APPLICATIONS OF A COLLABORATIVE LEARNING ONTOLOGY

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Abstract

The objective of the research presented in this article is to find representational mechanisms for relating and integrating the collaborative learning elements present in real practical environments, create an integrated ontology that considers and relates these elements, and make use of it to define new collaborative learning scenarios. It is therefore necessary to identify the key ideas underlying the notion of ontology that will be essential in subsequent application development: a list of the basic elements that give rise to a common vocabulary for collaborative learning, and the relationship and dependencies between them. The Activity Theory is used as a theoretical framework for organising the elements in the ontology. This ontology gives rise to the structured elements that form the concpetual structure for the definition and construction of CSCL environments, and the analysis and assessment of group collaboration.

Introduction

Collaborative learning is a kind of social activity involving a community of learners and teachers, where members share and acquire knowledge. As Vygotsky (1978) pointed out, "in a collaborative scenario, students interchange their ideas for coordinating when they working for reaching common goals. When dilemmas arise, the discussion process involves them in learning". When the learners work in groups they reflect upon their ideas (and those of their colleagues'), explain their opinions, consider and discuss those of others, and as a result, learn. In this way, each learner acquires individual knowledge from the collaborative interaction.

Collaborative learning systems are studied in the CSCL paradigm (Koschmann, 1996) which has been built upon a rich history of cognitive science research about how people work and learn. By combining the social and cognitive perspectives, it has the potential to help take important steps forward in understanding how learning might be achieved in real situations (Kolodner & Guzdial, 1997). As part of this social cognitive perspective, the socio-cultural theory proposes the Activity Theory (henceforth, AT) (Nardi, 1996) for representing the group activities where technology plays a role as mediator. Within this theory, an analysis model was developed for identifying and representing the human and artificial elements involved in joint tasks (Engeström, 1987). This socio-cultural framework provides the concept of a*ctivity* as a unit of analysis, with a rich internal structure necessary to make the context of a situation explicit, specifically the links between the individual and the social levels which stress the role of the tools as mediating artifacts.

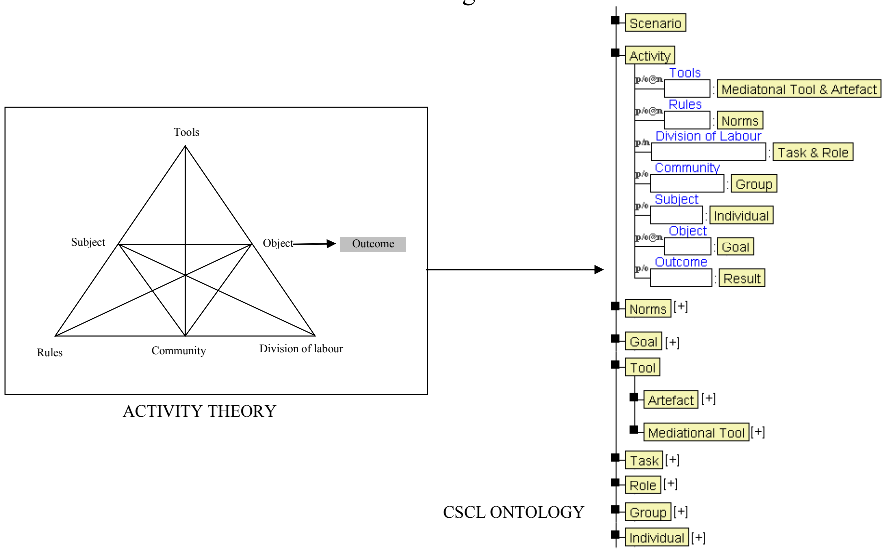

Figure 1. The representation of the AT components in the ontology

In previous research, several different collaborative scenarios have been undertaken with university students using the DEGREE system (Verdejo & Barros, 2000) and AT (Verdejo & Barros, 1999). The results of this work show that collaborative learning scenarios are described in terms of people with learning goals, group structure, tools that are available, roles that take into account the tasks, and the restrictions of the use of the system (all within a particular context and domain). Furthermore, it was found that all these elements are included in the activity concept: the *community* involved and the *social norms* that govern it, the *division of labour* to be followed, the *tools* to be used, the *subject* and *object* of the activity, and finally, the *outcome* produced by the group. The natural extension of this work, is therefore, to develop a computational model rich enough to represent the interrelations between the aforementioned elements, in such a way as to be able to exploit them for designing new collaborative learning scenarios and tools. Ontologies are appropriate for this purpose because they offer a meta-model that is able to represent the basic collaborative learning concepts (that give rise to a common vocabulary (Mizoguchi & Bourdeau, 2000)), and the relationships and dependencies between them. In this sense, the ontology offers a higher conceptual knowledge level to describe collaborative learning.

This paper is organized as follows: an overview of a CSCL ontology is presented in the next section; subsequently, two applications of it for collaborative learning applications are presented, and finally, some conclusions are drawn.

CSCL Ontology

Proposals for CSCL ontologies have already been made with the emphasis placed on such aspects as: goals and communication models and problem-solving methods (Ikeda et. al., 1995), learning tasks (Mizoguchi & Sinitsa, 1996), learning goals and group formation (Inaba et. al., 2000). However, in real collaborative learning scenarios all these elements are interrelated and/or interdependent.

The ontology presented here draws together in an original way the different aspects of collaborative learning placing the emphasis upon the relationship between them. The underlined concepts in the ontology have drawn from the authors' experience of designing CSCL experiments. This ontology is defined within the AT framework (which underlines the importance of *relating* and *integrating* its components), and its nodes correspond to the main concepts in an AT activity: tools, rules, division of labour, community, subject, object (goal) and outcome (figure 1).

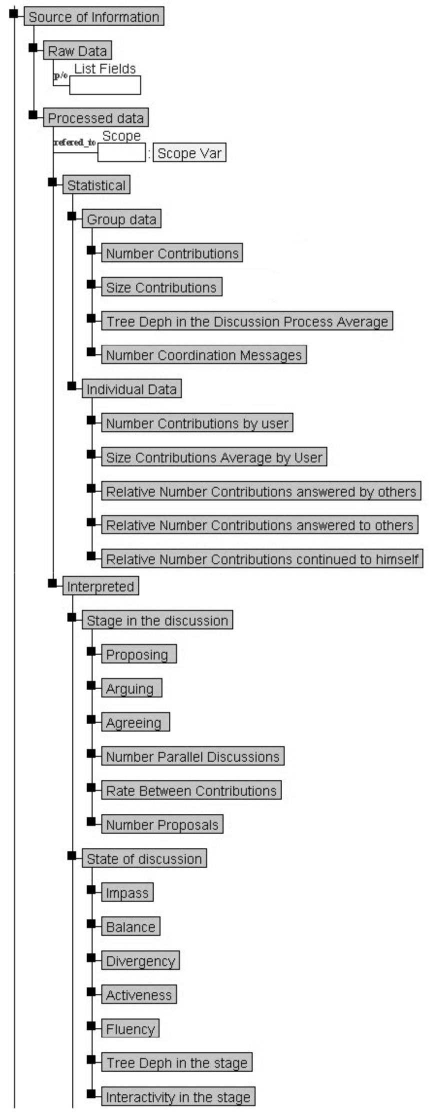

Figure 3. Nodes with some sources of information for analysis of collaboration

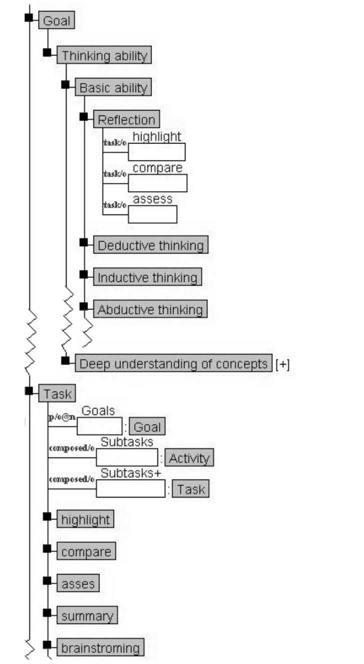

Figure 2. Part of the ontology illustrating the nodes goal and task (incomplete)

The structure and the knowledge represented in the previously mentioned ontologies have been refined to enable them to be incorporated under the corresponding nodes in this new ontology. Furthermore, the relationships and dependences between the concepts that make up this knowledge have been established explicitly. The ontology has been developed in XML and Java. Furthermore, additional code has already been developed to facilitate its use in some applications, which opens up the possibilities for reuse in other educational enviroments.

An example of part of the ontology can be seen in figure 2, where parts of the concepts "learning goals" and "learning tasks" are presented together with the way in which they are related. As can be seen, the node reflection is related to three tasks: highlight, compare, and assess, which in themselves are declared under the node task. The interdependencies (shown as labels in the figure) between the nodes represent the way in which concepts influence each other in collaborative learning scenarios. Therefore, this ontology can be seen to be more than just a simple hierarchical tree, since it models the complex relationships between the concepts it contains.

Futhermore, the ontology also includes knowledge which is not explicitly represented in other collaborative learning ontologies, i.e., knowledge about the study and analysis of the learning process, since as Brown (1983) points out, the learning "process" is as important as the "result". For this reason, the ontology has been completed with the concepts necessary for analysis and collaboration: observed and interpreted data from the group process and the analysis methods.

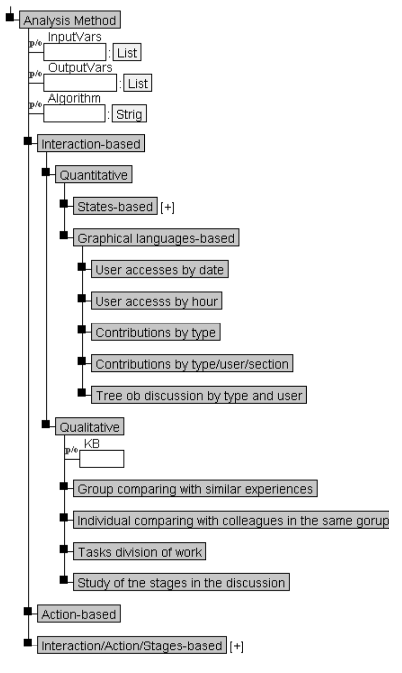

Figure 4. Analysis methods in the ontology

These concepts are expressed in two different nodes: Source of Information and Analysis method.

Firstly, the node Source of Information is needed to enable the representation of states of the learning processes and the participant attitudes, which is in itself divided into the following two nodes:

A Statistical node, whose contents are generated by interpreting the log of student activities in the scenario in terms of the elements that make up the collaborative environment. For example, given a scenario where a mediational tool has different categories, such as proposal, answer and question; and two roles that exist are writer and reader; a statistical variable could be "the number of contributions type-answer-made by a student with the role -writer-". These variables are explored in more detail in Barros & Verdejo (2000) and Barros, Mizoguchi &Verdejo (2001).

An Interpreted node, whose contents are inferred from the combination of the statistical data and a knowledge base composed of rules that relate statistical and process data. They represent the observed states of the learning processes and the participant attitudes, for example, the conversation flow can be defined to be based upon the user interactivity in the conversation, together with the average time between user contributions (both of which come from the statistical data).

Secondly, as can be seen in figure 4, the Analysis Method node contains three types of subnode in order to be able to represent three types of methods: Interaction-based, Action-based (Mulhembruck, 2001), Interaction-Action-Stage based. The first of which can be either quantative or qualitative. The qualitative methods are based upon inference techniques taken from artificial intelligence.

DEGREE, for example, uses fuzzy-inference as a qualitative analysis method for this purpose. Hence, in the ontology under the qualitative analysis node, there are several different approaches to performing qualitative analysis: group behaviour analysis, individual behaviour analysis, task summary, and study of the stages in the discussion (Barros & Verdejo, 2000).

CSCL ONTOLOGY APPLICATIONS

Now that the structure of the ontology has been discussed, it is possible to move on and consider some of its applications (figure 5). The ontology gives rise to the structured elements that make up the foundation necessary for the design and development of CSCL environments. Therefore, the development of such environments can be seen in terms of the selection of these elements, whose structure assists the design process. Furthermore, an analysis can be undertaken of the students' activities together with the declarative knowledge present in task definitions, the elements that need to be observed, and the rules which relate them. Finally, the combination of all this declarative knowledge enables the creation of coaching processes that assist the students in the learning process. What follows is a description of the first two of these applications. Its development will help to refine the knowledge in the ontology.

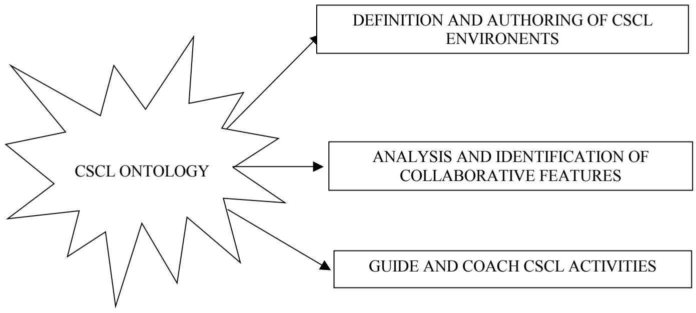

Figure 5. Possible applications of the CSCL ontology

Exploiting the ontology for the definition and construction of CSCL

Collaborative learning scenarios need to be tailored to specific conditions. This is achieved by assigning particular values to a number of parameters, AT deals with most of them as we have described above. As has been previously presented, the ontology offers an explicitly structured list of usable values for those parameters. To define a collaborative learning case (a scenario or group of them) a designer should select the relevant concepts (nodes in the ontology) and, if necessary, adapt them to fit the case.

The first of the applications to be considered here is a reengineered version of DEGREE (Barros & Verdejo, 2000), an asynchronous collaborative learning environment. The information handled is mainly textual, so a variety of editing tools and file management facilities are available. A shared workspace provides support for conversation in the form of semi-structured typed messages. When learners make their contributions they have to select a type from a predefined set which is referred to as a *conversational type*.

DEGREE has a configuration level aimed at defining the components used to support a collaborative scenario and installing a working environment for one or more groups. Workspaces are defined at this level by means of an authoring tool based on the CSCL ontology. The outcome of the configuration activity is a collaborative environment which enables the users to carry out the defined learning activities through asynchronous communication via Internet.

In this new version, the configuration level makes use of the ontology because it guides the designer in the process of specifying the collaborative learning scenarios due to its inherit structure.

When the designer selects a task, the configuration tool offers the most adequate mediational tools for the learning goals inherent in the task. The ontology includes the entry <u>Mediational tool</u> (as can be seen, on the left side of the figure 6), under the node <u>Tool</u>, having as one of its child nodes, <u>Conversational structure</u>, with the attribute “text” or “graphic” that indicates the type of representation that will be used in the collaborative environment. DEGREE works with textual information and its mediational tools will have this attribute set to “text”. The <u>Conversational structure</u> node contains a number of graph types (such as <u>experimental,</u> <u>constructive</u>, or decision making among others). In this case, the conversational graph experimental is selected and subsequently used to create the scenario that can be seen in figure 6 (on the top-right).

Another example in which we are applying the ontology is a new collaborative learning tool that is currently been developed. It can be used both synchronously and asynchronously and makes use of visuals languages (Hoppe et. al, 2000) to function as a mediational tool. The tool enables the user to work with graphical spaces, whereby the user can identify areas of images and build an argumentative discussion around them based upon the types of visual components that have been previously configured. The user can directly manipulate different areas of a space and add different related concepts to them. The result is a conceptual map that represents the group discussion.

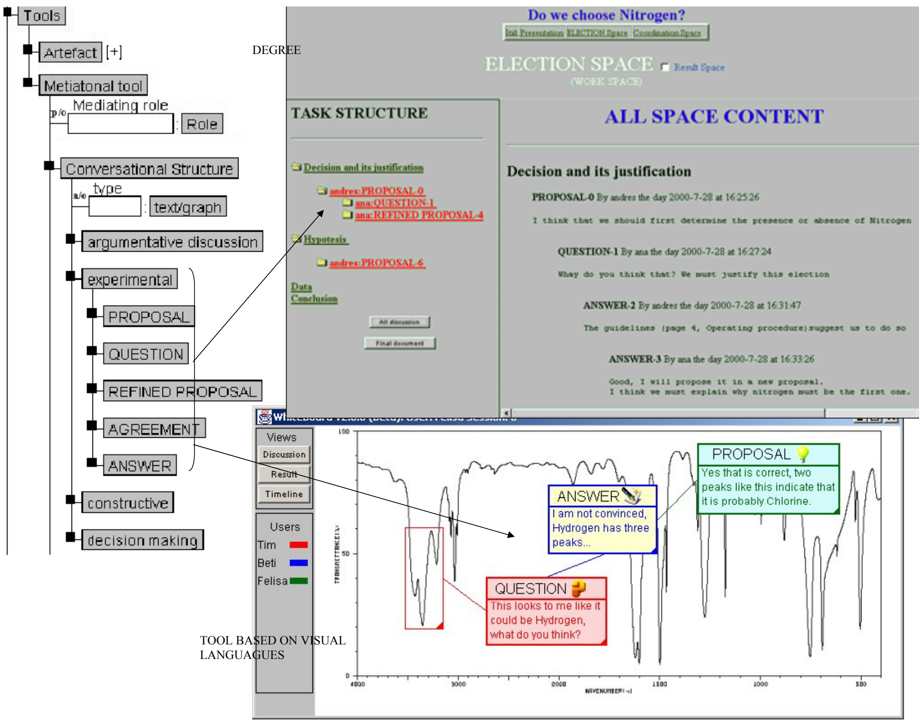

Figure 6. An example of how the ontology represents the same concept about its mediatonal tool, in two collaborative systems: above a system that works with textual objects and below one that works with graphical objects

Both the underling technology in this new tool and the way in which it functions are different from DEGREE. However, they share the same conceptual foundation represented by the CSCL ontology. For example, even though DEGREE uses textual objects and the other graphical objects, both are based upon related semi-structured contributions. The difference between them lies in the way in which the contributions are displayed and manipulated by the tools, not in the underlying conceptual relationships. This can be clearly seen in figure 6 where the three contribution types contained in the section of the ontology (shown at the left of the figure), are presented in different ways in the two different tools (shown at the right of the figure).

Exploiting the ontology for analysis and the assessment of collaboration

"Collaborative learning research has paid close attention to the study of pupils interactions during peer-based work in order to analyse and identify the cognitive advantages of joint activity" (Dillenbourg, Baker, Blaye, & O'Malley, 1996). The aim of analysis, in general, is to understand and to interpret the collaborative process in order to be able to asses the conditions and elements for effective learning.

In the computational approach, analysing the collaboration consists of collecting data from the participants' actions and interactions and subsequently inferring conclusions. Therefore, the first step in this analysis is to record all the accesses and the actions performed by the users when they are solving tasks. Conclusions can then be drawn by processing this raw data, taking into account the elements of the system configuration and subsequently the assessment criteria chosen by the observer requesting the analysis. These subjective criteria are stored in a knowledge base.

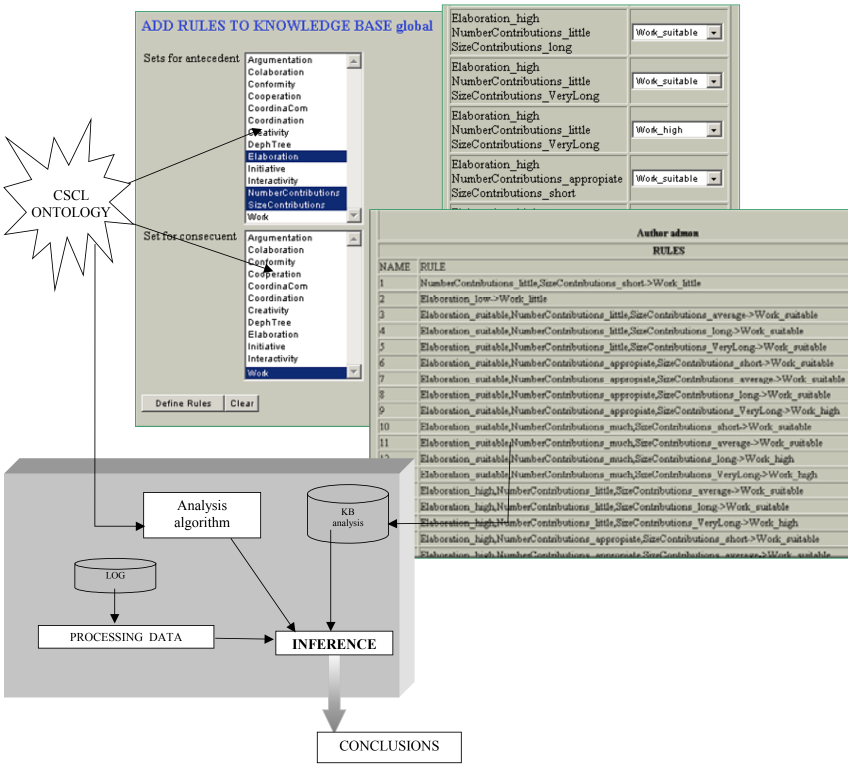

Figure 7. Edition of the rules for the analysis, and the inference analysis methods

The designer of such knowledge bases needs to reflect on what kinds of data can be computed from the logged data, and how to express the relation between them as rules. How can an ontology help in this process? It can help by providing every element involved in the analysis: configuration elements, processing criteria (generic tasks aimed at computing the input values to the processing rules), and the antecedents and consequents of these rules. The rules themselves are not stored as part of the ontology but in a number of knowledge bases.

An external tool for editing these knowledge bases has been implemented. It takes a list of variables selected from those available in the ontology as its input, whose fuzzy values are calculated from the logged data. As can be seen in figure 4 they can be found in the ontology under the source of information node. Variables included in the ontology could be, for example, NumberContribution (whose values are defined to be: *little*, *appropriate* and *much*) or SizeContribution (with values: *short*, *average*, *long* and *very long*). Furthermore, the ontology also includes other variables that have been subjectively inferred from the processed data rather than directly extracted from the raw logged data. For example, Work (an assessment of the group's work quality) with values such as: *little*, *suitable* and *high* can be computed by taking into account: NumberContribution, SizeContribution, and Elaboration.

A tool that uses the ontology as input is provided for editing the rules in DEGREE. The rules are edited by selecting the variables (both antecedents and consequent) that the tool takes from the ontology. Subsequently, the tool automatically generates the complete set of rules for all possible combinations of the fuzzy values. Finally, for each rule generated, one possible value has to be chosen for the consequent, or NULL if the rule is not to be considered. Furthermore, rules can be generated by chaining together other rules, since the consequent of one rule can be the antecedents of subsequent ones. This process is summarised in figure 7. It also provides an environment that enables the selection of an analysis method (declared in the ontology under the Analysis method node, in figure 4), the knowledge base, and a log of a collaborative group; and then visualizes the conclusions of the analysis.

Conclusions

In this paper a computational model has been presented which express the Activity Theory in terms of a CSCL ontology. This ontology offers a conceptual knowledge level representation for describing collaborative learning systems. It is based upon the structure and the knowledge contained in previous ontologies together with knowledge which was not explicitly represented in other collaborative learning ontologies, i.e., knowledge about the study and analysis of the learning process. Furthermore, relationships and dependences between the concepts that make up this knowledge have been established explicitly.

This ontology has been designed to be reusable by different tools in many collaborative learning scenarios due to the combination of the theoretical AT framework with an underlying XML-based representation.

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