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Studying participatory aspects of learning by means of a mixed evaluation method through three case studies

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Abstract This paper describes the application of a mixed-evaluation method, published elsewhere, to three different learning scenarios. The method defines how to combine social network analysis with qualitative and quantitative analysis in order to study participatory aspects of learning in CSCL contexts. The three case studies include a course-long, blended learning experience evaluated as the course develops; a course-long, distance learning experience evaluated at the end of the course; and a synchronous experience of a few hours duration. These scenarios show that the analysis techniques and data collection and processing tools are flexible enough to be applied in different conditions. In particular, SAMSA, a tool that processes

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interaction data to allow social network analysis, is useful with different types of interactions (indirect asynchronous or direct synchronous interactions) and different data representations. Furthermore, the predefined types of social networks and indexes selected are shown to be appropriate for measuring structural aspects of interaction in these CSCL scenarios. These elements are usable and their results comprehensible by education practitioners. Finally, the experiments show that the mixed-evaluation method and its computational tools allow researchers to efficiently achieve a deeper and more reliable evaluation through complementarity and the triangulation of different data sources. The three experiments described show the particular benefits of each of the data sources and analysis techniques.

Keywords Authentic learning scenarios • BSCW • Empirical case studies • Interaction analysis tool • Interpretive evaluation • Mixed evaluation methods • Situated learning • Social network analysis • Participatory aspects of learning

Introduction

The application of computer-supported collaborative learning (CSCL) techniques to authentic learning scenarios demands new theoretical and practical tools to analyze and assess the learning processes. Computer-assisted tools that process interaction data in order to provide different functionalities (e.g., monitoring, advice, etc.) are currently an active line of research in the field Soller et al., (2005). In spite of this interest, there is a lack of tools to support teachers in the regulation and assessment of their students' collaborative activities Dimitracopoulou (2005).

In regard to the need of theoretical frameworks to analyze CSCL experiences, the situated learning perspective Lave and Wenger, (1991); Wenger, (1998) provides an appropriate approach to study and understand learning in authentic situations. It considers the social and cultural contexts in which the experiences are produced, and emphasizes the close interweaving between the social and the individual aspects of human activity Wilson and Myers, (2000). The situated standpoint considers learning as participation in the social world. This participation has to be understood in terms of the *participatory metaphor* Sfard, (1998), which identifies participation with the process of becoming a member of a certain community. In CSCL, these forms of participation are externalized by interactions among the members of the community, which are totally or partially mediated by the computer. Therefore, from a situated standpoint, the analysis of learning in CSCL must take into account these computer-mediated interactions in the context of global methods that support the understanding of the meaning participants give to these interactions.

Social network analysis (SNA), Scott, (2000); Wasserman and Faust, (1994) is an appropriate discipline for the study of these forms of interaction. In contrast with the individualistic perspective that has dominated traditional research methods, SNA focuses on the study of the interrelationships among individuals and introduces 'structural variables' to measure them. SNA challenges assumptions of the statistical independence of social actors, and is in agreement with the emphasis on the mutual influence between individuals and their contexts of the situated approach. In recent years, social network analysis has been successfully applied in CSCL scenarios to the study of these participatory aspects of learning Nurmela et al., (1999); Cho et al., (2002); Reffay and Chanier, (2003); Harrer et al., (2005); Reyes and Tchounikine, (2005).

These works are mostly research-oriented studies that take computer logs as the input data and perform specialized social network analysis with the support of available software tools such as Ucinet Borgatti et al., (2002). This is normally complemented with other types of analysis, like qualitative analysis, which help to provide a deeper insight on the processes, such as including the content and meaning of the interaction in the study of practice Wenger, (1998), p. 283.

In spite of the contribution that these works have made to show the actual benefits of social network analysis, they do not describe generic procedures or provide practical tools that could be used by end users to perform similar analysis.

Therefore, there is a need to offer conceptual and practical tools that support end users in general, and practitioners in particular, in the analysis and assessment of participatory aspects of learning. In order to accommodate this demand, we have proposed a *mixed-evaluation method* Martínez et al., (2003a) that defines the combination of different sources of data (including ethnographic and automatically collected data) and analysis approaches (quantitative, qualitative and social network) in order to fulfill the requirements posed by CSCL situations.

The combination of data sources and analysis techniques frames the proposal within the mixed-evaluation-method approach Frechtling and Sharp, (1997); Greene et al., (1989); Johnson and Onwuegbuzie, (2004). This approach advocates for the opportunistic selection of qualitative and quantitative data collecting and analysis techniques in order to achieve the desired evaluation goals. Our proposal focuses on the complementarity and triangulation of the data sources and analysis techniques in order to achieve deep and reliable results; and in defining an evaluation schema that provides a more efficient process than a pure qualitative approach.

This paper assesses to what extent this framework is *generic*, so that it can be adapted to different learning contexts and evaluation objectives, and whether the social network analysis elements and tools defined for the framework are *appropriate* to measure structural properties of the interactions in CSCL experiences in an *efficient* way so that practitioners can use them without disrupting the normal activity in their classrooms too much. In order to validate these properties, this paper focuses on the application of the method to three empirical case studies and discusses the main conclusions obtained from them regarding the validation of the method. These case studies represent very different CSCL situations, from virtual to face-to-face-settings, as well as synchronous and asynchronous types of interaction. These situations were carefully selected to maximize feedback in the validation of the method.

The rest of the paper is structured as follows: the next section introduces the main characteristics of the mixed method, providing the basic information needed to understand its application to the three case studies that were used to validate it. Then, the paper describes how this validation was carried out: it outlines the main characteristics of each case study, presents an overview of the actual evaluations, and discusses the results obtained regarding the properties being assessed in each case study. The paper then summarizes the global results obtained regarding the validation of the mixed method. Finally, it presents the main conclusions and outlines the open research questions that have emerged from the empirical work reported in this paper.

Mixed method for the evaluation of participatory aspects of learning

The mixed method summarized in this section was proposed in Martínez et al., (2003a) in order to face the demands posed by CSCL to the evaluation of participatory aspects of learning. One of the most important requirements was the need to adapt the data collection and analysis techniques to the variety of evaluation contexts that can be encountered in CSCL. For this reason the proposal is not a monolithic method, but a generic framework defining an evaluation skeleton that has to be customized for each experience.

The overall evaluation approach draws on the principles of the qualitative case study research Stake, (1995), which is based on naturalistic research methods able to deal with the subjective and complex nature of the studied phenomena. However, the demands and opportunities posed by the new CSCL scenarios, as well as the need to provide a more efficient approach than the pure qualitative analysis, moved us toward the definition of a mixed-evaluation method. With this approach, we aim at defining a flexible evaluation schema that combines the new data collection and analysis methods provided by CSCL environments with more traditional ones (such as observations and interviews). This way, the evaluation can benefit from their complementarities.

The rest of this section outlines the main characteristics of the method. The purpose is not to describe it in full detail, but to provide the basic information for the understanding of the case studies. A more comprehensive description of the method can be found in Martínez et al., (2003a).

Method life cycle

The mixed-evaluation method, as depicted in Figure 1, uses several data sources and analysis techniques and is supported by automatic tools to increase the efficiency of the overall process.

In the method, all the analysis techniques are fed with data coming from different sources, from automatically collected log files to different types of ethnographic data. These sources aim to capture the different forms of interaction that arise in computer-network supported environments. The analysis techniques include quantitative, qualitative, and social network analysis. Quantitative analysis is used to account for the occurrence of actions or events, capture general tendencies in the studied phenomena, and relate them with the qualitative categories. Social network analysis has been introduced due to our interest in the study of participatory aspects of learning. Moreover, the social network and quantitative analysis act as "filters" that help to detect special or critical issues, e.g., aspects that catch the evaluator's attention and become the focus of the qualitative analysis, which is then used to understand these issues more deeply. This combination facilitates a more efficient method than a pure qualitative approach without loosing its strengths. Additionally, it provides for method as well as data triangulation, thus leading to an increase in the reliability of the results.

As shown in Figure 1, the study starts with the definition of a scheme of categories. This can be done empirically, based on the results of past experiences, or theoretically, according to the evaluation objectives. This scheme is refined during the study

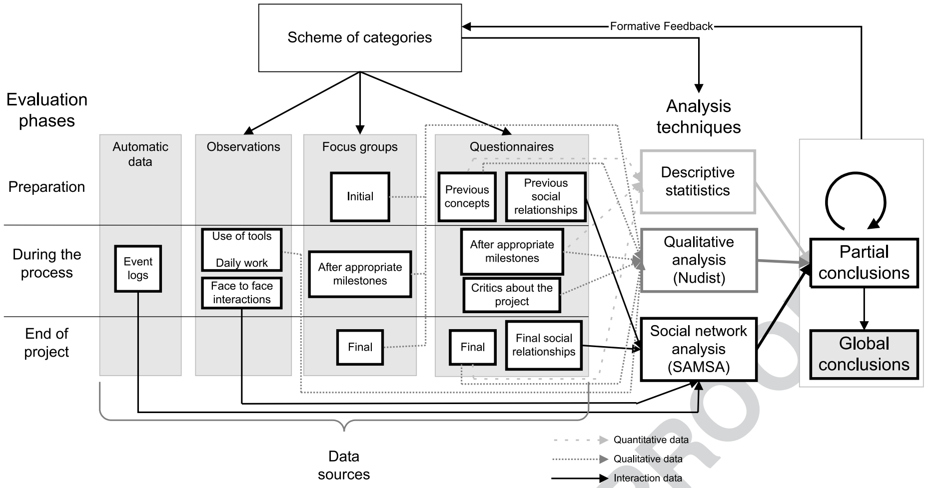

Figure 1 The proposed mixed evaluation scheme: data sources, methodology, timing, and analysis tools. Arrows show information flow paths

by the specialization of existing categories or the addition of new ones that emerge from the analysis.

The evaluation is a longitudinal process that evolves cyclically throughout the experience. In the first stages each type of analysis is performed independently, providing partial conclusions that can be confirmed or rejected by triangulation, or that can produce a new cycle of the evaluation process in order to gain insight about an emergent aspect. The main products expected from this process are the refinement of the initial scheme of categories and general conclusions that provide formative feedback on different aspects of the learning situation. Although this framework was initially thought to be useful for the evaluators or teachers involved in an action-research experience, further consideration indicates the results might also be used by different actors, such as the students themselves.

Integration of SNA in the mixed method

Taking into account that the proposal is oriented to end users, special care was taken in order to introduce SNA techniques in a way that is easy to interpret and use by non-experts. This need was addressed in the mixed method by the identification of a reduced set of SNA indicators, the definition of a small set of generic social networks suitable to represent CSCL relationships, and the development of a specific software tool to support the social analysis process.

In regard to the indicators, we identified the following SNA indexes to enable the study of participatory aspects of learning: *network density* (D), *actor's degree centrality* ($C_D(n_i)$), and *network degree centralization* (C_D) Wasserman and Faust, (1994). All of these indexes provide basic information about both the activity of the actors in the network and about its global structure. The appropriateness of these indexes for the mixed method is also confirmed by their use in other CSCL studies (see e.g. Nurmela et al., (2003); Harrer et al., (2005)).

In addition to the indexes, the proposal includes the definition of three types of generic networks suitable for the study of social interactions in computer-supported collaborative scenarios. They are: *direct relationship networks*, built from relationships between two actors (such as e-mail mediated interactions); *indirect relationship networks*, built from relationships that have been established through a shared object (like the creation and later reading of a document in a shared workspace); and *use of resources networks*, which are two-mode networks that relate actors and objects of the environment. The definition of these relationships builds on the generic model of collaborative action presented in Martínez et al., (2003b). This model defines three types of interaction (direct, indirect, and participation) that can be easily matched to the mentioned relationships. These generic networks can be particularized for each evaluation scenario, as will be shown in the following section.

Finally, the graphical visualization of the networks by means of sociograms can be considered a major feature of SNA for enabling evaluation processes. Using appropriate localization algorithms, such as multidimensional scaling (MDS), a sociogram can show important information subgroups of highly inter-related actors, relevant positions like the more and less prominent actors, etc. in an intuitive manner, Scott, (2000); Wasserman and Faust, (1994). The proposed mixed method considers the use of these graphical representations as a basic step in the analysis.

Tools that support the method

The mixed method includes a number of software systems that support evaluators in performing part of their tasks.

An important step in any social network analysis process is the conversion between the raw data representing basic interactions to social networks. In order to support this conversion, we have developed a tool called SAMSA (System for Adjacency Matrix and Sociogram-based Analysis). The input to this tool is composed by the interaction data represented in an XML syntax based on the aforementioned model of collaborative action Martínez et al., (2003b), and by the configuration parameters that customize the network. These parameters are: the set of actors, the type of the interactions that will represent the relationships in the network, and the time period (i.e., the initial and final dates) considered in the analysis. With this input, SAMSA builds a sociomatrix representing the social network and computes the indexes described in the previous section. It also shows the sociogram based on MDS and allows for the visualization of the actors' attributes.

In addition to SAMSA, the mixed method is supported by a tool that enables the management of questionnaires, Quest Gómez et al., (2002). Additionally, the framework defines the use of external software packages for the analysis of qualitative (Nud*IST; QSR, QSR, (1997)) and quantitative (any spreadsheet editor) data. As an aside, we shall mention here that Quest also serves as a support for collaborative activities by means of its use as a discussion facilitating tool.

Description of the three case studies

We undertook three case studies to validate the proposal and to assess its generality and the appropriateness of the social network elements defined in the method for studying the structure of interaction in CSCL. This section introduces the rationale for the selection of these experiences as the validation case studies and then it describes them, focusing on the main topics addressed in the actual evaluations.

A first decision was to apply the method to at least three cases to enlarge the scope of the validation and to avoid possible biases. However, this objective was problematic, because the mixed method requires the active participation of a group of evaluators in the collection and analysis of data in authentic learning scenarios during a certain period of time. It is difficult for a single team of teachers to have enough resources to perform three simultaneous case studies meeting these requirements. Therefore, the strategy followed was to perform one complete case study and complement its findings with two others that partially covered the evaluation principles described in the method. The three case studies were the following: the application of the mixed method to a Computer Architecture course in the University of Valladolid (CA-UVA case), a post-hoc evaluation at the "Application of Information Systems to Business" course at the Open University of Catalonia (AIB-OUC case), and the study of the use of an application oriented to the collaborative resolution of puzzles (Magic Puzzle case). While the first scenario was evaluated concurrent to the experience, using all data collection and analysis techniques and tools, the other two were evaluated after the experience was concluded and used only a few of the techniques and tools. This fact allows us to assess the importance of each of the data sources, the analysis techniques, and the computational tools. This is an important issue because our method aims to be adaptable to different scenarios and, therefore, it is necessary to identify, for each type of scenario, what elements of the proposal are compulsory in order to fulfill the evaluation objectives.

The three case studies and their main characteristics are shown in Table 1. As can be seen, the cases represent quite varied situations in the studied dimensions, which is another reason why these cases were expected to provide a good validation of the ideas of the mixed-evaluation method.

The following subsections describe the case studies in more detail. The description of each case includes an overview of the educational scenario to which it was applied; the validation objectives, i.e., the aspects of the method that were to be assessed with the experience; the evaluation design, explaining how the mixed method was adapted to the case; a summary of the main results obtained with the evaluation; and finally, a discussion of the lessons learned in each experience as they relate to the assessment of the method.

Table 1 Characteristics of the three case studies introduced in this paper

	CA-UVA	AIB-OUC	Magic Puzzle
Experience	Real	Real	Experimental
Num. of students	>100	> 130	2–4
Interaction (time)	Asynchronous	Asynchronous	Synchronous
Interaction (space)	Blended	Distance	Face-to-face
Scenario	Open task	Open task	Close task
Validation objective	Whole method	Off-line evaluation applied to a distance setting	SNA applied to restricted scenarios

Case CA-UVA: Validation of the overall approach

Learning scenario

The CA-UVA case is based on a longitudinal study that has been carried out during the last four years in the context of an educational research project Martínez et al., (2003a); Martínez et al., (2005).

The experience takes place in an undergraduate Computer Architecture course. This course is part of the core body of knowledge in the Telecommunications Engineering curriculum in Spanish universities. The 13-week-long semester is structured as a large project, divided into three sub-projects of about four weeks each. Students are organized in groups of two people, and assume different roles within the project (consultants and manufacturers) related to a case study that is modeled on a customer request. Instead of proposing only one customer request (i.e., case study) for all teams, five different situations are considered each year, but each group of students deals only with one of them. The fact that the groups of students have different customer requests enriches the learning process and promotes a more critical attitude, due to the contrasting requirements and solutions.

The CSCL systems used were: BSCW for document sharing and asynchronous communication and Quest Gómez et al., (2002), which supports synchronous debates in the classroom based on the results of previously submitted questionnaires completed by students with their opinions about the topics under discussion.

Validation objective

The validation objective in this case was to assess the evaluation method as a whole, with a special focus on the combination of the different sources of data and analysis techniques. More specific issues were also considered, such as the importance of the participation of teachers and students in the evaluation, the role of the data analysis tools to improve the efficiency of the process, and the extra workload that the evaluation added to the teachers and the students.

Evaluation design

The intrinsic evaluation objective was to study how students' ideas and attitudes towards collaboration evolved during the course, how this evolution was reflected in the social interactions among the different actors (students and teachers), and what was the influence of the resources (BSCW, laboratory) in this evolution.

With this objective, an initial scheme of categories was defined. The scheme consisted of six main categories that were themselves subdivided into more specific ones, resulting in 24 categories overall. Two of the main categories were "educational design" and "concept of collaboration." The former relates to the course schedule, its organization, and the teaching style. The latter was divided in several subcategories regarding the way in which students collaborate and how they perceive this collaboration.

The sources of data and analysis techniques used for this study resembled the generic scheme proposed in the mixed method (see Figure 1). The automatic data were provided by the BSCW log files. One external observer took systematic observations during the course in one of the laboratory groups. Four focus-group sessions were held with a group of ten volunteers, at the beginning and the end of the course, as well as after each sub-project submission. Finally, several questionnaires were collected during the course providing both quantitative and qualitative data.

The social network analysis was mainly based on the study of indirect relationship networks through BSCW. These networks were adapted to this case to represent the links between the actors who created a document in BSCW and those who read it. Additionally, we used social networks representing face-to-face interactions at the laboratory, based on interaction maps annotated by an external observer, and social networks representing the subjective perception of the interactions, obtained from specific questionnaires submitted to the students at the beginning and at the end of the course.

For each aspect being studied, assisted by the automatic tools that support the process (SAMSA and Quest), the evaluator carried out an initial analysis based on these networks, and/or on the quantitative data from questionnaires. Then the qualitative analysis was performed, focusing on the study of the aspects raised by these results. As mentioned before, this procedure increased the efficiency of the overall process, whose more demanding tasks are by far those related to the qualitative analysis.

The teacher was involved in the observations and the analysis process. Several iterations of the proposed mixed-analysis cycle were carried out during the course. The short-term results were used by the teachers in order to introduce changes in the course design that helped to achieve the desired education goals.

Main results

Due to space constraints it is not possible to describe the full analysis performed during all four years the experience has been applied and systematically evaluated. The main results related to the analysis of the pedagogical design itself and to the evolution of the concept of collaboration among the students are discussed in Martínez et al., (2005) and Martínez et al., (2003a), respectively. In this section we will focus on the analysis of the formative profiles promoted by the pedagogical design of this case.

The pedagogical design of the course, based on the principles of constructivism, promotes a change in the traditional roles of both teachers and students. Students are expected to be active and collaborative, whereas the teacher is expected to become a facilitator instead of the source of the knowledge. This change of roles can be described in more general terms as a formative profile of both students and teachers. We decided to focus on the study of these formative profiles after a first iteration of the method, using data gathered from social networks and qualitative analysis. In order to illustrate the analysis procedure, the rest of this section is devoted to show how the evolution of the teacher profile was studied.

Initially, the study of the social networks representing indirect relationships through BSCW helped to analyze whether students had an active role (i.e., create and read each others' contributions) or not. A high value of centralization (C_D), close to 100%, would mean that a reduced number of actors were active. As these networks are asymmetric, two values were computed: out-degree centralization (C_{OD}) and in-degree centralization, measuring the concentration of links starting and ending in the nodes, respectively. At an individual level, the normalized out-degree centrality of an actor ($c_{OD}(n_i)$) measures the percentage of actors that have read documents created by n_i, while the normalized in-degree centrality ($c_{ID}(n_i)$), reflects the percentage of actors that provided documents actor n_i has read. In a traditional teaching style the teacher simply transmits knowledge. Thus, the network would have had a very high C_{OD} (the teacher is the source of all links), and a low C_{ID} (most actors only receive links from the teacher). On the other hand, a network where actors share their work and read each others' reports would have a lower C_{OD}, and maybe a higher C_{ID}, possibly due to the teacher (and a sub-set of students) reading all the students' contributions.

Table 2 shows theses indexes along the three subprojects (Sp1, Sp2 and Sp3) for the teacher ($x00$) and some relevant student pairs ($x21, x23 \ldots$), as well as the network indexes (bottom line). In the first subproject, the out-degree centralization was very high (C_{OD}=82.40%), and several students had a null c_{OD}. These values made the teacher aware that he should encourage students to produce more documents to share. During the following phases of the course the evolution was positive: C_{OD} decreased, while C_{ID} maintained its value, between 40 and 50%, always lower than C_{OD}.

The sociograms representing the first and last phases of the course (see Figure 2) enable both a general overview of the evolution of the network as a whole, and of the properties of individual actors. At a global level, it is outstanding how the network became denser by the end of the course (it evolved from $D = 21.93\%$ to $D = 35.98\%$), showing a higher document exchange. At an individual level, the sociograms help to identify actors with special positions. For example, $x214$ and $x32$ are always peripheral, while the teacher $x00$ and some students, like $x22$, $x26$ or $x33$, keep the central positions in both phases. Finally, some students show an evolution in their participation that brings them from the periphery to the center ($x23$, $x24$, $x36$ and $x37$). These qualitative perceptions are supported by the centrality indexes shown in Table 2. The out-degree centrality of the teacher c_{OD} ($x00$) was always 100%, since all students read his documents. However, his c_{ID} ($x00$) increased from 16.67 to 44.44% as a result of the teacher becoming more involved in reading the

Table 2 Normalized centrality values for the indirect relationships networks in the phases of the course. Only a selection of the students is represented

n_i	Sp1		Sp2		Sp3	
	$c_{OD}(n_i)$	$c_{ID}(n_i)$	$c_{OD}(n_i)$	$c_{ID}(n_i)$	$c_{OD}(n_i)$	$c_{ID}(n_i)$
$x00$	100.00	16.67	100.00	16.67	100.00	44.44
$x21$	0.00	11.11	5.56	5.56	22.22	11.11
$x23$	0.00	22.22	16.67	77.78	11.11	77.78
$x24$	0.00	16.67	22.22	27.78	22.22	50.00
$x26$	33.33	66.67	72.22	38.89	38.89	77.78
$x32$	0.00	11.11	5.56	27.78	16.67	33.33
$x33$	50.00	33.33	72.22	22.22	27.78	44.44
$x36$	0.00	11.11	0.00	22.22	27.78	44.44
$x37$	0.00	11.11	11.11	22.22	27.78	22.22
	C_{OD}	C_{ID}	C_{OD}	C_{ID}	C_{OD}	C_{ID}
Net.	82,40	47,22	79,01	55,56	68,21	44,75

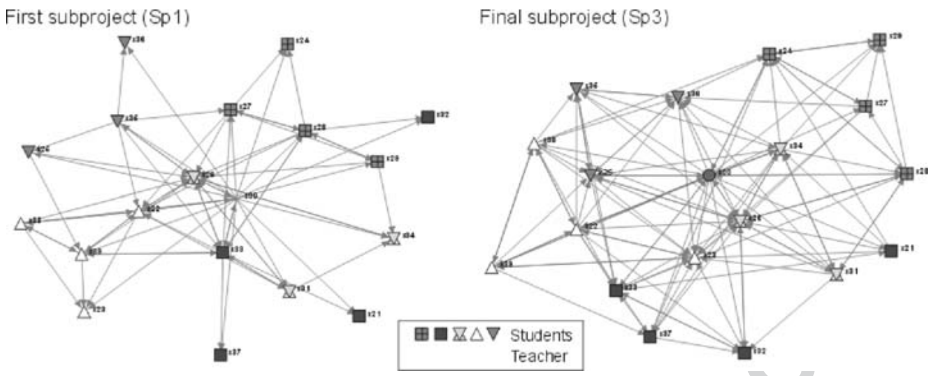

Figure 2 Sociograms of the "indirect relationships" networks at the beginning and at the end of the course. The node shapes identify the different customers and the teacher

documents generated by students, as part of his role as a facilitator. Similarly, $c_{OD}(n_i)$ also increased for students, due both to the fact they shared more documents, but also because they read those posted by others. This is initial evidence that the students were adopting the desired collaborative style in their interactions and becoming less dependant on the teacher.

Nevertheless, according to the mixed-evaluation method, this conclusion should be triangulated with data coming from qualitative sources. Indeed, observations at the laboratory confirm the role of the teachers as guides or mediators. For example, the observer annotated

> "... [the teacher] also goes through the computers and clarifies ideas and concepts. The tasks are very diverse: while some are working in the project, others are answering assignments"

(Observation. Third session).

Further, data from the questionnaires and from focus groups reinforced the idea that the students perceived the teacher as somebody supporting their work, but not as a "knowledge provider":

> "I studied philosophy at secondary school, and there I studied something called "maieutics"..., well, [the teacher] is maieutic ...He uses the Socratic method, he is between the knowledge and you. He is a mediator"

(Student A. Intermediate Focus Group);

> "The support received from the teacher was of great help, not for small problems, but for guiding my work"

(Student B. Final questionnaire).

In addition, students acknowledge the high availability of the teachers, which shows their commitment to their role as mediators:

> "I acknowledge the effort from the teachers to be available at any moment and any place. Maybe the monitoring they carried out is too exhaustive sometimes, as with all those review questionnaires."

(Student C. Final questionnaire);

> "[the teacher] is always answering questions, clarifying doubts to several students. As soon as he finishes with a group, others are asking him."

(Observation. Tenth session)

Therefore, the partial conclusions from the evolution of the social networks regarding the adoption of the role of facilitator by the teacher were confirmed by triangulation with the subjective perceptions of the students and of the external observer during the course.

A similar approach was followed to identify other features of both teachers and students and create profiles for them. Though the full account of the analysis that led to these profiles is out of the scope of this paper, we report here the main features detected in this preliminary study. For the teacher, some features or their profile were: teaching style centered on the students; good social abilities; reasonable skill in the use of computers and networks; previous knowledge on research strategies; capability to assume strong workloads; and commitment with student tutoring. The main characteristics defining the students' profile were: active-reflective learning style; background as required by the subject; capability to assume strong workloads; enough social abilities; and reasonable skill in the use of computers and networks. All these features are currently being validated in new case studies.

The example and results introduced in this section illustrate how different data sources and analysis techniques were used to study a specific aspect. This was one of the validation goals established for this case study, the main findings of which are discussed in the following section.

Lessons learned

This case study showed us that the different data sources and analysis techniques proposed within the framework were easily combined to complement the partial findings of each other and to get a comprehensive understanding of the social issues influencing collaborative learning. The social network analysis helped to identify aspects of the structure of the interaction at both the group and the individual levels, and helped to focus the evaluation on specific topics regarding this structure. Then, the qualitative data sources were used to go deeper into the opinions of the participants and their perspectives regarding the identified aspects. With this complementary analysis we could achieve the desired study of participatory aspects of learning in a more efficient approach than a pure qualitative study.

The evaluation was performed longitudinally throughout the experience, with the participation of the teacher throughout the process. This allowed us to apply part of the results and refine the course in a short-term formative evaluation cycle. These results emerged in a rather informal manner from the quantitative or social network analysis, or from the comments made by the evaluators after the observations or focus-group sessions. More formal and systematic results were obtained at the end of the course. These conclusions were applied to the design of the project the following year. This process can be considered a medium-term formative evaluation cycle. Although these two levels of formative feedback (short term and medium term) were satisfactory for the teachers, a more efficient approach would improve the feedback and provide better opportunities for the refinement of the learning processes being evaluated.

The efficiency of the process was a major aspect to assess in the validation of the method. The main positive result regarding this point relates to the improvement experienced due to the use of the automatic data analysis tools. More specifically, the use of Quest to manage the questionnaires, and of SAMSA to configure and perform the social network analysis proved to be a major improvement compared to previous experiences where these tools were not available. However, it was also clear that the process is still too demanding. This calls for a refinement of the evaluation framework in regard to the trade-off between the need of a deep understanding of the processes and the scarce resources that are normally available.

All these issues, together with the aspects raised from the other two case studies, will be discussed further in the following section.

Case AIB-OUC : A post-hoc evaluation in a virtual learning scenario

Educational design

The AIB-OUC case is based on a real collaborative learning experience that was carried out in the scope of an interdisciplinary virtual (distance) learning undergraduate course. The experience ran for a period of 14 weeks and involved two tutors and 122 students distributed between two virtual classrooms (C1 and C2). The students worked in groups of five or six members, with a total of 21 groups in the two classrooms. Students had to collaborate and develop a case study that simulated a real project in a company. In the first phase of the course, virtual groups were formed and consolidated by the students themselves, following a well-structured and guided virtual process supervised by the tutors. The case resolution consists of a set of target goals that are attained collaboratively (except the first one, which aims at studying and understanding the problem) during successive phases. The whole project was carried out mostly asynchronously; synchronous interaction occurred in few specific cases of decision-making. All asynchronous collaborative interactions were supported by a BSCW server.

The BSCW system was structured into two types of workspaces to resemble the course design and organization: A *general workspace*, where all the students belonging to the same virtual classroom could interact; and a *private workspace* for each group. The general workspace was used for the first phase of group forming and for general debates carried out at the classroom level; the private workspaces were used for the tasks related to the writing of the project deliverables that the groups had to collaboratively produce during the rest of the phases of the course.

Validation objective

This second study is a post-hoc evaluation of a course at a virtual university that poses quite different characteristics from those of the CA-UVA case study. First, it was totally based on distance interaction and completely mediated by the CSCL system, which means that the automatic analysis obtained from data recorded by the system provides more information than in the CA-UVA case study, or inversely, that other data sources and evaluation techniques could be used much less. Thus, in this case study, we could focus our attention on the different SNA indexes, relationships, and techniques we had identified within the method.

Secondly, BSCW was also used as the collaboration support tool, but with a different setup that the one used in the CA-UVA case. Before the analysis started, this setup, as well as the global course, was designed by an external team that had no connection with the authors. These conditions allowed us to test whether and how the method and the models that we had developed for the CA-UVA were generalizable to other situations.

This experience was performed a posteriori and we did not have access to the participants' opinions throughout the process. These limitations were expected to be helpful to assess the degree of completeness of this type of evaluation and detect what is lost when an evaluation is performed without all the elements defined in the general framework.

Evaluation design

Taking into account the aforementioned restrictions, we focused on three specific evaluation objectives, which could be considered as partial aspects of a more thorough evaluation. These topics were: The study of the students' participation in the general workspace, the subgroups activity in their private workspaces, and finally, the identification of the most prominent actors of the classrooms. The fact that the course was divided into two virtual classrooms, each one of them assigned to a different tutor, allowed us to study the influence of their different pedagogical strategies in the issues that we were examining.

The data sources and analysis processes are depicted in Figure 3. The main data source was the data log provided by the BSCW server, which had been collected during the course, and observation of the BSCW workspace, as it remained after the end of the course. The fact that all the interactions between the actors were mediated by the virtual workspace (i.e., BSCW) assured that the analysis based on these data would provide a complete view of the interactions that happened during the course. However, we should not forget that the data provided by log files gives only a superficial view of the actual interactions, and that the complementary data sources defined by the method, such as observations and questionnaires were not available.

The definition of the specific networks for the study of this case followed the division between a general and several private workspaces. At both levels, we built networks of the types defined in the method: direct relationship networks for the study of the asynchronous discussions; indirect relationship networks for the study of the links established through the interchange and sharing of documents; and use of resources networks, which allowed us to analyze the use of the different folders. For each one of these types, a network for the complete course was built, representing the global characteristics of the interaction at the virtual classrooms. We also built networks for each phase of the course in order to provide detailed information of these phases, and about the evolution of the indicators.

Taking into account the available data, the evaluation was performed almost exclusively by means of the social network analysis of the BSCW data log. The results of this analysis were contrasted with a final interview with the tutors of each classroom.

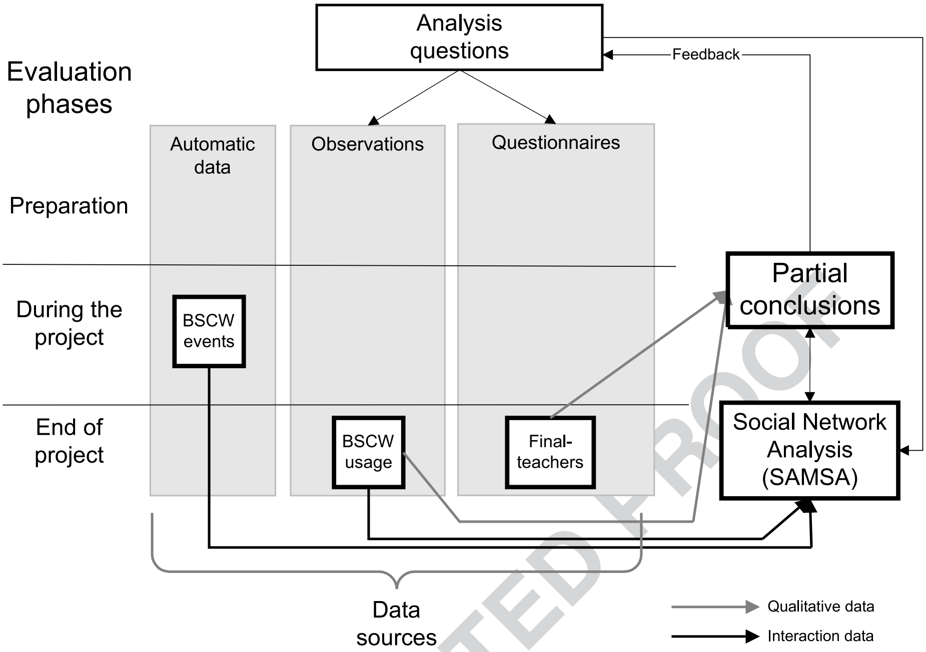

Figure 3 The mixed-evaluation scheme adapted to the AIB-OUC case study. Only the data sources that were actually used are depicted in the figure

Main results

This case study allowed us to focus on the study of all the social network analysis indexes, relationships, and techniques defined in the method. We provide here a sample of the analysis we performed at the two workspaces using the generic networks that had been customized for this case. The objective of this section is to illustrate their use and discuss their appropriateness for the study of the interaction structures that emerged from the collaborative work of the students during the course.

Direct relationship networks were used to study the debates in the general workspace. The analysis of these networks showed a very low density (0.48% in the whole course networks of both classrooms), with many isolated nodes, and centered on the teacher. This meant that very few students participated in the debates, which consisted mainly of single responses to the tutors' postings in the workspace.

Indirect relationship networks were much denser, with a similar overall density (20.59% in C1) and (25.36% in C2). However, the evolution of the indexes was very different in the two classrooms. The most outstanding difference appeared in the first phase, where there was a density of 6.89% in C1 and 21.73% in C2. Moreover, the sociogram of C1 showed that at least 20 students had not had any interaction at all during this phase. These were unexpected results, since at the group formation period students had to introduce themselves and look for other colleagues to make a group. What actually happened is that the tutor of C2 pushed the students to look themselves for their partners, while the tutor of C1 decided to intervene and form "artificial" groups with those students that had not done so by themselves.

Neither direct nor indirect relationship networks show the "places" where relationships are established, which would allow identifying the more active spaces in a system. Instead, resource networks represent the links between an actor that creates a document and the folder in which the document is placed. The design of the course added meaning to these networks because the tutors set up a folder for each phase of the course, and thus, the activity in each folder is also the activity in each phase. This analysis complements the conclusions obtained with the analysis of the previous networks, but it also gives new information. For example, in Figure 4, we can see that the activity in C1 was more intense on the folder for the creation of groups, corresponding to the first phase (ph1). It is also very easy to identify the students that only participated actively in the general workspace during this phase, or even did not create a document at all (the isolated nodes at the left).

Furthermore, similar networks were built for the private group spaces. They allowed evaluators to analyze and compare the interaction within each group, and also see their evolution throughout the course. In fact, they provided an interesting insight on the consequences of the different strategies for group formation: some of the groups belonging to C1 had problems in their interaction, with low densities and high centralization indexes (i.e., only some of the members contributed to the work).

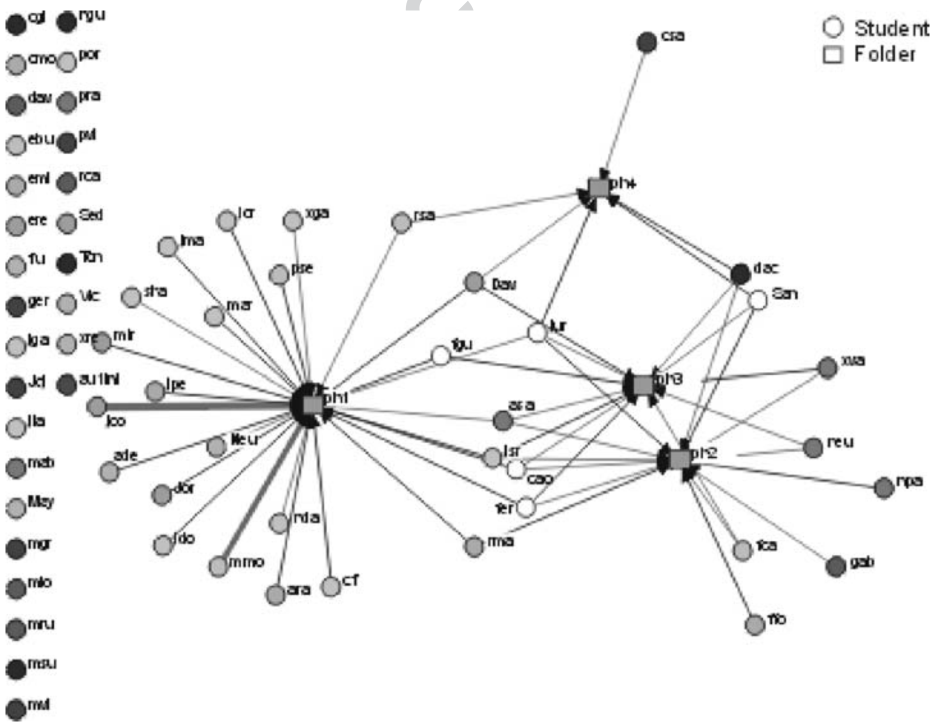

Figure 4 Sociogram representing the creation of objects during the course in classroom C1. Folders are represented by squared-shaped nodes and the students by round-shaped nodes. The labels ph*x* stand for phase number *x*

The interview with the tutor of class C1 confirmed that these groups were among the ones he had created artificially. On the contrary, this undesired interaction structure did not happen in any group in C2. Thus, we may conclude that the way the tutors faced the task of forming groups might have affected the way students collaborate. This was already a useful finding for the tutors, who mentioned their intention of changing the strategy for the formation of groups for the next year. However, in order to firmly state this conclusion we should have triangulated it with the subjective perspective of the students on their own collaborative processes.

Lessons learned

The case study presented in this section aimed at validating the adaptability of the method and the tools in a distance-learning setting, where interaction was almost totally mediated by the computer and where the absence of some of the elements prescribed by the method have been used to assess their importance for the fulfillment of the evaluation objectives.

First, the experience has confirmed that the method and tools proposed originally for the CA-UVA case study were *adaptable to an external environment*, where the course design and development had not been influenced by the team that proposed the evaluation method. In this external setting we were able to adapt the generic social networks defined in the method to the specific characteristics of the BSCW setup of this course. Therefore, and in spite of the restrictions posed by this case, this experience provided initial evidence that the method is generic and can be applied to environments of characteristics different than CA-UVA. The successful application of SAMSA to build the networks for this case showed that the model of interaction on which SAMSA bases the construction of the networks, as well as the data processing methods, were sufficiently generic for its direct application to different environments.

Additionally, the study showed the appropriateness of the proposed types of social networks and the chosen indexes for measuring complementary aspects of the structure of the interactions. The three types of predefined networks have shown flexible enough to be adapted to the specific characteristics of the workspace used in this case study. These customized networks have provided complementary information about the different activities in the workspace at the classroom, the small group, and the individual levels of analysis.

The fact that the case was a pure distance learning scenario enabled us to test whether the proposal, initially designed for face-to-face or blended settings, could be applied to pure virtual settings. In fact, we could process many more interactions of different types and provide a richer analysis from the data logs than in the CA-UVA experience because all the interactions were mediated by the computer, while in CA-UVA most of the interactions were face to face or outside the laboratory. However, the full evaluation of this case would have needed an account of the students' opinions on the studied phenomena. These opinions could have been easily collected by means of Quest if the study had been carried out in parallel with the course.

Indeed, the fact that the case was performed a posteriori, and with some important sources of data missing, confirmed the importance of carrying out the evaluation longitudinally with the learning experience and of the participation of teachers and students during the evaluation process. This participation is needed to gain insight into the meaning that the participants give to their interactions, and thus to achieve a real analysis of the evolution of their identity as members of a community.

On the other hand, this case has shown that given appropriate conditions, the simple and superficial output offered by the automatic analysis can support the teachers in monitoring their classrooms. For example, the aforementioned result that related some of the poorly functioning groups with those that the teacher had formed artificially was already useful. In fact, the tutor, based on these results, stated his intention to change his strategy regarding the forming of groups for the following year.

Case Magic Puzzle: The method in a controlled scenario of synchronous collaboration

Learning scenario

This experience is rather different from the previous cases. It is based on a collaborative synchronous application called Magic Puzzle oriented to the resolution of a simple jigsaw problem by young children. The application supports the interaction of small groups, from two to four people.

At the beginning of the game, each participant has a set of pieces that s/he has to put on the central panel. Any participant can take a piece from the central panel and place it in another position. In the version we used for the tests, there was no predefined turn-taking policy and the application allowed errors; i.e., a participant could place a piece in a wrong position.

The participants do not receive any feedback from the application except for the display of the central panel with the current state of the puzzle, as well as of his or her set of pieces in the private workspace.

Validation objective

The main objective in this experience was to reflect on the possibilities of applying social network analysis to a setting characterized by synchronous interaction in small groups, which is an unusual scenario for social network-based studies.

Additionally, we used this case to test the capability of SAMSA to represent social networks based on synchronous interactions on a direct manipulation interface, instead of the asynchronous interactions on a shared folder workspace used in the two previous cases.

Evaluation design

Taking into account that this case did not apply to an authentic learning scenario, the evaluation experience was designed as a set of controlled tests. These tests were performed in a single session with six volunteers. They were introduced to the main features of the application before the tests started.

Four laptops were used to carry out the experience. The setup allowed the participants to see each other while their screens were hidden for the rest of the players. Twenty games were performed overall. The session was video-recorded in order to allow for a detailed observation of the puzzle resolution processes and of the possible face-to-face interaction among participants.

Main results

The analysis of the videotape showed that participants remained silent and focused on their screens. Thus, the interaction was only mediated by the computer, and it should be studied by the analysis of the data logged by the application.

Data from the logs were processed by SAMSA, yielding simple social networks representing the links between a user that manipulated a piece and the one that had placed the piece on the shared panel. The sociograms representing these networks provided a clear view of the interactions that happened among the actors in the process of solving a puzzle. This observation led us to detect the possible use of the sociograms to provide feedback to the users (either the teachers or the students themselves) about the interactions among the group while solving a problem.

Following a standard principle in social network analysis, SAMSA did not draw the self-references. However, in this case, we observed that these self-links were quite frequent in the experiments, and meaningful to understand the process of the puzzle resolution. This led us to a second observation regarding the possibility of including self-references in the analysis of learning scenarios.

Lessons learned

This experience confirmed that the method, as it is globally defined, cannot be applied to these kinds of restricted experiences, as participatory aspects of learning only arise in authentic learning settings. Although this fact was known before the application of the method, the case serves to illustrate it and define more clearly its limits.

On a more positive side, the experience served to assess the flexibility of SAMSA and of the social network elements defined in the method. They could be applied to study the synchronous interactions from a direct manipulation interface provided by the Magic Puzzle which have rather distinct characteristics than the asynchronous interactions on a shared folder of BSCW.

The experience also raised the hypothesis that the information provided by the sociograms could help to support the self-regulation of the students while they are collaborating to solve the problem (in this case to complete the puzzle). This hypothesis is part of our current research work towards the definition of interaction analysis methods able to adapt to different needs, and thus, to provide different functions Marcos et al., (2005).

Moreover, we found that including self-references in the sociograms (e.g., an actor corrects his previous actions) could be relevant for several reasons. First, they can give an idea of the individual progress of an actor (e.g., he is very doubtful about where to place a puzzle piece). This is important to provide feedback to the actor, for regulation purposes. Moreover, if interaction with other actors happens through other means, a self-reference can actually be seen as an interaction (e.g., someone tells a student to move certain piece, and he does so). Interestingly, social network analysis techniques tend to ignore these self-references, as they are not meaningful in most of the scenarios. Thus, we may conclude that the use of social networks for supporting studentsŠ self-reflection requires a change in the way they are usually processed to be able to show and analyze the self-references.

Main findings and reflections

This section summarizes and elaborates on the results obtained from the validation process carried out by means of the three case studies described in the previous section. We will focus on the properties we wanted to assess from the start of the process, i.e., the adaptability of the method to new environments; the appropriateness of the social network analysis elements defined for the method; and its efficiency. Additionally, some concrete aspects that have emerged from the case studies will be also briefly introduced.

Generality of the mixed method

The mixed method was defined as a flexible framework that has to be adapted to the scenario where it is applied. One of the main goals of this paper was the validation of the method regarding its capacity to be applied to settings of distinct characteristics, which include the type of learning scenario, the type of interactions with respect to time and location, and the CSCL system that supported the experience.

The three experiences show that the overall proposal is flexible. It can be configured to study different evaluation objectives and used in different environments. The CA-UVA experience showed its suitability for face-to-face settings where the evaluator is able to observe the participants and interview them, as was the case in the CA-UVA case study. The AIB-OUC served to help us analyze the restrictions or new aspects that could be added to the evaluation scheme when applied to pure distance settings and when performed at the end of the experience.

Regarding this aspect, one of the main findings from the AIB-OUC case was that the fact that the method was applied to a distance setting did not present a problem, as most of the proposed sources of data can be collected by virtual means, for example, by virtual questionnaires or interviews, or by inspecting the evolution of the shared workspace during the process.

On the other hand, the fact that the evaluation in the AIB-OUC case was applied at the end of the experience meant that many of the analysis principles could not be met, such as the study of the evolution of the experience. Thus, this case study helped to stress the importance of performing longitudinal evaluations and following the whole process from its beginning (or better, before its beginning) until its end. It is evident that if the objective is to provide formative corrections, the evaluation has to be done in parallel with the course. But even if the mixed method is used for a deep study of a whole experience it should flow in parallel with the experience, which is the only way we can adapt the evaluation to the emergent issues in the cyclical process that has been proposed.

The generic social networks could be adapted to represent meaningful relationships for the three cases, and SAMSA has shown its capacity to accept and analyze inputs of different nature, like the asynchronous interactions on a shared folder workspace from BSCW (CA-UVA and AIB-OUC cases) and the synchronous interactions representing actions on a direct manipulation interface (Magic Puzzle case).

Although not shown in the examples provided in this paper, SAMSA can analyze data from other sources, like sociometries or interaction maps from observations Martínez et al., (2003a). The tool also allows the user to customize the network by selecting useful parameters, such as the period of the analysis or the actors that will be represented in the network. These parameters have been very useful in allowing SAMSA to be adapted to the particular needs of each study.

On the other hand, the Magic Puzzle case has also helped to clearly set the limits of the method, which only makes sense when applied to authentic learning scenarios where the tasks are open and there is place for an evolution of the subjects' ideas and attitudes towards participation.

Efficiency of the method. The trade-off between efficiency and completeness

The application of the method to the authentic learning scenarios showed that the combination of the different techniques defined in the method offers a more efficient procedure than a pure qualitative analysis approach. The software tools that support the process also play a fundamental role in the improvement of the methodŠs efficiency. SAMSA allows for automatic and transparent social network analysis processes, which would be very difficult to perform manually or with the support of a generic social network software package, and Quest gives the evaluator the ability to avoid all the mechanical steps typical in questionnaire processing without losing any flexibility.

However, the method is still very complex and resource demanding. This is mainly due to the need to analyze meaning and content, which is a consequence of the theoretical assumptions of the situated approach adopted by the proposal. Although there are several attempts to provide automatic language analysis tools, the current state of the art in this field does not meet the needs of this approach.

Therefore, the focus of current work to facilitate the use of the method relies on the definition of lightweight itineraries that explain how to adapt the method to available resources. These itineraries may not provide the same level of depth of the full process that is proposed here, but they can still be very helpful for monitoring groups interacting in authentic settings.

Issues related to social network analysis

These experiences have allowed us to test the capability of social network analysis to support the study of the structure of groups at different levels (community, small group, individual). Moreover, they have confirmed the appropriateness of the restricted set of indices and social network types defined in the mixed method for the study of these properties.

The experiences have shown the possibility of using social network analysis, composed of data from different sources and of different natures, combined with the complementarity of the information given by the numerical indexes and the sociogram's visualization of the networks, to not only confirm the information provided by the disparate sources, but also to use that data to complement each other and extend the study.

Some emergent results have also arisen from the studies, like the need to adapt the standard social-network procedures to the particular needs of learning environments, such as the need to include self-references in the representation of the networks, and the hypothesis about the potential use of social-network analysis to support students self-reflection, which emerged from the Magic Puzzle experience.

Globally, the cases have confirmed that social-network analysis is an appropriate approach for the study of the structure of the relationships in CSCL contexts, even with the restricted set of social network elements defined for our method. This is an important result, as the simplicity of these elements is expected to facilitate the use of these techniques by non-experts, an important feature to enable the generalization of a particular method.

The participation of the teachers and the students in the evaluation

The evaluation experiences show clearly that the role of both students and teachers in the process of evaluation is fundamental for its success. In the CA-UVA experience, teachers participated actively, providing for the triangulation of the results and thus increasing the reliability of the whole process. The AIB-OUC experience reinforces this result. The final intervention of the tutors confirming or discarding part of the partial results has been of great help to leverage the quality of the analysis. However, this case study could not yield definitive results regarding the study of participatory aspects of learning, mainly because it was not possible to contact students in order to include their perspective in the analysis.

The aim of the method is to be usable by end users, like teachers following an action-research paradigm or practitioners who apply a pedagogical innovation and want to analyze its results. Regarding this point, the cases have provided partial evidence that the method and the tools that support it are understandable and facilitate evaluation by non-experts. A systematic evaluation of these claims is to be carried out in order to confirm them or to detect what aspects of the proposal need further refinement in order to meet this goal.

Conclusions and open research issues

This paper has described and discussed the application of a mixed-evaluation method to three different CSCL scenarios in order to assess how general and effective the method is for supporting the study of participatory aspects of learning.

The CA-UVA case allowed testing the overall approach of the method and experimentation with different combinations of the basic data sources and analysis methods. The case showed the suitability of all of these elements for the study of participatory aspects of learning. The AIB-OUC case has shown that the method can be adapted to an external scenario and helped to analyze the appropriateness of the different social network elements defined in the framework. Finally, the Magic Puzzle case helped to define the scope of the proposal regarding the type of learning scenarios to which the method can (or cannot) be applied. Taken as a whole, the three cases have served to confirm the flexibility of the method, and also to define some requirements for its appropriate use, such as the need of the participation of the students and the teachers in the analysis.

Moreover, the experiences described in this paper can contribute to the promotion of the use of mixed-evaluation methods in CSCL, as they provide specific examples of how these methods can be applied in this field and show the benefits that can be obtained with them. In fact, the reported case studies confirm the general properties claimed for the mixed-method approach, especially the fact that it provides for flexible frameworks that can be further configured with regard to the underlying research questions Johnson and Onwuegbuzie, (2004).

In fact, two complementary uses of the method have been observed from the application of the method to the three case studies. The first one is the use of the overall method as it was originally defined for the study of participatory aspects of learning. The second has emerged from the experiences, and consists of the use of the social-network techniques and tools as monitoring tools to support teachers in their daily work. The first use of the framework requires the method to be applied to authentic learning settings, where evaluation questions related to participation in and belonging to a learning community are meaningful. The appropriateness of the mixed method for this purpose has been validated by its application to the CA-UVA case reported in this paper and the studies described in Martínez et al., (2003a) and Martínez et al., (2005). Regarding the second use, the experiences reported here have provided partial evidence that the social-network techniques and tools are able to provide useful information that allows teachers to monitor the activity in their courses and include short and medium-term formative corrections. This finding needs to be formally tested, and is in fact part of our current research work towards the design of adaptable interaction analysis tools Marcos et al., (2005).

These two complementary uses of the method can be viewed as a consequence of the flexibility of the mixed-method approach to adapt not only to different CSCL settings, but also to different evaluation goals. Indeed, the mixed method has also served as the basis of a new proposal of a generic framework for the evaluation of CSCL experiences. This proposal consists of an evaluation framework, composed of a skeleton and a set of guidelines that aim to support evaluators in defining their evaluation procedures. The skeleton provides a set of elements that must be taken into account in a CSCL evaluation, while the set of guidelines complement the skeleton by suggesting a set of itineraries to be followed depending on the evaluation purposes and the resources available. The framework has been described in TELL Project, (2004) and it is currently being applied to several case studies carried out in the context of a European e-learning project.

Regarding the efficiency of the method, our experience in applying it shows that the combination of analysis techniques defined in the mixed method helps to focus on salient aspects of the processes being analyzed, and thus provides for a much more efficient approach than a pure qualitative study. This conclusion partially challenges the statement by Johnson and Onwuegbuzie, (2004), who considers that these methods are more time consuming than mono-method approaches.

The software tools proposed with the method have shown to play an important role in improving the efficiency and the generality of the method. First, they have enabled the data collection and analysis techniques needed to carry out the studies. Second, the experiences reported in this paper have shown that SAMSA is applicable to different CSCL settings with distinct types of interaction data. This flexibility was due to the fact that SAMSA accepts a generic data input able to represent different types of interaction. This generic input is based on the proposal presented in Martínez et al., (2003b). In fact, the definition of a generic model for the representation of the interaction, shareable between different CSCL and interaction analysis tools, would provide for an easy reusability of these interaction analysis tools in different CSCL environments. This is part of our ongoing research within a Network of Excellence of the *IST Technology enhanced learning* program of the European Union Kaleidoscope, (2005).

In addition, another interesting research topic suggested by the experiments described in this paper is the adaptation of SNA indicators and techniques to the particular needs posed by CSCL, like the need of including self-references in the representation of the social networks. Recent research in the field also reports similar approaches (see Reyes and Tchounikine, (2005), 1). Another emergent result is the idea of using the social-network elements defined in the method not only for supporting teachers in their evaluations, but also for supporting students during their collaborative activities. In this line, we are currently working on the adaptation of SAMSA to meet the needs of different user profiles Marcos et al., (2005).

Finally, the empirical work produced important results regarding the social aspects that influence the success (or failure) of collaborative learning in authentic scenarios. These observations could lead to the definition of the characteristics of the desired teacher and student profiles. These features might have a positive influence on the accomplishment of learning goals in CSCL settings, and therefore they can play an important role in the design of future training programs for both teachers and students. Underscoring this importance, a research project is currently under way with the purpose of refining the initial definition of the profiles presented in this paper.

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