Wiring Role Taking in Collaborative Learning Environments. SNA and Semantic Web can improve CSCL script?

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Abstract—**Over the past years the concept of role in distance education has become a promising construct for analysing and facilitating collaborative processes and outcomes. Designing effective collaborative learning processes is a complex task that can be supported by existing good practices formulated as pedagogical patterns or scripts. Over the past years, the research on technology enhanced learning has shown that collaborative scripts for learning act as mediating artefacts not only designing educational scenarios but also structuring and prescribing roles and activities. Conversely, existing learning systems are not able to provide dynamic role management in the definition and execution of collaborative scripts. This work proposes the application of Social Network Analysis in order to evaluate the expertise level of a learner when he/she is acting, with an assigned role, within the execution of a collaborative script. Semantic extensions to both IMS Learning Design and Information Packaging specifications are also proposed to support roles management.**

Index Terms—**social network analysis, role management, learner profile, e-learning, learning design.**

I. INTRODUCTION

The research field on Technology Enhanced Education (TEE) suggests that the collaborative dimension is one of the most important factors to take into account when trying to ensure a high level of sustainability of e-learning. Computer Supported Collaborative Learning (CSCL) today, is a well-recognized field in literature and a challenging study, research and experimentation sector.

It is widely acknowledged that in CSCL the spontaneous collaboration through standard software does not necessarily lead learners to play functional and complementing roles that foster discussion, knowledge sharing and argumentation [1]. In order to overcome this difficulty, the scientific community has recently developed and sustained the validity of new theoretical approaches related to CSCL Scripts [2].

The collaboration scripts are didactic scenarios [3] that specify a sequence of collaborative phases through complex instructions. Different authors define CSCL scripts as "instructional sequences" that organize learning activities into phases. Each phase is defined by five specific items: the activity (or activities) that learners have to perform, the group composition, the assignment of roles (to learners within the group), the interaction modes and the phase timing.

CLSC scripts are fundamental to guide collaboration. Typically, the unguided collaboration among team members can lead to detrimental learning [4]. Scripts are expected to facilitate learning by guiding peers collaboration and engaging all participants in activities, that trigger the activation of their cognitive and metacognitive processes [21].

The concept of role is becoming a significant construct in CSCL, because roles also facilitate members' awareness of overall group performance and of peer contributions [5] and are relevant for distributing, coordinating and integrating sub-tasks to attain a common goal. The role taking is a core learning mechanism [6] and is defined as the assignment of roles and their functions to real learners in the context of CSCL group activities.

In order to take advantage from the opportunities offered by the CSCL scripts, the research needs to stand the strains toward effective solutions to exploit learners' expertise (manifested within a community environment) for improving the assignment of roles in the scripts instantiation phase.

Moreover, current languages for Learning Design (LD), as several studies demonstrate, have lacks and deficiencies in supporting the aspects related to the role taking [6]. Such languages have to be extended in order to fully support roles and facilitate the role taking task.

IMS-LD is an useful language to model a wide range of learning scenarios but it provides only a general description of the learning environment in which learners, tutors, etc. interact. The idea of the paper is to provide a mechanism to describe such environments in more details by using a well-known ontology namely SIOC. Although SIOC is not learning-specific it provides a ground to construct "environment template" to be used in specific instantiation of IMS-LD scenarios. Moreover, SIOC gives us the chance to "freeze" a collaboration session and reuse it in different scenarios and the chance to provide a better (with respect to IMS-LD) role specification for the collaborative script. The second main objective of the work is to support the role binding by means of an automatic tool able to suggest the most suitable user for a given role. These suggestions are generated by using a combination of SNA and CNA algorithms which can be applied on the data coming from previous collaboration sessions (possibly represented in SIOC).

In line with these considerations, this work proposes: (i) the extension of existing learner profiles specifications in order to add information about expertise levels the

learners manifest while playing specific roles within the execution of CSCL scripts, so to support automatic assignment of roles to learners improving the setting of collaborative groups; (ii) the extension of an existing learning design language (i.e. IMS Learning Design) to support role-based scripts; (iii) a method based on Social Network Analysis (SNA) able to evaluate the aforementioned expertise levels by analysing learners' interactions during CSCL scripts execution and the subsequent updating of learner profiles.

To achieve this aim, first of all the paper describes the background and motivations of this work and its contributions. Then, the scripted roles model will be presented and also our proposal of its implementation within the IMS Learning Design. The two final sections are devoted to integrate the SNA to update learner profiles (in their social and cognitive dimensions) and to simulate how this model works on web forums. At the end, the paper presents some conclusions and suggests some future works.

II. BACKGROUND AND MOTIVATIONS

A CSCL script can be described a set of instructions prescribing how students should form groups and how they could interact and collaborate to solve a problem [2]. IMS Learning Design[1] (IMS-LD) is a modelling language used to represent educational scripts (also CSCL scripts) enabling computer support for script definition and execution.

In the last years, several authoring tools and players, such as RELOAD, CopperAuthor, COSMOS, LAMS and Collage [7], have been developed, to facilitate the task of CSCL script design for learning scenarios. Some other tools [23] also allow the creation of dynamic CSCL scripts where the flow of activities changes according to learning outcomes [25] [26].

These tools are examples of general purpose editors that use IMS-LD to formalize the collaborative activity flows. Unfortunately IMS-LD seems to be not the best solution for roles definition and utilization.

The concept of role, used in IMS-LD, conflicts with the semantics usually assigned to the concept of group in CSCL [1]. In IMS-LD, a role also identifies a group of participants. During the instantiation phase, more than one participant can be assigned to the same role forming a group. Moreover, more than one role can be assigned to the same learning activity (by means of the role part construct) also using the same environment. In this way, it is possible to have more participants (with different roles) acting within the same learning activity.

Although, IMS-LD specifications do not explicitly support the possibility to define a group where its members play different roles, this is not impossible to simulate, by using IMS-LD, constructs and also to allow the assignment of the same learner with several roles to the same learning activity.

In fact, as described in [24], IMS-LD allows each user to play only one role at a time. Often, in real scenarios, a learner may play a role in a moment, for instance the "*listener*" and a different one in another moment, for instance a "*writer*" although he/she is in the same learning group.

We guess that the limitations of IMS-LD, with respect to roles and groups, are due to the general-purpose aim of this language. Furthermore, when a more detailed description of learning activities and environments is needed, the same limitations come out. The aforementioned limitations are more evident in collaborative learning scenarios, when the setting of groups is particularly critical.

This work proposes an approach that tries to overcome to the lacks of IMS-LD regarding the representation of CSCL scripts by exploiting SIOC[2] (Semantically-Interlinked Online Communities) ontology to represent collaborative environments and particularize roles.

With respect to roles identification, two perspectives emerge in the related literature: scripted roles and emergent roles [8]. Scripted roles are roles assigned by teacher (or other support actors) to structure the collaborative learning scenario; they improve both learning processes and their outcomes. Emergent roles are that roles that spontaneously raise or are negotiated by group members without any interference by the teachers (or other support actors) [27] [28]. In this paper, we mainly focus on scripted roles.

Scripted roles can be content-oriented (the summarizer role for example directly focuses on the learning content and can lead to higher levels of knowledge construction) as well a process-oriented (the project planner role, for example, fosters individual responsibility and coordination affecting learning indirectly) [8].

This work proposes both a taxonomy for scripted roles and an extension of the IMS Learner Information Packaging (IMS-LIP) specifications in order to take care about roles played by learners during the CSCL scripts execution and the score of proficiency with respect to their performances. In particular, the taxonomy is represented using SIOC schema in order to link roles with collaborative environment.

The presence of roles information in learner profiles and in collaborative environments is used to support instructors in binding learners, roles and groups appropriately within the CSCL scripts instantiation-enactment phase, so improving the development of cognitive and social capital inside a collaborative script.

The last component of the approach proposed in this paper concerns the evaluation of learners' performances during the execution of a CSCL script with respect to the role played. For this task, we propose the application of Social Network Analysis (SNA) techniques to evaluate the learners playing roles (represented with SIOC) within collaborative environments in the context of a CSCL script described using IMS-LD.

Used SNA techniques adopt specific indicators to state some individual and group features related to interaction patterns, taking shape during collaborative activities, e.g. density, centrality, cohesion. SNA techniques are used both to support teachers in assigning the right role to a specific learner during the enactment of an CSCL script and also in evaluating students on the base of the emerging roles they develop during interactions and collaborative activities.

The analysis considers two dimensions characterizing the interactions within a group of students: social (quantity

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[1] http://www.imsglobal.org/learningdesign/

[2] http://sioc-project.org/

and structures of the exchanges) and cognitive (contents of the exchanges).

III. ONE APPROACH FOR TWO CONTRIBUTIONS

Learner Profiles and SIOC Environments are central components. The latter provide two main features: (i) the semantic definition of collaborative environments with admissible roles, and (ii) the semantic organization of data produced during collaborative sessions.

The first contribution is exploited in the Learning Design phase where instructor designers map empty groups to one or more roles defined in the selected SIOC Environment. The second contribution is exploited by the Profile Update phase that uses data produced by SIOC environment during the collaborative session, in order to update Learner Profiles with new information (obtained through the application of SNA) regarding the ability of learners to play the assigned roles in the last collaborative learning experience.

Furthermore, Learner Profiles are also used to sustain the teacher (or other support actors) when he/she has to assign specific roles to learners during the Instantiation-Enactment phase, where some LMS services are used to get users' account information and bind them with the IMS-LD document (provided in the design step).

The main aspects of the proposed approach are shown in figure 1 where the life cycle of a CSCL script is depicted.
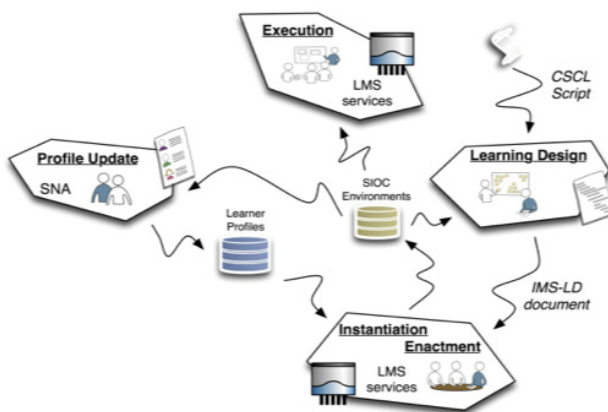

Figure 1. CSCL Script Lyfe Cycle

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During the Execution phase, the LMS services are also used to run the instantiated IMS-LD process with real users and to activate enabled collaborative services (described with the available SIOC Environments) referenced in the IMS-LD process itself. During the Execution phase, the LMS services also tracks in SIOC the actions and the data of users in the collaborative environment.

In the next sections, we will provide more details about (i) the model used to represent scripted roles information in Learner Profiles, (ii) the use of SIOC in order to define the structure of collaborative learning environments and their utilization in combination with IMS-LD, (iii) the application of SNA on SIOC data to calculate values estimating the ability of learners to play the assigned scripted roles.

IV. SCRIPTED ROLES IN LEARNER PROFILES

An approach that aims at defining effective (for knowledge construction) collaborative learning activities through dynamic binding of CSCL roles, needs to consider the Learner Profile as a critical structure at the centre of the system. Profile information include personal data, learning preferences, learning plans, learning history, accessibility requirements, competency assessments (skills, knowledge and attitudes), certifications, degrees, and the status of participation in the current learning.

A recommended solution for the interoperability problem is to work with standards and specifications as far as possible for modelling Learner Profiles. Among those available, PAPI Learner[3], IMS-LIP[4] and Dolog LP[5] focus on learner's performance and achievements while eduPerson[6] focuses on interoperability between higher education institutions. In particular, IMS-LIP is designed to describe the learner, to record and manage learning-related history, goals and accomplishments.

A previous work presents a general taxonomy [9] used by scientific community to classify the learner profile attributes into eight categories, where each of them is divided into sub-categories: personal data, relations, goals, achievements and learner's history, accessibility and preferences, interest, context, security. Since IMS-LIP offers the best covering of sub-categories in the aforementioned taxonomy, we choose to extend this schema in order to deal with the collaboration activities and, in particular, with CSCL roles.

The information, we would like to store within an IMS-LIP document, is related to each CSCL activity a specific learner is (or has been) involved in. For each activity, we propose to define at least the following tuple:

<typename, status, learningactivityref, name, scripttype, scriptedrole, level>

The IMS-LIP fields, exploited in order to store the aforementioned information, refer to the detailed information about activities in which the learner is involved in (activity data structure in the IMS-LIP

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specifications). In particular, the sub-fields to use are: "typename" (in this field we store the value "CSCL Activity"), "status" (for values like "Active", "Inactive", "Completed" and so on) and "learningactivityref" (we use it to refer to the activity identifier within the IMS-LD script).

The use of the extension field is also needed, so we propose the definition of the following three sub-fields: "scripttype" (the name of the executed CSCL script in which the learner is involved in), "scriptedrole" (the CSCL role played by the learner) and level (a value representing the ability of the learner to play his/her role).

Until now, the basic scripts recognized and formalized in literature (to be selected for the "scripttype" field) are Jigsaw, ArgueGraph, Peer Reviews, Dyade and Argumentation. From the scriptedrole viewpoint, it is possible to refer to some latest studies [8] that recognize content–oriented roles (i.e. Starter, Editor, Summarizer, Cybrarian, Revisioner, Info-Broker) and process-oriented roles (i.e. Task Manager, Balancer of Participation, Monitor, Critician, Theoretician, Disseminator).

Furthermore, the level presents a value that summarizes the ability of the played role. We can use the same vocabulary to represent the admissible values for this field: very active, active, passive or inactive.

With respect to figure 1, in the Instantiation-Enactment phase, the enriched learner profiles offer useful historical data that supports teachers when they have to assign roles to learners for specific CSCL script-based experiences. Being informed by a Learner Profile, a teacher can make his/her choice by considering the expertise and the ability of the learner to play a given role in a particular script or by stimulating the learner with a role never played in that context, and so on.

V.   EXTENDING IMS-LD ROLES SUPPORT

We have chosen IMS-LD to represent CSCL scripts, and we have focused on the main situation that we aim to handle: representing a collaborative activity (defined on the same environment, i.e. a Web forum) where two groups of learners are defined and each group gathers learners with several CSCL roles.

Because of the problems previously described in using IMS-LD to formalize the collaborative activity flows, we use SIOC to improve the IMS-LD roles to manage groups' information. In particular, we can build a tree starting from the root Learners (considered the group of all learners) where the second level is configured by segmenting the set of learners in two groups called "LearnersGroupOne" and "LearnersGroupTwo".

The third level of the tree is obtained by segmenting each second level group using the admissible roles e.g. if in the "LearnersGroupOne" includes only learners with roles of summarizers and disseminators, then we have to divide the group in the two subgroups "LearnersGroupOneSummarizers" and "LearnersGroupOneDisseminators".

This operation is repeated for all admissible roles and for all groups. Now, we can define the IMS-LD learning activity called "CollaborativeActivityOne". To establish which groups of users can act on such activity we define two IMS-LD role parts and attach them to the first IMS-LD act of the script. The role parts are:

- "CollaborativeActivityOneSummarizers", defined by linking the "LearnersGroupOneSummarizers" group to the "CollaborativeActivityOne" activity;
- "CollaborativeActivityOneDisseminators", defined by linking the "LearnersGroupOneDisseminators" group to the "CollaborativeActivityOne" activity.

In the same way, we can then define other role parts for the same activity with the others groups of the third level.

The next step consists in associating IMS-LD activities and collaborative environments. As already explained in previous sections, IMS-LD lacks of adequate support for the definition of collaborative environments and of CSCL roles. For this reason, we propose to use the SIOC ontology to define a class of collaborative environments including, for instance, Web forums, blogs, instant messaging, etc.

SIOC Environments have to be referenced by IMS-LD scripts such that the groups defined in IMS-LD have to be linked to the roles defined in SIOC. SIOC is able to exploit Semantic Web technologies to describe the information that online communities own about their structure and contents, and to find related information and new connections between content items and other community objects. Figure 2 represents main classes of the SIOC ontology.
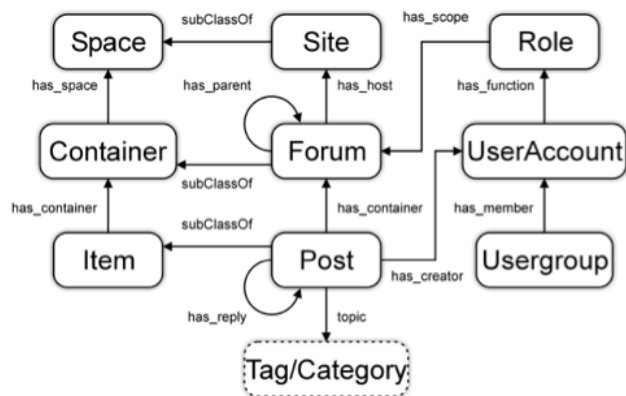

Figure 2.   SIOC main concepts

The SIOC Core Ontology is specified using RDF/OWL languages that make it easy for software to process some basic facts about the terms and consequently about the things described in SIOC documents [22].

In particular, we defined two subclasses of "sioc:Role" called "cscl:ScriptedRole" and "cscl:EmergentRole", but for the aims of this paper, we developed a model only for the first one. Then we focused on the first one by creating two subclasses called "cscl:ContentOrientedRole" and "cscl:ProcessOrientedRole". After, we defined

- "cscl:Starter",   "cscl:Cybrarian",   "cscl:Editor, cscl:Infobroker",   "cscl:Revisioner"   and "cscl:Summarizer"   as   sub-classes   of "cscl:ContentOrientedRole" and "cscl:Disseminator",
- "cscl:Balancer",   "cscl:Critician",   "cscl:Monitor", "cscl:Planner", "cscl:Theoretician" as subclasses of "cscl:ProcessOrientedRole".

To exploit the SIOC schema for defining a collaborative environment linked to a IMS-LD document, we need to create a forum by instantiating the "sioc:Forum" class and link it with instances of desired roles. An extended IMS-LD editor can support these tasks.

In Figure 3 we show a sample extension (the "imsld:SIOC" element is inserted into the existing "imsld:service" element) of IMS-LD specifications in order to support the definition of environments based on SIOC.
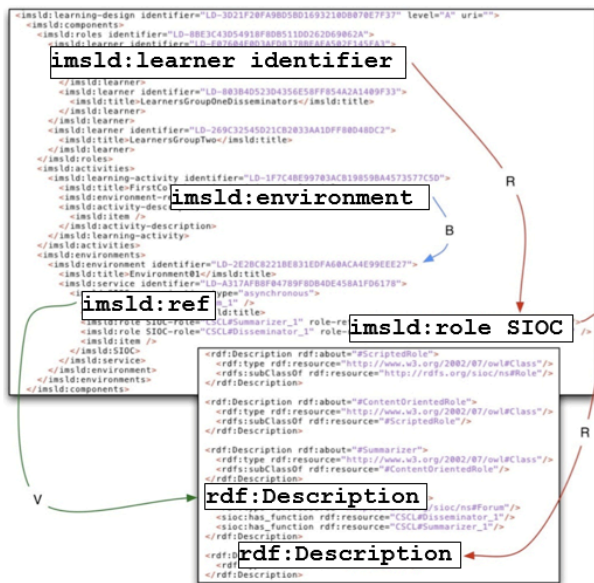

Figure 3.   References between IMS-LD and SIOC

In our example, we prepared a forum environment (CSCL#Forum_1) by instantiating the "sioc:Forum" class. The forum is linked to the environment defined in the IMS-LD document by means of the element "imsld:ref" within "imsld:SIOC".

Note that "FirstCollaborativeActivity" refers to the defined environment (arrow with label B in Figure 3). Moreover, the property "sioc:has_function" is used to link the created environment to the instances ("CSCL#Disseminator_1" and "CSCL#Summarizer_1") of specific roles that are able to act in it. It is important to show (arrow with label R in figure 3) that there is a correlation between groups defined in the IMS-LD document and roles defined in the SIOC document.

This correlation allows to associate CSCL roles to groups of learners (real people is linked to IMS-LD groups during the instantiation-enactment phase).

VI.   APPLYING SNA TO UPDATE LEARNER PROFILES

The analysis of the significant interactions (role social dimension) and of the knowledge acquisition (role cognitive dimension) of a learner within a collaborative group can be exploited in order to assign a value summarizing the ability of a learner to play some specific scripted roles.

The two aforementioned dimensions can be analysed by using the Social Network Analysis (SNA). In particular, we take care of the following: (i) the actions of an individual X are not independent from the actions of an individual Y (in fact, a message sent by X to Y is computed in the out-degree of X and in the in-degree of Y). Obviously, here it isn't considered whether a message has been read or not, while in the case of reading posts (as it will be clarified in table I) the dependency between individual actions of two actors hasn't the same

dependency; (ii) the messages between learners (social dimension) and co-occurrences of words in user-generated texts (cognitive dimension) are also important to our aims.

In the latter case, more than monitoring and analysing the specific roles played by students, SNA allows to weigh the participation/contribution of each student to the activity.

A.   Social dimension

The social dimension could be seen as the relational level of CSCL roles and be identified by using SNA applied to messages exchanges between learners during one or many collaborative sessions [10]. Before starting to describe SNA indices and the related roles, we clarify some aspects about data elaboration for deriving the SNA indices.

In particular, we focus on learners within an on-line group that cooperate within a Web Forum (instance of the class "sioc:Forum") with discussion topics and posts (instances of the class "sioc:Post"). Discussion topics indicate different arguments that are discussed by the participants. Posts are messages written by users to participate in a discussion and are associated to a specific topic (started by an authorized user with a post).

A discussion thread (instance of the class "sioc:Thread") is a sequence of post p1, …, pn where pi is a reply (properties "sioc:has_reply" and "sioc:reply_of") to pj (with i > j). Typically, if the post pi is a reply to pj then the title of pi is formed by concatenating the string "Re:" to the title of pj. Thus, from a SNA perspective, each message sent by the student X to the student Y is computed as a connection from X (out-degree) to Y (in-degree) and it determines the total degree (in and out) of each of the two students.

At the same time, by considering a weighted model that takes into account all the messages sent and received by all members, it is possible to derive the interactional structure of the group and determine the relevance of each member for the collective activity and the structural functioning of the whole group.

From this point of view and as regards the scripted roles, the social dimension focuses on process-oriented scripted roles (as defined in the previous sections). As regards the emerging roles, the social dimension allows the teacher to analyse and evaluate the students' involvement in group discussion, their central or peripheral participation, their influence in proposing idea or in mediating relations, etc.

The next step is to define which SNA indices could be more effective for describing (and analysing) specific types of roles. In table I there's our non-exhaustive proposal about SNA indices particularly effective to evaluate learners' ability to play some specific process-oriented role. These SNA individual indices have been chosen by considering their connection to two of the most important dimensions measured by the SNA to analyse group management: density (a whole measure about the group interactivity in terms of connections, messages sent or receives and, in our case, also message reading) and centralization (a whole measure of the leadership of a group in terms of closeness to the group members, power in intermediate interactions and flow of information managed.

TABLE I.   MAPPING BETWEEN SNA INDICATORS AND CSCL PROCESS-ORIENTED ROLES

SNA Index	Description	Roles
Neighbourhood degree (in and out)	This index is represented by two measures: *in-degree* and *out-degree*. The in-degree of a learner *X* is the number of learners who have written posts in reply to posts of *X*, while its *out-degree* is the number of learners to which *he/she* replies with at least one post.	High values for *in-degree* and *out-degree* measures indicate that learner *X* has been a good *Disseminator* and/or a good *Monitor*.
Messages sent (out) and received (in)	This index is calculated (for a learner *X*) as the ratio between sent messages (posts written by *X*) and received messages (posts written by other participants in reply to *X*'s posts).	A *Disseminator* presents a ratio in favour of sent messages, while a *Critician* provides punctual interventions with prevalence of received messages. A *Balancer* expects a more or less equal responsiveness ratio.
Messages reading	This index is calculated (for a learner *X*) as the ratio between the received messages (posts written by other participants in reply to *X*'s posts) and the number of messages that have been read by *X* (to capture this information we need to track user actions).	For a *Monitor*, it is important to have low values for this index.
Closeness centrality	It identifies learner *X*'s centrality basing on her/his closeness (in terms of direct and indirect ties) to other participants. It is calculated as the inverse of the sum of the distances between *X* and other participants. The distance between learner *X* and learner *Y* can be defined as the minimum distance (considering all discussion threads) between a post of *Y* and a reply of *X* [17].	*Disseminators* and *Criticians* typically have high values for the closeness centrality index.
Betweenness Centrality	It identifies the learner *X*'s centrality basing on her/his mediation function in interactions. This measure is calculated as the sum (for all couple of learners *A* and *B*) of the ratios between the number of shortest paths (between posts of *A* and *B*) containing a post of *X* and the total number of short paths (between posts of *A* and *B*) [17].	*Balancers* have high values for this index (high centrality).
Flow Between Centrality	It identifies a student's centrality basing on the quantity of information she/he manages compared with group total [17].	*Disseminators* have high centrality, *Balancers* have medium centrality, *Task Managers/Planners* have medium/low centrality.

B. Cognitive dimension

The cognitive dimension foresees the application of SNA to the textual data to observe how to the argumentations of a learner are central with respect to the knowledge domain. This dimension focuses on content-oriented scripted roles (as defined in the previous sections). Many scholars have recently suggested the effectiveness of mixing SNA with Text Analysis [11; 12; 13], particularly in studies in which the analysed texts derive from an interactive and collaborative work within a group [14; 15; 16]. The idea is to use the Network Text Analysis (NTA) on tags attached to any single post of the Web forum. For each post *p* we consider the existence of $tag_1, …, tag_n$.

Tags can be represented in a SIOC Environment using the SCOT ontology[7]. In particular, a "scot:Tag" instance is related to an instance of "sioc:Post" by means of the scot:tagOf property. By using the model proposed in [18], the SIOC Environment derives the matrix of similarity i.e. the matrix that shows the co-occurrences of terms, namely the strength of their association inside a given text.

By applying SNA to this matrix, it is so possible to look at the structure of discussions, by focalizing on more central (relevant) or peripheral lemmas of the discussion, regarding the whole group or each member. By comparing lemmas of the whole group's discussions with lemmas proposed by each student, it will be possible to have an idea of the relevance of his/her contribution to the discussion.

As for the social dimension, also for the cognitive dimension the first step is to define SNA indices that can be effective in monitoring and analysing this dimension of interactions. The table II presents two SNA indices that in our opinion are useful for evaluating the ability of learners to play some specific process-oriented role.

Social and cognitive dimensions define different and important aspects of collaboration activities within a group. The social dimension represents for the teacher a sort of student's profile perspective about his/her manner of collaborating by considering the interactions with other group's participants (neighbourhood degree and messages sent and received), the attention devoted to his/her network (messages reading), his/her leadership and status (closeness and flow between centrality), and also his/her mediating role (betweenness centrality).

The cognitive dimension gives teacher another type of student's profile focused on the centrality of the content that he/she has generated with respect to his/her goals. These two aspects represent also the specificity of our model with respect to previous models which focalised their attention principally on the structure of exchanges and therefore only on the social dimension [19].

In our perspective, both dimensions are crucial since a student could have many connections and exchanges with other students, but the content of the messages could be out of topics and not give relevant contribution to the collective goal. Otherwise, a content that is very focused on the main topics could seem not so important if the student is not central and active during the collaboration activities.

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7 http://scot-project.org/

TABLE II.
MAPPING BETWEEN SNA INDICATORS AND CSCL CONTENT-ORIENTED ROLES

SNA Index	Description	Roles
Degree centrality	It identifies the centrality of a term by means of quantity of connections of a term with other terms, i.e. the more a term has connection with other terms, the more it is central. In our vision the *degree centrality* of tag X is the ratio between the number of different tags used in the Web forum together (to tag the same posts) with X and the total number of different tags used in the web forum.	*Starters* have high *degree centrality* values because the discussions start from their contributions. *Revisioners* also have high values for this index.
Eigenvector centrality	It defines the centrality of a term not only by means of quantity of connections, but also by considering the centrality of the related terms. The more a term is connected to terms with high *centrality*, the more it is central. In our vision the eigenvector centrality of a tag X is computed by summing all degree of centrality of tags used together (to tag the same posts) with tag X.	*Summarizers* and *Infobrokers* have high values for eigenvector centrality index because they have to follow the main subjects of discussion.

VII. APPLICATION OF THE MODEL TO WEB FORUMS

After having described and defined the SNA indices that compose our model, we propose an example that could help in clarifying and understanding the effectiveness of SNA in monitoring and analysing scripted and emerging roles.

SNA is applied to SIOC data coming from collaborative sessions during a CSCL script execution. This work deals with the case of collaborative sessions based on discussion Forums, but the approach is general because SIOC is able to model data coming from several collaborative tools (e.g. blogs, wikis, instant messaging, etc.).

At the same time, in SIOC data, there is a registration of the messages' content and this allows the application of Network Text Analysis (NTA) to messages' contents. In particular, the analysis is focused on how the argumentations of a learner are central with respect to the treated knowledge domain (the discussions).

The table III shows which types of SNA and NTA indexes are associated to some of the scripted roles proposed in [20]. In particular, we will focus on four process-oriented roles (Disseminator, Monitor, Balancer and Task Manager) and four content-oriented roles (Starter, Summarizer, Revisioner an Info-broker).

The table suggests which types of SNA and NTA indices are pertinent in analysing specific roles and, based on what is expected from the specific roles, it defines the foreseen level of the most important indices. It can be used for monitoring (on-going) and analysing (retrospectively) the adaptation of users to the assigned roles.

The role of "disseminator" should be characterized by a high value in neighbourhood degrees since this means that it has relations with many other members of a group. At the same time, a disseminator should also be very central as regards the closeness centrality, i.e. he's very next (in SNA terms) to many other group members. Finally, a disseminator should also have a high value in flow between centrality since it is expected that he/she manages many information compared with the other members.

For the "monitor", it is more important to have relations with many other members of the group (high neighbourhood centrality) for having and perceiving the "feelings" of participation of the entire community. The balancer, on the contrary, has the principal functions of mediating between different ideas and positions (high value in betweenness centrality) and take into account the many different points of view (high value in flow between centrality).

The "task manager" needs relations with all the community members for managing the task completion (high value in neighborhood degree) and to manage many types of flow of information (high degree in flow between centrality) for the better organization of community activities.

For the role of "starter", it is important to have many relations (neighbourhood degree) and quick connections (closeness) with the other community members, but he/she should also have a high relevance as regards the contents proposed (degree centrality). The same is for the role of info-broker, even though in this case it is more important that he/she suggests the most important contents emerged during discussions (eigenvector centrality).

The role of "summarizer" needs to take into consideration the most important contents coming from discussions (eigenvector centrality) and reorganize them for a summary to send quickly to all the other group members (closeness centrality). Finally, the functions expected from a revisioner need relations with many other members (neighborhood degree) in order to consider the different ideas and points of view evolved during discussions (that should be found in the relevance of the subject treated).

TABLE III.
EXAMPLES OF SCRIPTED ROLES AND THEIR RELATIVE SNA INDEXES

SNA indexes	applied to relations and exchanges				applied to contents (NTA)	
Scripted Roles	Neighborhood Degrees	Closeness Centrality	Betweenness Centrality	Flow Between Centrality	Degree Centrality	Eigenvector Centrality
Disseminator	High	High		High		
Monitor	High					
Balancer			High	High		
Task Manager	High			High		
Starter	High	High			High	
Summarizer		High				High
Revisioner					High	
Infobrokers	High	High				High

VIII. CONCLUSIONS AND FUTURE WORKS

In this paper, we proposed an approach aiming to improve the whole IMS-LD life cycle in order to support the role taking for CSCL scripts.

In particular, we have extended: (i) the IMS-LD design phase by exploiting SIOC to define collaborative environments and their admissible roles, (ii) the IMS-LD instantiation-enactment phase by extending the learner profiles by using information on the ability of learners in

playing some specific roles, (iii) the IMS-LD execution phase by evaluating the learners' role playing, using the Social Network Analysis (SNA).

The most important and novel aspect of the proposed approach resides in the two methods used to construct students' profiles: SNA and text analysis (the NTA). Thanks to the integration of the two methods, it is possible to differentiate the students' participation (active and passive) into the collaborative web environments, not only on the base of quantitative data (such as quantities of contacts, messages, etc.), but also by taking into account the contents of those messages and their relevance within the group discussions.

Starting from this work, future Web Learning Environment (WLE) should be designed to allow teacher to define ongoing user's profile based on indices proposed on this paper so that group collaboration can be as effective as possible. At the same time, the suggestion of this paper drives to design WLE that, if necessary, allows a diversification of tools and contents based on the students' profiles as regards both their relations and exchanges, but also their contents relevance and interests.

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