A Methodological Framework for Project-based Collaborative Learning in a Networked Environment

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Abstract: In this work we present a new way to use existing technology in a real learning context. We investigate and propose a scenario based on collaborative work of virtual groups of students developing a software project. Our intent is to promote learning through collaborative implementation of a project in shared workspaces. This raises several important issues that concern virtual group formation techniques, group regulation and role-playing by students. Other important aspects are related to the pedagogical side and include setting project development phases, assessment, tutor role, student tracking, and the tutor's understanding and awareness of the social and cognitive processes. We consider them to be fundamental concerns and influencing factors in supervising, guiding and enhancing the collaborative learning process. Our approach describes the bases of a methodological framework for collaborative project development and proposes some solutions to the above matters. It also allows for the exploration of new forms of collaborative learning and teaching.

Keywords: Project-based collaborative learning; asynchronous virtual learning environment; conditions/methods for collaborative learning.

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1 Introduction

One of the basic requirements for education today is to prepare learners for working and living in an information society in which knowledge is the most critical resource for social and economic development. Expertise and networked activities increasingly characterise the emerging nature of this work. Elaborating, managing and extending knowledge while collaborating productively with others and functioning within networks of experts will be essential for the interactive and open organisations of the future.

Besides this generic objective, in the context of distance learning, one of the fundamental issues is to provide quality teaching and learning. This fact is even more imperative today when the rapid development of information and communication technologies has initiated a shift from conventional distance learning to network-based learning. The result of these technological advancements has given rise to virtual learning environments or virtual campuses where the communicative process is crucial. In this context, the Open University of Catalonia [1] has built a large and complex organisational virtual campus that provides an innovative model for distance learning and teaching.

In this broad networked learning community infrastructure, our work seeks to investigate and facilitate learning and social interaction. In particular, we have started exploring the possibilities for new forms of learning and teaching by proposing a methodology that promotes and encourages learning and collaboration through forming smaller communities of learners working together. We investigated different methodological approaches to and scenarios for networked collaborative learning,

considering several factors such as: the nature of the experience (the types of virtual collaborative learning activities), the individual and group objectives, assessment issues, tutor and student roles and commitment level, and the technology used for the implementation of the different practices.

In this paper, we describe a methodological framework that uses existing technology, namely, the Basic Support for Cooperative Work (BSCW) system [2], and applies an innovative scenario for developing a Project-Based Collaborative Learning (PBCL) practice that is adequately embedded in a real practically oriented educational context. In this context, we examine the conditions and methods that influence and enhance active learning through collaborative project development in shared workspaces as well as some methods for triggering collaborative processes. Our approach brings new expectations and requires changes in the attitude and reward structures for both learners and teachers, such as new roles, different pedagogic and learning methods, and technological and training support that enable learners to build up social structures, enhance learning and develop critical thinking skills.

The paper is organised as follows. Section 2 describes our research method and summarises the results of a preliminary study. In Section 3, we describe in more detail the organisational structure of our methodological framework. In particular, we present the innovative elements of the proposed approach, explain the key design issues related to planning and organisation of the learning spaces, propose a way to deal with the collaborative realisation of the project development phase, and finally discuss the project assessment issues. Section 4 presents a preliminary analysis of the experimental results and reports on the effects of this Computer-Supported Collaborative Learning (CSCL) setting on both the learners and the tutor. We especially examine one group functioning problem that arose in the progression of the groupwork and the solution proposed to tackle this problem. Furthermore, we discuss the role of the tutor in this CSCL experience, the ways the tutor supervised and guided the learning process of the students, and his awareness of the social and cognitive processes involved. Finally, Section 5 presents a global evaluation of the PBCL experience and discusses the present state of our experimental work.

2 Research method

The main goal of our research is to investigate how cooperation and collaboration can facilitate and encourage learning and social interaction among distance learning students in a virtual learning environment. On the one hand, traditional research on cooperative work and learning focuses on questions about how different group structures, labour division, and collective incentives can optimally improve the speed and quantity of learning [3]. On the other hand, emerging research on CSCL introduces the notion of knowledge management [4] and support for coordination in a collaborative application [5]. In fact, some recent research approaches examine the conditions under which effective collaborative knowledge building is achieved [6]. The omission of social interaction in computer-based learning environments has been a particularly worrying problem for a long time [7,8]. Nowadays, however, the situation tends to change since recent research on CSCL is exploring the ways technology can facilitate social interaction [9].

Despite the growing attention and experience related to social interaction in both research and pedagogy, we are still rather ignorant of the processes involved in it, particularly, in virtual collaborative learning and shared knowledge building in the workplace. In fact, there is a need for the development of theoretically well-grounded scenarios and tools for collaborative learning that can adequately support knowledge management and team coordination in a global virtual educational environment. Although there exist a few well-developed networked learning environments that support collaboration (e.g., [10]), several aspects remain unclear. For example, it has not been studied sufficiently yet how different practices and networked learning environments can fit different virtual learning community needs and cultures, and support social learning and different group structures and styles.

To face this challenge, we have designed, developed, analysed and evaluated authentic collaborative pedagogical experiments within a virtual learning environment. We followed a model-based approach including initial apprehension of the problem with 'formalisation' of the application domain for understanding collaborative work and learning in a virtual environment. This initial model was based on the concept of *communicative situations* [11]. In particular, on the one hand, the work aimed to identify the different types of situations that a group of students might find when engaged in performing a learning activity. On the other hand, it determined the type of communication / interaction the group needed to be involved in so that it carried out the activity successfully. These findings set the theoretical basis of a framework for understanding the communicative aspects of collaboration.

The next step of the approach consisted of performing a further empirical study of collaborative work and learning. In particular, we conducted two successive preliminary experiments in a distance education course, called 'Information Structures'. The first experiment consisted of testing how our initial model could be used to support collaborative problem solving activities carried out by small virtual groups of students. The second one aimed at promoting a new way of studying and learning the contents of that specific computer science course. It was primarily based on performing collaborative learning activities by small, autonomous, self-regulated virtual groups without active participation of the tutor. The key design issues of this experiment concerned the conceptualisation, planning and setting up of a networked learning structure, called *Virtual Study Group (VSG)*, aimed at supporting different collaborative learning experiences according to the learning objectives and styles a learning group specified [12].

Both experiments were based on the BSCW system, a groupware tool that enables asynchronous as well as synchronous collaboration over the web. BSCW is a 'shared workspace' system, which supports document upload, event notification, group management and much more [13]. A shared workspace (or group space) is a folder that can be accessed by other people beyond its owner, typically by a group of registered users. A shared workspace can contain different kinds of information such as documents, pictures, URL links to other web pages, threaded discussions, member contact information, etc. The contents of each workspace are represented as information objects arranged in a folder hierarchy. Members can transfer (upload) information from their local machines into a BSCW workspace and set access rights to control the visibility of this information or the operations that can be performed on it by others.

An important feature that the BSCW system provides is the awareness information that allows group members to coordinate their work. The event service (activity reports)

of the BSCW system provides users with information on the activities of the other group members, with respect to the objects within a shared workspace. Events are triggered whenever a member performs an action in a workspace, such as uploading a new document, downloading ('reading') an existing document, modifying a document and so on. The system records the events, and presents the recent events to each member. This particular feature proved to be very useful in our experience both for the students during the collaborative project development and for the tutor in supervising, tracking, guiding and assessing the group and individual student performance. Sections 3 and 4 illustrate how the BSCW system supports the needs of the project-based collaborative learning.

The outcomes of this study shed light on several important aspects, such as the factors that influence virtual group formation, the characteristics of effective learning teams regarding the group formation, the learning process, the group dynamics (communication, interaction, etc.), and the student and tutor roles. In addition, we gained interesting insights about the management and building of shared knowledge, the software products that supported collaboration and the principles used for individual and group assessment.

After the preliminary studies, our theoretical framework for virtual collaborative learning was modified to account for the observed outcomes and to explore new ways of collaborative work and learning. We initiated a new pedagogical experiment with a virtual class of 17 students divided into four virtual groups of four to five students. Our initial objective was to investigate a new way of working and learning the contents of the computer science course 'Software Development Techniques', based on the collaborative development of a project through the BSCW system. A further objective aimed at understanding how the best possible cooperation could be established and evolved and how successful coordination could affect the best implementation of the project in such working groups. We refer to this collaborative learning experience as Project-Based Collaborative Learning (PBCL), and we explain it in more detail in the next section.

3 Project-based collaborative learning: a methodological framework

In this section, we describe the methodology followed to implement the pilot experiment of PBCL in the course 'Software Development Techniques'. The key design issues are based on the conceptualisation, planning and setting up of the existing networked learning structure (VSG) mentioned in the previous section. It integrates both synchronous and asynchronous communication, though, at present, collaboration is mainly based on the latter due to the characteristics of our distance learning students.

The new experiment incorporates some important innovative elements, which differentiate the process and development of PBCL from the ones employed in the previous experiments. These distinctive elements are the following:

PBCL forms the fundamental objective of the course since it constitutes its spinal column; for this reason it is the project, which is really evaluated at the end. The goal of the project is twofold: it allows the students to exercise knowledge acquired in previous courses as well as in the current one. To that end, the project forms a significant part of the course content itself and constitutes the means on which the study, learning process, and evaluation of the students' knowledge are based.

PBCL explores new ideas and introduces new concepts in collaborative learning including:

- clearer and concrete roles attributed to the group members
- a specific and more detailed methodology that focuses on how a project can be managed better and carried out successfully
- a guide, which helps students in both planning the project (task/activities distribution, timing, etc.) and choosing an adequate group structure
- a methodology of collaborative work that explains the strategies to be followed in order to achieve the best possible collaboration among the group members in a virtual environment during the project.

3.1 Planning PBCL and organising learning spaces

Groupwork in virtual environments requires special attention; thus it is a principal objective of a course including PBCL. This type of collaboration is necessary, since, when working on the project, students are often faced with situations where the group members have to make decisions that have effects on the successful continuation and completion of the project. The project to be implemented should simulate a real world problem, which would give the students an idea of how to tackle real-life complex problems as a group. Thus, students have the chance to learn and practise the following:

- methods of groupwork on a project
- decision making in collaborative work
- when and how to communicate with the other group members
- what types of roles the various group members can have and what related responsibilities each member should assume
- how to plan and distribute the different tasks of the project among the group members
- what questions arise from working and learning in groups in a virtual environment

Given this context, the organisational structure of our methodological framework is planned in three consecutive layers: *initiating, forming* and *performing*. All the three layers are set up on the BSCW networked collaborative environment.

3.1.1 Initiating: set up a debate on a case of virtual collaborative learning

The main goal of the first phase of our approach is to introduce the students to the new experience. To that end, a specific case is presented to the students for asynchronous discussion in a BSCW virtual workspace. The purpose of the case study is multiple.

First, to prepare the students to tackle better the next phase (group formation). Group formation is considered a very important step in groupwork and learning. For this reason, students are engaged in a discussion to find out what kind of information they will need to know about their classmates, so that they form adequate groups at the next phase.

Second, to get an initial feeling and information about the way their classmates think of groupwork and learning.

Third, to become familiar with the BSCW tool and get to know the various functionalities it offers.

Finally, this discussion constitutes an initial, practical step towards the realisation of a group activity through an exchange of opinions and ideas, which can further motivate and push the students to be engaged in the real groupwork afterwards.

3.1.2 Forming: group formation

This phase involves three main actions*: introducing, negotiating* and *norming*. Students first introduce themselves by presenting relevant information that their classmates could use to choose possible candidate group members. Then, an interaction between possible candidates begins in order to form a group. This involves negotiation, taking into account various factors that affect collaboration, such as work pace, available amount of time, temporal coincidence, level of student knowledge/expertise, student attitude and especially the individual goals and the type of responsibility and commitment the student is willing to take. After a process of acceptance or refusal of the different intentions, negotiation will finally result in an initial proposal of group formation.

Finally, to achieve a reliable and definite learning group that could deal successfully with the project development phase, an internal discussion begins between the members of each group about the details of the working methodology and the structure of the group. The purpose of this discussion is to reach an agreement on the group norms and structure. As for the group structure, the group members choose among the following three options:

- *Democratic*: work distribution is performed in an equal way to all group members while everyone assumes the same types of responsibilities.
- *Democratic with coordinator*: the role of coordinator is assigned to a different group member in each phase of the project development; the coordinator guides and manages the work in the phase under question. The group, however, works in a democratic manner.
- *Project leader*: there is a member who assumes the coordinator role of the whole work during all the project development phases.

3.1.3 Performing: project development in virtual groups

After a group is formed and its norms are clearly specified, it is the time for *performing*: group members should be engaged in a collaborative work for implementing the project, using a common virtual BSCW workspace. To incite and promote collaborative interactions and make collaborative work and learning possible, we lead students through a guided process that involves achieving several learning objectives.

Since the groups have to achieve specific goals, we create a context in which students have to collaborate with concrete rules and purposes. Moreover, the timing and order of carrying out these learning objectives is a very important factor for the successful completion of the project. The time period for completing the project is four months; hence careful planning of the project development phase is needed; we describe it next.

3.2 Project development phase

This phase consists of five specific learning situations related to the process of a software project development. Each learning situation is associated with a particular learning objective to be achieved by the group. This objective is very important for the definition of the learning situation, organising its structure and planning the interactions that will take place. A learning situation is clearly delimited by a variety of factors, which also determine the dynamics established within the group. These factors are the following:

- the individual goals of each group member
- the group goals to be accomplished; these goals are determined by the group as a whole in a consensual manner based on individual goals
- the characteristics and idiosyncrasies of each member
- the needs, expectations, interests, potentials and motivations of each member
- the commitment that a member establishes with the group.

Importantly, since in the *norming* phase (see 3.1, Group Formation) the type of commitment that each member establishes with the group is made clear, the members are able to determine more easily both the group objectives and the expectations of each member.

Consequently, the learning situations in which the project is structured are adapted and refined to meet the above premises.

Below we describe each learning situation in detail by specifying both its purpose and content. This specification is crucial for designing the learning situations in the most adequate way.

Project specification/analysis

Purpose: Study of the problem, analysis/specification of its requirements. Preliminary planning and timing.

Content: Students should discuss how to plan the work; they should study and understand the problem: what the problem asks for (analysis of the problem requirements), and specify which initial states they start from and which final goals they wish to achieve. Because a deep understanding of the problem is needed, students should work collaboratively through the whole phase. The specification document should be circulated among all the members of the group until a definite one – up to this phase – is agreed.

Project design/planning

Purpose: Settle the problem solution and come up with the design of the application through an exploration process and by identifying possible subsystems and class hierarchies (amongst others) through an exploration process of the application. Verify and validate the obtained design.

Content: Students should plan the problem solution by clearly indicating both the proposed methodology and the decisions made (selected from the various alternatives considered). Students' work should be done by collaborating closely between each other and should reflect the debate and the proposed alternatives. A proper task distribution should be applied to members, specifically once the hierarchies, subsystems etc., are identified.

Project implementation

Purpose: Implement the designed classes, interfaces and subsystems in a programming language

Content: Students split the implementation work into smaller tasks and work individually, each programming a specific set of classes. Meanwhile they can interact any time they need some input from the others' work. Finally, they work in a group in order to integrate the different classes, interfaces and subsystems, thus obtaining the final implementation of the whole application.

Project testing

Purpose: Perform the necessary testing in order to check the proper functioning of the application.

Content: Students should apply basic testing techniques in order to design adequate sets of tests to verify the correctness of their program.

Project report

Purpose: Elaboration of the project documentation.

Content: Students should collaborate in order to prepare a project manual and a self-explanatory report about the project implementation.

The organisation of the shared work/learning spaces follows the structure of the project learning situations whereby the group takes care of the internal organisation of each learning situation regarding the document management and the structure of the asynchronous interactions. Thus the group space includes different subspaces each one corresponding to a learning situation. In particular, these subspaces serve as repositories for the project objects (documents, discussions, etc.) and facilitate the communication among members. There might be also other subspaces, e.g. for virtual meetings, which typically serve as auxiliary subspaces.

3.3 Assessment issues

The project assessment consists of two types of evaluation: formative and additive. Through the formative evaluation, the tutor does an active and detailed tracking of the student's activities in order to evaluate the whole learning process and the contribution to the collaborative work of each group member. For this reason, students are requested to

make all their contributions explicit in the shared workspace. These contributions concern both the interactions (asynchronous discussions) and the actions (document creation and modification, and performance of other tasks such as virtual meeting planning, etc.).

The tutor also applies a qualitative evaluation to the reflection process followed by the students and to the collaborative methodology applied when working in-group. This evaluation is individual for each group member. The daily workspace activity report sent automatically by BSCW facilitates this task.

As far as the additive evaluation is concerned, the tutor performs an objective assessment of the different documents and reports produced in the different learning situations of the project development and of the final project report (group evaluation).

So, the final project assessment is the combination of the formative and additive evaluation. This assessment is further complemented by an individual qualification to a report, present in the examination centre, on which each student elaborates. This final report has two important goals: first, to obtain a student self-assessment (critical reflection of the student about the project outcome and his/her own participation in the collaborative work) and, second, the student's assessment of the group (evaluate both the work performed by the group as a whole and the functioning of the group).

4 Results and insights from the PBCL practice

This section presents an initial analysis of the experimental results and reports on the effects of this CSCL setting on both the learners and the tutor. We especially examine a group functioning problem that arose during the evolution of the groupwork and the solution proposed to tackle this problem. Furthermore, we discuss the role of the tutor in this CSCL experience and the ways in which the tutor supervised and guided the learning process of the students and was aware of the social and cognitive processes involved.

4.1 The dynamics established during the evolution of collaborative work

During the *project-specification* learning situation, some groups that had chosen the *democratic* option to define their group structure, had difficulties in establishing their functioning basis. Due to this, they were unable to meet the deadlines of the implementation and delivery of their product in this learning situation.

Consequently, in the following learning situations they applied the hybrid structure 'democratic structure with coordinator'. By doing so, the working dynamics established in each learning situation were characterised by democratic decision making but a coordinator was always present to guide the task distribution to the group members. He/she also managed the whole process of task implementation, and controlled the timing and the final product of the learning situation in which he/she was in charge.

In this way, every group member was in charge of the coordination of a particular learning situation, that is, of a section of the project. It was interesting to see that this group structure worked well and proved to be the appropriate structure for most of the groups in this experiment.

4.2 The tutor and student roles

- Regarding the participants' *roles*, we identified some desirable traits that support collaborative learning. So, on the one hand, the tutor could:
- act as a facilitator (plan and organise) and guide (counsel and show 'direction')
- motivate and offer cognitive support (make suggestions, give recommendations, clarify doubts, stimulate creativity, encourage independent thinking and its role and contribution to the group work)
- set limits and assess both the individual learner and the group as a whole.

On the other hand, the student should be:

- responsible, curious, persistent, and take the initiative
- willing to collaborate, to learn new information and new ways to learn (through collaboration) and to use technology to achieve virtual collaboration
- able firstly to organise his/her own work and help/contribute to the organisation of the group work.

Indeed, in our methodological framework, the tutor constitutes an important figure who plays a guiding, supporting and evaluating role in the learning process. Thus, during the whole process of groupwork, students received continuous support for their work and learning.

More specifically, on the one hand, the tutor was attentive to the way collaborative interactions were carried through. In particular, the tutor was aware of the students' conceptual problems and doubts about the project development and thus could intervene to provide any tutorial assistance needed, monitor progress and make sure that groups were working and learning productively.

On the other hand, students also received whatever instruction and scaffolding they needed to prepare themselves for productive engagement in collaborative learning activities. This training ranged from general methodological instructions about groupwork and collaborative learning, specific guidelines, orientations and strategies about how to carry out a learning situation collaboratively to technical support regarding the tools used for implementing the experience. For example, the training showed the students how to pay attention to and benefit from contributions of the other group members, how to share and integrate the ideas of others, and how to handle disagreements constructively.

4.3 Student tracking and awareness

Student tracking and awareness influence to a great extent not only the successful completion of the project but also the whole collaborative learning process. Our experience shows that the tutor needs to apply a careful and well-studied strategy in order to relieve the overload and difficulties that this process represents. To that end, we settled on an *active tracking* based on several objectives, such as:

- reminding the students continuously that they are not alone 'fighting' against a project that requires thousands of code lines

- being aware of increasing difficulties as the project evolves and hence proposing ways out for the students when they get stuck due to technical difficulties
- being aware of certain undesirable situations within the group and hence proposing to the students reasonable yet human solutions to critical situations concerning group functioning
- providing group dynamic incentives so that students get more and more interested in the project
- observing individual member skills and giving adequate orientations.

It is worth mentioning here that we established two kinds of tracking, namely, *individual tracking* and *group tracking*. At an individual level, the objective was to track closely the contributions of the individual group members, while group tracking aimed to trace the group activities. In this way we were able to orientate correctly both individual and groupwork.

We have observed that the tracking process had much to do with the communication flows settled in the collaborative framework. We distinguished the following three main communication streams:

1 between the tutor and the individual members

2 between the tutor and the different groups

3 among the members of the same group.

A major difficulty with the tracking and awareness process is the rather large amount of information to be processed which might lead to a saturation of the tutor's available time. In our framework, we found a trade-off by directing part of the communication flow to the coordinators of the groups.

5 Conclusion: global evaluation of the experience

At the end of the experience, students answered a questionnaire whose purpose was to collect their opinions and impressions about their learning process and outcomes during the collaborative elaboration of the project. In principle, all agreed that the project was closely represented a real situation and that they learned a lot from this practice. Moreover, they became conscious of the needs and functioning of collaborative work and learning and how to face a variety of problems that arise in a virtual group.

In the students' opinion, collaborative work can be successful if all members show goodwill and responsibility. They also believe that collaboration is necessary to deal with such large projects. In general, a positive evaluation was attributed to this experience both by the students involved and the tutor. Finally, students noted that this practice made them feel confident enough to be willing to get involved in the virtual collaborative development of a real-life project.

There are, however, some limitations and drawbacks of the framework we presented here. First, given the importance of the tutor's role, the number of group spaces in this framework should be small. This is due to the large amount of information generated within the group spaces and the overall communication of the tutor from the tracking

process. Second, the group activity is permanently *threatened* by the overload of the group members (caused by the collaborative process), which could eventually cause some members to be unable to fulfil their commitment to the group goals and hence make it impossible for the group to complete the project.

For the time being, we are exploring new ways of PBCL based on our experience from previous experiments. In particular, we are trying to address the following questions that have been raised in our research before and need a more thorough analysis and study: How similar are the subjective learning situations experienced by the students to the beliefs of their tutor? Are the collaborative learning situations beneficial to all students or are their group members suffering from work overload, conflicts or others' problems? What specific roles does the tutor have to take in supervising and guiding the learning process of the students? What is the most adequate scaffolding process the tutor should follow to be aware of the students' weak and strong points and thus be able to intervene in order to repair deficiencies and monitor the group more effectively? It would be very interesting to investigate ways to process all the information that is available both in the global shared workspaces and in the specific group spaces and which allows for efficient student tracking and awareness. To this end, we plan to use different statistics to draw more concrete conclusions from the data we have at our disposal, based on different criteria.

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