Journal of Universal Computer Science, vol. 17, no. 2 (2011), 332-347
submitted: 17/9/10, accepted: 7/12/10, appeared: 28/1/11 © J.UCS

Enhancement of Collaborative Learning Activities using Portable Devices in the Classroom

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Abstract: Computer Supported Collaborative Learning could highly impact education around the world if the proper Collaborative Learning tools are set in place. In this paper we describe the design of a collaborative learning activity for teaching Chemistry to Chilean students. We describe a PDA-based software tool that allows teachers to create workgroups in their classrooms in order to work on the activity. The developed software tool has three modules: one module for teachers, which runs on a PC and lets them create the required pedagogical material; second, there is a PDA module for students which lets them execute the activity; finally, a third module allows the teacher set workgroups and monitor each workgroup during the activity.

Keywords: CSCL, learning activities design, PDAs.
Categories: L.6.2, L.7.0, K.3, K.3.0, K.3.1

1 Introduction

Collaborative Learning has been successfully used as a learning practice for many years, rising above individual learning in several social and superior factors, such as critical, creative, and meta-cognitive thinking skills [Johnson, 98]. Small groups of apprentices are the focus of the Collaborative Learning approach.

Collaborative learning can be defined as the united work of a group of apprentices in search of an academic goal, through tasks or activities, which must be developed by both a cognitive mediator and by the group of apprentices [Adams, 96]. However, this definition does not reflect one of the issues we consider more relevant in this kind of activity: the social interrelations within the group. These desired group interrelations can be expressed though social interdependences. A social interdependence is when one person's results are affected by the other person's action [Johnson, 89]. Social interdependences can be either positive or negative. Positive interdependences (or collaboration) are achieved when the individuals work together in order to reach a common goal. Negative interdependences (or competition) shows when individuals work against each other to achieve a goal that only one or few of them can reach [Johnson, 02].

It is important to note that group work does not enhance learning by itself. Only through interrelations between the teacher and the groups of students, and also through certain conditions, learning can be achieved. This kind of learning not only teaches academic objectives, but also it can teach transversal abilities like teamwork, critical thinking, tolerance, communication skills, etc.

Recently, collaborative learning has become more respected, being included in most new and reformed curriculums. Recent reform focuses on teaching transversal abilities via inclusion of collaborative learning activities in the classroom.

Over the past few years, there has been a great interest in using technology in order to support collaborative learning. In Chile, the use of Information Technologies for supporting Collaborative Learning could represent a way for science to contribute directly to a better society, in particular to enhance educational systems. In this context, Computer-Supported Collaborative Learning (CSCL) is indeed the research area that studies how to support with technology (software and/or hardware) teachers and groups of students working in collaborative learning activities.

Using collaboration and teamwork and distributing tasks in an optimal manner, it is possible to develop technology-supported collaborative learning tools, i.e., software tools that support collaborative learning activities. These tools should incorporate positive interdependences, which allow creating dependences between students that participate in a collaborative learning activity. This allows team members to learn at the same rate, through equal participation. It is important to mention that it is not about students learning an academic objective, but also about their learning abilities such as teamwork, and responsibility delegation.

Collaborative learning activity development and technological support require thoughtful analysis and design. According to our experience, great tools are not achieved by making learning easier for students, but by helping the teacher to monitor and evaluate activities [Collazos, 04]. The objective user of a CSCL application should be the teacher, because he/she knows what should be taught to students and the best way to do it. Also, teachers can collaborate in creating learning material that can be reused as necessary. It is important to show that collaborative learning should be seen as a complementary part of traditional learning. In an integrated learning system, students should be able to perform collaborative activities, both individually and competitively, because after school, they will be confronted with these kinds of situations. On the other hand, it is hard to measure the real value of IT supporting collaborative learning. The amount of existing CSCL tools are slim, particularly in Chile, so it is necessary to create a bigger set of tools to be used in school in order to measure its impact in the educational process.

This paper presents a computer tool that supports a Collaborative Learning activity, which helps teach Chemistry to Chilean high school students. In the next section the design of the collaborative activity is shown. Section 3 describes the technological issues involved to support the designed activity. In section 4 we present the developed tool. Section 5 presents a usability analysis of the developed tool. Finally in section 6 we present the conclusions and our proposals of future work and extensions.

2 Collaborative Learning Activities Design

In order to design our collaborative activity we first study the design and execution of these activities in a context without technological support. Figure 1 is a use case diagram for observing the activities.

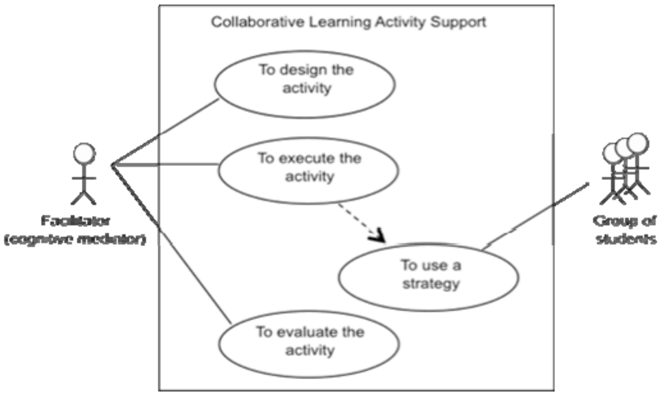

Figure 1: Use case for modelling the creation, use, and evaluation of Collaborative Learning activities

According to this model we have two main actors: the cognitive mediator (usually the teacher) and the group of students. It is necessary as a first step that the cognitive mediator designs the collaborative activity. Designing the activity takes several steps, including determining the environment, the participants, the material required, and the learning objectives. After the teacher designs the activity, he/she can execute it in the classroom, where students shall use collaboration strategies in order to complete it. These strategies are crucial to the development of social interrelations and must be monitored by the teacher. Finally the cognitive mediator must evaluate both the collaborative activity and every group work results, in order to improve future work sessions.

In our case, the collaborative activity design was defined in the field of study of Chemistry, particularly taking into consideration concepts such as molecular construction and representation through covalent links. This topic is part of the official Chemistry content of the curricula defined by the Chilean Ministry of Education.

It is important to us that students gain transversal abilities such as teamwork and individual responsibility. In order to achieve this, we propose small groups of 3 to 5 students. These groups will be able to collaborate with each other and support each other both socially and academically. The designed activity includes positive interdependences that allow the group activity to be performed following certain rules that encourage real collaboration within group.

2.1 Common Goal Positive Interdependence

To achieve a common goal positive interdependence, students must perceive that they can learn if and only if the other members of the group achieve their own learning goals. In our particular activity, students in each group are looking, as a team, to build a complex molecule representation. Without everyone's participation it would (and should) be impossible to build the proposed molecules, i.e., to achieve the common goal proposed by the teacher. As shown in figure 2, the team must rely on each other to achieve their goal because the resources are distributed among the group members.

2.2 Resource Positive Interdependence

In order to achieve a resource positive interdependence, we divided the required material among the group members. Each member of the group must have only a part of the necessary material required to complete the task. Consequently, these resources must be combined in order to achieve the group common goal. We are using a *shared puzzle* metaphor, as shown in figure 2. Each participant contains an integral piece of the puzzle. In our Chemistry activity, each group member is given just a fraction of the total base molecules needed to build the complex molecule representation. They are also given dummy molecules in order to make the exercise more difficult. Distributing molecules in such a way generates resource interdependence within the group.

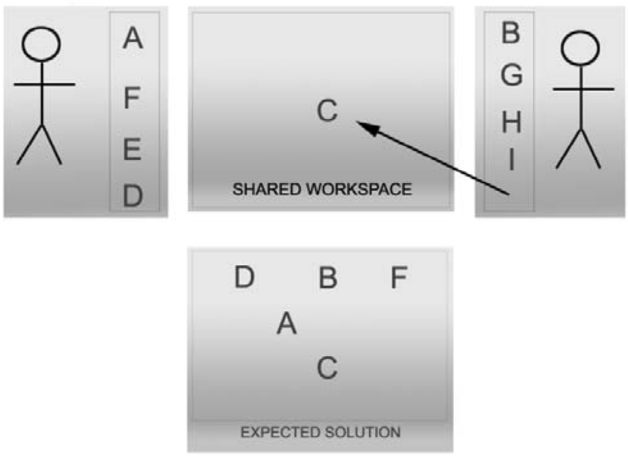

Figure 2: Resources and goal interdependences. The work elements are distributed and a common space is shared

2.3 Environment Positive Interdependence

Environment or surrounding positive interdependence is achieved when students work in the same physical space. The cognitive mediator must strive for the environment to be the optimal for the activity. During the execution of our activity, students can communicate face to face, because they are working in the same space, like shown in figure 3. This face-to-face communication is possible mainly due to the use of Pocket

PCs, which allow students to gather around in circles, or in a way that permits a fluent communication. Effective communication is essential for learning. This eventually allows students to generate simpler and more effective collaboration strategies, and encourages communication among them, which is a key instrument for groups to collaborate and learn.

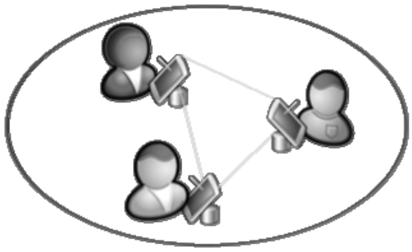

Figure 3: Environment interdependence. The participants can talk directly to each other and can move around the classroom

3 Technological support to a synchronous face-to-face activity

Once the collaborative activity is set and well defined, is important to understand the best way to support it with technology [Bustos 09, Valdivia 09]. Designing a computer tool to support Collaborative Learning could include some restrictions for students strengthening the inclusion of positive interdependencies. Technology could also help the teacher with monitoring and evaluating these activities, being this issues high priority for the cognitive mediator. On the other hand, technology could work in opposition of communication, or personal relationships, so is essential that the use of technology is used as a enhancing tool to the activity [Wurst, 08]. In our activity, the chance of restraining resources through software could let us see a first analysis of the advantage of using CSCL tools.

We have found certain points within the previously mentioned collaborative learning activity where technology could contribute effectively. This could apply to other similar collaborative activities (synchronous, in the classroom, etc.). This support can be better explained by focusing on the main actors.

3.1 Supporting the cognitive mediator

The cognitive mediator - usually the teacher - plays a key role within the collaborative learning process because he/she is in charge of the design and execution of the activities. This actor is our final user, and the main goal of the software tools must be to support him/hem work. We have found some situations where technology could better support this role. Technology should enhance the mediation capabilities, in order to make the activity as fluid and interesting for the students, thus allowing them to learn in several ways. The monitoring process is one of the main tasks of the teacher, and this activity can be supported by technology (as we will show later).

3.2 Collaboration and academic objectives monitoring

It is ideal that in a collaborative learning session, the cognitive mediator could monitor the progress of the groups of students. By reviewing in real time the actions of the students, he/she could understand the group's dynamic and balance the learning within the group, or can help to achieve the academic goals. Monitoring several groups that are in the same activity can be very hard without the use of software that makes this process more efficient. In software-less collaborative learning sessions, the cognitive mediator has to walk through the groups and observe who is doing what in each group. This can clearly make the cognitive mediator loose a large amount of information, and also intimidate the students, forcing them to act unnaturally. On the contrary, using software tools the cognitive mediator can easily identify all the participants and can view in real time their participation in the activity while being unobtrusive.

3.3 Collaboration and academic objectives evaluation after the work session

In both synchronous and asynchronous learning sessions, the cognitive mediator could require, for a follow-up analysis, every step executed by students. The analysis of the student's strategies, particularly for collaboration, can be a key factor for redefining the activity in a better way, by creating better groups, assigning roles or focusing the activity in such a way that students learn in a better way. Creating logs that record the actions executed in an activity, which also identify students, could be an excellent tool to improve work sessions in the future. Also, logs could be a very useful way to develop metrics of learning in collaborative applications, in order to improve the group work process for future work sessions.

3.4 Learning sessions administration and execution

The required time needed to execute a learning session could become a negative factor to include collaborative learning activities in a regular basis in the classroom. An activity design implies defining groups, assigning students, defining roles and on top of it, the execution of the activity. Usually the teacher must distribute certain materials and also assign physical spaces amongst other things. This can make it harder to execute an activity in a short period of time. Technology could benefit most of these issues. For example, creating sessions where the amount of students changes dynamically. Software can be provided to automatically adjust the activity to the groups. The distribution of digital material will become a simple and dynamic step, reducing the cost of the process, both in money and time, in the long run.

3.5 Material creation for the learning session

During an activity execution, the cost of acquiring the necessary material can become a real problem for the cognitive mediator. In particular, the need to recreate the activity with a new set of students or even the same set of students, but with a new level of difficulty is even harder. Digital material created through software, could be a simple and convenient replacement to physical material as paper. With this kind of solution, it is very easy to reuse many times the material or even use it as a base for new material. Therefore, the collaborative learning activity could be executed within the same group of students, with different levels of difficulty, with different objectives, or even with a new set of students. The material really takes a predominant role in the activities that require it. With this, the easy setup of the material and its reutilization can become a main factor. If it can be done in independent instances from the activity execution, it can become an efficient and comfortable process for the cognitive mediator. This ultimately decreases the needed time to execute the activity. The distribution of such material could be managed in public repositories, allowing cognitive mediators from different places access several activities for their students

4 The developed software tool

ColaboQuim is the name of our software tool that intends to support the teaching of chemical molecules construction. This tool is divided in three main modules that are designed for building material, executing the activity, and monitoring it. The collaborative activity consists, as previously mentioned, in having the students learn to build a predefined macro-molecule using for this, smaller and simpler base molecules. The design of this activity consists of a synchronous work session where students have access to: a public virtual space that is seen and shared by the whole group, and a private virtual space, where the base molecules are stored.

4.1 Overall architecture

ColaboQuim is designed on top of a hardware architecture shown in figure 4. This architecture design was based on our previous work [Guerrero, 06; Alarcon, 06].

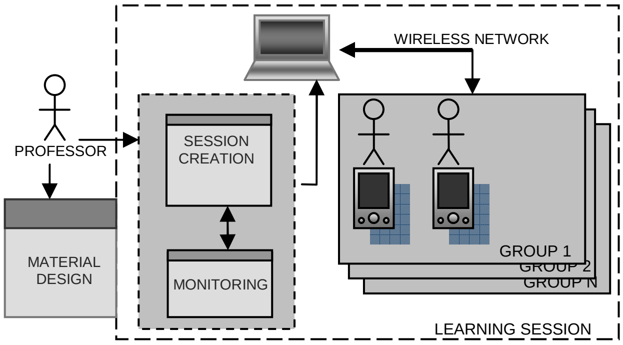

Figure 4: Architectural diagram of the developed tool. The diagram includes the PC and PDAs modules

This architecture requires one Pocket PC for each student and a PC or laptop for the cognitive mediator, in a local network. The architecture is simple, but it requires an extra device – a wireless router- that could be replaced by a peer-to-peer software framework. This software limitation in the other hand solves the problem of kids getting distracted, since the teacher has control over the network itself, allowing the students to go to internet to find data or just allowing them to use the software in a local network with no external access. This makes the students focus on the problem instead of getting distracted with the technology itself.

Peer to peer connectivity could also be developed. The material designer, session creator, and monitoring module are executed in the cognitive mediator's computer. The use of Pocket PCs or similar mobile devices permits face-to-face communication within students, and also group forming in real spaces, as opposed to virtual groups occurring in e-learning networks. Several other applications have been constructed using Pocket PCs as way of collaboration, like AULA [Paredes, 08], in which a discussion process occurs while executing the activity. The PDAs would allow this discussion to be immediate. There have been other uses of PDAs in asynchronous collaboration, through the use of PDAs such as DomoSim-Mob [Molina, 05]. Regarding this point, several researchers have shown that computing mobile devices, particularly when they have access to Internet, can be a distracting factor during the lectures [Reisman 05, Adams 06, Fried 08]. In our case, the PDAs are connected to an Intranet but they are not connected to the Internet.

On the other hand, the use of desktop PCs requires an important restriction of mobility, which would restrain communication and impact the learning in a negative way [Casas 09].

Due to the technological restrictions of our educational system, cheap and reusable hardware is required. The hardware would be considered an investment to the educational facility, so it is important that the development of several educational features is handled and also that the hardware can be shared and distributed within several groups and activities. The use of Pocket PCs due to their lower cost over PCs or portable computers, and also the ability to save in storage space makes the hardware selected optimal. For the cognitive mediator, the use of a larger device is necessary, but it is suggested that a laptop could be suitable for this activity, both for its portability and because the hardware requirements are suitable for this software. The laptop could eventually be used in a different setup like the ad-hoc mobile networks used in other PDA applications, by using a topology discovery method such as AODV [Lee08]. There were several collaboration patterns that were used, but an Upper-Layer middleware based in those patterns could have made the development easier. There are already studies of middleware for collaborative meetings [Zurita, 08], but the patterns presented in this educational software could benefit a middleware that is made for collaborative learning.

4.2 Technical aspects

The software tool was developed using .NET compact framework for Pocket PCs running Windows CE, and .NET framework for the cognitive mediator's modules. Most computers in the classroom use Windows as an operating system, therefore the selection of .NET and C# for its compatibility and integration to the operating systems on the hardware was selected. The network communication was done using UDP for simple message broadcasting using multicasting, and TCP for direct messages to the main server.

4.3 The molecule designer module

The collaborative activity design is performed only once, however, several molecules must be created and designed for each executed activity. Material construction necessary for each activity can become a problem for teachers. It is very important to solve teacher's need to rely on reusable material either for new learning sessions or for different groups of students. Due to this, a tool has been implemented to create material for this kind of activities (molecules). The cognitive mediator must build and save molecules before asking students to build their own. This helps to evaluate students' work, because it allows comparing, in real time, the result of each group. An application was created to design base molecules (see Figure 5), which are intended to build bigger structural ones. Structural molecules can be used as objective molecules for groups.

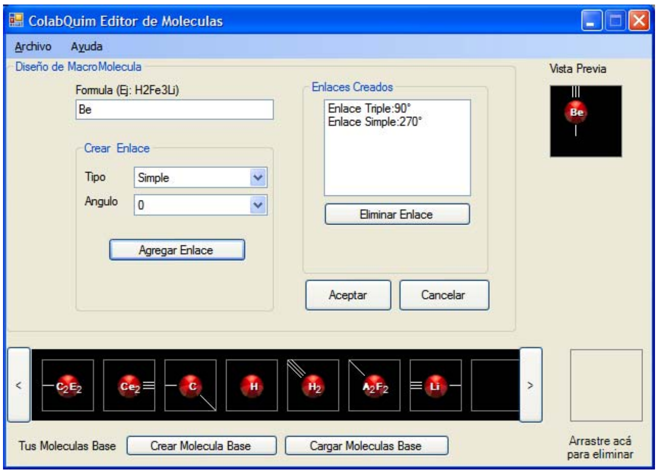

Figure 5: Software module 1 (in Spanish). Main screen of the tool that permits the teacher to create the base modules (required material)

We used the eXtensible Markup Language or XML for portability in the representation of the molecules, allowing this way letting the cognitive mediator create material in any computer with the software installed. The molecule designer module uses an interface to create base molecules, which are represented by a sphere containing the molecular representation, and links – single, double or triple links. This links can be associated to different angles of connection. This module also uses an interface similar to the one provided to the students' module that allows the teacher to build structural molecules in certain gridded space, by dragging and dropping molecules (see Figure 6). These structural molecules will be used later during in the collaborative learning activity.

The building method uses simple interaction as double-click to rotate, and a context menu, which allows deleting a molecule from the space.

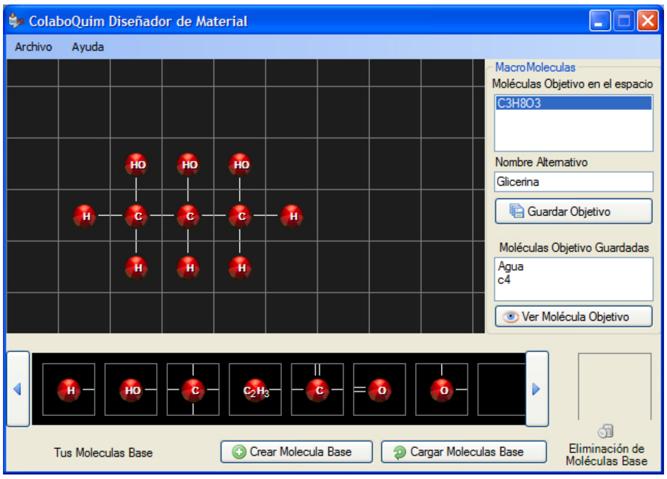

Figure 6: Software module 1 (in Spanish). Second screen of the tool that permits the teacher to create the macro modules using the base ones

Once the teacher creates a structural molecule, he/she can save it to be later used in the session administrator module, where it will be assigned to a group and then compared to the group's result to see if students are doing things well. The system is extensible, and it could allow the use of a repository for the distribution of material.

4.4 Session manager and monitoring modules

The collaborative activity allows students to create structural molecules in real time. Due to the fact that this activity is synchronous, it requires a tool that helps the teacher monitoring students' progress for each group. The tool must help him defining groups and assigning learning objectives. The following application intends to solve these problems and also permits the teacher to evaluate the activity. Using a wizard-link interface, the teacher follows steps to complete these tasks.

The session manager tool obtains structural molecules previously created in the Material Designer module. This tool manages students, helping the teacher with a list of students available to create groups. This is helpful in situations where the number of students in a classroom is dynamic (as usually is). The amount of groups that will be participating in the learning activity is the first input the teacher must set when the session is starting. This number must be determined by the teacher depending on the complexity of the molecules, the difficulty of the problem or the amount of students available. It is not required for the groups to be the same size, but this is advisable.

The cognitive mediator must assign a structural molecule for each group. He/she also defines which structural molecule will be the current group objective molecule.

Once the groups are defined, and the molecules are assigned, a learning session is started. The flow of this process and the corresponding software interfaces can be seen in figure 7. The software waits for the groups to be gathered (and each student to activate the module in their respective Pocket PCs), and it monitors them. The learning session uses messaging through a simple wireless network. For this, a wireless router is required. The monitoring interface (see figure 8) lets the teacher watch in real time what each student in each group is doing in their public space.

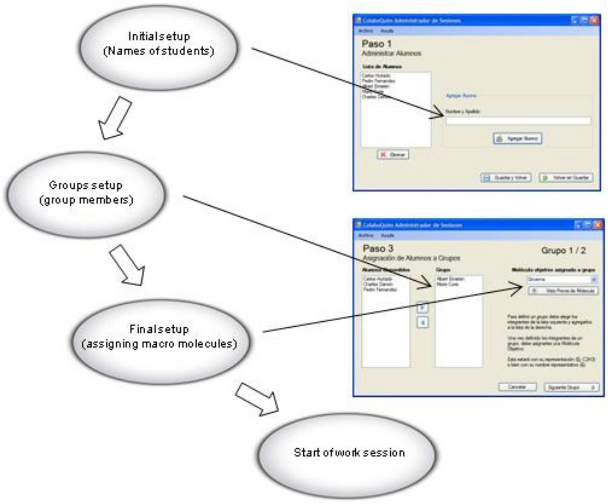

Figure 7: Work session setup flow

The teacher can see in this interface exactly the same that the students are looking in their Pocket PCs. Each action a student performs in their module is registered and shown in this interface. Using a colour coded system the teacher can identify each student. This monitoring interface helps the teacher obtain the following information: state and progress; learning objectives; and collaborative work.

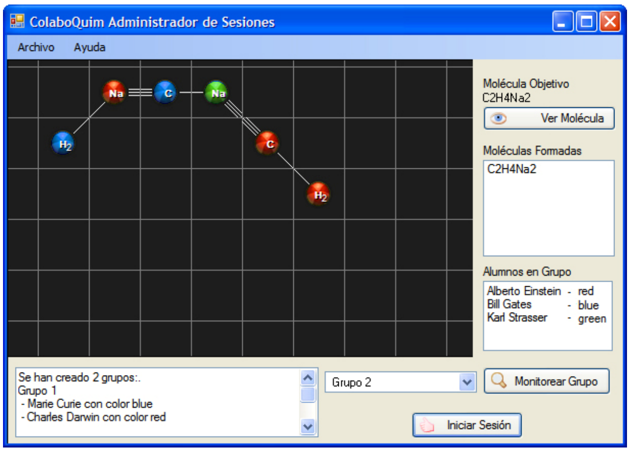

Figure 8: Interface for monitoring the activity (in Spanish)

4.5 Students' pocket PC client module

In order to work in the collaborative activity, each student uses a Pocket PC with the ColaboQuim client software installed. This software allows student to participate in a ColaboQuim learning session (see figure 9).

Through the use of the Pocket PCs, the student can gather with their partners in the group, and can communicate face-to-face with each other. The use of desktop PCs could obstruct the possibility of strategy creation. On the other hand, executing this activity with paper and pencil as material, could allow sharing the resources without restriction allowing one student to do all the work, therefore stopping collaboration by blocking the positive interdependences.

The designed architecture (a PDA module for students plus a desktop module for the teacher) provides the most flexible solution in order to support with technology the designed collaborative learning activity.

Figure 9: ColaboQuim client. Public and private area of the interface for the PDA students work module (in Spanish)

Initially, the cognitive mediator sends messages to each PDA with the team information. That allows him to remotely set up the teams. The students use their PDAs to identify the teams in the physical space, and followed by that, the students receive their group goal -the construction of a particular molecule through the software tool. For each student in the group, a set of molecules is assigned and stored in their private space. The colour of their molecules is a unique identifier for that student within the group. This is very important since the action over the molecules, like "move" or "rotate", are only available for the students' own molecules. A student cannot change anything over their partners' molecules in the public space. This allows the Resources interdependence to be fulfilled.

Students can move or rotate their molecules through simple interactions like drag and drop and double-tap respectively. Each student must define a strategy to move their molecules from their private virtual space to the group public shared virtual space. The public space is fully synchronized, so each action of students in their Pocket PC is shown in each teammate's interface. In the same manner, the teacher, through the monitoring module can observe in real time what is happening in the public space of each group.

The teacher can monitor how good the students are performing the task by checking how alike the objective molecule and the structural molecule created by each group are. The teacher can finish the activity when the objective is accomplished. With this, students loose the possibility of using a “trial and error” strategy, while reinforcing the collaboration strategy.

5 Usability analysis

Since this educational software is very graphical, we felt important to evaluate the usability of the tool by using several interface heuristics. This allowed us to solve the relation between the interface of the software and the user requirements and the functionality. We took several usability heuristics such as Learning, Efficiency, Recognition, Errors and Satisfaction [Nielsen, 00]. The study was done as a way to improve the software, by enhancing the interface. We conducted a heuristic evaluation, with a few expert evaluators.

Each evaluator reviewed the interface without assistance, and scored the interface using a scoring sheet that analyzed the heuristics associated to different aspects of the software interface, focusing primarily in the cognitive mediator’s interface. This scoring sheet required a one to two hours long analysis of the interface, that le to the answering of the evaluation. The result of the analysis gave us a list of interface issues that required improvement, and it allowed us to focus on the biggest problems first. We used four expert evaluators that responded our questionnaire online. The evaluators had experience in educational software and human computer interaction, which showed to be extremely valuable in the analysis of the software interface. We found initial deficiencies in several areas of the software such as error prevention, documentation, aesthetics and consistency. After several redesign iterations, those items were solved, and the interface was made efficient for the cognitive mediator, in several sections of the interface (see figure 10).

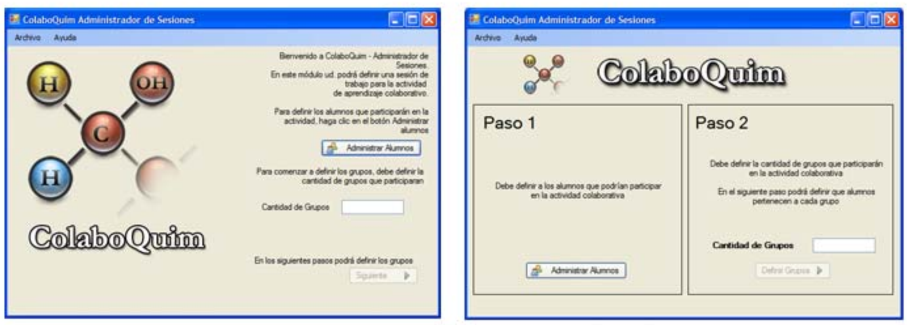

Figure 10: Initial screen modification example: Before (left) and after (right) the heuristic evaluation

The most critical elements to solve were Error Prevention, Recognition of errors, and Help and Documentation. Some of the comments the evaluators gave us where:

- "Don't use the same icon for buttons with different actions."
- "The Save Objective button has no feedback, therefore the user can't know if it saved or not."
- "The help takes you out of the context of the software (it takes you to a Word Document)."

The analysis of these and other comments led us to do the following redesigns:

- Redesign of the icons to maintain consistency throughout the interface.
- Redesign of the menus to maintain standards.
- Inclusion of contextual help and tooltips.
- Redistributed buttons and tools in order to improve the aesthetic and improve the guidance to the process.

An observation lab would have benefited the study of the interface with final users, but the complexity and the technical resources required did not allowed us to test the application for interfaces purposes, which would have been beneficial for the improvement of the tool.

6 Limitations of the Study

It is important to note the limitations of this study. This study was conducted in an exploratory way to develop a software tool that would directly use the collaborative interdependences as a way to enhance education. For this purpose we created a tool that helps the teaching a particular chemistry subject. Many more school subjects could have been used and directly benefited from collaborative interdependences. An extension of this work on other school subjects, in order to have a complete set of tests in different age groups would have improved the results, of how these particular interdependences support the educational process.

The amount of user testing done in this study could be increased in order to have more quantitative data. In order to accomplish this, the experiments require more equipment, and more suitable testing environments.

Finally, the collaborative aspect of this tool could have benefited from a non-competitive game scenario that could have added a more direct inclusion of fun and entertainment instead of just the intrinsic fun generated by working for a common goal with other people.

7 Conclusions and Future Work

The current paper shows the design of a collaborative learning activity to support Chemistry contents. Particularly it focuses on the building of structural molecules with covalent links. This is an academic content in the second year of the high school curriculum in Chile. We present a tool with two modules: PC and Pocket PC, to support the cognitive mediator's work and groups of student in order to participate in the previously designed learning activity.

In our project we use Chemistry contents. However, any other educational content can be used if the activity is designed according to the guidelines we show in our example, i.e., using positive interdependences and dividing the material among the students in a "puzzle-based" way (using a "collaborative puzzle" metaphor).

The main value of the developed tool is that it shows a way to naturally include positive interdependences in a CSCL tool, and it also shows mechanisms to help the teacher to monitor the activity. Monitoring is of great value in collaborative learning, because it gives vital information for the cognitive mediator to evaluate students' work and allows him to take immediate corrective actions. With quick and precise interventions the teacher could create a real positive impact in students' learning, impact that could not be accomplished if the teacher did not have these kinds of tools.

Even though the results are particular to this experiment, the main concepts of monitoring for the teacher, and a shared space could be also easily integrated with other subjects and problems. Math equations, story and sentence construction, and several other subjects that are based around construction of something complex using simpler pieces could be done in a collaborative manner, and thus adapting it to use the positive interdependences and the collaborative puzzle metaphor already mentioned.

The hardware used – mobile devices – seem particularly effective in these kinds of applications. The fact that they allow direct communication while executing actions that can be collaborative makes it a perfect device for the educational collaborative tasks. It also allows the cognitive mediator to monitor in a really unobtrusive way, and therefore enhance group learning.

More testing is required in order to improve the usability of the developed tool, and also testing supervised by educators in several iterations in order to review the level of learning that the kids are obtaining with these kinds of tools. It is suggested that double blind testing will be done with students that are in the stage of learning this particular chemistry subject, in order to compare the results and determine that the collaboration provided by this tool improves learning skills in short and long term.

Acknowledgements

This work has been partially supported by LACCIR grant No. R0308LAC001.

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