Studying social aspects of computer-supported collaboration with a mixed evaluation approach

A. Martínez[1], Y. Dimitriadis[2], B. Rubia[3], E. Gómez[2], I. Garrachón[1] and J. A. Marcos[1]

[1]School of Computer Science Eng.
University of Valladolid
amartine@infor.uva.es

[2]School of Telecommunication Eng.
University of Valladolid
{yannis, edugom}@tel.uva.es

[3]Faculty of Education
University of Valladolid
rubia@doe.uva.es

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, ethnographic methodology.

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 (e-mail and a web shared workspace), 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.

Furthermore, besides discussing the effectiveness of these evaluation tools, we will show later in the paper some interesting remarks derived with them. In particular, we will elaborate on the technological and educational elements that can favour collaboration, and also those that do not support it, or even limit it.

The rest of the paper is structured as follows: next section presents the research method and tools that have beeb designed and used in the evaluation. Then, the educational setting to which the evaluation was applied is 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.

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

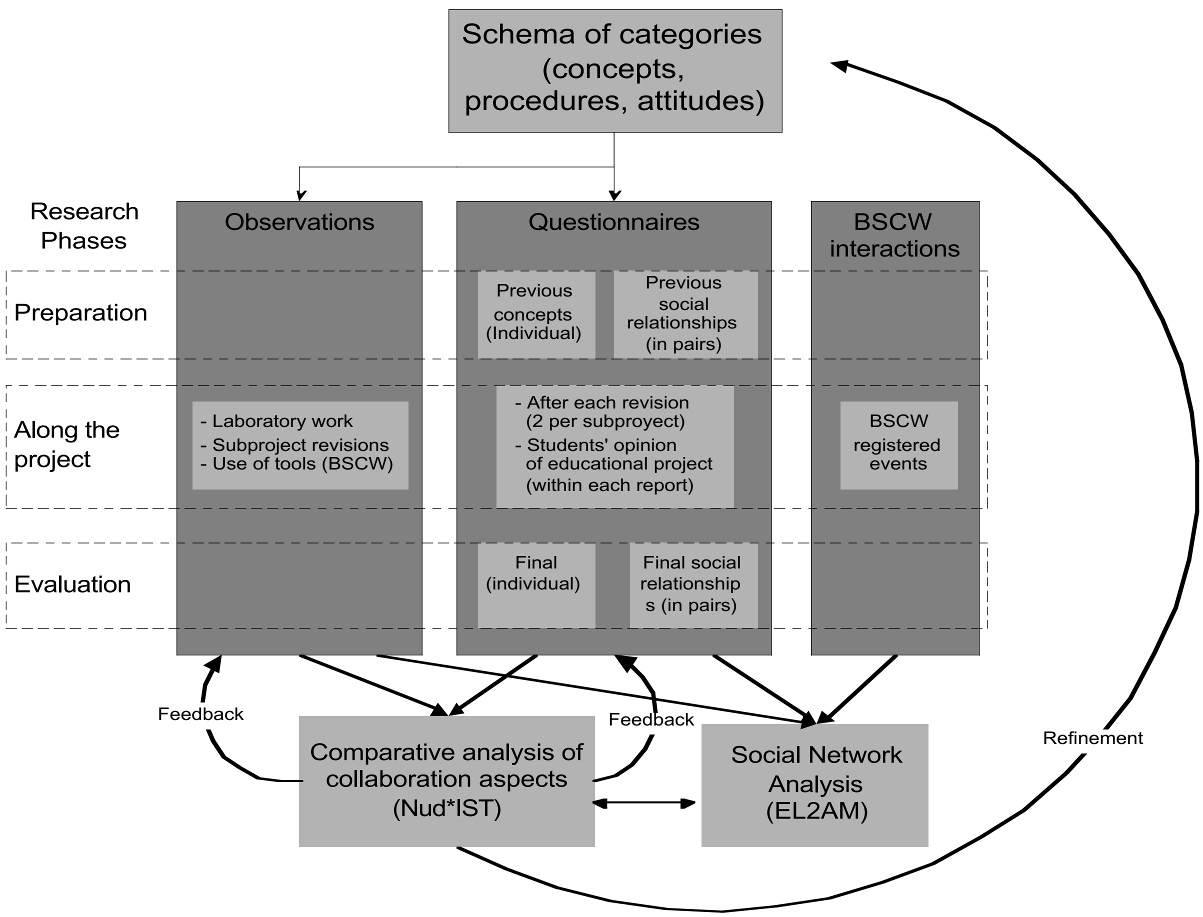


Figure 1. Schema of the research method. The analytical processes (comparative analysis and social network analysis) are interconnected, giving feedback to each other. They are performed along the process, and their intermediate results are used to give feedback to the collection of data.

additional forms of interactions, 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.

A core objective of our approach is to define a good combination of the different sources of data. As shown in figure 1, our research method uses ethnographic data from a variety or sources, mainly questionnaires and formal observations. For the network analysis part of the study we used students' questionnaires on social relationships, and the automatic events recorded from the shared workspace. Network analysis is benefited by the use of 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. 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 subsection explains with more detail how we adapted social network analysis techniques for their use in our study.

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.

Processing events from shared workspaces with social network analysis

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.

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.

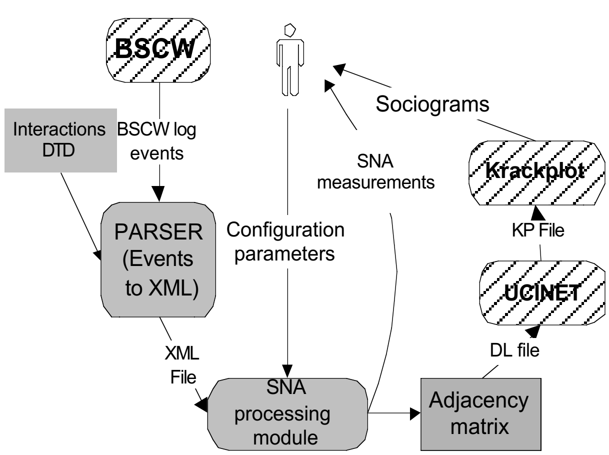


Figure 2. Automatic processing of BSCW event logs with EL2AM.

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 links are the lines 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.

EDUCATIONAL DESIGN

The above described evaluation method has been being applied for the last two years to an innovative educational experience in a course of Computer Architecture in studies of Telecommunications Engineering. 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.

In our project, the main objective consists in bringing together the three existing types of engineering courses, i.e. lectures, simple assignments and laboratory work. The modality of project-based learning applied to certain case studies was found to be especially appropriate for the fulfillment of this objective. It was necessary to integrate the whole process in a single project, in which lectures provide the introductory basis, exercises take into account realistic conditions, and lab work serves for seeking evidence in the form of information or experimental results. All these modalities can contribute to the achievement of the final project goal. Then, the project work should be structured in a sequence of educational situations, that in turn should be decomposed in specific activities. Such a structure, proposed in DELFOS, allows a clear identification of objectives and means for every activity and situation.

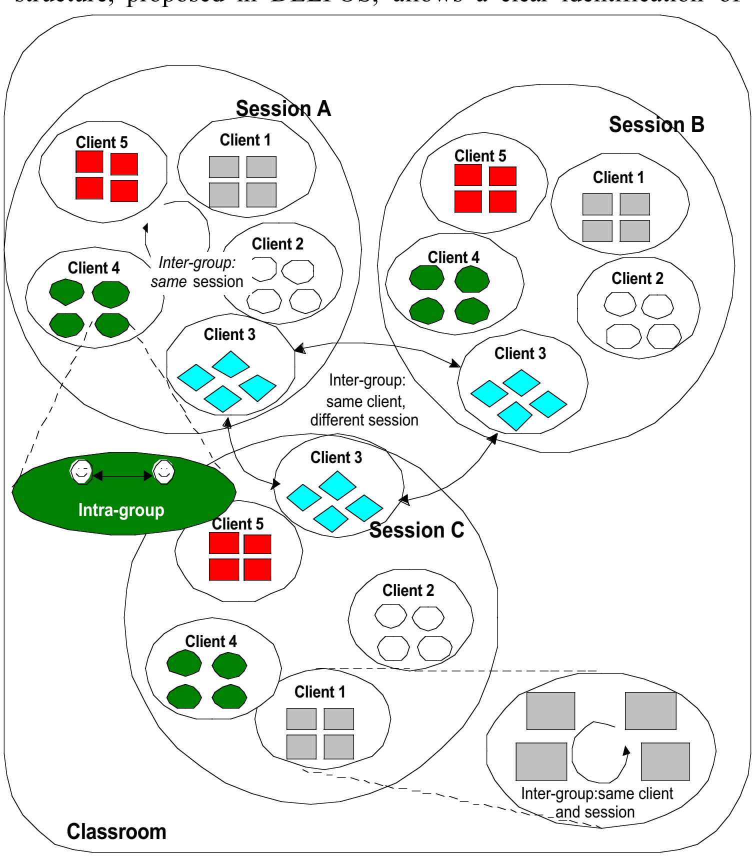


Figure 3. Structure of the class showing the levels of expected collaboration.

On the other hand, each project is based on a specific case study, with a limited scope and real-world data. However, one single case study for all students provides limited knowledge and does not show that different premises/restrictions lead to different solutions. Therefore, a well-thought selection of several case studies may broaden the learning horizon, produce conflicts and give rise to debates among various student teams.

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 3, 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.

The project is divided into 3 subprojects (*situations*, using DELFOS terminology), where different subsystems (CPU, memory hierarchy, etc.), or techniques (analytic models, real machine benchmarking or simulations) are studied. Each subproject presents two milestones: in the intermediate one basic decisions are made, collected through questionnaires and used in a synchronous debate, while in the final milestone of each subproject, a formal technical report has to be produced and delivered to the CEO/director/customer. 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.

With respect to the roles, professor acts as customer/producer CEO/Engineering Dept director, while students assume the work of engineers in the consulting firm and manufacturing company.

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 are used 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 all these types of collaboration, as part of the educational project. In addition, they offer means of registering the interaction information, so that collaboration can be deeply evaluated by means of the evaluation tools described beforehand.

Collaboration was expected to develop at three different levels: *intra-group,* with the elaboration of the reports for each one of the sub-projects; *inter-group*, between groups that shared client or session; and finally, at *classroom* level, in the debates, which were thought as a means for promoting synchronous discussions among the students with the help of the debate organiser. Next section explains and discusses our experimental work, explaining how we applied the evaluation method described beforehand to the study of these three levels of collaboration.

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, specially regarding the use of SNA in the study of BSCW indirect interactions.

For the evaluation of collaboration, we had four sources of data: technical reports and regular student questionnaires evaluating the educational project, that were deposited in the BSCW shared workspace; systematic observations collected in the diary of an external observer along the course; grades and observations made by the teacher; and computer logs provided by BSCW.

For the study supported by social network analysis, we defined the following networks:

1) *Aspects of collaboration network:* It represents interactions between the groups, taken from a questionnaire in which each group listed the groups they had collaborated with, stating the type of collaborative *activity* (sharing information, discussing, or solving doubts), and the *scenario* in which this interaction took place (laboratory, BSCW, other)
2) *Asynchronous discussions network:* It aims at the study of discussion activity in the shared workspace. When a student comments on a previous note left in BSCW, a link is defined from this student to that who created the first note.

3) *Indirect relationships network*: Relationships mediated by the use of the shared workspace. A link is defined between an actor that creates an object and the actors that access it for reading.

For measuring the networks, 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.

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 in our study. A sociogram represents a network as a graph in which each node represents an actor and links are the lines between actors.

The networks were applied in conjunction with the coding activities performed with Nud*IST, in an iterative process that eventually led us to identify concepts, procedures and attitudes towards collaboration arising from the educational activity. We were also able to identify the actual use of the technological support and compare it with the perceptions of the students.

Students' previous experience and attitudes towards collaboration were surveyed in a questionnaire at the beginning of the course. 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. The questionnaire 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 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 encourage new forms of collaboration, promoting new attitudes and an enrichment of the concept of collaboration itself. In the following, we will present and discuss the results of the analysis applied to the three levels of collaborative interactions we considered in our study.

Intra-group perspective

Collaboration at the intra-group level was mediated by the task of writing the reports for the sub-projects and joint work in the lab, or collaboration *at* the computer, in terms of Crook (1994). The sub-projects were assessed by the teacher, and constituted part of the final grades. Interactions at this level are not mediated through the computer, and their evaluation relies on the questionnaires and the observations of an external researcher.

Collaboration at this level was acknowledged as very positive by the students. From their answers to an initial questionnaire and processed using NUD*IST, we detected that new aspects of collaboration were perceived, like the need of *planning, knowing* each other, learning to *listen,* as well as *broadening* the individual point of view. Reasons for the general success of this level were found in sharing of a common objective (writing the reports), and the fact that this level of collaboration was already present in the culture of the students, as mentioned beforehand. In many cases, the pairs that formed the groups had a long experience in working together. However, some students acknowledged a progress in the planning and coordination of tasks, as one student briefly says: *"Collaboration already existed between the group members, only our organisation for carrying out the project has improved"*. We can conclude that, although collaboration at this level was already a well established practice for the students, new aspects of collaborative learning emerged due to the different kind of task they had to perform.

Inter-group perspective

This perspective considers each group as a unit that interacts with other groups of the environment, with whom they may or may not share the same laboratory session, the same client, or other external relationships like friendship or living in the same residence. Collaboration at this level presents different conditions than at the *intra-group* level. Interactions between the different groups could happen *through* BSCW, as well as by other traditional means. We wanted to study how the division in clients and sessions had affected the collaborative structures, and if this reflected a change in attitudes towards collaboration. It was expected that the division of the whole class into five clients would promote the interaction with partners sharing the same client. In particular, we expected that BSCW would support the asynchronous interaction between groups having the same client but different laboratory session.

The teacher encouraged the students to participate by adding notes in the BSCW workspace, in the form of asynchronous discussions on topics related to the project. Additionally, space in the laboratory was arranged so that groups of the same client sat next to each other.

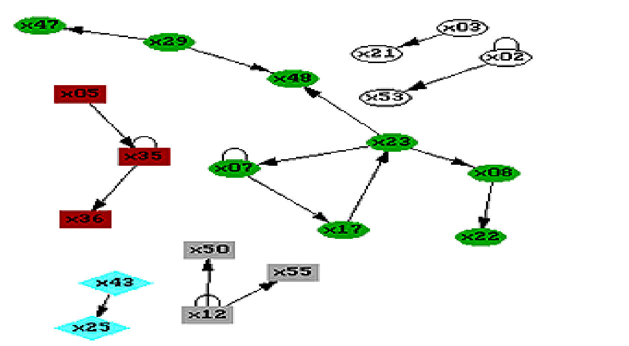
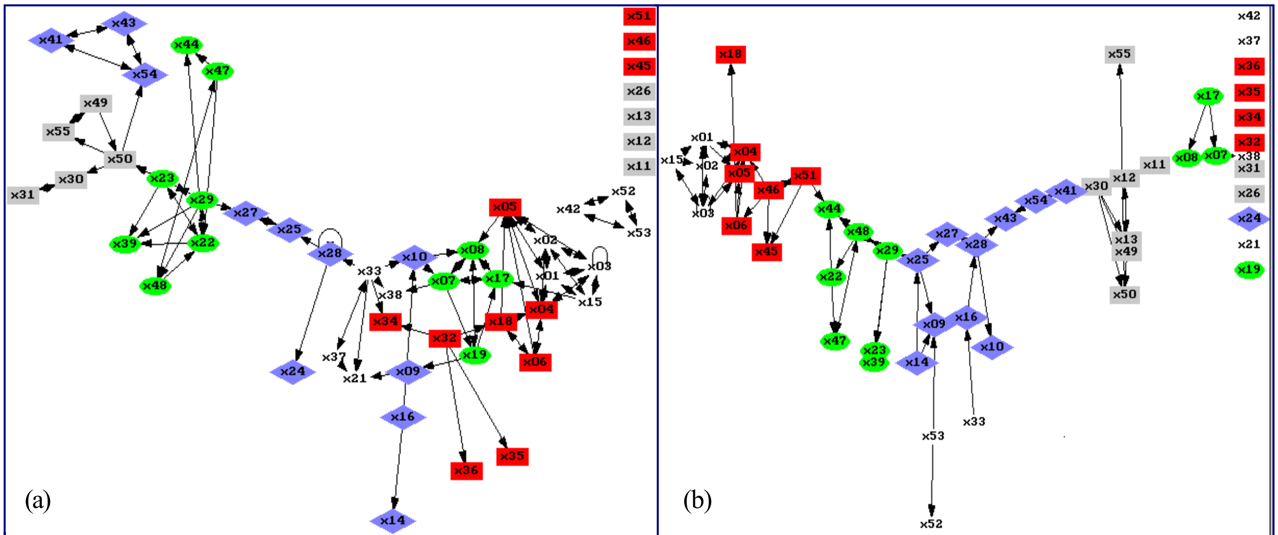


Figure 4. BSCW asynchronous discussions represented with MDS. Arrows point to the author of a note which has been answered by the other actor (origin of the link).

On-going observation of the BSCW workspace showed a low use of the threaded discussions. This is confirmed by the study with social network analysis. Figure 4 shows the sociogram representing the asynchronous discussion network. It is clear that the use of this collaboration activity 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.

When the second subproject started, the teacher added some folders with possible discussion items, in order to encourage the discussion activity of the students. This was not successful, with only three students adding a note to the discussions initiated by the teacher. 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. 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.In summary, we can see that the use of the asynchronous discussions had a bad relation between cost and perceived benefits, being this the reason for its failure. In order to have a complete understanding of this problem, it is needed to assess the general interest of the students in the activity of discussing itself, independently of which media they use for this task. This aspect was considered in the second study, based in the *aspects of collaboration network*, built from the questionnaires, whose results are shown in figure 5 and tables 1 and 2.



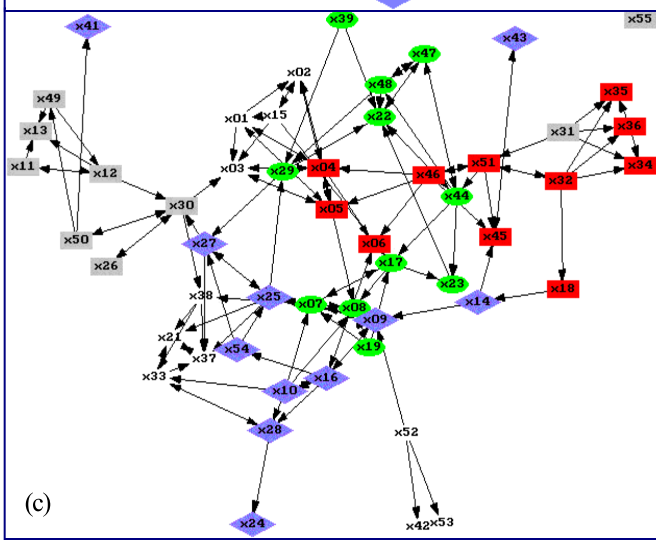


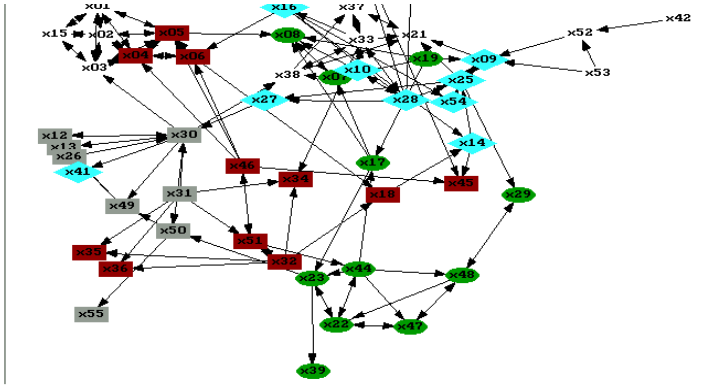
Figure 5. Sociograms representing the relationships of the *aspects of collaboration* network, represented with MDS. The following collaborative activities are represented: 5(a) *discussions*, 5(b) *sharing information*, and 5(c) *solving doubts*. Different shapes and colours represent the five clients. It can be observed how the nodes are grouped around their client, specially in the sociograms representing discussions (b) and sharing information (a). It is also possible to see how in (c) there are less isolated nodes, which explains the higher density of the *solving doubts* network (see table 1).

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 1. 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.

Table 1 shows that *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. These aspects are also shown in the sociograms in figure 5.

Focusing on table 2, we can see how collaboration through BSCW was almost ignored in the answers of the students. This reinforces what was said above regarding the debates. Comparing collaboration inside and outside the lab, we see how the latter, in spite of being more dense, has a higher centrality, which means that less groups concentrated more activity. E-I indexes show that relationships between groups of the same client are more frequent than external links, although in external collaboration this relation decreases.



COLABORATION SCENARIO	Density	Centrality	E-I index (clients)
Total collaboration in the lab	0,0392	8.41%	-0.611
Total collaboration outside lab	0,0486	12.29%	-0.358
Total collaboration through BSCW	0,0013	3.56%	-0.500

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.

Outside 2-cliques	Relationship
X12 x30 x49	Client
X13 x30 x49	Client
X30 x49 x50	Client
X01 x02 x03 x04 x05	Client + Other
X01 x02 x03 x15	Client
X04 x05 x06 x46	Client
X07 x08 x17 x19	Client
X07 x08 x10	Client + Other
X09 x21 x25	Client + Other
X09 x52 53	Client + Other
X10 x28 x33	Client + Other
X16 x28 x33	Client +Other
X17 x23 x44	Client
X21 x33 x37 x38	Client
X22 x44 x47 x48	Client
X22 x23 x44	Client
X25 x27 54	Client

Figure 6. List of 2-cliques and sociogram of the *relationships outside the classroom*, visualised with MDS. It is possible to see how different groups sharing a client are close to each other.

In order to have a closer view of this fact, we processed the network in order to find *2-cliques* (groups of nodes connected by at most an intermediate node) of the *collaboration outside the lab* relationship. As shown in figure 6(a), 11 out of 17 cliques detected where wholly composed by groups of the same client, while the other 6 cliques were composed by two groups sharing client plus another group. Cliques of the relation *collaboration in the laboratory* (not shown due to space restrictions) are still more structured around clients. Again, 17 cliques were encountered, 13 of them shared a client and the other four were composed by groups of the same client plus one group of another client. E-I index, as shown in table 1, is -0.611. Observations pointed out that the fact that the laboratory was set up in order to sit groups of the same client close together is one reason why the relationships among co-client groups were reinforced in the laboratory. This mediation of space is also present in the mixed cliques encountered, where two of them can be regarded to the fact that the *external* group (i.e. the one not sharing client) used to sit nearby the other two in the laboratory.

However, almost no clique of the ones detected above included all the groups sharing the same client and session. This means that although the educational project helped to define new interrelationship patterns in the classroom, collaboration among groups with the same client was not homogeneous, with some clients not presenting any strong relationship with their co-client groups.

Students' answers to the questionnaires confirm the fact that, at least theoretically, sharing a client presented opportunities for collaboration "*the fact that several groups have a common client, leads to a higher interrelationship between components, regarding sharing information and solving doubts*". However, the fact that this did not work always in practice, and that the perceptions vary among students, is shown in the following statement, made by one student that shared client with the one previously cited "*Collaboration between groups of the same client and turn has not been as expected*". In fact, different perceptions have been found quite frequently in our study. Causes of these differences were not the focus of our study, but point out at an interesting line of research.

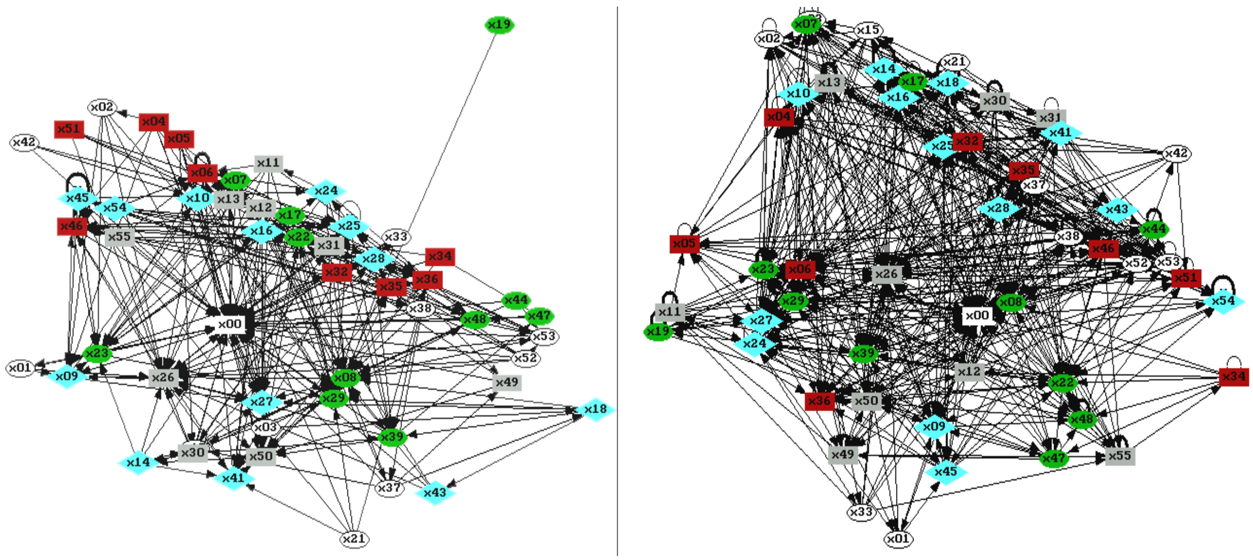


Figure 7. Indirect relationships mediated by the shared workspace, represented using MDS. Figure 5(a) represents activity during the 3rd subproject. Figure 5(b) represents activity during the final project report. The teacher is represented by the white square with the label x00.

Classroom perspective

Under this perspective, the analysis aimed to discover to which extent the students felt and acted as *members of a community*. We also wanted to gain insight in whether or not BSCW supports this change of mentality.

The setup of the BSCW environment promoted a view of the classroom as a whole, where every group could access the information of the rest of the groups, independently of the client or session they belonged to. Therefore, sharing information in BSCW can be considered an interaction at the classroom level. One important feature of this interaction is its indirect nature.

This perspective was studied by means of the third network, representing *indirect relationships* mediated through BSCW. For building it, the event files were parsed with EL2AM looking for the creation of objects and the later accesses to these objects. Links were created 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 2 shows the analytical measurements of these networks, and figure 7 shows the two sociograms corresponding to the two periods of time.

	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 2. *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.

Measurements of these networks show how density is higher compared to the ones discussed beforehand, being higher in the final project network. 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. Although the networks are more dense, centralisation shows how the relationships depended upon the activity of a smaller 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 7, showing the sociograms, 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.

The results of this 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. Another 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.

Other means intended for classroom-level collaboration were the synchronous discussions in the project milestones (revisions). The students gave a high value to the *preparation* steps assisted by the debate organiser, 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.

CONCLUSIONS

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 were promoting collaboration. We have observed how the possibility of establishing direct interactions in the classroom explains at least partially the lack of use of some of the computer-mediated means for collaboration. It would be interesting to compare these results with activities held in pure distance settings. We have observed several forms in which sharing a task with a common goal (intermediate reports in groups, final report in big groups, preparation of the decision tables of the debates) has promoted collaboration. Some of these forms of collaboration were known for the students (intra-group level), but the kind of tasks they had to perform helped them to develop new collaborative attitudes beyond the ones they reflect on the initial questionnaire. We have shown how BSCW and the *debate organiser* helped to mediate interactions in which students could *indirectly* share their information and ideas with the rest of the classroom. However, this indirect forms collaboration was not perceived as such by the students. As a conclusion, we see that the *concept* of collaboration itself has to be elaborated with the students, in order to improve their awareness about the collaborative activities they are actually performing or are able to perform, and their potential benefits. The role of the teacher is seen as very important in this objective.

The experience has lead us to a refinement of the evaluation method. We have detected the need of focusing on a smaller group of students, carrying a deeper study, with interviews, audio recordings, and observations. With this, we aim at refining the results obtained this year, and at exploring how they relate to *knowledge construction*. Additional software tools for the support for the process are under development, including a questionnaire designer which will be integrated for the automatic processing of answers with EL2AM, and a second version of the debate organiser.

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