Chapter 7

SCRIPTING COLLABORATIVE LEARNING IN AGENT-BASED SYSTEMS

Gerardo Ayala
Universidad de las Américas-Puebla

Abstract: The chapter discusses an agent-based perspective of scripting for CSCL environments. It presents two approaches for supporting scripting collaborative learning in agent-based systems: (1) on the macro-level of collaborative learning, where agents may support the organization of the learning process through facilitating group configuration and task selection; and (2) on the micro-level of collaborative learning, where agents may support awareness and coordination of activities. Both approaches are presented for two kinds of domains: (i) pedagogically structured and (ii) not pedagogically structured domains. For both cases, the types of support on the macro and micro levels are examined.

1. INTRODUCTION

Cooperation scripts can be designed for organizational processes, at the macro level, and for detailed work processes, at the micro level. Both approaches have their differences when we have a pedagogically structured knowledge domain or a non structured knowledge domain. These two approaches are complementary; at the macro level, scripts support the structure of the collaborative process in order to promote productive interactions, and at the micro level by coordinating the collaboration. This chapter discusses the role of software agents for these two approaches, from the computer science perspective of scripting for CSCL environments, supporting communication, cooperation and coordination, which are the fundamental issues for effective collaborative learning.

From the computer science perspective of scripting, cooperation scripts are integrated in the components of the learning environment and may be *imposed* or *induced*. An imposed cooperation script is presented explicitly to the learners, who have to carry out a set of activities in a specific order. It may cause in the learner a loss in motivation due to a loss of autonomy in the learning activity. An induced cooperation script is embedded in the design of the learning environment, and provides learners with a high amount of freedom, but it is based on the assumption that learners have an *internal culture-acquired* cooperation script, and are aware of the learning opportunities and benefits of collaboration.

Following an imposed script implies a coercion degree, which is the degree of freedom that the learners have in following the script (Dillenbourg, 2002). It is reported in this volume, by Lauer and Trahasch, that, for adult learners, a high degree of coercion might affect motivation. Also it is believed that scripts in a CSCL environment increase the cognitive load of the learner and have the risk to make the groups interact in a non natural way (Dillenbourg, 2002).

1.1 Software agents and cooperation scripts

One of the benefits of implementing software agents is that they can release the cognitive load of the user. The semiautonomous nature of interaction between the learners and software agents provides a low coercion degree, providing one step towards a shift from paternalism to autonomy in inducing cooperation scripts, as proposed by Runde, Bromme, and Jucks in this volume. From this perspective of semi autonomy in user-agent interaction (Norman, 1994) a software agent presents proposals and the user decides among those.

Considering the risk that cooperation scripting in CSCL environments can lead us away from the genuine path of collaborative learning (Dillenbourg, 2002) we believe that the role of agents should be to induce collaborative scripts that regulate collaborative learning without interfering with the social dynamics of the group.

Software agents must support collaborative scripts that are simple to follow and easy to adopt. Therefore, the role of software agents supporting scripting in CSCL environments should be:

- Work on behalf of the learner in order to reduce her cognitive load while she follows a cooperation script.
- Distribute the coercion load over the interaction, coordination and task levels, maintaining a low coercion degree by inducing the appropriate collaborative interaction patterns in the learners.
- Keep the learner aware of activities, resources and the collaboration opportunities by following a cooperation script in the activities of a collaborative learning task.

1.2 Pedagogically and not pedagogically structured domains

The nature and representation of the domain knowledge plays an important role in the design of the cooperation script and the modelling of the agent. We may have a *pedagogically structured domain*, which is a knowledge repository that consists of identified knowledge elements organized in a pedagogical structure (i.e., a knowledge base). On the other hand, we may have a *non pedagogically structured domain*, which is a repository of digital documents organized in a taxonomy but not necessarily with a pedagogical structure (i.e., a digital library).

1.3 Organizational and detailed work processes

The organizational processes that we consider in this chapter, for cooperation scripts at the macro level, are *group configuration, learning plans* and *tasks assignment.* The detailed work processes for cooperation scripts at the micro level are *coordination* and the *social construction of knowledge.* While the organizational processes of group configuration and task assignment are induced scripts, implemented with proposals from the software agent, the scripts for the coordination, for collaborative problem solving and the social construction of knowledge, are imposed scripts.

2. SCRIPTING ORGANIZATIONAL PROCESSES

This section presents the considerations to model software agents supporting collaborative scripting for organizational processes. Because of the social nature of these processes and the characteristics of an agent, it is more feasible that software agents induce the script. For a CSCL environment, software agents can be modeled in order to induce a cooperation script that allows the learners to:

1. Make an appropriate group configuration, based on the capabilities and learning interests of the learners.
2. Assign learning tasks that ensure the existence of zones of proximal development (Vygotsky, 1978) and maintain the productivity of the learner in the community or group.

This requires a learner model, as a set of beliefs the agent has about its learner. For pedagogically structured domains, software agents can propose groups and determine the zones of proximal development of the users by keeping a representation of the learners capabilities in the learner model. In the case of not pedagogically structured domains, software agents propose discussion groups and individual learning plans to the users, by keeping a representation of the interests of the community members in the learner model, together with a record of those popular and relevant digital documents for the community.

2.1 Designing a cooperation script for the organizational processes

For the organizational processes, the attributes of the script are group configuration and task assignment. In general terms, the core mechanism, at this macro level, is to maintain learning opportunities for the learners.

For pedagogically structured domains, in order to induce a cooperation script for task assignment, the software agent requires a learner model, considered as a set of beliefs the agent has about the capabilities of the user, based on her application of the knowledge elements in the domain knowledge. With this information the agent is able to propose learning tasks that generate zones of proximal development for all the learners in the group. For non pedagogically structured domains, the software agent maintains a learner model as a set of beliefs about her interests, in order to propose discussion groups of people with common interests and to keep an individual learning plan.

The design of the interface implies spaces for group configurations, access to open learner models, a space for a learning task proposal, and for the establishment and communication of commitments between learners.

2.2 GRACILE and CASSIEL

In GRACILE, a collaborative learning environment for Japanese grammar, we have a domain knowledge base representing the grammar rules (Ayala & Yano, 1995). The rules are considered knowledge elements and are organized in a pedagogical structure that relates them, according to their internal structure, components, complexity and use. Cooperation scripts in an environment like GRACILE can be defined for group configuration and task assignment.

For GRACILE we implemented a *mediator agent* that assists the learners in the group configuration and in maintaining zones of proximal development in the group (Ayala & Yano, 1996a, 1996b). Using a learner model the mediator agent is able to determine a *structural knowledge frontier*, as a set of knowledge elements pedagogically related to those the agent believes the learner already internalized. In order to determine the learner's zone of proximal development, the agents cooperate and determine a *social knowl-*

edge frontier of the learner, which is defined as the set of knowledge elements the agent believes have been internalized by other members of the learning group. The mediator agent uses the knowledge frontier in order to generate group proposals with zones of proximal development, and task assignments determined to keep the existence of zones of proximal development in the group members.

As an example of an agent based learning environment with a non pedagogically structured knowledge domain, we have developed CASSIEL. CASSIEL was designed based on concepts of lifelong learning and web based repositories, for virtual communities of practice (Ayala, 2002). Cooperation scripts in environments like CASSIEL can be defined for the configuration of discussion groups and the maintenance of an individual learning plan.

The theoretical foundation of collaborative knowledge construction in CASSIEL is the theory of Nonaka and Takeuchi (1995) from the area of knowledge management. Nonaka and Takeuchi (1995) have proposed a theory of the creation of knowledge that has been applied for learning organizations (Morabito, Sack, & Bhate, 1999) and, in general terms, proposes that knowledge in an organization is constructed through the phases of *socialization*, *externalization*, *combination* and *internalization*.

Our interpretation of that theory is as follows: The individual's personal ideas are shared (socialization). When these ideas become of the interest of other participants they are justified and formalized (externalization) becoming shared beliefs, which once validated by the group (combination) are considered new knowledge in the community. Those new knowledge resources in the repository are promoted and, with their use, become knowledge of the participants (internalization). Internalized knowledge plays a role in the generation of new ideas, and the process begins again (Ayala, 2003).

In CASSIEL, a *user agent* maintains a learner model as a set of beliefs about the interests of the learner. We consider that the interests of the learners are the basic issue for successful collaborative learning and interaction in a virtual community based on a digital collection of educational resources (Ayala & Paredes, 2003). The user agent supports collaboration and adaptability, maintaining the model of the learner and assisting her in the configuration of discussion groups. The user agent is designed to help the user to maintain a personalized learning plan, by maintaining a list of resources considered of the interest of the learner as well as of the interests of other participants in the community. The learning plan represents also those resources considered popular in the community, relevant for the learner or new. Following a learning plan, the learner maintains her membership in the community, being aware of what is going on and being able to participate in a more productive way.

2.3 Group configuration

The learner model is the key element for the group configuration proposal generated by the agent. For pedagogically structured domains, the learner model is revised any time the learner makes a right or a wrong construction or answer that implies the application of a knowledge element. For non pedagogically structured domains, the learner model is mainly a representation of the interests of the learner, which are inferred from the navigation of the user in a digital repository, her bookmarks and annotations.

In an agent based CSCL environment, a group configuration should be generated as a proposal from the software agent to the learner. Such proposal must be constructed considering the beliefs of the agent about the capabilities and learning interests of the learners. The agent works on behalf of the user by proposing a selection of participants among all members of the community that have the potential to collaborate with her, and provides information concerning other learners. The group configuration may be seen as an imposed script or an induced one, if it is negotiable.

In the case of a pedagogically structured domain, as in GRACILE, the mediator agent holds a learner model as a set of beliefs organized as follows:

- The learner's capabilities
- The learner's goals
- The opportunities of assistance to the learner from other learners in the current group, generated based on the beliefs of other mediator agents about the capabilities of their learners.
- The registration of the knowledge elements applied in the tasks selected by the learner, so the agent can infer the selection criteria of the learner: selecting learning tasks based on the feasibility (pedagogically related with those already learned), popularity (already learned by others) or relevance (importance for advancing in the domain) of the knowledge elements with respect to the group. This information is useful for constructing a group proposal.

Learner modeling in GRACILE was based on Vygotsky's theory of social learning (Vygotsky, 1978). We represent the learner's actual development level as the set of knowledge elements which the mediator agent believes can be applied by the learner without any assistance. The learner's potential development level is represented by the knowledge used by the learner with the assistance of other learners or from the domain agents. Vygotsky defined the zone of proximal development as the distance between the actual and the potential development level of the learner and it is considered the space of knowledge elements with more possibilities to be internalized by the learner.

In order to propose a group configuration the agent needs to represent the learner's assistance and learning opportunities in a CSCL environment. We have defined the learner's *group-based knowledge frontier* (here after referred as GBKF) (Ayala & Yano, 1996a) as the *union* of the following two sets:

1. *Structural knowledge frontier*: the set of complex domain knowledge elements related to simpler elements believed to be already internalized by the learner.
2. *Social knowledge frontier*: the set of domain knowledge elements believed to be internalized by the members of the current learning group but still not believed to be internalized by the learner.

The learner's *candidate knowledge for relevant collaboration* (hereafter referred as CKRC) consists of the *intersection* of these two sets. The CKRC is then a subset of the GBKF which represents those still not internalized knowledge elements that other learners have internalized and which are structurally related to the learner's internalized elements.

In order to construct the GBKF and the CKRC the mediator agents cooperate by exchanging their beliefs about their learners' capabilities. Upon request the mediator agent informs other mediator agents in the network about the changes in its beliefs about the capabilities of its learner (Ayala, 1996a).

According to our results the mediator agent should, if possible, propose heterogeneous small groups (4 participants) formed by 2 advanced learners, 1 novice and 1 intermediate level learner (Ayala & Yano, 1997). The mediator agent will present a group proposal configured by two advanced learners who have learning goals corresponding to knowledge elements not necessarily pedagogically related with those already internalized (leadership), one intermediate level learner that has learning goals corresponding to knowledge elements pedagogically related with those already internalized (criteria of feasibility), and a novice learner that may have learning goals by any criteria (popularity, feasibility or leadership).

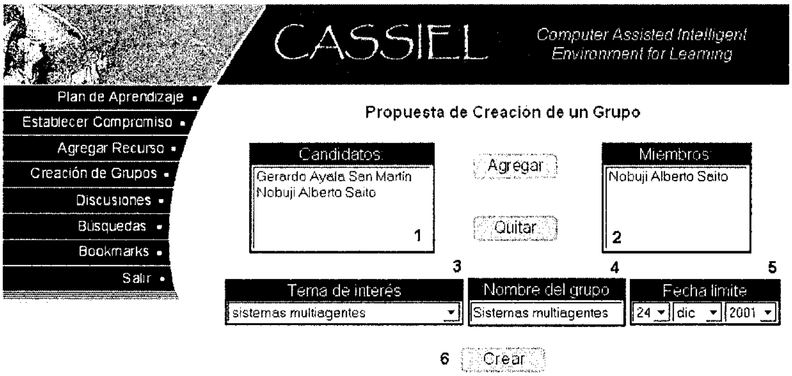

Figure 7-1. The user agent in CASSIEL proposes its learner the establishment of a discussion group. 1: list of candidates; 2: list of selected peers; 3: topic of interest; 4: name of the group; 5: deadline to respond to the invitation; and 6: create and send the group proposal to the candidates.

For non pedagogically structured domains, the group configuration is based on the interests of the learners. The user agent in CASSIEL maintains a learner model based on the interests of the learners, considering the taxonomy of a repository of digital documents. The user agent supports the knowledge socialization phase by proposing the configuration of groups for the exchange of new ideas with those members believed to share common interests with her. The members of the community which are believed to have similar interests to the learner's are shown in a proposal list (see Figure 7-1). The learner selects from them those members to be invited to the discussion group. They will receive an invitation via an email message. They can accept or refuse to participate.

2.4 Task assignment

The approach for a pedagogically structured domain of an interaction script implies task assignment in the joint problem to be solved by the group. An intelligent task assignment by the agent is necessary in order to ensure collaborative learning opportunities for the participants.

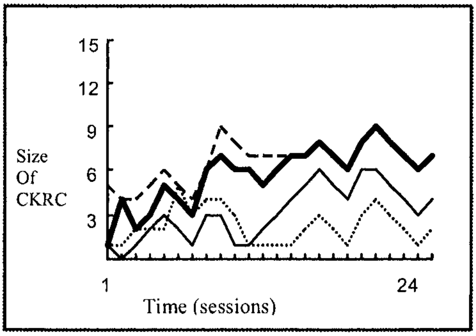

Figure 7-2. Maintenance of zones of proximal development (Candidate Knowledge for Relevant Collaboration, CKRC) by conforming an ideal group by the mediator agents in GRACILE. (Ayala & Yano, 1996b)

In the case of GRACILE each mediator agent proposes to its learner those tasks where knowledge elements in the CKRC set are applied. This results in the enhancement of her assistance opportunities in the group, promoting the creation of zones of proximal development within which she can work and be assisted by more experienced learners in the group. Figure 7-2 presents the results of intelligent task assignments that maintain the zones of proximal development for a group that was configured as described in the previous section. Each one of the four lines refers to a group member. During 24 sessions (horizontal axis), the mediator agents cooperate in order to maintain the size of the CKRC for their learners, by proposing tasks that imply the maintenance of the social knowledge frontier. In this way, all group members have collaborative learning opportunities and are motivated to participate.

In the case of non pedagogically structured domains, as in CASSIEL, a user agent supports the knowledge socialization and the knowledge internalization phases in the knowledge creation process, supporting social awareness and concept awareness. Social awareness is necessary for socialization, and it is provided by the communication of the interests, intentions and capabilities of the members of the community. Keeping social awareness requires an appropriate configuration of groups with people who share interest. Concept awareness is provided by information concerning the new, relevant and popular resources in the repository, so the learner is invited to make annotations and discuss their content with the community. It allows the reflection of the learner about her current level with respect to those members with the same interests. Concept awareness is necessary for maintaining a learning plan and therefore the competitive advantage of the learner in a lifelong learning context.

3. AGENTS SUPPORTING SCRIPTING DETAILED WORK PROCESSES

This section presents the considerations for modeling software agents that support collaborative scripting as a detailed work process, at the micro level. The detailed work process that we consider here is the learners' collaboration or cooperation. While the organizational processes of group configuration and task assignment are based on proposals from the software agent, the script for the coordination of collaborative problem solving can be seen as an imposed one, complemented by the necessary awareness. In order to follow a script for the collaboration process, the software agent requires to make its learner aware of the collaborative process in the joint problem, and also aware of the collaboration opportunities in the group.

For a pedagogically structured knowledge domain, we present how software agents can be modeled in order to support a cooperation script for learners' coordination and make the learners aware of their collaboration opportunities in the group. For a non pedagogically structured knowledge domain, software agents can support the coordination of activities in the construction of knowledge in a community of practice, based on a digital repository in the web. These activities are the establishment of a digital resource, the recommendation of a resource, provide annotations, reject a resource, to establish relations between resources in the repository, and collaboratively organizing the repository.

3.1 Agents supporting the detailed work processes

The workspace in GRACILE, as a CSCL environment for Japanese grammar and expressions, is a dialogue to be constructed by the group, applying those knowledge elements that correspond to grammar rules that refer to the learner's zones of proximal development in the group (Ayala & Yano, 1996a).

In GRACILE the joint problem is the construction of a dialogue, as a collaborative learning activity where learners share knowledge helping them to act and to understand sequences in specific situations, as speech acts. Each learner is committed to the group, by the task assignment, to construct a sentence for the dialogue, which must correspond to a speech act (requesting, answering, greeting, etc.).

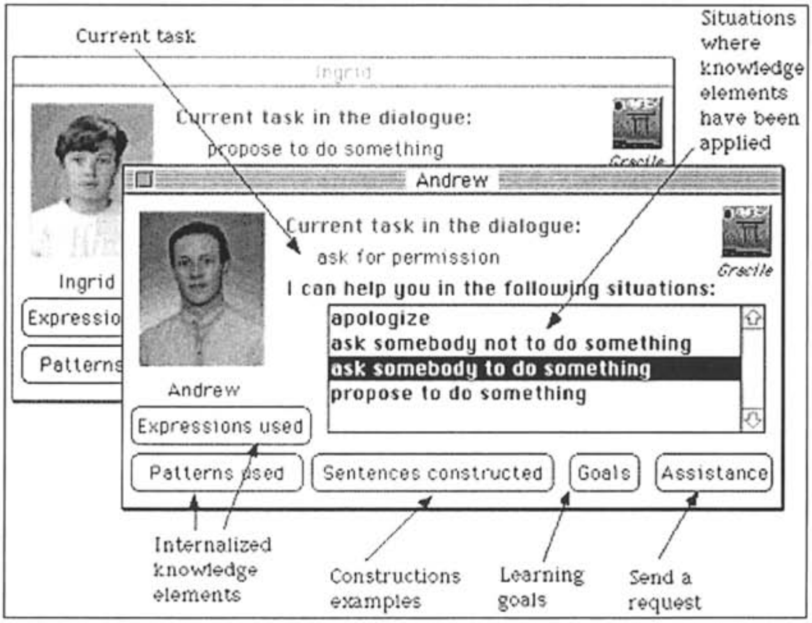

Figure 7-3. Access to open learner models in GRACILE (Ayala & Yano, 1996a)

The dialogue is the problem to be solved by the group, and its structure can be considered as a script that indicates the tasks assigned to each learner. The mediator agent in GRACILE can keep the learners' awareness on the environment and promote the collaboration possibilities of the learners in the group by supporting the communication of the capabilities of the learners, as well as their constructions considered as a correct application of knowledge elements.

For non pedagogically structured domains, as in CASSIEL, an *information agent* assists the learner in the location of relevant resources in a repository and keeping her aware of the changes and annotations by other group members. Also, a *facilitator agent* assists the learner in the organization of her ideas, beliefs and knowledge to be provided to the rest of the community. It supports the phase of knowledge externalization and provides workspace awareness (Ayala, 2003).

3.2 The learners' coordination script

Scripts for these detailed work processes are implemented by communication interfaces that prompt learners to participate in collaborative activities, and do not allow discussions out of context of the joint problem. In the approach for pedagogically structured domains, the environment, not the agent, maintains the control of the participants in the problem solving process. The role of software agents here is concerned with the maintenance of awareness that allows the learners to know their collaboration possibilities in the group.

The mediator agent in GRACILE keeps the learner aware of the environment and promotes the collaboration possibilities of the learners in the group by supporting the communication of:

1. The learning goals of the learners, so they can be aware of the intentions of each other.
2. The learners' commitments, so they know the tasks the learners are going to perform and who is going to assist whom.
3. The learners' capabilities, so they will understand who would be able to assist them in a given situation.

The mediator agent keeps the learners aware of the collaboration possibilities in the group by allowing the access to the information in the open learner models (see Figure 7-3).

In GRACILE, when constructing a sentence for the common dialogue, a learner can make a request for assistance from other learners in the network via her mediator agent. After consulting the capabilities and commitments in the learner model of a given group member, the learner may decide to send her a request of assistance. Also, the learner may ask the mediator agent to send requests of assistance to anybody. In such a case, the mediator agent sends the requests only to the members of the learning group considered able to help. A request of assistance consists of:

1. The situation in which assistance is needed for the application of domain knowledge (i.e., a situation in the dialogue represented by communicative acts like "apologize", "ask somebody not to do something", "make a proposal", etc.).
2. An additional message (text) explaining details of the help needed.

During collaborative writing of a dialogue, the mediator agent allows the learners to discuss the appropriateness of their constructions. When learners disagree about a construction in the dialogue they cooperate constructing a new sentence, discovering the differences between their prior beliefs and alternative applications of domain knowledge in a given situation. In order to support an alternative viewpoint for the common workspace, the learner has to justify it with an example considered valid, previously accepted by the learners. In this way the environment allows the identification and resolution of differences in the application of domain knowledge.

In the case of non pedagogically structured domains, coordination is necessary for the process of knowledge construction by the members of the community. Software agents should be modeled in order to guide learners through the complex work of knowledge construction.

From this perspective of scripting, in CASSIEL the agents assist the learners in structuring the social construction of knowledge, maintaining a model of the learner's interests in order to support diverse types of awareness. The approach adopted for knowledge construction is the one for *constructive web-based learning environments*, based on the development of new documents, annotations and relations between them (Wolf, 1996).

An *information agent* is important in order to keep the learner aware of the location of relevant resources in the shared knowledge repository and of the changes and annotations in the repository by other group members. Keeping workspace awareness requires information about new documents added by the community and their corresponding annotations. Annotations are required in order to preserve quality and social acceptance of the digital documents in the repository constructed by the members of the community. Workspace awareness is necessary during knowledge externalization and knowledge combination.

A *facilitator agent* assists the learner in the organization of her ideas, beliefs and knowledge to be provided to the rest of the community. It supports the phase of knowledge externalization and provides workspace awareness. It also supports the construction of the relations between a given situation and a resource, representing the correct application of knowledge for a given problem. This task awareness is required in order to promote the application of knowledge in the community, in the form of annotations to the resources, mainly as stories of success.

4. CONCLUSIONS

There are two approaches from the computer science perspective of scripting for collaborative learning in agent-based CSCL environments: one as an organizational process, at the macro level, and the other as a detailed work process, at the micro level. Agent modeling and cooperation script design are the issues in the development of processes at the macro level for group configuration and task assignment, and at the micro level, for learners coordination.

The pedagogical organization of the knowledge domain is an important issue in the modeling of cooperation scripts and their support by software agents.

The role of agents in supporting scripting in CSCL environments must be to reduce cognitive load in the learner, following the script, and keep her aware of learning opportunities and available resources. At the macro level, the agent modeling issue for supporting the scripting must be oriented to provide learning opportunities for the users, while at the micro level the key aspects are coordination and awareness.

At the macro level, agents' support for cooperation scripts refers to group configuration and task assignment. For pedagogically structured domains group configuration is based on the learners' capabilities, and task assignment is based on the maintenance of zones of proximal development for the participants. For non pedagogically structured domains, group configuration is based on the interests of the learners, and task assignment on community membership.

At the micro level, cooperation scripts refer to coordination, and awareness. For pedagogically structured domains, agents provide support by presenting open learner models representing the capabilities and constructions of the participants, making people aware of collaboration possibilities during problem solving. For non pedagogically structured domains, the support consists in coordinating the participation of learners in the construction of a digital repository, being aware of the changes in the repository and being assisted while including new documents, annotations and relations between resources.

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