W(L)-goal), activity goals for the whole group (W(A)-goal), interaction goals for a learner (Y<=I-goal), and goals of individual development for a learner (I-goal). Here, to construct Learner's GM, we refer to the I-goal Ontology.

Table 1 shows the I-goals in our Learning Goal Ontology[1]. The process to acquire a specific knowledge includes three qualitatively different kinds of learning: accretion, tuning, and restructuring [17]. Accretion is to add new information to a learner's preexisting schemata, and to interpret the information in terms of relevant preexisting schemata; tuning is to understand the knowledge through applying the knowledge to a specific situation; and restructuring is to consider relationship among knowledge and reconstruct the learner's knowledge structure. Concerning development of skills, there are also three phases of learning: cognitive stage, associative stage, and autonomous stage [1, 7]. Cognitive stage involves an initial encoding of a target skill into a form sufficient to permit a learner to generate the desired behavior to at least some crude approximation; associative stage is to tune the target skill through practice. Errors in the initial understanding of the skill are gradually detected and eliminated; and autonomous stage is one of the gradual continued improvements in the performance of the skill.

2.2 Learner's Growth Model

As Table 1 shows, although there is a variety of learning goals for a learner, growing process of a learner can be simplified as the process of knowledge acquisition and the process of skill development. There are four states concerning the process of knowledge acquisition: nothing, accretion, tuning, and restructuring, and four states concerning on skill development: nothing, cognitive stage, associative stage, and autonomous stage. Now, we want to consider simplified learning process to acquire one declarative knowledge and to master one skill concerning the knowledge. So, the state of restructuring on knowledge acquisition is remained as a heterogeneous state, because learners identify relationship

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[1] Of course, our ontology does not exhaust all learning goals. At present, we rely on learning theories to construct the ontology and these goals are extracted from the theories which are often referred in CSCL papers.

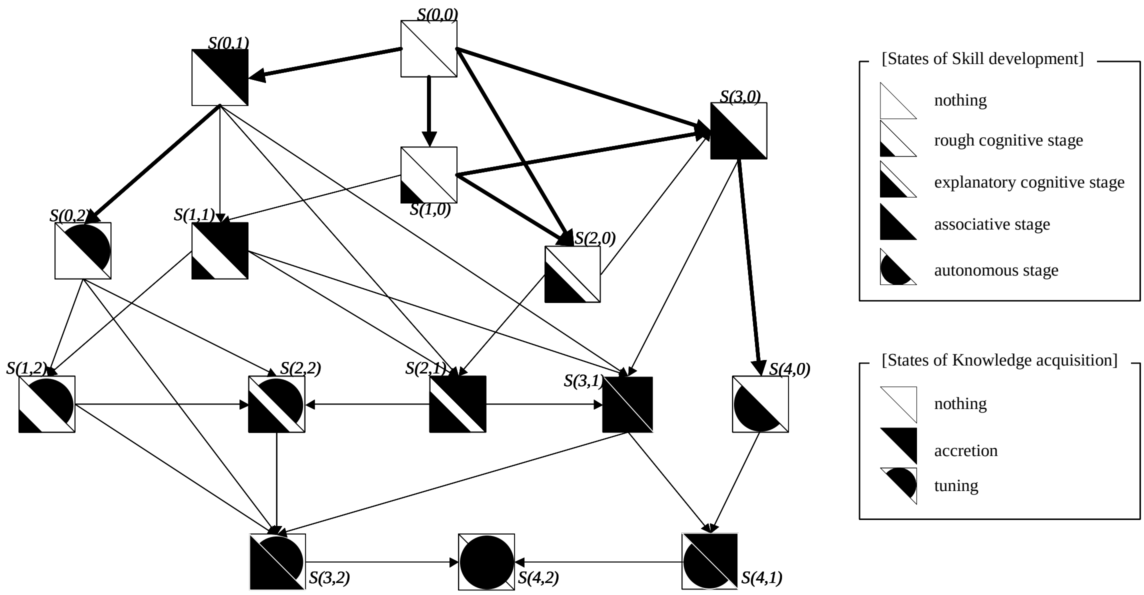

Figure 2. Learner's Growth Model

among some knowledge and (re-)construct knowledge structure in this state. On the other hand, we want to distinguish the state of cognitive stage in skill development into two states: rough-cognitive stage and explanatory-cognitive stage. The original meaning of the cognitive stage that Anderson said is identified as explanatory-cognitive stage [1]. It seems to be rare to encode a target skill into a form sufficient to permit a learner to generate desired behavior. Usually, we learn a skill at first by observing a process in which other person uses the skill. In this situation, we get partial information about the skill and it is not sufficient for us to generate the desired behavior. Therefore, there are three states concerning the process of knowledge acquisition: nothing, accretion, and tuning, and five states concerning on skill development: nothing, rough-cognitive stage, explanatory-cognitive stage, associative stage, and autonomous stage.

We propose the Learner's GM as Figure 2. There are fifteen possible states: multiply three (knowledge acquisition) by five (skill development), and the product is fifteen. In the figure, the arrows show possible transitions among the states, and *s(x, y)* means the state: *x* means a state of skill development and its state is represented as a symbol in the left triangle; *y* means a state of knowledge acquisition and its state is represented as a symbol in the right triangle: for example, *s(0,0)* means that the state of skill development is "nothing" and the state of knowledge acquisition is also "nothing". *s(0,1)* means "nothing" and "accretion", *s(0,2)* means "nothing" and "tuning". *s(1,0)* means "rough cognitive stage" and "nothing", *s(2,0)* means "explanatory cognitive stage" and "nothing", *s(3,0)* means "associative stage" and "nothing", and *s(4,0)* means "autonomous stage" and "nothing".

3. Augmented Growth Models: Form-augmented GM and Task-augmented GM

Based on the Learner's GM, we construct two types of augmented GM in order to generate recommendations of learning patterns. In this section, we describe these augmented models and their validity.

3.1 Growth Model augmented by Learning Forms: Form-augmented GM

There is a variety of learning forms; for example, learning by teaching, learning by observing, learning by drill and practice, and so on. Every learning form is proposed to give learners specific educational benefits. To recommend a user suitable learning forms to the user's intended tasks and learning goals, we need to clarify relationship between the educational benefits and learning forms. We have surveyed some learning theories like Cognitive Apprenticeship [5], Anchored Instruction [4], Peer Tutoring [6], LPP [13], Distributed Cognition [18], Sociocultural Theory [23], Cognitive Flexibility [21], Cognitive Constructivism [15], Observational Learning [2], and so on, and clarified learning forms proposed in each theory and educational benefits for each form in our CL Ontology.

Here, we represent the relationships using the Learner's GM and we call this model Form-augmented GM. Figure 3 shows examples of the Form-augmented GM. The black arrows mean applying the learning form will facilitate the transitions; the dotted black arrows mean that it will be possible the learning form facilitates the transitions; and the states and arrows which are gray-out are not desired in the learning form. In the figure, three types of learning forms are represented: learning by observation in Observational Learning; learning by practice in LPP, and learning by apprentice in Cognitive Apprenticeship. As you know, although all of these three learning forms are effective to develop a learner's skill, the difficulty in mastering a skill and the effectiveness according to the development process are different each other. In the figure, we can see the Observational Learning is effective for learners who have nothing about the skill (*s(0,y)*), and then the learners will grow into rough cognitive stage of the skill (*s(1,y)*). Applying the form LPP, learners will grow into associative stage (*s(3,y)*) through rough cognitive stage (*s(1,y)*). Applying the form Cognitive Apprenticeship, learners will also grow into associative stage (*s(3,y)*), the learners, however, will pass through two states before reaching the associative stage (*s(3,y)*): rough cognitive stage (*s(1,y)*) and explanatory cognitive stage (*s(2,y)*). It means that if a user wants a learner to reach associative stage of a skill, the form of LPP and Cognitive Apprenticeship will be effective, while the Observational Learning will not be sufficient. Moreover, the form of Cognitive Apprenticeship will be easier than the form of LPP to reach associative stage, because there

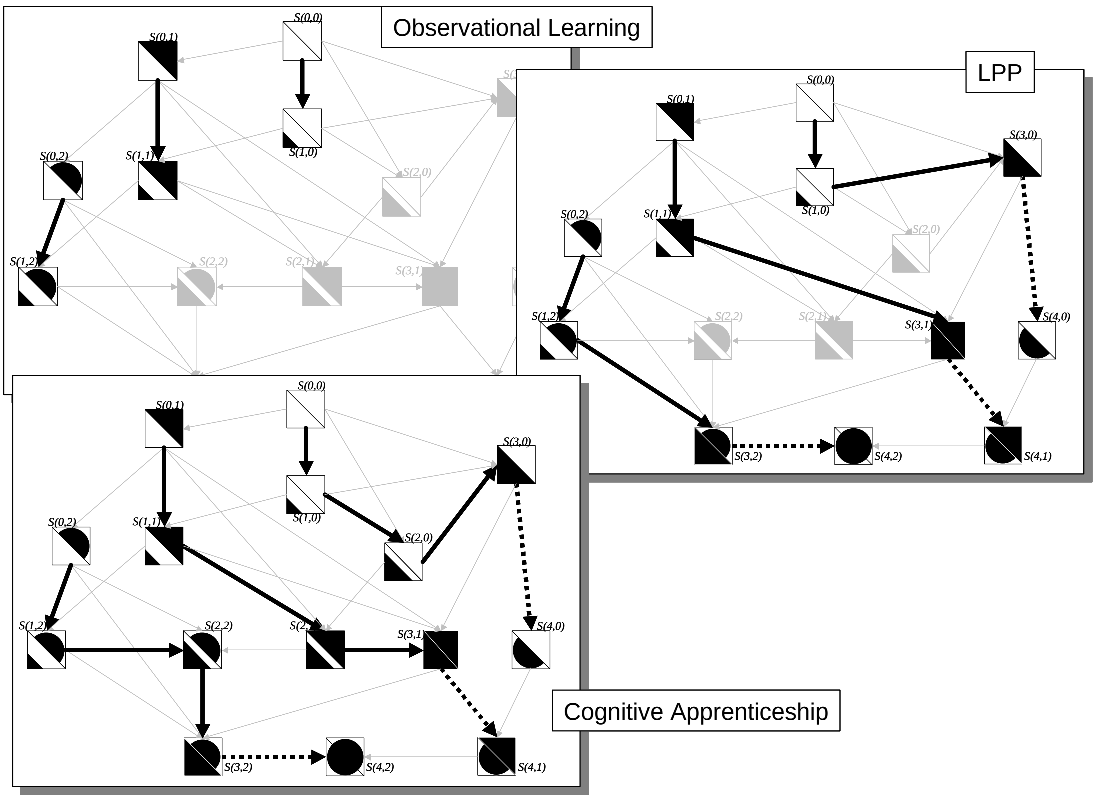

Figure 3. Examples of Form-GM

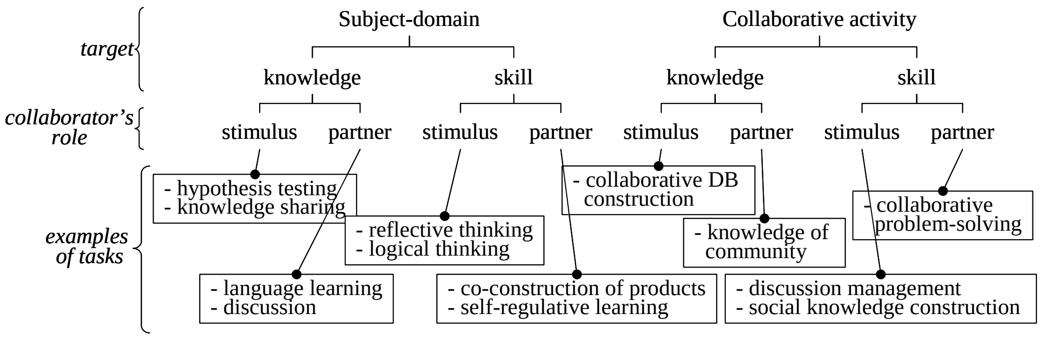

Figure 4. Characteristics of typical tasks for collaborative learning

are more steps in the form of Cognitive Apprenticeship than LPP. As Skinner said, the learning process should be divided into a very large number of very small steps [20]. It is easy to learn there are many steps to reach a goal.

By representing the processes of a learner's growth in each learning form, it will be facilitate to understand differences between learning forms, and which learning form is effective to promote a specific process. It will be also easy to compare difficulties in each learning form to reach specific state in the model by counting the number of the states which are passed through from the initial state to the goal state.

3.2 Growth Model augmented by Learning Tasks: Task-augmented GM

Task-augmented GM is a model to represent relationship between characteristics of learning tasks and a learner's growth process using the Learner's GM. Different types of learning tasks are used in CL session. Each learning task has its subject-domain and types of collaborative activity: for example, to solve the eight-puzzle (subject-domain) in competition with other learners (collaborative activity), or to find rules in an ecological system (subject-domain) by testing hypothesis collaboratively with other learners (collaborative activity). Some designers regard learning about subject-domain as important, and some designers regard learning about collaborative activity as important. We mean learning about content-specific knowledge and skills by the term "learning about subject-domain"; we mean learning knowledge of community and collaborative skills by the term "learning about collaborative activity". Simply, it is possible to learn about subject-domain in individual learning, however it is hard to learn individually about collaborative activity. There are both knowledge and skills as things to learn. To collect learning tasks and characterize them, it is important to consider what the target to learn is in each task. Figure 4 shows characteristics of typical tasks for CL. In the figure, there is one more factor to characterize the tasks: collaborator's role. Although all of the tasks require learners to collaborate each other, there seem to be two types of reasons why the designer intends the learners to collaborate. One is for the role of stimuli, and another is for the role of partners. To act as the role of stimuli, knowledge or skills need to be distributed among the learners: if each learner has different knowledge, skills, or viewpoints, the learners stimulate each other and they will be able to get new knowledge or opportunities to use skills. On the other hand, to act as the role of partners, knowledge or skills need to be shared among the learners: each learner has almost the same background knowledge or has the same skills, therefore the learners form a situation to use the knowledge naturally, or use the skills helping each other or cooperatively.

We plot these eight types of tasks into the Learner's GM to represent what types of tasks are effective to what process of learner's growth. Figure 5 shows a Task-augmented GM which represents possible transitions in the task to master skills in subject-domain with other learners as partners. The learners who join in the task have the same learning goal to

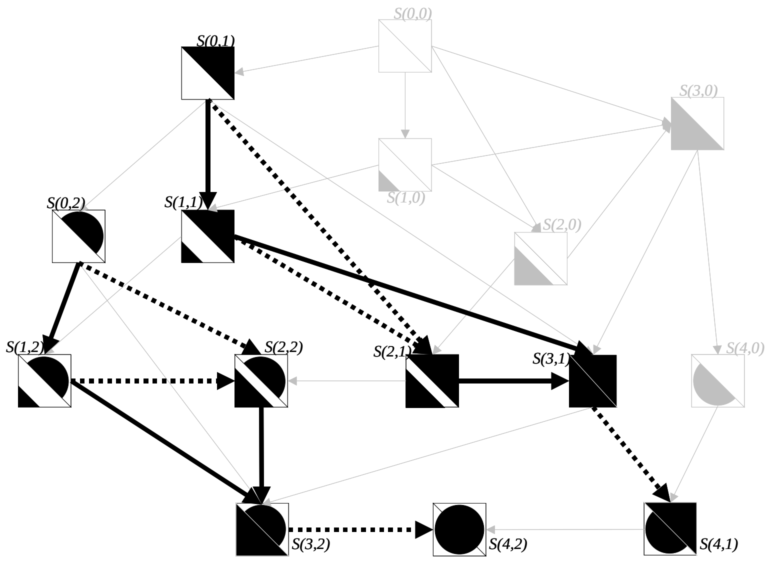

Figure 5. An example of Task-augmented GM

master a skill through accomplishing the task collaboratively. So, if the learner has nothing about the skill, the learner will be able to get knowledge how to use the skill by observing the other learner's behavior (transitions from *s(0,y)* to *s(1,y)*). If a learner has some knowledge how to use the skill (*s(1,y)* or *s(2,y)*), the learner will be able to grow into the next stage (*s(3,y)*) through using the skill. Moreover, it will be able to expect learners to teach each other on the skill. So, the transition from *s(0,y)* to *s(2,y)*, and the transition from *s(1,y)* to *s(2,y)* are possible by the other learner's help.

Next, to check the validity of the characteristics of the tasks and plotting into the Task-augmented GM, we survey CSCL case studies and classify the tasks used in each study. We have collected 66 tasks from the proceedings of CSCL conference [22]. Table 2 shows the result of classification of the tasks. Many studies use CL as a means to learn about subject-domain, and no study deals with the task to learn knowledge on collaborative activity with other learners as partners. All tasks can be characterized as one of the eight types of the tasks. Then, we check the learning goals the researchers intend learners to attain through the tasks. We prepare Task-augmented GMs like Figure 5 for each type of the task, plot learning goals in each case study into the Learner's GM, and compare the Task-augmented GM and each case study. The result shows that the Task-augmented GM includes each case study's learning goals: for example, in the study which is intended learners to learn a skill in subject-domain with other learners as partners, the learning goals are included in the transitions from *s(0,1)* to *s(4,1)* or the transitions from *s(0,2)* to *s(4,2)*.

4. Conclusions

In this paper we describe Learner's GM and two types of augmented GM: Form-augmented GM and Task-augmented GM. At present, we prepare eighteen types of Form-augmented GM and each Form-augmented GM is inspired by Learning Theories like Cognitive Apprenticeship, LPP, and so on. The validities of these Form-augmented GMs are

Table 2. Classification tasks using in case studies

Target	Subject-domain				Collaborative activity			
	Knowledge		Skill		Knowledge		Skill	
Collaborator's role	Stimulus	Partner	Stimulus	Partner	Stimulus	Partner	Stimulus	Partner
Number of tasks	*11*	*16*	*11*	*13*	*8*	*0*	*6*	*1*

supported by the learning theories. In addition to them, we have a few Form-augmented GMs to represent traditional learning forms which are often used in schools. Concerning Task-augmented GM, we have eight types, and their validities are supported by the data collecting from CSCL researches. Learner's GM is a format to represent the effectiveness of learning forms and of learning tasks. If users give characteristics of learning tasks, the system can identify possible learning goals by the task, and possible learning forms for the task. Similarly, if the users give a learning goal, the system can recommend suitable learning forms and suitable learning tasks. Moreover, we have proposed the Theory-based Group Formation mechanism and constructed the system to propose suitable group formations for intended learners inspired by learning theories with the mechanism [10, 11]. Connecting the system with this learning pattern recommendation system, we can provide more useful information for the users.

Now, we simplify the Learner's GM to represent acquisition of one declarative knowledge and mastering one skill, and except restructuring process of knowledge structure. It is our future work to include it into our model. Moreover, we will collect and examine other sources to develop our classification of collaborative tasks and forms.

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