PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
ESCUELA DE INGENIERIA

COMPUTER SUPPORTED COLLABORATIVE LEARNING ONTOLOGY

JULIAN IGNACIO QUIROGA SUBIABRE

Thesis submitted to the Office of Research and Graduate Studies in partial fulfillment of the requirements for the Degree of Master of Science in Engineering (or Doctor in Engineering Sciences)

Advisor:
MIGUEL NUSSBAUM

Santiago de Chile, (January, 2008)

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A toda mi familia que me ha apoyado enormemente, esto es tan suyo como mío…

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I would like to sincerely thank to all the people who helped me to complete this work.

To my family, for their support in many aspects, without them this project would have not been possible to finish.

To my adviser, Miguel Nussbaum for his support and guidance and also for his confidence in proposing me this task. To Rosa Alarcon for her time and constant disposition to clear my doubts.

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RESUMEN[1]

El aprendizaje Colaborativo ha demostrado ser una importante herramienta para cambiar las dinámicas al interior de la sala de clases brindando nuevas posibilidades para profesores y estudiantes.

A pesar de esto hasta ahora no se cuenta con estándares para describir y representar el contenido y las actividades colaborativas, ya que los estándares se han enfocado en solucionar los paradigmas del E-Learning, que se caracteriza porque la interacción entre alumnos y profesores se da de forma unilateral y centralizada en el profesor entregando contenido a sus alumnos excluyendo cualquier posibilidad de colaboración ya que asumen un rol pasivo.

Hasta ahora algunos estudios han tratado de solucionar esta problemática pero no han alcanzado todavía el grado de madurez necesario para abordar debidamente la tarea, mostrando importantes vacios cuando se trata de describir una actividad de aprendizaje colaborativo.

Con el fin contribuir a la representación del contenido y de las actividades colaborativas es que el presente trabajo introduce un modelo de metadata que describe las actividades CSCL y el contenido que en ellas se construye, identificando sus atributos más relevantes. La metadata es descrita mediante una Ontología.

Palabras Claves: Ontología de Aprendizaje Colaborativo Mediado por Computadores, Ontología, Metadata

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ABSTRACT

Collaborative Learning has proved to be an effective way to change classroom dynamic fostering new capabilities for teachers. Despite this until now Collaborative Learning does not count with standards to describe and represent the activities and its content, because actual standards have focused in solving E-Learning paradigms where the interaction between students and teacher is unilateral and centralized in the teacher delivering knowledge to his students, excluding any form of interaction because of the passive role of the students.

Some studies have tried to overcome this difficulty but have not reached yet the necessary grade of completeness to accomplish the task, showing some important holes when trying to describe a collaborative activity.

With the aim of contribute to the representation of collaborative learning activities and its content is that the present work introduces a metadata model that tries to describe CSCL activities and the content built on them with its most relevant attributes. The metadata is described through an ontology.

Keywords: Computer Supported Collaborative Learning Ontology, Face to Face CSCL, Ontology, Metadata

INTRODUCTION

1.1 Brief Introduction

Collaborative Learning has proved to be an important strategy for transforming the dynamics inside the classroom fostering that way new interaction modes for teachers and learners. Despite this until now Collaborative Learning does not count with standards to describe and represent the learning activities and its learning content, because actual standards have focused in solving E-Learning paradigm where interaction between students and teachers is unilateral and centralized in a teacher delivering knowledge to his students, excluding any form of interaction. Computer Supported Collaborative Learning, CSCL, might be defined as a networked computers system supporting group members, controlling and monitoring their interactions, distributing information, regulating tasks promoting that way skills and abilities acquisition.

To make CSCL really useful its representation must focus in both, the content and the activity itself, making that way possible to exploit the synergy between developers and teachers. However, to achieve this, is necessary to describe and represent the content and the activities in a complete and correct way, unfortunately this has been a goal of the E-Learning community, leaving aside all the aspects of CSCL, and very few proposals until now have tried to overcome this difficulty. This difficulty brings some important complications for the creation of CSCL applications, because it is not possible to reuse the objects and extend Collaborative Learning activities in a useful way, wasting important efforts involved in creating the content and the activities. This situation in part is caused by of the lack of standards regulating and guiding the creation of CSCL material, and leaving the whole community working in ad hoc ways.

In the present work an analysis of the actual E-Learning standards is presented as well as the metadata developed so far. All the mayor proposals for CSCL metadata developed until now are analyzed together with all its deficiencies when trying to describe Collaborative Learning aspects. To gain insights in activities and content development, a couple of editors that allowed us to determine, compare and diagnose the developed metadata for CSCL content were developed.

With the intention of contributing in identifying relevant metadata for CSCL an ontology is presented in Chapter 2.

1.2 Hypothesis

In order to reuse content, diminishing cost and exploiting the synergies among developers and teachers from CSCL it is necessary to have a common understanding in the way the learning content and the activities must be represented.

The main hypothesis of this work is that by identifying and storing metadata during CSCL activities it is possible to preserve the context where a learning situation had occurred, such context must consider at least the CSCL activity that frames the situation as well as the learning content involved. Such context preservation may help later information recovery (as in Digital Libraries) or may facilitate sharing experiences with other students.

The fundaments for this hypothesis relies on the effects of considering context during context based search in Digital Libraries (Dichev 2006, Knežević 2005) and E-Learning environments (Jovanović, 2007), as well as the recent attempts of identifying metadata in CSCL (Tamura 2003, Friesen 2005, Amorim 2006, Vega-Gorgojo 2005). Actual standards show several complications when trying to describe relevant features included in a Collaborative Learning activity hampering retrieval and reuse of all these learning activities and objects.

Another base of the hypothesis is that all the proposed metadatas and Ontologies for representing CSCL until now, still have not reached the degree of completeness to describe whole CSCL characteristics, presenting several difficulties in specific aspects of the collaboration among students, making not feasible the representation of an activity with all due aspects.

This proposal is a contribution to achieve a more comprehensive description of the CSCL.

1.3 Related Work

There are studies that show how to overcome the difficulties around a Metadata model for CSCL, being the most relevant:

a) Collaborative Learning Entity Metadata (Tamura, 2003)

Tamura (2003) developed a Collaborative Learning Entity Metadata (CLEM) that represents design, practice, and evaluation of collaborative learning activities. CLEM's aim is to describe CL not only from a technical perspective but also from a pedagogical and learning standpoint in order to represent, extract, share, reuse, and exchange the knowledge in collaborative learning activities. This metamodel defines four main classes to represent whole CL characteristics and its features:

i) Teacher: Characterizes the teacher and the possible group of teachers directing the activity.

ii) Outcome: Any learner's outcome that results from the collaborative activity such as activity log, working memorandum, voting results and others.

iii) Environment: Represents the various entities around the learner, i.e., the learning environment of the classroom, field of work, tools, and learning materials.

iv) Learner: Describes the Learner itself, the Groups, and the set of Learner Groups class.

The problem with his approach is that he does not consider the activity and its attributes, he does not make any distinction between synchronous and asynchronous activities or group location because does not identify if the collaboration is face to face or distributed.

b) Metadata for Collaborative Learning (Friesen, 2005)

Friesen (2005) presents a Metadata for Collaborative Learning characterizing synchronous and asynchronous text-based communication among participants. Friesen defines four main classes: Environment, Expression (utterances), Participant and Expression Content focusing mainly in data exchange.

The problem with this proposal is that the focus is in characterizing only synchronous and asynchronous text based communications, but despite this he does not consider, among any of its parameters, the distinction between synchronous and asynchronous activities. Furthermore the considered expressions are mainly utterances, not all the kind of content involved in a pedagogical activity, besides he does not consider the learning activity and its attributes either.

c) Ontology to Describe Semantically the IMS Learning Design Specification (Amorim, 2006).

Another recent work developed by Amorim (2006) presents a learning design ontology based on the IMS Learning Design specification (the de facto metadata standard for learning design) where the elements of the IMS LD are modeled in a concept taxonomy in which the relations between concepts are formally represented along with a set of axioms defining semantics of the concepts.

The problem with his ontology is that it describes the main elements of the learning design process in order to overcome the expressiveness limitation found on the current XML-Schema implementation of the IMS LD conceptual model, but it does not consider collaborative interactions.

d) Semantic Description of Collaboration Scripts for Service Oriented CSCL (Vega-Gorgojo, 2005).

Vega-Gorgojo (2005) presents a Semantic Description of Collaboration Scripts for Service Oriented CSCL Systems, trying to overcome IMS LD problems when describing CL. He enables semantic description of CL features, conform to the existing standards like IMS-LD. This approach allows a more complete description of the CL activities making possible to store whole scenarios involved in the interaction. In that sense Verdejo (2003) presents a repository designed to store collaborative learning designs making this feasible.

The problem with his approach is that it describes the Collaboration Scripts for Service Oriented CSCL Systems trying to overcome IMS LD problems to describe activity types, their collaboration properties and learning tools with this standard, but does not substitute a metadata for CSCL.

Table 1-1: CSCL Metadata Studies

Study	Author	Description	Problem
Collaborative Learning Entity Metadata	Tamura	Represents design, practice, and evaluation of collaborative learning activities	Does not consider the activity and its attributes, does not make any distinction between synchronous and synchronous activities or group location
Metadata for Collaborative Learning	Friesen	Metadata for CL characterizing synchronous and asynchronous text-based communication among participants	The focus is in characterizing synchronous and asynchronous text based communications only
Ontology to Describe Semantically the IMS Learning Design Specification	Amorim	Learning design ontology based on the IMS LD specification where the relations between concepts are formally represented	Serves to describe the main elements of the learning design process to overcome the expressiveness limitations found on the current XML-Schema implementation of the IMS LD
Semantic Description of Collaboration Scripts for Service Oriented CSCL	Vega-Gorgojo	Semantic Description of Collaboration Scripts for Service Oriented CSCL Systems trying to overcome IMS LD problems when describing CL	Describes the Collaboration Scripts for Service Oriented CSCL Systems trying to overcome IMS LD problems to describe activity types

In addition these proposals does not considers the underlying theory of Learning and Cognition in Collaboration (Dillenbourg, 1999) where is described if the interaction is according to the socio-constructivist theory stated by Piaget, the socio-cultural theory (Dillenbourg, 1999) by the Vygotskian approach or the shared cognition approach (Dillenbourg, 1999). This is relevant to describe the collaborative world, several studies (Dillenbourg 1999, Johnson 1999) suggests this is one of the most important characteristics to describe the collaboration among students, also determines the effects, involved environment, and even so was not considered until now.

1.4 Objectives

As seen in Table 1-1 proposed Ontologies have yet issues to overcome, for this reason the primary objective for the present work is the development of an ontology that enriches the described CSCL proposals with metadata for describing and representing CSCL content and its activities, reusing and reshaping the proposals described before (Table 1-1).

To achieve this goal several specific objectives were established:

a) An analysis of the standards and specifications developed until now for E-Learning Metadata analyzing its advantages and maturity.

b) Determine which aspects of CSCL are covered (and in what grade) by actual E-Learning standards and specifications, identifying its applicability, besides the uncovered areas and features of actual standards when trying to be used for CL purposes.

c) Review mayor existing proposals until now about CSCL Metadata together with their problems, what relevant aspects are considered or missed in these proposals, their advantages and shortcomings. All of these to establish the features covered and what is necessary to make a specification of metadata for CSCL.

d) Develop two editors to create face to face CSCL content together with their activities, these editors are supported by a framework which is a middleware application for interacting with the repository of objects through Web Services. All of this to test the applicability of the developed ontology encountering its advantages and shortcomings.

e) Develop an ontology to overcome the relevant problems encountered to actual standards and specifications when applied to CSCL found in c), that have not been solved by actual CSCL Metadata proposals, represent the ontology in a formal language, and provide examples of its use and advantages.

1.5 Methodology

The starting point was to review mayor existing standards in the E-Learning area determining their similarities and areas in common with CSCL, it was considered as well whether these standards can be applied to describe and represent CSCL metadata and in what aspects this description is not complete, revealing unresolved necessities when representing CSCL aspects.

The next step of the research was to review mayor existing proposals until now in CSCL area, what aspects are covered, satisfied necessities, their applicability and usability.

Considering all the aspects unresolved of the existing proposals an ontology will be presented, this ontology tries to overcome the needs found when defining and representing CSCL world, and that way tries to represent it adequately. To develop this ontology the Protégé editor was used, in order to obtain an RDF representation of the ontology which is the standard language for this purpose.

In order to test ontology's applicability we developed a couple of CSCL face to face editors, which through the help of a middleware framework allowed us to test the applicability of the ontology trying to overcome the problems the ontology proposes to solve and finding that way actual contributions of the ontology.

1.5.1 E-Learning standards problems

Most of the proposals and standards for E-Learning until now can be resumed in a model consisting of an Asset (web browser displayable content) with an ECMAScript (JavaScript) API to interact with the Runtime Service and the Learning Management System (LMS) (Friesen, 2003), that way developers are able to create content according to the standards accepted by the industry.

Unlike E-Learning community, CSCL community lacks standards for guiding and directing the creation of CSCL content and activities description, probably because it is a field under development. The standard for E-Learning metadata, developed by the IEEE (IEEE 1484.12.3 Learning Object Metadata, LOM), was conceived for a single student, self-directed scenario, possibly with the support of one teacher (Friesen, 2003), excluding that way collaborative dynamics such as data exchange among students or teachers, floor control (e.g. teachers setting the pace of the activity, peers accomplishing a task independently, etc), coordination, and communication. In a classic E-Learning scenario data exchange involves a content server and probably several disconnected students that consumes content or provides reports to the content management systems, but not other members or roles (e.g. peers, tutors, etc.), which is a mandatory requisite for developing rich collaboration among students (Friesen, 2003).

When trying to describe collaborative activities through accepted standards such as IMS-LD we found some important limitations. Most of the tools required to support a collaborative activity cannot be described in actual standards. Each activity type (e.g. an edition or a debate) has some distinguishing properties, such as specific outcomes and roles that should be identified in a collaboration script. Another issue is that collaborative activities cannot be properly described because IMS-LD does not provide means to specify how individuals interact with each other within each step of the activity.

Recent studies (Manclús Tur 2004, Ip 2003, Mödritscher 2003) have shown some extensions to the JavaScript API trying to add collaborative functionalities in order to support collaborative activities but these studies have resolved some particular issues concerning data exchange among users using the server, but these collaborative activities are not able to deliver content to the user as expected in a collaborative context. Data exchange among users is one of the requisites to create E-Learning content but to create effective CL is essential to achieve the necessary conditions of effective CL activities (Zurita, 2004). As stated by Cortez & Nussbaum (2004) these conditions are not fulfilled by the standards mentioned earlier, but according to Zurita & Nussbaum (2004) with the help of MCSCL activities implemented via wirelessly intercommunicated Handhelds is possible to address most of the weaknesses found in a CSCL activity and overcome these shortcomings.

Another problem of the E-Learning standards is the supported data format, the content considered as standard compliant can be considered displayable by web browsers (Friesen, 2003) but mobile computers does not support HTML or JavaScript in a complete way, only provide light versions of it, making that way not possible to create E-Learning content for these devices, as a consequence E-Learning standards does not consider these mobile technological devices

1.5.2 Model for developing collaborative E-Learning content

In order to solve some of the problems encountered when trying to create CSCL content we propose a model for developing collaborative E-Learning content. The "Collaborative Content Framework" which is a middleware application between the server and the editors that facilitates the creation of CL activities, the exchange of information with a server allowing that way to reuse all the functionalities common for all the editors.

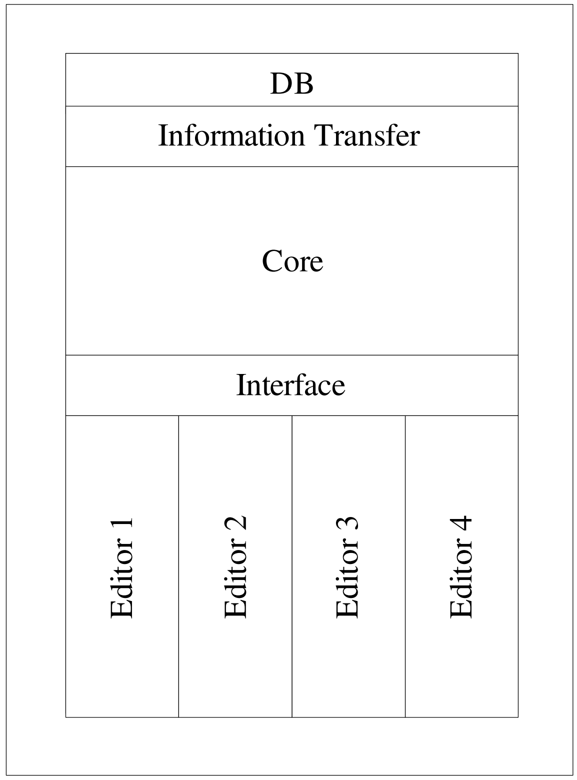

Figure 1-1: System Layers Arquitecture

The model was implemented in a five-layered system where the first layer corresponds to each editor with its specific functionalities such as face to face editors or any other editor for CL; there is no restriction for the editors but to implement the second layer. The second layer groups the necessities of CSCL content editors, contained in the first layer, into an API to provide the common functionalities needed to create these contents. All editors must implement these mandatory functions to ensure correct functioning of the Framework. The API does not restrict any particular functionality needed by the editors all it need is to be implemented.

The Core layer is responsible of providing all necessary functions to the editors so they can integrate with the rest of the system, for instance verifies if the editors effectively implement the interface and provides the services to create editors activities, reuses some common functionalities for the storage of the information and communicates with the upper layer, the Information Transfer layer.

This layer uses a web services to transmit data via SOAP protocols, given the facilities they provide for transmitting data over the web.

The database server layer provides a database engine fully compatible with the documents and functions provided on the client side by the interface. To increase model's performance and to ensure XML documents are correctly formed and to be totally certain data stored is valid, XML Schemas were developed and that way the model can validate documents integrity. These schemas are available by client and server side and must be fulfilled by both parts.

The core of the system verifies editor's integrity and offers a set of services including:

- Users account administration: the framework verifies user existence and checks its attributes to set right user properties in the framework.
- Activities definition: The framework allows the creation of groups of questions, choosing from all available editors, and to set this group of questions with some particular activities attributes.
- Sequencing control: The set of questions composing an activity can be ordered as desired setting this property in the framework.

1.5.3 Applications of the Model

In the following sections we examine two specific applications of the Model for developing collaborative E-Learning content. The first application shows an editor to create activities encouraging collaborative discussion between students altering classroom dynamic and making them work in a collaborative way. The second application uses slides to promote discussion among group members.

These systems can be considered as face-to-face CSCL systems (Zurita, 2004), whose functioning is based on theories of Collaborative Learning and Computer Supported Collaborative Learning (CSCL)

The aim is to promote a face to face CSCL system helping the teacher to transform classroom dynamics. The idea is to move from a teacher-centered arrangement, where the teacher delivers knowledge to a passive class of children, to one where children are active agents of the class and the teacher acts as a mediator. To achieve this, the students are organized into groups, where each child has a hand-held device (Pocket PC) interconnected via Wi-Fi.

Each group consists of three children (Dillenbourg, 1999) working face to face with the support of the technology, where they are required to answer a set questions working collaboratively on their Pocket PCs. According to Cortez & Nussbaum (2005) random group formation will provide opportunities for every student to develop different discussion strategies along with many others.

As stated by Cortez & Nussbaum (2005) these systems clearly supports most important features needed to conform effective CL activities proving to be effective on its aim. It is also clear, from presented problems of E-Learning standards, that any of these supports all of the characteristics needed by this system. In order to overcome this we developed two editors to create content for the mentioned system.

a) Questions Editor

This application of the model is based on the face to face CSCL system proposed by Cortez & Nussbaum (2004) where they propose a face to face computer supported collaborative learning system that uses wirelessly networked hand-held computers to create an environment for helping students assimilate and transfer educational content.

This editor promotes discussion among group members using questions consisting of a statement and a set of alternatives as originally stated by Cortez & Nussbaum (2004). Each question element is rich text and can contain formatted text, images, tables and any other element normally used in text editors.

The number of alternatives can be set in a default number and can also be changed by adding more alternatives to the question by dragging the element to the questions elements area. The only restriction is that all questions must have at least two alternatives and one question statement in order to be a well formed question.

Once the question is set up with all its alternatives and statement the user must indicate the correct answer and then the question is complete.

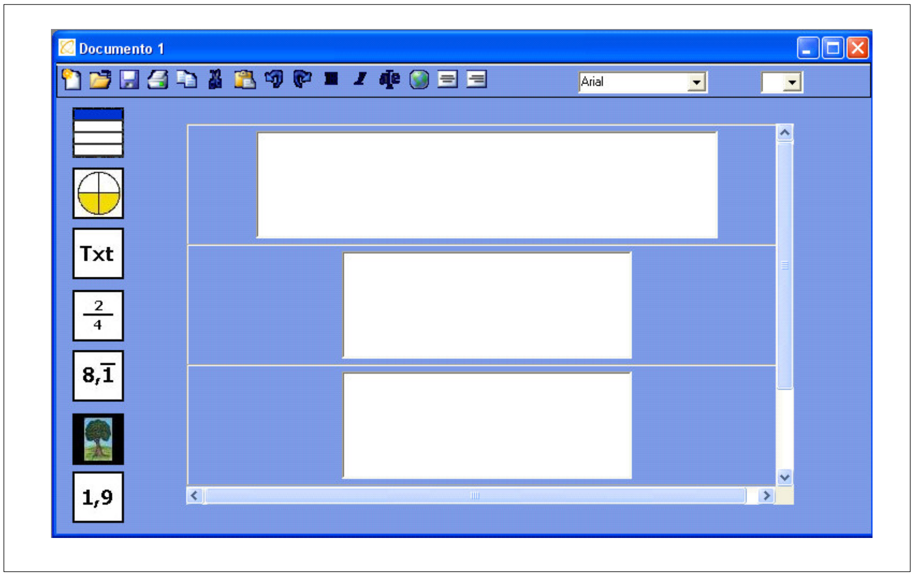

Figure 1-2: Questions Editor View

The logic of the collaborative activity for any given group is shown below in Figure 1-3. The members of a group must reach a unanimous agreement before answering the question. This is achieved through discussion among the members. If the students do not agree on an answer, the system will keep asking the same question again until all group members concurs. Only then the answer will be validated, if the answer is incorrect, the system alerts the group with their error and requires them to reconsider the same question, with the previously selected alternative excluded, proceeding this way until the correct answer is achieved, and then the group can proceed to the next question.

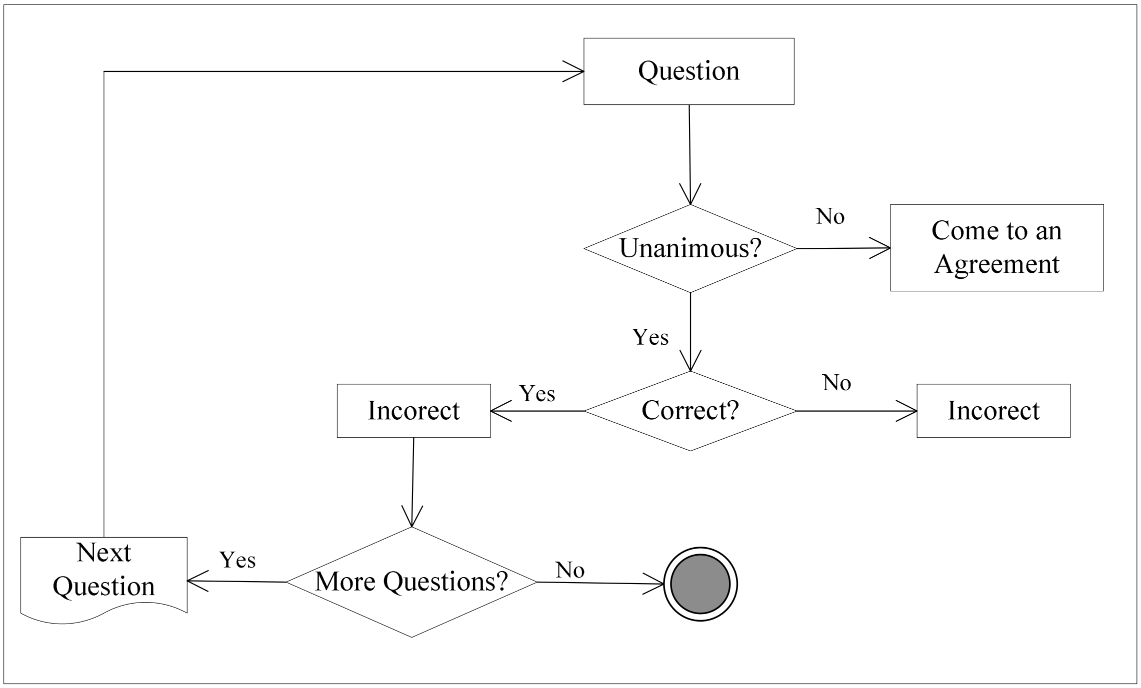

Figure 1-3: Activity Player Decision Diagram

The definition of this CSCL face to face Editor according to the developed Ontology (Chapter 2) is shown below. As described in Figure 1-4, the ontology provides more information regarding collaborative interaction than the activity model (Figure 1-3) such as Prerequisites, Synchrony or Location of the activity.

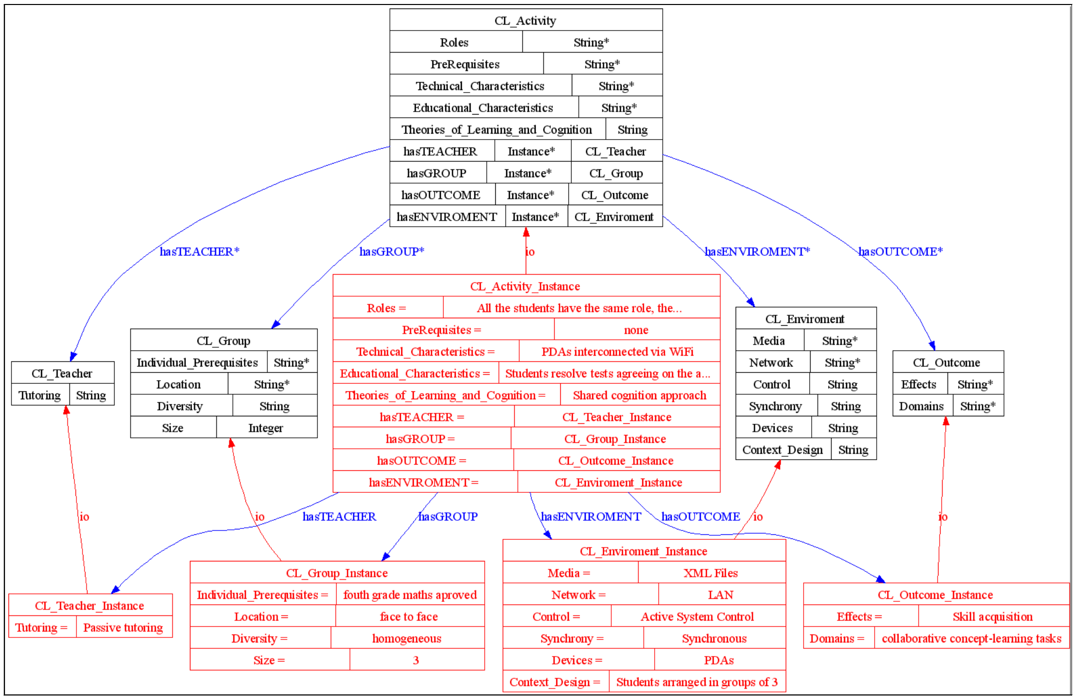

Figure 1-4: Questions Editor Ontology Instance

b) PPT Editor

The second application of the model instead of text uses slides to complement the contents explained to the students, the idea is to alternate between questions with complementary content to reinforce the ideas and promote discussion among group members.

This editor explains content using presentations, where each presentation consists of one or more slide, and each slide can contain formatted text, images and other predefined elements. The number of slides is not fixed, but at least must be one slide per presentation.

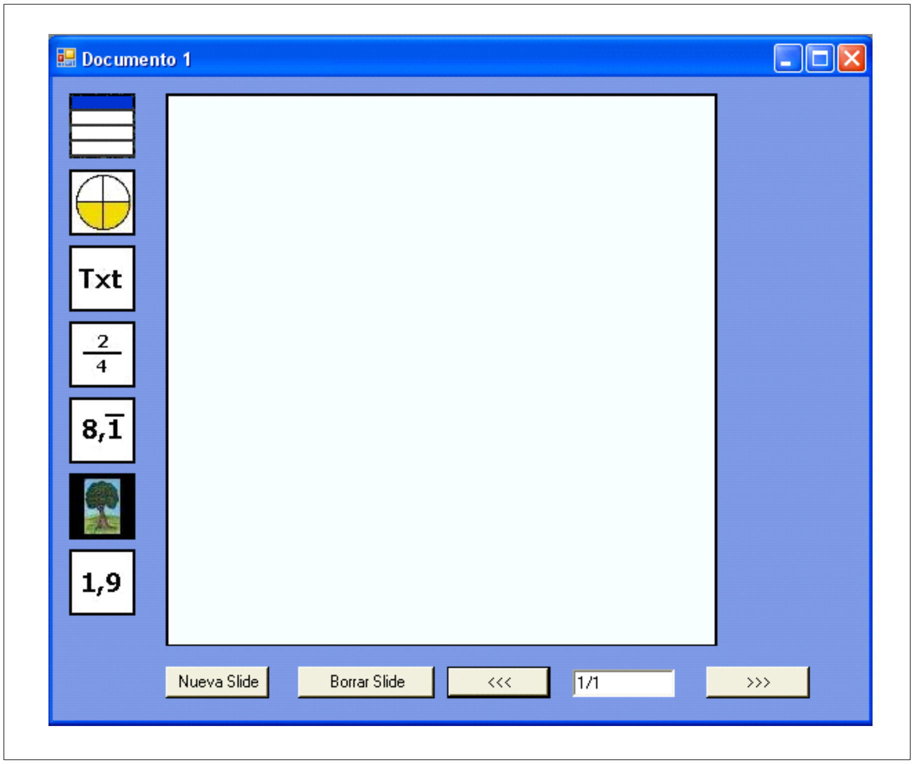

Figure 1-5: PPT Editor View

The obtained definition of this CSCL face to face editor is presented in Figure 1-6. Again the model in Figure 1-6 provides more collaborative information the applications interface, otherwise they would remain implicit hampering search and reuse of applications components.

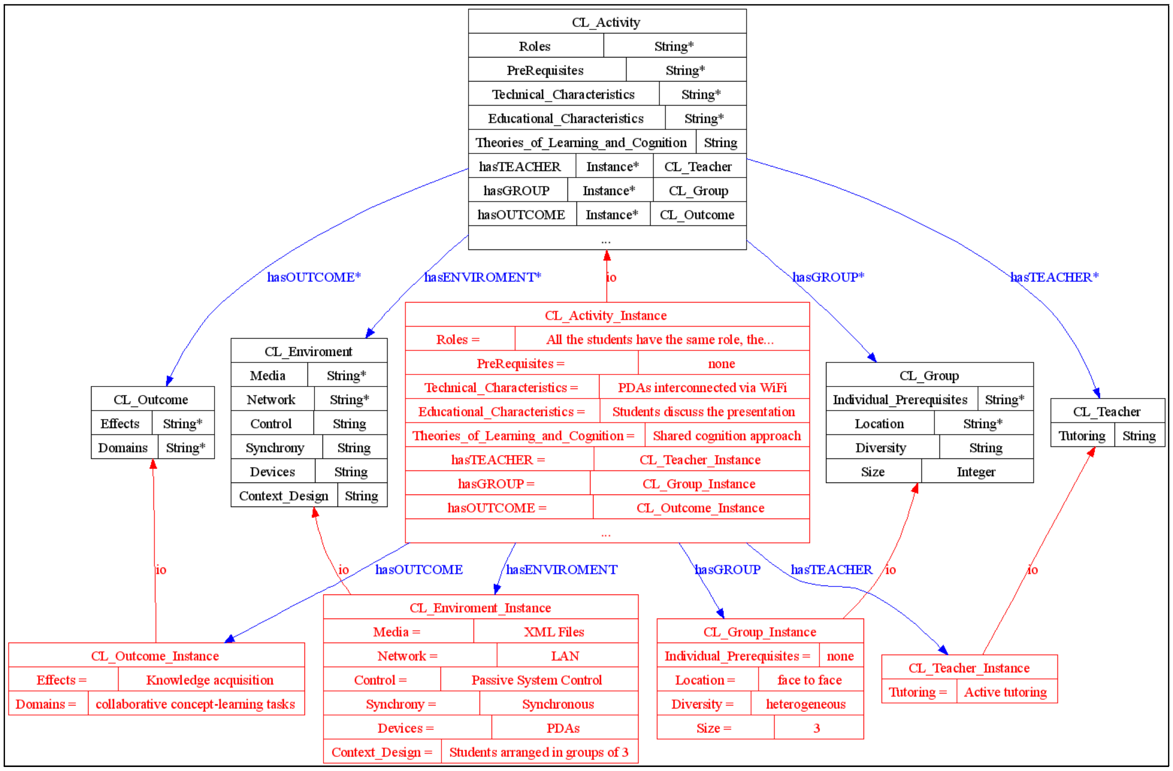

Figure 1-6: PPTs Editor Ontology Instance

1.6 Expected Results

The results of the present work are an Ontology described in RDF Language, that describes and represent relevant CSCL features, making possible to represent CSCL activities and its content.

We expect that the Ontology facilitates the storage of learning activities and learning objects without loss of contextual (activity) information, along with its content, being able to reuse and exchange this content and activity descriptions with all the CSCL community contributing to the development efforts of the area.

Until now the description of the Collaborative Learning activities and content has been left aside in the E-Learning standards and specifications. Such metadata presents some shortcomings when trying to accomplish the task of representing the collaboration among students or learners. This has been more evident in the last years when technological advances has made possible the growth of numerous instances and institutions exploiting Collaborative Learning. As there is not a common understanding about the characteristics that must be included when describing a collaborative activity or the way these activities must be stored into repositories for future use and exchange with other developers (Verdejo 2006, Verdejo 2003, Vega-Gorgojo 2005).

Generally these properties remain implicit hampering its reuse because whole context cannot be preserved, losing some important features. This way the importance of the ontology becomes relevant, even though the difficulty implied into describe and categorize every single one of the characteristics of the CSCL is big, in that sense this ontology aims to be a contribution to overcome this issue.

1.7 Conclusions

The possibilities achieved by new technologies have opened a new world to explore for developing CL activities and today is not possible to reuse these activities and its content with all the expressiveness collaborative activities have in a easy way, due to actual expressiveness shortcomings important efforts must be invested to accomplish this objective, actual standards and specifications have left aside several characteristics that enriches the description of these activities and hinders the reuse of this material.

The study of actual specifications and standards shows that does have the generality to overcome in some way these deficiencies, showing that the need for setting up the basis for a CSCL Ontology is a necessity for the development of the area. The study and analysis of the most important proposals for a CSCL Ontology shows that have not succeeded in overcoming these problems, leaving some aspects unconsidered, so the description of the CSCL activities and its contents has some important deficiencies attempting against its usability.

When trying to define mayor characteristics that composes a Collaborative Learning activity and its content, the main drawback is that the community have not defined yet the boundaries of the collaborative world leaving the domains open to the interpretation and there is not a consensus into what must be included and what not, being not possible to make a solid establishment of these basis.

To gain insights and have a deeper understanding about the creation, storage and retrieval of activities and its content for future reuse, we developed two editors of face to face CSCL activities and content, allowing us to find out the advantages the proposed ontology and identifying implicit information.

All the previous work made us possible to have the necessary considerations to develop an ontology, trying to overcome most of the uncovered aspects encountered so far, and then test its usability and validate that identified shortcomings were overcome.

Despite all the drawbacks and the complexity of the task, the CSCL Ontology has proved to be an effective way to describe and represent the dimensions needed to describe the collaborative activities along with its content, showing that the definitions implied in the ontology are useful for the representation of the activity and improving the storage of the activities and content developed, allowing the correct reutilization of all these material, without loss of information, because the ontology allows to make explicit information that until now has been considered implicit.

The presented ontology was successfully tested using two editors that have proved to be effective and rich in its collaborative context, allowing to complete and discover information that until now remained implicit in the descriptions of traditional applications.

1.8 Perspectives for future work

The realization and operation of the model so far has proved to be useful to create context rich Collaborative Learning content as it was intended. This made possible the validation of the ontology as was the purpose of creating the model and the editors in first place. This validation resulted successful but despite all the efforts done (due to the lack of consensus within CSCL community) there is not a way to be completely sure that all included features satisfies completely all the dimensions to take into account when describing a CSCL activity or CSCL content.

This is the main motivation to keep searching and improving the ontology, until there is no consensus about what implies a CSCL activity and its content, the ontology cannot be complete and this is the main perspective for future work.

Another interesting point for future research is the compatibility between actual IEEE LOM Metadata and the proposed CSCL Ontology, although it is true in the realization of the CSCL Ontology, the characteristics that were common for both remained unchanged it is important to check until what point the IEEE LOM and CSCL Ontology must live separated. Is important to clarify all the different aspects and study if is possible to unify both into one single metadata for describing Learning objects of all kind.

CSCL ONTOLOGY PAPER

Abstract: Collaborative Learning has proved to be an effective way to change classroom dynamic fostering new capabilities for teachers. Despite this until now Collaborative Learning does not count with standards to describe and represent the activities and its content, because actual standards have focused in solving E-Learning paradigms where the interaction between students and teachers is unilateral and centralized in the teacher delivering knowledge to his students, excluding any form of interaction. It is because of this the present work introduces an ontology developed to represent CSCL content according to Collaborative Learning necessities.

Introduction

Collaborative Learning (CL) activities in the classroom can be understood as the commitment of three to five participants in a coordinated effort to reach a specific educational objective (Cohen 1994, Davidson 1992, Dillenbourg 1999). When students work in groups in a collaborative setting, better academic results can be obtained (Johnson, 1999), students learn more, retain longer what they have learned, develop abilities of superior reasoning and critical thinking and feel more valued and confident (Gómez, 2001). Computer Supported Collaborative Learning (CSCL) can be understood as a computer-based networked system that supports group members by controlling and monitoring their interaction, distributing information, regulating their assignments, rules and roles and providing them a shared interface, promoting knowledge acquisition (Cortez, 2004).

Mobile-CSCL systems (mCSCL) exploit portable devices as the computing platform in order to allow learners to operate in a more natural interactive environment, where face to face interactions can take place. Research done in the area suggests that mCSCL facilitates coordination, communication, organization, negotiation, interactivity, and mobility (Zurita 2003 , Zurita 2004) increases communication and allows learners a higher engagement in the learning activity as they can share the wireless devices, distribute, aggregate and share information (Stead, 2005).

CSCL and mCSCL applications have to consider at least both, the learning activity and the learning content. A learning activity can be identified as the process followed by learners (i.e. explanation, disagreement and mutual regulation), that triggers in learners specific cognitive mechanisms (such as knowledge elicitation or internalization) (Dillenbourg, 1999). Learning content refers to what is taught and/or learned. If CSCL or mCSCL applications keep activity and content tightly coupled then reuse of any of these two elements is challenged. On the other hand, when they are decoupled they can be reused diminishing application development efforts.

For instance, in Cortez & Nussbaum (2004) work, collaborative activity is decoupled from the content, the activity definition consists in a collection of XML files where are the expansion modules, or plugins, containing the specific pieces of software required for the activity's full functionality. On the other hand, content is downloaded from a Learning Objects repository as XML files.

Furthermore, under this scenario it will be possible for developers or teachers to share content and even share good interaction design. However, in order to achieve this goal it is necessary to describe or represent systematically both activity and content. Fortunately, this has been the goal for E-Learning community for the past few years and various institutions have collaborated in order to develop standards and specifications for content and activity reaching some level of maturity and consensus (i.e. IEEE LOM, IMS LD and SCORM). Unfortunately, CSCL aspects have been out of the main focus of this standarization effort and a few recent proposals are addressing the issue (Tamura 2003, Friesen 2005, Amorim 2006, Vega-Gorgojo 2005).

In the present work we present an analysis of the standards supporting E-Learning and the metadata developed, as well as its limitations for supporting CSCL. The E-Learning paradigm consists of a single student, self directed, possibly assisted by one teacher (Friesen, 2003) and behind a desktop computer. This paradigm does not take into account neither collaboration settings and requirements (e.g. coordination, negotiation, communication) nor computing platforms limitations and constraints (Friesen, 2003).

The paper is organized as follows, section 2 presents current standards for E-Learning and its relevance in the industry and evolution. Section 3 describes current metadata shortcomings when trying to represent CSCL content and presents some related work attempting to enrich current E-Learning standards with CSCL support. In section 4 we present an ontology for the definition and representation of CSCL content, and finally in section 5 we present some discussion and conclusions.

Standards in the E-Learning Industry

Since the early 90's there has been a great movement toward standardization on the E-Learning industry. E-Learning is defined as *"the delivery of a learning, training or education program by electronic means. E-Learning involves the use of a computer or electronic device e.g. a mobile phone, in some way to provide training, educational or learning material"* (Stockley, 2004). The usage of metadata for describing E-Learning elements has been a widely accepted approach. Metadata is data about data, and it comprehends information about learning objects, learning content structures, learner attributes, learning goals, competencies and others.

Several institutions around the world have been working in parallel trying to define proper standards, between those institutions, the most important are the Aviation Industry CBT Committee (AICC), the Alliance for Remote Instructional Authoring and Distribution Networks for Europe (ARIADNE), the Institute of Electrical and

Electronics Engineers Learning Technology Standards Committee (IEEE LTSC), the IMS Global Learning Consortium, the Dublin Core initiative and the Advanced Distributed Learning initiative (USA's Department of Defense). From these institutions only IEEE LTSC can produce standards, all the other ones produce specifications that later have been embraced as standards (and de facto standards).

IEEE LTSC's most relevant standards for our purposes are:

1. *IEEE 1484.12.3 Learning Object Metadata (LOM):* Central to modern standards is the concept of Learning Objects or LOs which can be understood as small molecules or bricks containing learning material (content). Others define it as any entity digital or not, which can be used, reused, or referenced during technology supported learning (LOM, 2002).

2. *IEEE API 1484.11.2 Standard for Learning Technology, ECMAScript Application Programming Interface for Content to Runtime Services Communication:* it basically defines an ECMAScript (e.g. a JavaScript) API in charge of the communication between the object itself and the applications displaying it.

3. *IEEE Data Model 1484.11.1*: This standard describes the data model supporting the data interchange through previously defined data between the educational object and the RTS (runtime service) used to display the content.

The IMS Global Learning Consortium, on the other hand, proposes the IMS Simple Sequencing, IMS Content Packaging that defines an activity as a conditional sequence of LOs, IMS Learning Resource Metadata which is a subset of IEEE LOM core elements. The AICC CBT Messaging Interface that describes the way the messages are being interchanged. The Dublin Core Metadata Initiative (DCMI) proposes a general-purpose metadata that describes cross-domain information resources.

All these organizations conform what might be called a suite of specifications in various categories, as a whole they represent 71% of all specifications proposed (48 of a total of 71) (Marcus, 2006).

A convergence has taken place, and the most influential initiatives (IMS, ARIADNE and Dublin Core) have aligned their models according to the IEEE LOM. The result of these efforts is the *Sharable Content Object Reference Model* (SCORM), which is a reference model that integrates different efforts in standardization process and is called the *de facto* standard because of its wide adoption in the E-Learning industry (ADL, 2004). Despite all the efforts, E-Learning is in the middle of standardization process and have not yet included other series of officially accepted specifications.

SCORM uses the data description proposed by the IEEE LTSC *metadata specification Learning Object Metadata (LOM)* along with *IMS metadata elements* allowing different levels of aggregation, format, platform and languages, *IMS Simple Sequencing Specification* having basic dependencies definition and to describe courses use the *IMS Learning Resource Metadata* based on the *IEEE Learning Technology Standard Committee* and ARIADNE (ADL 2001 & 2003). Table 1 summarizes the specifications gathered in SCORM as well as the provider organization.

Table 2-1: SCORM Specifications

Specification	**Organization**	**Description**
Runtime Communication	ADL, also being standarized by IEEE	APIs for communication among LMS and SCO
CMI Data Model	AICC, adopted by ADL and standarized by IEEE	defines vocabulary and answers between LMS and SCO
Learning Object	IEEE, also adopted	Defines learning

Metadata	by IMS and ADL	object categories
Aggregation Model	IMS, adopted by ADL	How to package course contents

IEEE Learning Object Metadata is a data model used to describe learning objects and other digital resources used to support learning. The main purpose of LOM is to allow reusability of learning objects. To achieve this purpose, collaborative activities were characterized in 9 main characteristics as shown below.

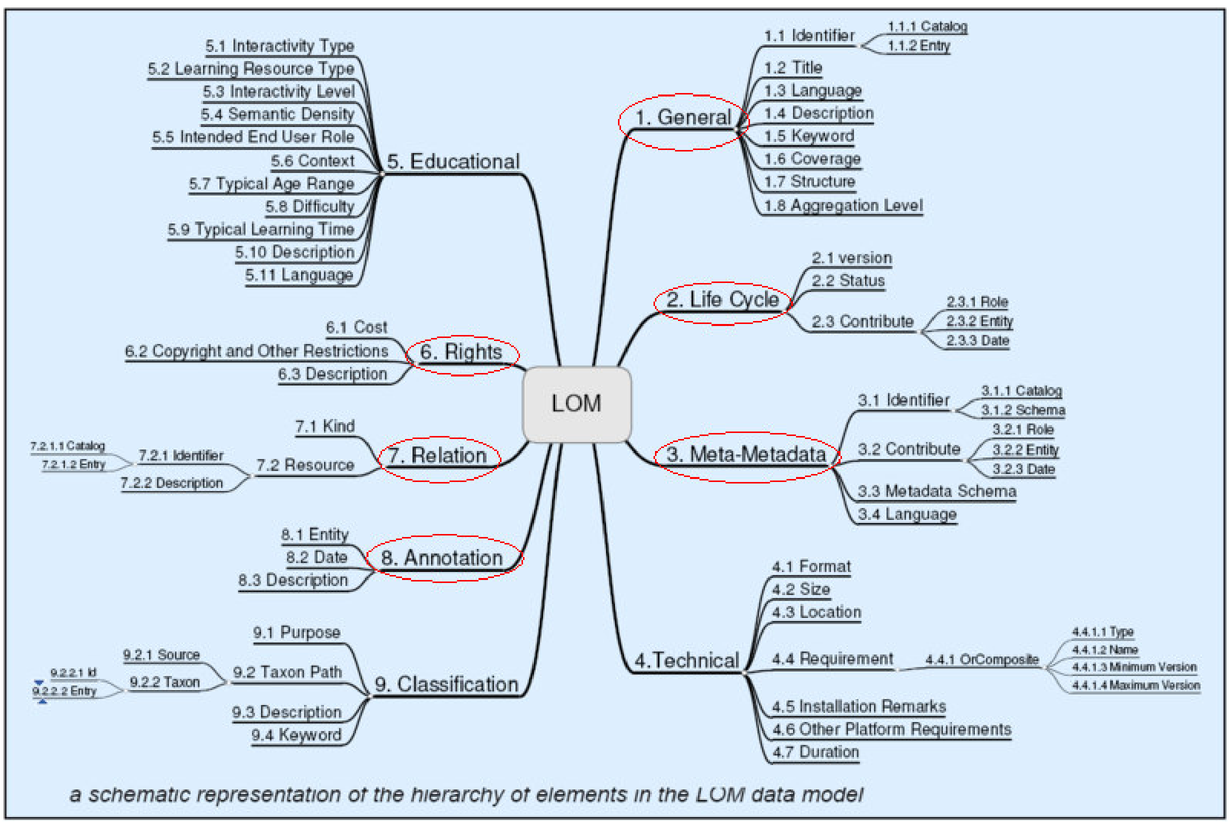

Figure 2-1: IEEE LOM

Of these 9 main characteristics some remain unchanged for collaborative activities (marked in figure 2-1) because are reusable without problems such as General, Life Cycle, Meta-Metadata, Rights, Relation and Annotations. In the other characteristics there are some features that do not apply because they are incomplete or should be considered in other way, especially in educational and technical features.

Another important specification to describe collaborative activities is IMS Learning Design, IMS LD is a metalanguage for describing learning designs focusing on the organization of the learning activities. The specification major components are explained using (in IMS LD terminology) a theatre metaphor:

- Roles assumed by learners, teachers, tutors etc.
- Activities performed by the roles
- Environment consisting of learning objects and services.
- The scenario is called method and contains play, acts and role-parts.

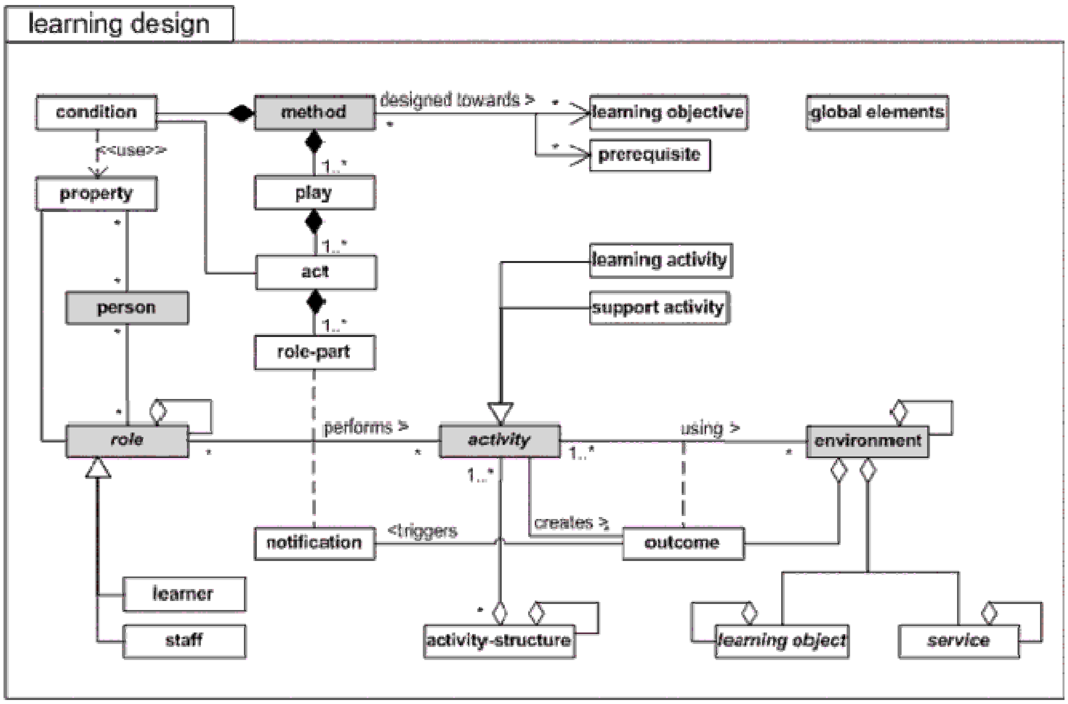

Figure 2-2: IMS LD

Standards relevance for the E-Learning Industry

The use and adoption of standards in the E-Learning community is fundamental for its development because the levels of reuse that could be achieved would allow the occurrence of mass scale economy, facilitating users and developers synergy for the creation of E-Learning content around the world. Among the many advantages of E-Learning standards are:

- Increase efficiencies and lowers costs: because standards make possible reuse of information more efficiently by sharing the same structure, being able to share content between different Learning Management System (LMS) without problems. Costs are also saved in training, because best developers practices have been added.

- In addition, commitments with proprietary tools (owning special licenses over the content) can be avoided.
- Lower risks: developing E-Learning content according to standards lowers the risk of having obsolete content, because this can be reused and easily adapted. Also avoids the risk of having technologically obsolete content because adopting newer standards will not require significant upgrades.
- Increase user experience: standards are developed to make learning more dynamic and motivating for the learners making that way a better learning.
- Development and use of international standards produce a direct cost saving and the information technology systems can be used in a wider range of applications, and more efficiently. Better, more efficient and interoperable systems, content and components will produce better learning, education and training, which have a positive effect upon all societies. (ISO/IEC JTC 1 Business Plan).
- Develop RAID content. Reusable (content easily modifiable and usable by different tools); Accessible (be used and searched by learners and developers); Interoperable (be operative in different hardware, OS and browsers); Durable (does not require mayor upgrade when newer version appears) (ADL 2001 & 2003).

Computer Supported Collaborative Learning (CSCL)

Unlike E-Learning community, CSCL community lacks standards for guiding and directing the creation of CSCL content and activities, probably because it is a field under development. The IEEE Learning Object Metadata was conceived for a single student, self-directed scenario, possibly with the support of one teacher (Friesen, 2003), excluding that way collaborative dynamics such as data exchange among students or teachers, floor control (e.g. teachers setting the pace of the activity, peers accomplishing a task independently, etc), coordination, and communication. In a classic E-Learning scenario data exchange involves a content server and the student that consumes content or provide reports, but not other members or roles (e.g. peers, tutors, etc.), which is a mandatory requisite for developing rich collaboration among students.

When trying to describe collaborative activities accepted standards such as IMS-LD has some important limitations. Tools required to support a collaborative activity cannot be described in actual standards (Friesen, 2003). Each activity type (e.g. an edition or a debate) has some distinguishing properties, such as specific outcomes and roles that should be identified in a collaboration script. Another issue is that collaborative activities cannot be properly described because IMS-LD does not provide means to specify how individuals interact with each other within each step of the activity.

Recent proposals (Tamura 2003, Friesen 2005, Verdejo 2006, Amorim 2006, Vega-Gorgojo 2005) attempt to extend metadata models for supporting CSCL features. For instance, Tamura (2003) developed a *Collaborative Learning Entity Metadata* (CLEM) that represents design, practice, and evaluation of collaborative learning activities. CLEM's aim is to describe CL not only from a technical perspective but also from a pedagogical and learning standpoint in order to represent, extract, share, reuse, and exchange the knowledge in collaborative learning activities. This metamodel defines four main classes to represent whole CL characteristics and its features:

1. *Teacher:* Characterizes the teacher and the possible group of teachers directing the activity.
2. *Outcome*: Any learner's outcome that results from the collaborative activity such as activity log, working memorandum, voting results and others.

3. *Environment*: Represents the various entities around the learner, i.e., the learning environment of the classroom, field of work, tools, and learning materials.

4. *Learner*: Describes the Learner itself, the Groups, and the set of Learner Groups class.

The problem is that does not consider the activity and its attributes, does not make any distinction between synchronous and asynchronous activities or group location because does not identify if the collaboration is face to face or distributed.

Friesen (2005) presents a *Metadata for Collaborative Learning* characterizing text-based communication among participants as synchronous or asynchronous. Friesen defines four main classes: Environment, Expression (utterance), Participant and Expression Content focusing mainly in data exchange. The problem with this proposal is that the focus is in characterizing synchronous and asynchronous text based communications only, but despite of that does not consider between any of its parameters the distinction between synchronous and asynchronous activities. Another issue with this proposal is that the expressions considered are mainly utterances not content involved in a pedagogical context, besides does not consider the activity and its attributes either.

Another recent work developed by Amorim (2006) presents a learning design ontology based on the IMS Learning Design specification (the de facto metadata standard for learning design) where the elements of the IMS LD are modeled in a concept taxonomy in which the relations between concepts are formally represented along with a set of axioms defining semantics of the concepts. The problem with this ontology is that serves to describe the main elements of the learning design process to overcome the expressiveness limitations found on the current XML-Schema implementation of the IMS LD conceptual model, a standard considered as seen in the present work that does not consider collaborative interactions.

Vega-Gorgojo (2005) presents a Semantic Description of Collaboration Scripts for Service Oriented CSCL Systems trying to overcome IMS LD problems when describing CL, enabling semantic description of CL features, conform to the existing standards like IMS-LD. This allows a more complete description of the CL activities making possible the storage of the whole scenarios involved in the interaction. It is in that sense Verdejo (2003) presents a repository designed to store collaborative learning designs making this feasible. The problem with this approach is that describes the Collaboration Scripts for Service Oriented CSCL Systems trying to overcome IMS LD problems to describe activity types, their collaboration properties and learning tools with this standard, but does not substitute a metadata for CSCL as such.

Up to our knowledge, no further studies have been presented so far. Studies presented above attempt to characterize collaboration and presents conceptual models that can serve as the basis of metadata definitions. However, they do not consider attributes that may describe the sort of collaboration being realized or characterized by the CL Activity itself. Next section presents an ontology that integrates all the reviewed proposals and extends them in order to allow a more complete characterization of the CSCL area.

CSCL Ontology

Ontologies are data models representing a set of concepts within a domain as well as the relationships between those concepts, and are used to reason about the objects within those domains. This brings a series of advantages like enabling reuse of domain knowledge and share common understanding about the information structure. To represent these data models formal languages are used, being the most popular the OWL Web Ontology Language. OWL was designed to provide a common way to process the semantic content of web information. It was developed based on XML, XML Schema, RDF and RDF Schema, so it may be considered an evolution of these web languages in terms of its ability to represent machine-interpretable semantic content on the web. RDF is a datamodel for objects ("resources") and relations between them provides a simple semantics for this datamodel which in turn can be represented in XML syntax.

The proposed CSCL Ontology was written in OWL using the Protégé editor and considering most relevant concepts in the CSCL domain, integrating as well standards and research done so far. The Ontology was built around five main concepts:

1. *Activity:* the Collaborative Activity is the core of our ontology, around it are situated the rest of the characteristics complementing activity's characterization. To describe the collaboration process among group members there are three main theories of Learning and Cognition in Collaboration (Dillenbourg, 1999) the socio-constructivist theory by Piaget, socio-cultural theory stated by Vygotsky and the shared cognition approach. There may be more, if that occurs then they should be simply incorporated through this concept. Another dimension needed to describe the activity is activity roles, defining learner's behavior along with their participation within the activity.

   Activity prerequisites are other part of the description, where are stated the necessary conditions to support correctly the activity.

2. *Environment*: All the elements needed to support the CSCL activity are contained within this concept, network type indicating if it is LAN, WAN or Internet supported network. Another part is the devices needed to play the activity, the control of collaborative interactions referring to the mode of delivery of the collaborative environment by the system. Other important dimension of the CSCL world refers to activity synchrony describing if the activity is realized in real time or asynchronously.

3. *Outcome*: as a result of the activity there are expected effects in learners (Tamura 2003, Friesen 2005) being in part defined by the theories of Learning and Cognition and being identified as Skill acquisition, Joint planning, Categorization, Memory tasks, perspective-taking, planning, problem solving, concept-learning tasks and designing tasks.

4. *Group*: characterization of the group developing the activity, collaboration is given when two or more (Dillenbourg 1999, Friesen 2005) persons interact and because of this, several characteristics must be formalized to fully describe the group, such as its size (number of learners within the group), location (how are situated) if the learning is face to face or distributed, group´s diversity (Dillenbourg, 1999) describing group heterogeneity because for the socio-constructivist approach this provides the conditions for generating socio-cognitive conflict but for the socio-cultural approach it provides conditions for internalization. Another characteristic is individual pre requisites (Dillenbourg, 1999) of each group learner, so far it has not been a main concern but can be an issue for types of collaborative activities.

5. *Teacher*: activity's tutoring and supervision by the teacher or group of teachers is another main characteristic of the collaborative activity, this means how is defined the participation of the teacher within the activity.

To maintain compatibility with actual IEEE 1484.12.3 Learning Object Metadata (LOM) standard, the ontology continue representing those general characteristics where are no differences between the standard and collaborative characteristics such as identifier, language, plus some other general characteristics. This gives the advantage of reducing differences with actual standards and reduces the gap between the standard and developed ontology, keeping in mind, in some point, the intersection between collaborative learning and learning alone.

The core and focus is in the Activity class, around the activity is organized the rest of the elements needed to describe the CL. Some snippets of the applicability of the ontology are shown below, they describe how ontology's concepts can be instantiated.

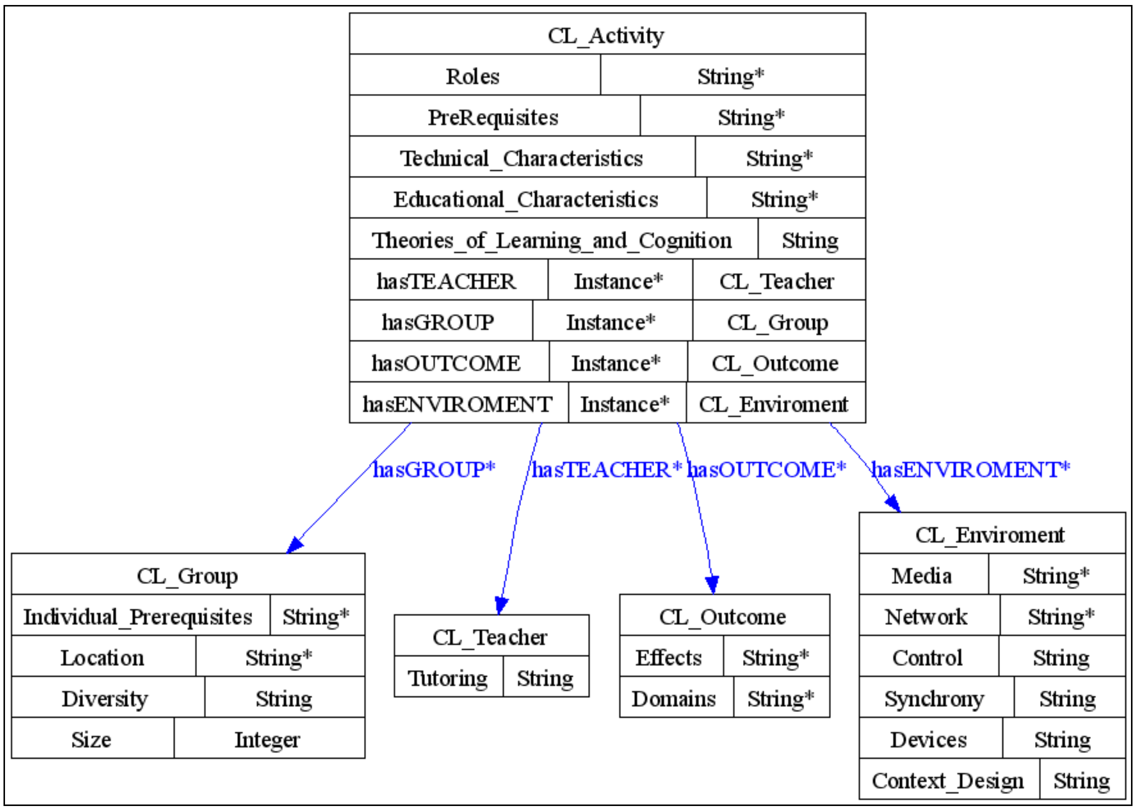

Figure 2-3: Ontology Diagram

There are some important characteristics unconsidered until now like the theory of Learning and Cognition in Collaboration (Dillenbourg, 1999) where we describe if the collaboration is given according the *socio-constructivist* theory stated by Piaget, *socio-cultural* theory, by Vygotskian approach or it is a shared cognition approach. This is relevant to describe the collaborative world, several studies (Dillenbourg 1999, Johnson 1999) suggest this is one of the most important characteristics to describe the collaboration among students, also determines the effects, the involved environment, and despite all of these it was not considered until now. A graphical version of the snippet is shown in Figure 2-4 where is represented the Theories of Learning and Cognition identified as relevant for CL Activities.

```
<owl:ObjectProperty rdf:ID="hasTheories">
  <rdfs:domain rdf:resource="#CL_Activity" />
  <rdfs:range rdf:resource="#Theories_of_Learning_and_Cognition" />
</owl:ObjectProperty>
<owl:Class rdf:ID="Socio-constructivist">
  <rdfs:subClassOf rdf:resource="#Theories_of_Learning_and_Cognition" />
</owl:Class>
<owl:Class rdf:ID="Socio-cultural">
  <rdfs:subClassOf rdf:resource="#Theories_of_Learning_and_Cognition" />
</owl:Class>
<owl:Class rdf:ID="Shared_cognition_approach">
  <rdfs:subClassOf rdf:resource="#Theories_of_Learning_and_Cognition" />
  <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Shared cognition approach<
</owl:Class>
```

Figure 2-4: Theories of Learning and Cognition for CL Activities

Another characteristic needed to describe CSCL activities are the necessary prerequisites the activity may have (Dillenbourg, 1999), it may be necessary some element as necessary conditions for the activity to be realized, and until now this feature of collaborative activity remained uncovered.

```
<owl:ObjectProperty rdf:ID="hasPreRequisites">
  <rdfs:domain rdf:resource="#CL_Activity" />
  <rdfs:range rdf:resource="#Prerequisites" />
</owl:ObjectProperty>
```

Figure 2-5: Activity's Prerequisites

To describe CSCL another important issue uncovered until now was the synchronicity of the activity, although it is true Friesen (2005) stated a metadata describing this characteristic of collaborative activities, this metadata does not make any explicit distinction between synchronous and asynchronous activities leaving this characteristic unresolved to describe activity's nature, when this is a relevant characteristic in some collaborative practices such as in face to face collaborative activities, where the collaboration is in a synchronous way or in distributed collaboration where the interaction can be given in a asynchronous way.

```
<owl:Class rdf:ID="Sincrony" />
<owl:Class rdf:ID="Synchronous">
  <rdfs:subClassOf rdf:resource="#Sincrony" />
</owl:Class>
<owl:Class rdf:ID="Asychronous">
  <rdfs:subClassOf rdf:resource="#Sincrony" />
</owl:Class>
```

Figure 2-6: Activity's Synchrony

Another important characteristic to describe the nature of the collaborative activity is the composition of the group (Dillenbourg. 1999), the collaboration between the students inside a group might be determined by their homogeneity or heterogeneity, and according to that is how the activity is designed, so is relevant for the accuracy of the metadata obtained to describe this feature of the collaboration unconsidered until now.

```
</owl:ObjectProperty>
<owl:ObjectProperty rdf:ID="hasDiversity">
  <rdfs:domain rdf:resource="#CL_Group" />
  <rdfs:range rdf:resource="#Diversity" />
</owl:ObjectProperty>
<owl:Class rdf:ID="heterogeneous">
  <rdfs:subClassOf rdf:resource="#Diversity" />
</owl:Class>
<owl:Class rdf:ID="homogeneous">
  <rdfs:subClassOf rdf:resource="#Diversity" />
</owl:Class>
```

Figure 2-7: Activity's Group Diversity

Within the activity's environment another relevant feature, unconsidered until now, is the Network in which the activity is built, according to the nature of the activity is how the network should be constructed, if the activity is designed to be distributed or face to face determines some aspects to consider for supporting the activity in a correct way. For this reason this characteristic must be considered to describe the activity and its environment.

```xml
<owl:ObjectProperty rdf:ID="hasNetwork">
  <rdfs:domain rdf:resource="#CL_Enviroment" />
  <rdfs:range rdf:resource="#Network" />
</owl:ObjectProperty>
<owl:Class rdf:ID="LAN">
  <rdfs:subClassOf rdf:resource="#Network" />
</owl:Class>
<owl:Class rdf:ID="WAN">
  <rdfs:subClassOf rdf:resource="#Network" />
</owl:Class>
<owl:Class rdf:ID="Internet">
  <rdfs:subClassOf rdf:resource="#Network" />
</owl:Class>
```

Figure 2-8: Activity's Network Environment

All the mentioned characteristics above have been unconsidered so far by actual proposals of CSCL metadata and is in that sense this Ontology tries to be a contribution to overcome some of these shortcomings when describing its activities and content.

Applications of the Ontology

With the application of the ontology several possibilities are reached for activities developed decoupled from the content. Cortez & Nussbaum (2004) presents an activity player where the definition is independent of the content and organized into plugins, and to define or describe the activity making it reusable with the specifications and standards developed until now would not be feasible. Several features would be dismissed due to lack of accuracy in current specifications and because most of the work has focused in E-Learning leaving aside CSCL.

To be able to decouple the activity from the content, exploiting the capabilities of storing and then retrieving the material, a *Model for developing collaborative E-Learning content* was developed, gaining insights into the ontology's impact, complexity, achieved flexibility and testing that way our hypothesis. The applications of the model are based on the face-to-face CSCL system proposed by Cortez & Nussbaum (2004) where they proposed a face to face computer supported collaborative learning system that uses wirelessly networked hand-held computers to create an environment for helping students assimilate and transfer educational content.

The first editor, called *Questions Editor,* promotes discussion among group members using questions consisting in a statement and a set of alternatives as originally stated by Cortez & Nussbaum (2004). Each question element is rich text and can contain formatted text, images, tables and any other element normally used in text editors.

The resulting ontology's instance of this CSCL face to face Editor is shown below and the advantages are that many of the features contained in this ontology were not considered until now (such as Prerequisites, Synchrony or Location of the activity), the description of the activity is according to the most descriptive characteristics of the CSCL allowing to maximize the efforts to reuse the content and store it in a repository (Verdejo, 2003) giving completeness to the description of the activity.

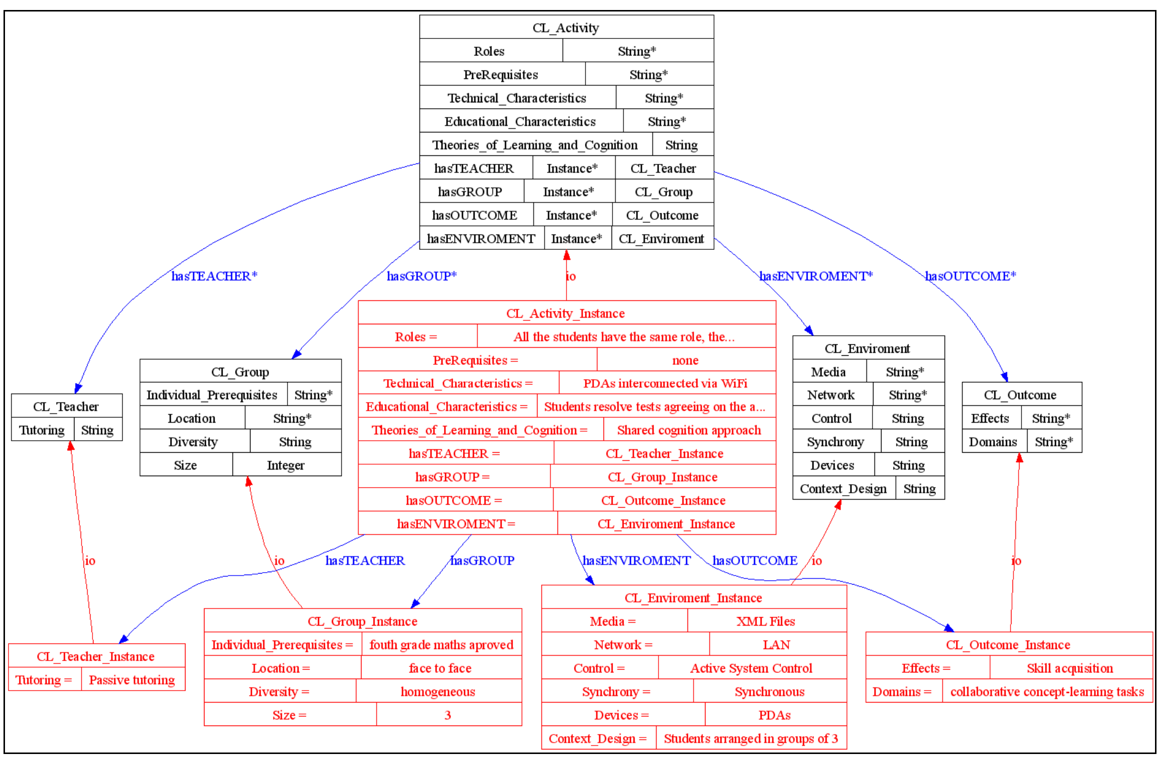

Figure 2-9: Questions Editor Ontology Instance

The obtained description of this CSCL face to face editor with actual proposals of CSCL Metadata would be incomplete, as mentioned earlier, but with the application of the developed ontology we have tried to overcome this issue including these excluded characteristics into our description. One example of this is group's instance shown above, where the diversity of the students of the group (heterogeneous or homogeneous) was unconsidered so far being a relevant attribute of the activity (Dillenbourg, 1999).

Another aspect now considered is the location where the collaborative activity is given, and for the particular instance of this editor turns out to be a face to face activity, for some other instance (such as forums) the activity can be distributed and not necessarily face to face. The network where this particular activity is supported is another relevant aspect to describe the environment of the activity, for this particular case is a Local Area Network (LAN) as stated by Cortez & Nussbaum (2004).

The Theory of Learning and Cognition in Collaboration (Dillenbourg, 1999) is relevant to describe the collaborative world, several studies (Dillenbourg 1999, Johnson 1999) suggest this, but was unattended until now, and for the nature of this activity we think it corresponds to the *Shared Cognition Approach.*

All these characteristic mentioned earlier are a sample of the ontology's applicability in aspects unconsidered until now in the descriptions realized by actual CSCL Metadata proposals.

The second application of the ontology is the *PPTs Editor*, that instead of text uses slides to complement the contents explained to the students, the idea is to alternate between questions with complementary content to reinforce the ideas and promote discussion among group members. This editor explains content using presentations, where each presentation consists of one or more slide, and each slide can contain formatted text, images and other predefined elements.

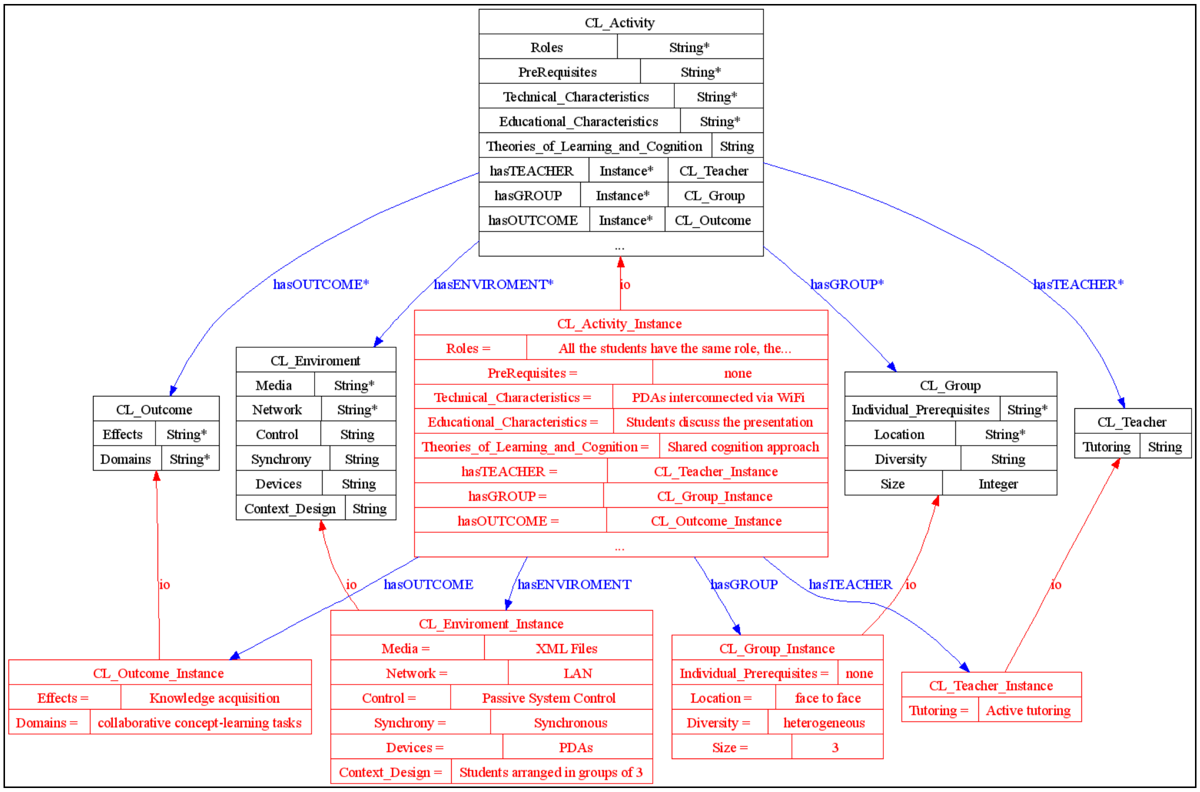

Figure 2-10: PPTs Editor Ontology Instance

There are some similarities but also there are some different characteristics when describing the nature of the activity and the content, the control of the activity is a Passive control, the slides are presented and the main role is of the teacher, his tutoring role now is active, different from the passive role the teacher had in the Questions Editor.

Another relevant aspects of this editor is that as Outcome promotes Knowledge acquisition, directed by the teacher, the aim of the slides is to deliver content, this also explain the diversity nature of the group, is not necessary to have homogeneous students so the group's diversity is heterogeneous.

There are more characteristics in the ontology but due to restrictions of time could not be tested in a practical way.

Discussion and Conclusions

The need to represent Collaborative Learning activities and its content adding capabilities for reusing them between developers and teachers is growing everyday because actual standards and specifications have failed in its attempt of doing this so far. The possibilities achieved by new technologies have opened a new world to explore for developing CL activities and today is not possible to reuse these activities and its content with all the expressiveness the collaborative activities have, actual standards and specifications have left aside several characteristics that enriches the description of these activities and hinders the reuse of this material.

To describe and then store the CSCL material are numerous advantages when decoupling the activity from the content such as diminishing the efforts needed to develop the application and allowing reusability, but to make this concrete a formal definition and description of the CSCL world is needed. The present study shows an ontology created to define and represent a Computer Supported Collaborative Learning activity according to mayor dimensions encountered so far to do this in a correct way.

As mentioned in the paper, current standards and specifications have excluded a lot a features needed to support and describe collaboration in a complete fashion and the aim of the presented model is to afford this problem by creating an ontology to overcome this gap. The task itself is ambitious but completely necessary for the development of the area, discussion is open in every dimension of the CL world and we expect to contribute to the formalization of concepts and its discussion.

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