Combining qualitative evaluation and social network analysis for the study of classroom social interactions

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ABSTRACT

Studying and evaluating real experiences that promote active and collaborative learning is a crucial field in CSCL. Major issues that remain unsolved deal with the merging of qualitative and quantitative methods and data, especially in educational settings that involve both physical and computer-supported collaboration. In this paper we present an evaluation in a university course of Computer Architecture that took place during the last two academic years. Such a study was performed using a new tool that allows an automatic processing of computer logs using social network analysis, as well as the Nud*IST qualitative research tool. Extensive experimental results allow us to reflect and draw conclusions on the changes of attitudes towards collaboration, as well as the limitations and necessities for successful CSCL systems in such settings.

Keywords

Qualitative and quantitative evaluation, social network analysis, project-based learning, ethnography.

INTRODUCTION

An important shift in the dominant educational paradigm has been observed during the last decade. This change can be expressed as a student-based teaching/learning process, where students construct their own knowledge through active and cooperative methods (Jonassen, Peck, and Wilson, 1999). The wide distribution of networked computers and their introduction in classrooms has given new opportunities to set up collaborative learning situations in ways that are not restricted to pure distance learning or face to face settings (Crook, 1994).

Although higher education studies should have pioneered the introduction of these methods, due to their close relation to modern research studies, such a change has occurred rather slowly. Cultural problems appear to be a major obstacle for their successful introduction (dePaula, Fischer, and Ostwald, 2001). These problems are to be faced by increasing the number of innovative experiences and elaborating on them.

Our approach to evaluation draws on *classroom based research* (Stake, 1995). The inclusion of computer-based settings adds new challenges to evaluation, but it also provides new resources for its support. Neale and Carroll (1999) present a framework for the evaluation of distance learning, in which the authors apply quantitative and qualitative methods and data, gathered from both traditional fieldwork sources and computers. Our approach shares with them the research principles, and the need of considering different sources of data. However, the problems posed by distance learning environments are different from the ones of real classrooms, and therefore, new issues have to be considered, such as the combination between computer and human supported activities, the richer possibilities for social interaction, etc.

We are interested in the study of situative, participatory aspects of learning (Sfard, 1998) as they occur in curriculum based experiences. Nurmela, Lehtinen, and Palonen (1999) have demonstrated the usefulness of *social network analysis* for the study of the *participatory* aspects of learning. Social network analysis (Scott, 2000) is an approach that focuses on the study of patterns of *relationships* between *actors* in communities. Its methods are very well suited for the study of relationship patterns established through computer mediated communication tools (Lipponen, Rahikainen, Lallimo and Hakkarainen, 2001). However, the methods of social network analysis are flexible, and can be applied to other settings. In this paper we will apply them to the study of interactions through a shared workspace system.

For two years we have been involved in the introduction of project-based learning with case-studies in a course on Computer Architecture in studies of Telecommunications Engineering of our university. The general description of the project can be found elsewhere (Dimitriadis, Martínez, Rubia, and Gallego, 2001). One major obstacle we found in the initial deployment of the project was how to deal with the passive and individualistic attitudes of the students, often present in Spanish university.

This paper presents and discusses the methods and tools we have used for the evaluation of this educational project, and more in particular for the assessment of whether it favours collaboration among students of individualistic tradition. Part of the data for this analysis comes from computer based tools that students use to fulfil the course requirements (BSCW event logs), while other data are collected by traditional means (formal observations, questionnaires). Here we will show how to prepare and process these data for its use with social network analysis (Scott, 2000), and qualitative research tools such as Nud*IST (QSR, 1997). Therefore, we will be able to combine information such as the actual interactions held among students and their own perception of collaboration, expressed in several questionnaires.

The rest of the paper is structured as follows: next section outlines the educational design to which the evaluation was applied. Then, the research method and tools used and developed for its support are introduced. Third section presents and discusses the experimental work and results. The paper finishes presenting our findings from the application of the evaluation method and issues for future research.

EDUCATIONAL DESIGN

The definition of the educational project is based on the conceptual framework DELFOS (a Description of tele-Educational Layer-Framework Oriented to learning Situations) (Osuna and Dimitriadis, 1999). It provides an educational model, a methodology based on participatory analysis and design, and a conceptual architecture for the definition of CSCL applications. Following the principles of the educational model of DELFOS as well as the directives of the IEEE/ACM Computing Curricula (Turner, 1991) the project aims to provide contextualised, integrated and meaningful knowledge; promoting active, intentional and collaborative learning.

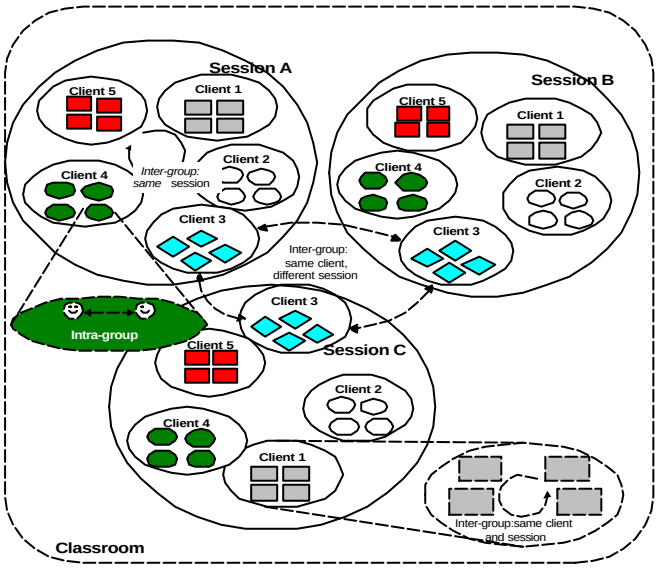

Figure 1. Structure of the class showing the levels of expected collaboration.

The students face a project whose objective is the design and evaluation of computer systems oriented to a number of market sectors (i.e. producers of computer equipment, consulting firms, and clients). In order to have distinct perspectives of the problem, 5 case studies are defined, covering different market sectors and system requirements. As shown in figure 1, in each laboratory session of a maximum of 40 students, at most 4 groups of 2 students each dealt with one out of the 5 case studies independently. Students assume the roles of a consulting firm and a computer manufacturer, and the teacher assumes the role of the client, and of the director of the producer companies.

The project is divided into three subprojects that study a specific issue of the whole problem. Each subproject presents two milestones: in the intermediate one, basic decisions are made, collected through students' *technical decision* forms that are used in a synchronous debate. In the final milestone, besides the decision forms and the debate, each group has to submit a formal technical report to the client. At the end of the whole project a technical report is collaboratively produced among all groups that deal with the same case study in each session.

The pedagogical design was supported by the following telematic tools:

- *BSCW (Basic Support for Co-operative Work):* A robust software package (GMD-FIT, 2001) licence-free for educational uses, managed by the German Institute GMD and developed through several European Union projects. Its role consisted in serving for asynchronous document sharing and threaded discussions. It records data logs registering every action performed on the shared workspace, which were used as a source of the analysis, as explained in the following section.
- *Synchronous debate organiser:* its role is the support for the synchronous debates that take place in the project milestones (reviews). It permits the definition of a technical decision form by the teacher with close and open questions, the presentation to the students, and the collection of the responses presented in a table, pointing out possible conflicts (alarms). These alarms help to introduce discussions in the debates.

- *Other tools:* e-mail for communication purposes, as well as simulators and other tools related to the computer architecture domain were used by the students.

These tools were aimed to support and enhance collaboration, as part of the educational project. Additionally, they offer means of registering interaction information, a very valuable support for the understanding of actual computer-mediated interactions, as described below.

RESEARCH METHOD

Our approach to evaluation is based on the principles of *classroom-based research and development* (Stake, 1995). This approach draws on naturalistic research methods able to deal with the subjective and complex nature of the studied phenomenon. Case-based studies performed under this perspective are based on the analysis of interactions of the participants in the contexts where these educational actions take place. Some assumptions of this approach have to be reconsidered with the introduction of telematic support. This is because the new setting provides additional possibilities of interaction, dislocated in time and/or space, that must be considered. For example, students can interact directly *inside* or *outside* of the classroom, or *through* the computer system in different ways. Crook (1994) presents the different forms of interactions present in these settings and shows the need of enhancing the techniques and data sources for evaluation, beyond those used in traditional classroom research.

As mentioned beforehand, we are studying the possibilities of social network analysis as a means for the study of participatory aspects of learning. We set out to define and apply a research method in which social network analysis techniques were to be combined with the general qualitative evaluation, and where different sources of data were used in order to increase our understanding of the computer supported collaborative processes.

The two analysis perspectives (qualitative categorization and social network methods) are closely interrelated: features arising from the social network processing can be further studied with the help of the coded data, and vice versa. Results obtained with social network analysis give a new perspective to those obtained with the analysis of fieldwork data sources. They also allow the researcher to identify the actual use of the technological support and compare it with the perceptions of the students.

Another objective of our approach is to define a good combination of the different sources of data. Network analysis is also benefited by the use different sources (Garton, Haythornthhaite, and Wellman, 1997). While questionnaires are better for capturing perceptions, the study of data collected automatically may be better for measuring actual use of the tools and the relationships of the students, which is completed with the formal observations.

Our research method uses ethnographic data from a variety or sources (questionnaires, formal observations, etc.). For the network analysis part of the study we used students' questionnaires on social relationships, and the automatic events recorded from the shared workspace. We also considered the use of audio recordings, but it was discarded. Audio recordings of a real laboratory where about forty students are working in pairs do not provide understandable information unless each pair is recorded individually, and this still gives many problems of noise and interferences. Moreover, our research questions were focused on a classroom perspective rather than on the collaboration processes within each pair, and therefore, the audio recordings were not finally considered.

The qualitative data was processed using NUD*IST (QSR, 1997), a well known data analysis package, applying a coding schema that develops along the process. This was combined with the social network analysis measurements. Next section explains with more detail how we adapted social network analysis techniques for their use in our study.

Processing events from shared workspaces with social network analysis methods

The application of social network analysis to the study of a shared workspace poses two questions. The first one regards to the definition of social networks appropriate for this type of environments. The second one is of practical nature: how to translate the data logs provided by the shared workspace to a representation suitable for its processing by the software packages that will be used to perform the analysis.

Social network analysis is based on the study of interrelationships between actors. Interactions mediated by shared workspaces are not *direct*, such as the ones provided by computer mediated communication systems, more frequently found in social network analysis studies (Garton, Haythornthhaite and Wellman, 1997), (Lipponen et al. 2001). In a shared workspace, the actions performed by different users on common objects define *indirect* relationships. This is the principle we have used for the definition of the networks in our study. We were interested in those techniques giving information about structural properties of the network as a whole, and particularly, those related to *cohesion*. They serve to measure the extent to which all members of a population interact with all other members. We used *density* and *degree centralisation* (Scott, 2000). *Density* measures how much *knitted* a network

is. Its values range between 0 (network with no links) and 1 (fully interconnected network). *Freeman's degree centralisation* gives an idea of the dependency of the network on a small number of actors. It takes values between 0 and 1, with 1 representing the most centralised structure.

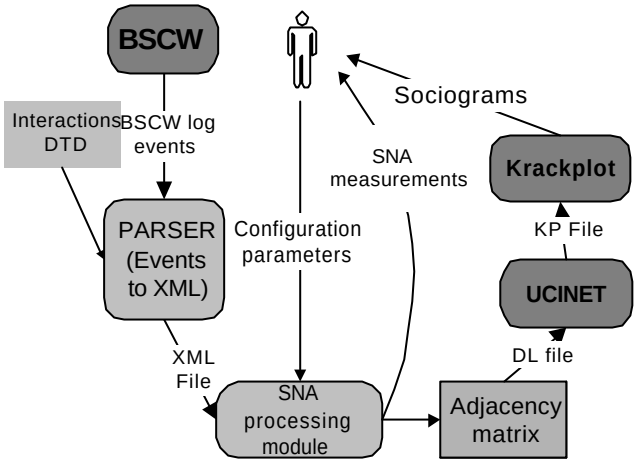

Figure 2. Automatic processing of BSCW event logs with EL2AM.

Additionally, cohesion techniques can be applied in order to detect network sub-structures, such as *cliques* (groups of fully interconnected actors). These cliques were compared with the structures pre-defined by *attributes* of the actors (i.e. the *client* they belong) using the *E-I index* (Krackhardt, Blythe, and McGrath, 1996). This measurement compares the number of links between actors of the same type (same client in our case) and between actors of different type. The index ranges between −1 and 1, with −1 indicating that all ties connect nodes of the same type and vice versa.

Graphical representations of the networks (*sociograms*) were also used. A sociogram represents a network as a graph in which each node represents an actor and lines are the links between actors.

The second issue to face was how to transform BSCW event logs into a suitable format for its automatic processing. We have developed a tool called EL2AM (Event Logs to Adjacency Matrices) (Martínez et al. 2001). It transforms the BSCW events into *adjacency matrices*, a widely used representation of social networks, in which the value of an element a_{ij} represents the value of the link between actors *i* and *j*. As shown in figure 2, EL2AM takes BSCW event logs and translates them to XML format. The XML file describing the actual interactions is then used by a *configuration module* that allows the researcher to select and configure the network she wants to study. It allows for the definition of several parameters, like the period of time and the set of nodes to be included in the network. With the parameters and the XML file, the tool constructs adjacency matrices, suitable for being processed by social network analysis packages, such as UCINET and Krackplot. XML was chosen as an intermediate format in order to promote interoperability. The syntax of the XML file has been defined in generic terms, so that the tool can be applied to other data logs, provided that this files include enough information to build a social network.

EXPERIMENTAL WORK

The educational setting described here was applied twice in the 4th (out of 5) year of the Telecommunications Engineering School, University of Valladolid, Spain. The complete class of 100-120 students is divided in 3 sessions of 40 students (maximum), in which the elementary unit consists of groups of 2 students. Given that they are faced with 5 different case studies, 3-4 student groups assume the same case study within each session. The 13 week-long semester corresponds to 3 subprojects of 4 weeks each, where the reviews (synchronous debates) take place every 2 weeks. Elaboration of the final report started in the 6th week, in which each set of groups that shared the task of writing a report (same client and session) had regular meetings to discuss their respective solutions and the different versions of the final report (schemes, drafts, etc.).

The experimental work took place in two phases during the fall semester (September to February) of the academic years 1999-2000 and 2000-2001. While evaluation of the initial deployment served to refine the design, the second year the revised project was extensively and systematically evaluated, in order to assess its effectiveness at fulfilling the mentioned objective of providing contextualised, integrated and meaningful knowledge. General findings of this evaluation can be read in (Dimitriadis et al. 2001). We will focus now on describing the method we applied for the assessment of how the educational design helped in promoting collaboration, and in which aspects the technological support was successful in the support of group interactions. We will also elaborate on the evaluation process itself

We applied the above explained method to the evaluation. Students' previous experience and attitudes towards collaboration were surveyed in a questionnaire at the beginning of the course. The analysis showed that their experience consisted mainly in work in pairs performed for many other laboratories along their studies. In many cases, these pairs are stable along several years. It also showed a good predisposition towards collaboration, with 56 out of 67 students rating it as positive. The underlying *concept* of collaboration as manifested by the students was found to

be "collaboration as *helping"* and *"collaboration as being helped"*. Therefore, although globally on favour of the *idea* of collaborating, the students had a rather poor *concept* of what collaboration implies, and not enough practice in collaborative tasks beyond working in pairs.

One objective of the educational project was to promote new concepts and attitudes towards collaboration. After the initial questionnaire, we decided to focus on the concepts of *collaboration as discussing* and *collaboration as sharing information*. It was expected that the collaborative writing of reports and the sharing of clients among several pairs would help to develop these two concepts. Students were encouraged to use BSCW in order to maintain debates and share information.

In the rest of this section, we illustrate with some examples how the combination of social network and qualitative analysis can offer interesting insights in an evaluation project that aims at evaluating how the attitudes towards collaboration are influenced by an educational design supported by technological resources.

Collaboration *as discussing*

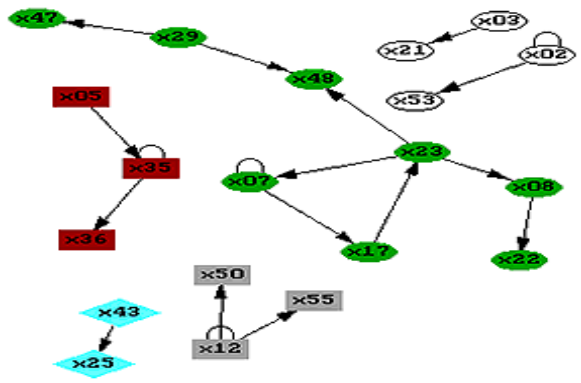

Figure 3. BSCW asynchronous discussions. Arrows point to the author of a note which has been answered by the other actor (origin of the link).

In order to study the discussing activity held through BSCW, a social network was defined so that a link is defined for every note in which a student replied to other student's previous statement. Figure 3 shows the sociogram representing all the activity registered along the semester. It is clear that the use of this feature was very low, with only 20 groups involved in the task of writing notes. The *E-I index* of this network is -0.9 which shows that, when performed, discussion activity linked members of the same client as it was expected.

On the other hand, there was a total of 2147 reading events, which shows that the interest in debates was high, in spite of the low number of contributions.

These results are coherent with initial findings from on-going observation of the BSCW workspace that showed a low (and decreasing) use of the threaded discussions along the course. Higher use in the first subproject is explained by the encouragement of the teacher, the more exploratory nature of the first sub-project, in which a main task was to define the characteristics of the client, and the initial disorientation towards the work they had to develop. Additionally, after the first subproject, students had the time to identify who shared client with them and moved to face to face interaction. In the questionnaire, the students give reasons for this low use: some of them mention practical difficulties in accessing the network. Related to this, but with a more subtle cause is the lack of time argued by some students, which is related to the value they give to this telematic tool. Others said that there was no need of discussing through BSCW when they could meet each other. Additional issues are the lack of confidence in their own knowledge, the absence of a discussing culture, and the fear to participate openly *in front* of the class.

Collaboration as *sharing information*

This perspective was studied by means of a second network, in which *indirect relationships* mediated by BSCW were represented. For building it, EL2AM parses the event files looking for creation of objects and later accesses to these objects, and defines links between the creator of the object and all actors that access it. We studied two periods of time: the first corresponds to the 3rd subproject and the second to the writing of the final project report. Table 1 shows the analytical measurements of these networks, and figure 4 shows the two sociograms corresponding to the two periods of time.

The *E-I index* is positive, which means that sharing a client is not relevant in these indirect relationships, reinforcing our view of sharing information through BSCW as a classroom-oriented interaction. We see that density is much higher in these networks than the previous one, being even higher in the final project. However, although the networks are more dense, the high values of centralisation show how the relationships depended upon the activity of a small number of actors. Comparing the measurements taken with the teacher and without him, it is possible to see that the networks depended highly on his contributions. Figure 5 is clear on this, noticing that *x00* represents the

teacher. It is possible to perceive his central position in the two cases, although in the final project this *centrality* is shared with other nodes.

	Density	Centrality	E-I index (clients)
BSCW (3rd subproject incl. teacher)	0.0950	66.92%	0.649
BSCW (Final project report incl. Teacher)	0.3573	55.76%	0.547
BSCW (3rd subproject)	0.0853	31.22%	0.582
BSCW (Final project report)	0.1787	31.60%	0.478

Table 1. *Indirect relationships network* results corresponding to two different periods of time: 3rd subproject and final project report writing. The two first rows shows results including the teacher and the two last without him.

Additional analysis procedures

As explained above, the research method not only considers social network analysis of event logs, but other sources of data for fulfilling the analysis. We provide here two brief examples of additional procedures: network analysis based on data from students' questionnaires, and the analysis of the lack of success of synchronous debates as other space of collaboration, based exclusively in field data.

Network analysis was applied to data gathered from student's questionnaires in which they were asked to list the pairs with whom they had collaborated, and for what kind of activity (discussing, sharing information, solving doubts). Table 2 shows the results of the social network analysis of this study. It is possible to see how *solving doubts* is the most acknowledged collaborative activity, being also the most decentralised, whereas *sharing information* is the most scarce relationship (lowest density). E-I indices show how *sharing information* was more affected by the fact of sharing a client than solving doubts. *Discussion* activity shows the highest centrality, which means that this relationship depends on the activities of less groups than the others, i.e. is less equally distributed.

COLABORATIVE ACTIVITIES	Density	Centrality	E-I index (clients)
Discussions	0.0385	8.48%	-0.5
Sharing information	0.0269	7.39%	-0.653
Solving doubts	0.0464	4.30%	-0.328

Table 2. Analytical results from the *aspects of collaboration* network. *Density* and (*degree) centrality* have been calculated with UCINET 5. *E-I index* has been obtained with Krackplot 3.2.

The synchronous discussions held in the project revisions were intended as a medium for experimenting classroom-level collaboration. We studied this activity with the questionnaires and the observations. The students gave a high value to the *preparation* steps of the activity, assisted by the debate organiser (see description above), which included the tasks of collaboratively filling out the technical decision forms, and reviewing the tables with the responses of the rest of the groups. This helped to detect conflicts in the technical decisions, and therefore, can be regarded as a medium for knowledge construction. However, the synchronous sessions were not successful in promoting live classroom-level discussions, as it was intended. The normal interaction pattern observed in them was *teacher-student-teacher*, i.e., interactions were initiated by the teacher and finished by him. Students were reluctant to participate openly in the debates. Instead of a space of interaction, students saw this task as a hard test in which they had to show their knowledge as asked by the teacher, but not as means to discuss their own points of view. In conclusion, revisions promoted collaborative interactions at the intra- and inter-group levels; the *decision tables* helped to construct knowledge, but the students did not consider them as a form of collaboration; finally, the synchronous sessions were not perceived as a place where collaboration could take place, but as a *normal* class where the students had to show their knowledge to the teacher, which explains how traditional classroom culture is an obstacle that must be faced in order to obtain the intended results in the application of innovative experiences.

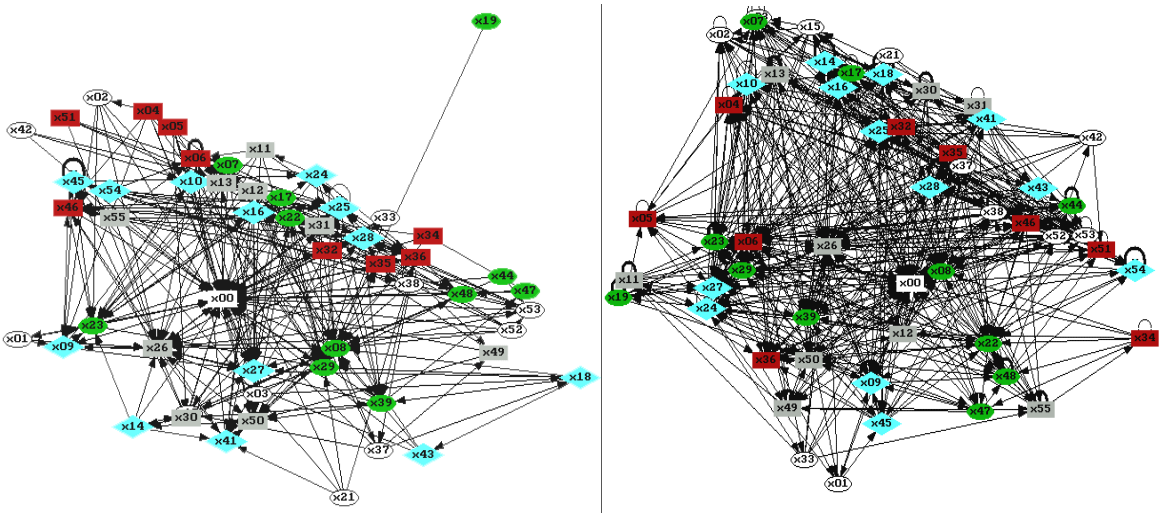

Figure 4. Indirect relationships mediated by the shared workspace, represented using MDS. Figure 4(a) represents activity during the 3rd subproject. Figure 4(b) represents activity during the final project report. The teacher is represented by a white rectangle labelled x00.

Discussion

The results of the analysis show that BSCW was used mainly as a repository of data at a classroom level, with relationship patterns independent of session and client. The tool was mainly used as a means for the distribution of information between the teacher and the students, but it also had a role in improving information sharing among students. Recalling that *information sharing* in the questionnaires was the most scarce and dependent on client relationship, we can conclude that BSCW was helpful in breaking existing difficulties towards sharing information. Other finding of this study is that when the collaborative task implies a bigger group, as it happened in the writing of the final report, the shared workspace becomes more useful as a tool for exchanging information.

CONCLUSSIONS AND FUTURE WORK

Evaluation of innovative curriculum experiences is a complex task that needs several perspectives in order to be fully understood. The introduction of computer support in the classroom poses new problems but also new opportunities for evaluation. We have shown the design and application of a mixed evaluation method, relying on both quantitative and qualitative data collected from computer logs and by traditional means. In it, different methods complement each other in order to gain a better understanding of the processes. Log files give information about the actual use of the computational environment, difficult to grasp by other means. Their treatment with social network analysis tools has proven very useful for an intuitive visualisation of the relationships, and for performing analytical studies. On the other hand, qualitative data and analysis provides information that is needed to complement the results obtained with social network analysis. Although we have focused in the study of the *participatory* aspects of learning, the mixed method we have defined can be also a means for assessing the *acquisition* aspects of learning, an aspect not covered by social network analysis, as shown by (Nurmela, Lethninen, and Palonen, 1999).

Additionally, we have faced the problem of automatic processing of computer event logs through the development and use of EL2AM, and the intermediate XML syntax defined, that allows the use of the tool with other environments. One long-term goal of our research group is the development of a set of modular tools that can be used for the understanding of collaboration in CSCL environments (Martínez, 2001). EL2AM has been developed as part of this general objective, and its usefulness has been tested in this experiment.

We have discussed the application of the research method to a real case, focusing on how and if the educational design and the technological support promoted new concepts and attitudes towards collaboration. The previous questionnaire helped us to refine the educational project, pointing to two collaboration attitudes that we should promote: collaboration as discussing and collaboration as sharing information. We have shown how the different sources of data can be used to study the problem from different views, complementing each other.

The experience has lead us to a refinement of the evaluation method. We have detected the need of carrying out interviews with the students along the course in order to let them explain issues that are not possible to understand with the questionnaires. Social network analysis will be performed several times along the process in order to study the evolution. Another issue we are facing is the definition of a more efficient method. For example, we have modified some questionnaires and reduced the number of observations, according to our previous experience. This is a very important issue, as we view evaluation as a process that runs alongside the course and feeds its design in a iterative fashion. This is not possible to achieve if the method of evaluation adds a very high load to the already demanding daily tasks.

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