The role of ontologies in collaborative systems

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Abstract—This paper deals with the role of ontologies in collaborative systems. The research field of collaborative systems and their support by information and communication technologies describes theory called CSCW (Computer Supported Cooperative Work). During last few years the CSCW has been evolving and extending e.g., CSCL (Computer Supported Collaborative Learning) has emerged. With a well-defined ontology structure, CSCL can accumulate the knowledge representation of learning objects, including participant background, group information, instruction designs, learning activities and learning outcomes.

I. INTRODUCTION

Collaborative learning is a type of social activity involving a community of learners and teachers, where members share and acquire knowledge. As Vygotsky [1] pointed out, “in a collaborative scenario, students interchange their ideas for coordinating when they are 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 [2] 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 take important steps forward in understanding how learning might be achieved in real situations [3]. As a part of this social cognitive perspective, the socio-cultural theory proposes the Activity Theory (AT) [4] for representing the group activities where technology plays role as a mediator. Within this theory, an analysis model was developed for identifying and representing the human and artificial elements involved in joint tasks [5]. This socio-cultural framework provides the concept of activity 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 artefacts.

Computer Supported Collaborative Learning (CSCL) is based on the idea that knowledge should not be simply transferred from a teacher to the learner but it should be built in a learner's head while he interacts with each other in group activities. CSCL has grown out of wider research into computer supported collaborative work (CSCW) and collaborative learning. The technological development must react to new requirements from end-users (teachers, students, lectors, etc.) such as boundary crossing, knowledge creation around shared objects, project-based learning, etc.

One of the main advantages of CSCL is possibility to scaffold or support participants in learning together effectively (collaboration). This feature consists of several parts as objects that motivate activities, decision models, activity models, communication models and principles, participant’s roles, etc.

These parts of a collaborative environment can be realized through a sophisticated vocabulary in terms of which we can describe them. AI techniques based on symbolism need primitives or a set of basic vocabulary for representing knowledge and objects. They reflect conceptualization of systems under consideration. Ontology can be described as a system of basic vocabulary usable across various knowledge domains.

The main idea of this approach 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 achieving the goals 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.

II. RELATED WORK

The main component of a collaborative learning in the web-based environment is to realize the social context, group and individual learning processes and communication between each participants and their environment [6]. In other words, learners are provided with intelligent browsing support for externalized knowledge from other participants [7]. Ontologies formalize and clarify the knowledge structure of specified domain in order to enable knowledge sharing [8]. Thus, ontologies are interesting approach for describing knowledge of learning objectives and learning activities to provide knowledge reuse and knowledge composition.

Ruth Wilson extended the potential benefits of ontologies further to the higher education, including the sharing of information across education systems, providing frameworks for the learning object reuse and enabling intelligent and personalized support [9]. The development of CSCL ontologies is focused on overcoming limitations of current IIS (Integrated Information Space) from domains of Artificial intelligence and Education [10], on interaction analysis support [11], learning object repository [12], context representation [13], on describing terms of learning design, learning contents and learning resources [14] as well as on defining collaborative learning tasks, goals and actions [15].
The related works shows an important role that ontology plays in a virtual collaborative learning environment in order to obtain maximum social educational utilisation from collaborative learning, while allowing each learner to pursue his private benefit. With a well-defined ontology structure, CSCL can accumulate the knowledge representation of learning objects, including participant background, group information, instruction designs, learning activities, learning outcomes, etc. Effective knowledge representation enables an intelligent browsing and searching capability.

A. Plan ontology

Plan ontology [16] models plans as the descriptions that represent sequences of tasks from a given situation to a new, expected one. These descriptions are abstract and independent from a computational system design: they are reusable and easy-to-customize representations of the objects and activities involved in multiple action domains.

The main components of plans are: task, goal and agent-driven role:

- A plan is a description that is conceived by a cognitive agent, defines or uses at least one task (a sequence of actions), one role (played by agents), and has at least one goal as a proper part.
- Tasks and agent driven roles are types of concepts, while goals are descriptions, proper parts of plans.
- The control units (e.g. choice between the following alternatives) from traditional planning and workflows are represented as control tasks, also defined within plans.
- Tasks may be connected to roles by a ‘target’ relation.
- Plans may also have situations as pre- or post-conditions.
- Plans as descriptions are different from plan executions: the latter are situations. Goal situations are situations that satisfy a given goal.

B. IMS LD

The core concept of the Learning Design Specification [19] is that regardless of pedagogical approach, a person gets a role in the teaching-learning process, typically a learner or a staff role. In this role, he or she works toward certain outcomes by performing more or less structured learning and/or support activities within an environment. The environment consists of an appropriate learning objects and services to be used during the performance of the activities. The type of role and the set of relevant activities in a concrete part of the process is determined by the method or by a notification.

The method is designed to meet learning objectives (specification of the outcomes for learners), and presupposes certain prerequisites (specification of the entry level for learners). It also consists of one or more concurrent plays that consist of one or more sequential acts. An act is related to one or more concurrent role-parts and each role-part associates exactly one role with one activity or activity-structure.

The learning process is modelled in the method on the notion of a theatrical play. A play has acts, and in each act has one or more role-parts. The acts in a play follow each other in a sequence (although more complex sequencing behaviour can take place within an act). The role-parts within an act associate each role with an activity. The activity in turn describes what the role is doing and what environment is available to it within the act. In the analogy, the assigned activity is the equivalent of the script for the part that the role plays in the act, although less prescriptive. Where there is more than one role-part within an act, they are run in a parallel.

A notification is triggered by an outcome and can make a new activity available for a role to perform. The person getting the notification is not necessarily the same person who creates the outcome. For instance, when one student completes an activity (= an outcome), then another student or the teacher may be notified and set another activity as a consequence. This mechanism can also be used for learning designs where the supply of a consequent activity may be dependent on the kind of outcome of the previous activities (adaptive task setting designs).

The explicit roles specified in this language are those of a learner and staff roles. Each of these can be specialized into the sub-roles, but no vocabulary is put forward for this. It is left open to the learning designer to name the (sub)-roles and to specify their activities. For example, in simulations and games a different user can play different roles, each performing different activities in a different environments.

![Figure 1. IMS LD model of collaborative environment](image)

Activities can be assembled into activity-structures that aggregate a set of related activities into a single structure, which can be associated to a role in a role-part. A structure can model a sequence or a selection of activities:

- In a sequence, a role has to complete the different activities in the structure in the order provided.
- In a selection, a role may select a given number of activities from the set provided in the activity-structure.

This can, for instance, be used to model situations where students have to complete two activities, which they may freely select from a collection of e.g., five activities contained in the activity-structure.

C. MOSIL CSCL

Kaleidoscope/MOSIL project [20] has developed a conceptual model of the script modelling language that presents the conceptual structure of the collaborative learning script. It conceptually represents the grammar of a script modelling language. A CSCL script is defined as a
computational representation of a collaborative learning process.

Each CSCL script has its learning objectives and design rationale:

- Script consists of a set of roles, activities, transitions, artefacts, and environments.
- Both persons and groups can become the members of roles.
- A group can have subgroups and person members.
- An activity may be atomic or may consist of the set of networked activities and even other scripts. A transition specifies a temporal preceding relation between two activities.
- Actions may be performed by users during an activity or by the system before/after an activity or accompanying a transition.
- An object may be created and shared in and/or across activities as an intermediate product and/or as a final outcome.
- An environment can contain sub-environments and may contain tools and contents.
- A tool may use objects as input parameters and/or output parameters.

An expression may use other expressions or properties that may be atomic or may have an internal structure. A condition consists of a logical expression and actions, transitions and/or other conditions. Actions, properties, expressions, and conditions are useful elements for modelling the dynamic features of collaborative learning processes and have very complicated relations with other elements (e.g., CSCL scripts, roles, activities, artefacts, persons, groups, environments, and so on). For example, an action may use attributes of entities as parameters and change the values of attributes of certain entities.

D. CSCL ontology

CSCL ontology [15] is defined within the Activity Theory (AT) [4] 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 (see Figure 3). 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.

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 [21] 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.

CSCL 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.

III. TRIALOGICAL LEARNING ONTOLOGY

The trialogical learning ontology (see Figure 4) is the core domain ontology of KP-Lab system and provides the common semantics for all KP-Lab applications and tools. It defines concepts and notions of trialogical learning that are needed for the implementation applications’ interactions and data exchanges.

A. Knowledge practices laboratory (KP-Lab)

This integrated project sponsored by European Commission within the "Sixth Framework Programme" started in 2006 and will run for 5 years. The first three years are the R&D phase; existing and/or newly developed tools will be tested against these requirements in real situations within various pilot cases. The last two last years will be devoted mainly to finish longitudinal
experiments, dissemination activities and exploitation planning.

The project is based on the idea of trialogical learning. Trialogical learning [17] refers to the process where learners are collaboratively developing shared objects of activity (such as conceptual artefacts, practices, products) in systematic fashion. It concentrates on the interaction through these common objects (or artefacts) of activity (see Figure 5), not just among people or within one’s mind.

Figure 5. How individuals and a community develop shared “authentic” objects

We can understand trialogical learning as a generalization of several independent theories and approaches describing the creation of a new knowledge, e.g.:

- Carl Bereiter’s knowledge building approach which emerged from cognitive studies in the educational context;
- Yrjö Engeström’s theory of expansive learning based on Activity Theory;
- Nonaka and Takeuchi’s model of organizational knowledge creation.

KP-Lab technology builds on emerging technologies, such as semantic web, real-time multimedia communication, ubiquitous access using wireless devices, and interorganisational computing. There are also non-technical tools as the change laboratory (the idea is to arrange on the shopfloor a room or space in which there is a rich set of instruments for analyzing disturbances and for constructing new models for the work practice).

The multinational consortium integrates expertise from various domains, including pedagogy, psychology and engineering as well as end-users and key representatives from the corporate/business sector to provide authentic environments for research and piloting. The project involves 22 partners from 14 countries, as well as many schools, universities, companies and work places and other prospective end-users.

B. KP-Lab system

KP-Lab system consists of many applications and tools where each one is serving a different purpose but most of them are accessed through a virtual environment, the KP-Lab portal. This is the tool that the end users will see, use and get accustomed with. The information and applications of the KP-Lab Portal may be viewed or used through a web browser. The user environment consists of a set of tools that enable collaborative knowledge practices around shared knowledge artefacts:

- **Shared space** application is a learning system aimed at facilitating innovative practices of sharing, creating and working with knowledge in education and workplaces based on trialogical learning theory. It supports users’ collaboration according to different working practices and allows viewing of shared knowledge in flexible manner. It provides a set of tools for knowledge building and process management. The personalized, temporal and faceted views allow users to describe and visualize shared knowledge objects, their associations and state in different arrangements.

- **Document centred collaboration** tools for writing of simple text objects within a shared space, for asynchronous collaborative writing (Wiki), for Web2.0 based synchronous document editing and for chat.

- **Semantic multimedia annotation** tool that allows users to annotate in a synchronous or asynchronous way multimedia contents such as video, audio, and text

- **Change laboratory** application which provides features for planning, organizing and carrying out work research processes based on the Change Laboratory theory (developmental work research that provides reflective feedback of participants’ work) in an asynchronous or synchronous manner.

- **Collaborative semantic modelling** application that supports collaborative use of visual models and the development of languages used in visual modelling.

- **Meeting support** application (Map-It) that aims at generating in automatic manner a written/graphical record of a conversation.

C. KP-Lab system model

KP-Lab system model consist of several domain ontologies that provide framework for end-user tools. The biggest challenge is to design the right granularity of domain ontologies so that maximum stability is provided for application ontologies. Figure 6 presents the three-layered ontology architecture of KP-Lab system.
Three types of domain ontologies are identified:

- **Trialogical learning ontology** defines core concepts and notions of trialogical learning. This ontology is shared by all applications and tools of KP-Lab, providing the common semantics needed for the data interoperability.

- **Domain of discourse ontologies** that model the concepts and their relations in a domain of discourse.

- **Technical ontologies** that model technical concepts related to the services provided by the KP-Lab platform, integration of tools, etc.

Application ontologies specialize and integrate the above domain ontologies for the requirements of the given application or tool. These include:

- Shared space
- Semantic multimedia annotation
- Collaborative semantic modelling
- Change laboratory
- Map-It

General ontologies for general (i.e. reusable across application domains) descriptions of objects, actors and activities are needed. Such are:

- Content metadata – potential candidates: Dublin Core (DC) and its DC-Ed (Dublin Core Education Working Group) extensions.
- Persons and organisations for general description of people and their affiliations – potential candidates: vCard or FOAF.
- Modification events – potential candidates: CIDOC CRM and Kaleidoscope Common Format
- Concept schemes – potential candidates: SKOS

KP-Lab system model is stored within RDFSuite (knowledge repository) and it has been developed at FORTH-ICS in Greece. RDFSuite consists of the Validating RDF Parser (VRP), the Schema-Specific Data Base (RSSDB), an interpreter for the RDF Query Language (RQL), and an interpreter for RDF Update Language (RUL). RDF Parser (VRP) is a tool for analyzing, validating and processing RDF schemas and resource descriptions. The RDF Schema-Specific Data Base (RSSDB) is a persistent RDF Store for loading resource descriptions in an object-relational DBMS by exploiting the available RDF schema knowledge.

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