Partially accepted in Computers and Education

Multiple Mouse based Collaborative one to one Learning

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Abstract

Exchange is a Collaborative Learning application originally developed for wirelessly interconnected Pocket PCs, devoted to engage students and their teacher in a face to face Computer Supported Collaborative Learning (CSCL) activity, in a Single Input Single Display (SISD) mode. We extended Exchange to support a Single Display Groupware (SDG) mode as well. In the new version, Exchange-MM, three users interact on the same display using three different mice (Multiple Mouse) being mediated by the technological network, while preserving the original collaborative interaction. We describe the Collaborative Learning activity, the software architecture that supports both interaction modes and present a usability analysis performed with second graders. These show that as in CSCL, SISD mode, in SDG with MM the technological network favors communication, negotiation, interactivity, coordination and appropiability between group members'.

Keywords: Collaborative learning; Single Display Groupware; Multiple Mouse; Computer-mediated communication.

1. Introduction

In a traditional classroom students are expected to work individually on their assigned tasks and not interrupt others. Verbal exchanges with other students are usually discouraged. Interactions with teachers are usually reserved to respond questions. On the other hand, students are asked to work in small groups without a clear guidance and mediation. When students have the opportunity to effectively work in a collaborative way, they develop a common understanding, as well as verbal, cognitive and social abilities. When students work as peers in their own context, they often understand better other students' needs, their focus, and the best way to explain a particular subject. Recipients benefit of peer learning because they get the opportunity of experience new thinking approaches. Helpers benefit because when they explain their ideas to others, they have to verbalize their understanding, making explicit the difference between what is in his/her mind and his/her utterances, and by doing so, obtain a clearer perspective of the topic (Gillies, 2006).

When children work collaboratively together, in small groups, they show increased participation in group discussions, demonstrate a more sophisticated level of discourse, engage in fewer interruptions when others speak, and provide more intellectually valuable contributions to those discussions (Shachar & Sharan, 1994). The group should initiate a debate and negotiate, trying to eliminate the different group members' dissonances by attempting to

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convince each other of changing their ideas and converging finally, to a common solution (Ai'meur, Frasson & Lalonde, 2001).

Computer Supported Collaborative Learning (CSCL) uses the computer to sustain the collaborative learning process supporting cooperation, discussion of ideas, resolution of conflicts and resolution of problems (Bricker, Tanimoto, Rothenberg, Hutama & Wong, 1995), all of them basic social and cognitive abilities to strengthen learning's deepening and refinement (Marzano, 1992). When students in a CSCL activity work in the same physical space and see each other directly, the activity can be characterized as a *face to face CSCL*, or *collaborative 1:1* learning. In face to face CSCL the technological network coordinates and synchronizes the social network mediating the activities and the social interaction of the peers (Zurita & Nussbaum, 2004-a). In this way, the common problem of students working in small groups without guidance or mediation in schools can be reduced. The risk is having students that do the work assigned to others or do not want to work. It is even possible that some student(s) might be singled out of the group interaction because of social or academic considerations (Slavin, 2006).

There are different ways of implementing face to face CSCL: one of them is using wirelessly interconnected handheld devices (Single Input/Single Display, SISD), and a second one is Single Display Groupware (SDG) or Multiple Input/Single Display (MISD). In the first case (SISD), the technological network organizes the social network in small group of peers making possible different learning activities (Cortez, Nussbaum, Rodríguez, López & Rosas, 2005; Zurita & Nussbaum, 2004-b). In the second case (SDG) multiple co-located learners interact simultaneously on a single common display (Stewart, Bederson & Druin, 1999). The use of multiple inputs has been studied by a few researches in order to demonstrate the effects of using multiple inputs working on a unique screen (Paek, Agrawala, Basu, Drucker, Kristjansson, Logan et al., 2005). They have also compared the use of single and multiple mice modes (Pawar, Pal & Toyama, 2006; Pawar, Pal, Gupta & Toyama, 2007). They have found that children controlling their own input device in a collaborative setting, show less off-task behavior and boredom and became more active suggesting more engagement in the activity (Scott, Mandryk & Inkpen, 2003). However, in all these cases the software doesn't provide mediation to foster collaboration, leaving this responsibility to the users.

In this paper we present a collaborative activity supporting both modes, SISD and SDG. In the former case, a Pocket PC application is used as the technological infrastructure. In the second case, three users interact sharing the same display and using their own mouse; the group of users is mediated by a single standalone computer preserving the original collaborative aim. In section 2 the collaborative activity is described, in section 3 the software architecture is explained, in section 4 a usability analysis is presented. Finally section 5 has the conclusions and future work.

2. Exchange as a SI/SD – SDG activity

Exchange is a collaborative learning application that supports two scenarios: students wirelessly interconnected controlling their own input devices and their own display (Single Input/Single Display, SISD) (Zurita & Nussbaum, 2004-b), and students sitting behind one PC controlling their own input device within a shared display (SDG), or Exchange-MM. The activity is the same in both scenarios. The application assigns to each group member a question and an answer that not necessarily match (i.e., the answer may not satisfy the question). Students are forced to engage in a face-to-face negotiation so that they identify the correct question-answer pairs and interchange their answers until each group member has the correct pair (Fig. 1).

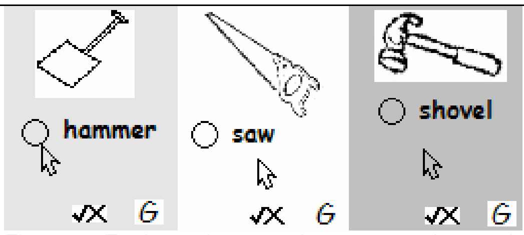

Fig. 1.1: Each student receives a question and an answer, but some pairs (question/answer) are incorrect.

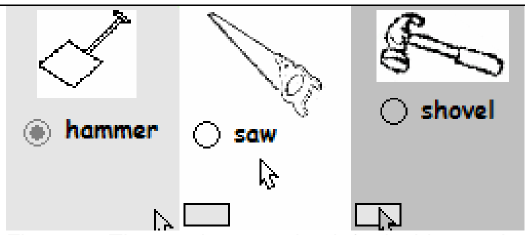

Fig. 1.2: The student on the left decides to hand his answer (hammer), and selects it. The other two students may reject the offered answer, and only one of them can accept it by clicking the accept button.

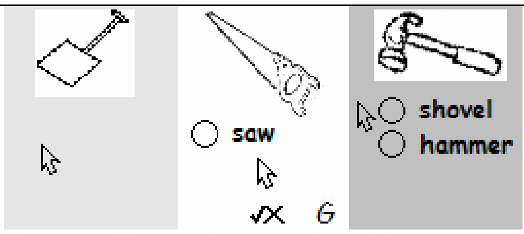

Fig. 1.3: The student on the right accepts the answer given by the student on the left. Now, he or she has two answers and must decide which one to yield to the other participants.

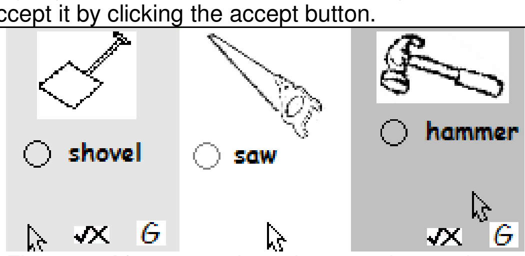

Fig. 1.4: After some interchanges the students decide they have the correct questions/answer pairs. Then, they ask the system to verify the pairs, performed in the figure by the center student. If all pairs are correct, the system sends them to the next set of pairs, otherwise they have to repeat the exercise.

Fig. 1: Exchange Activity, shown in the Exchange-MM version.

On Exchange-MM version (SDG), each participant has a mouse which controls a cursor of a specific color. Although a cursor can go to any place of the screen, the commands that each participant executes are only recognized by the part of the screen of the same color as the corresponding mouse. This allows sharing a common space while simultaneously permitting each child to contribute to the collaborative activity (Tse, Histon, Scott & Greenberg, 2004), as illustrated in Fig. 2.

Fig. 2: Three children sharing a screen in the Exchange-MM application.

In both scenarios, the application allows a balanced involvement of the three group members through a coordination mechanism that forces each participant to perform a task. To successfully complete the activity, a child must not only achieve its own individual goal, but also help to ensure that all children in the group reach their goals. Once the activity is successfully completed, the program reinforces students and moves them to the next question. As positive interdependence (Johnson & Johnson, 1997) is an important feature in a collaborative learning activity, the application rewards groups that perform well, so that group members' assistance to their mates is acknowledged (Slavin, 2006). In addition, the social interaction between participants is promoted. In order to receive or give an object, group members have to communicate their ideas, express their opinions and concepts, and negotiate among them. Consequently, pedagogical and social support networks between the participants emerge from the activity. Thus, the activity inside each group is collaborative and noncompetitive; nevertheless, a competitive component between the different groups within a classroom exists, which encourages motivation and focus on the activity within a group.

3. Software Architecture

Exchange was initially defined as an SISD, mobile CSCL application (mCSCL), where both, students and teacher, engage in a collaborative activity supported by wirelessly interconnected handheld devices. Exchange was extended to a desktop based environment through the use of Multiple Mouse (MM) resulting in a SDG version called Exchange-MM. Both architectures are described in this section.

Exchange's architecture is based on the teacher-student (master-slave) paradigm (Zurita & Nussbaum, 2004-a) and supports a classroom scenario where the teacher coordinates activity progression and students work in groups. Exchange's main components are shown in Fig. 3. It comprises a set of abstract classes (*ExchangeBase*, *BaseNetManager*, *BaseForm* and *BaseStatusArray*) that must be implemented either as a master copy (*ExchangeMaster*) or a slave copy (*ExchangeSlave*). *BaseNetManager* provides the wireless network communication support and *BaseForm* handles the user interface. *ExchangeMaster* and *ExchangeSlave* communicate with one another through *BaseNetManager* implementations (*MasterNetManager* and *SlaveNetManager respectively)*.

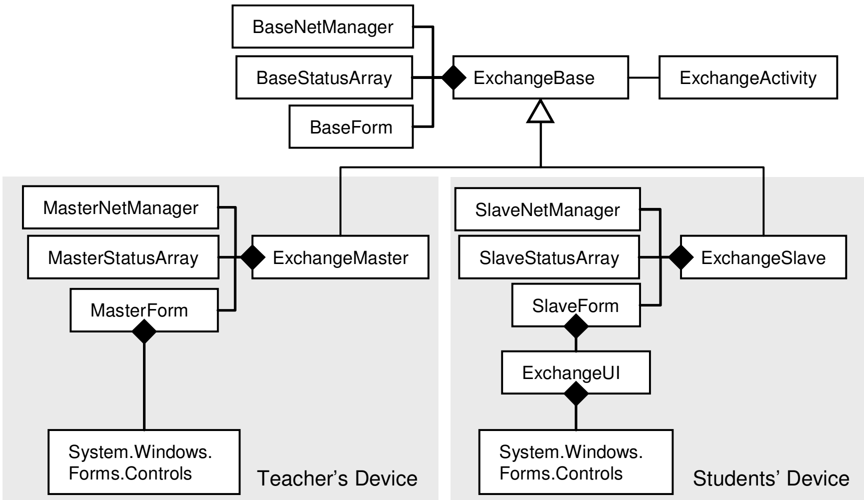

Fig. 3: Exchange architecture's main components. The abstract classes are at the top in the figure. The grayed region on the bottom left represents the Teacher's version implementation (master copy) and the grayed region on the bottom right represents the Student's version implementation (slave copy).

The master copy is owned by the teacher (left side of Fig. 3); one of its most relevant functionality is to synchronize slave copies owned by students (right side of Fig. 3). This process requires that slaves report events to the master, who in turn updates its own *MasterStatusArray* (Fig. 4). This array is a global state vector that comprises all students' state vectors (SlaveStatusArray). Both *MasterStatusArray* and *SlaveStatusArray* are implementations of *BaseStatusArray.*

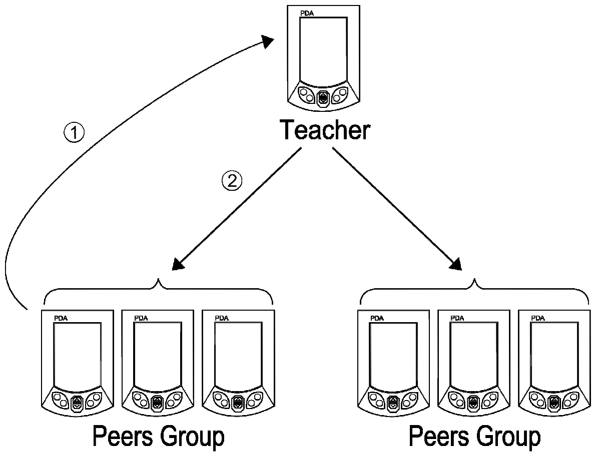

Fig. 4: Exchange's coordination scheme for Pocket PC. When one of the peers (student's device) informs about an action occurrence (1), it may force an update situation, where the master (teacher's device) forces in turn all the participants to update their own states (2).

In Exchange, learning activities are modeled as a series of actions (e.g. giving or receiving answers, verify the answer, etc.), or *ExchangeActivity* instances. Tanto la copia del profesor como la copia de los alumnos se mantiene sincronizada. El mecanismo de sincronización de Exchange (SISD) (Fig. 5) consiste en envíar un mensaje con la acción realizada por el alumno desde su parte de la aplicación (Slave), vía WiFi, a la aplicación del profesor (Master). Como respuesta, la copia Master verifica la validez de la acción y de ser necesario genera un nuevo estado. Cada cierto tiempo, la copia Master envía un Array con el estado de todos los estudiantes a todos los Esclavos; cada esclavo acepta únicamente la información que le corresponde (Fig. 5).

As activities are distributed and performed concurrently, concurrency and consistency problems can occur (i.e. two students simultaneously want to receive the third student's answer). To avoid this, the master validates the potential new state, and if valid, updates *MasterStatusArray* and broadcasts it to the slaves so they update their own state vector (Fig. 5). As the master copy receives all the students' actions, it provides the teacher information about the whole activity, allowing him to focus his help on those students who need it the most (i.e. the last group to perform a task, a group that fails often). User's graphical interface (*MasterForm* and *SlaveForm*) is a specialization of a .NET library (*System.Windows.Forms*) along with the typical controls triggered by a single mouse (*System.Windows.Forms.Controls*).

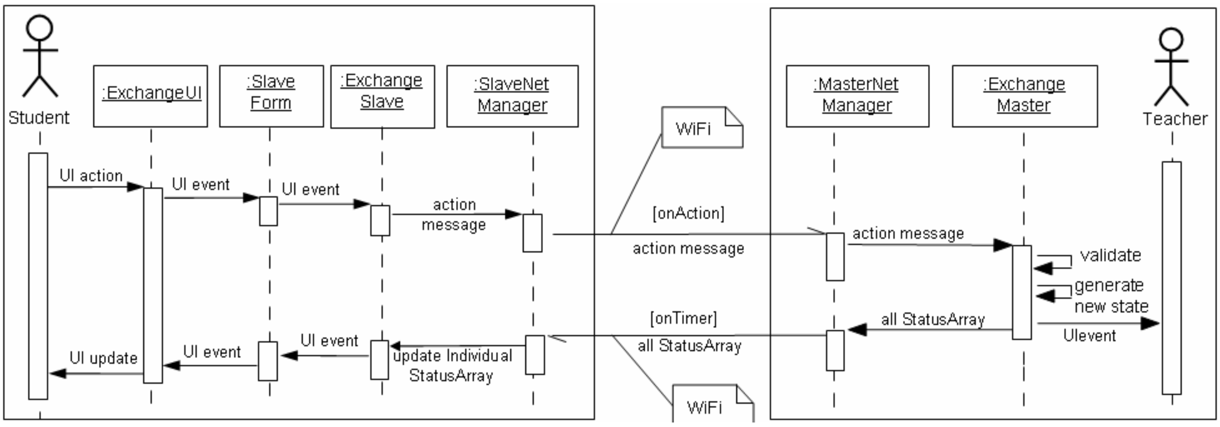

Fig. 5: Diagrama de secuencia del mecanismo de sincronización de Exchange (SISD). El recuadro de la parte izquierda corresponde a la aplicación de los estudiantes y el de la derecha a los profesores. Ambas aplicaciones se sincronizan mediante mensajes vía WiFi.

Exchange-MM (SDG) extends the previous version by exploiting two patterns, the mediator and the observer pattern (Gamma, Helm, Johnson & Vlissides, 1995). Unlike the previous version, in Exchange-MM the mediator is formalized and made explicit. The mediator pattern consists of a mediator class that encapsulates knowledge regarding the methods of a set of controlled classes (colleagues). Instead of sending messages among them, colleagues send messages to the mediator when needed. The mediator passes messages on to any other classes that need to be informed. In our implementation, Mediator corresponds to the *MM-ExchangeMaster* class (Fig. 6), it receives messages and updates the state vector for every peer.

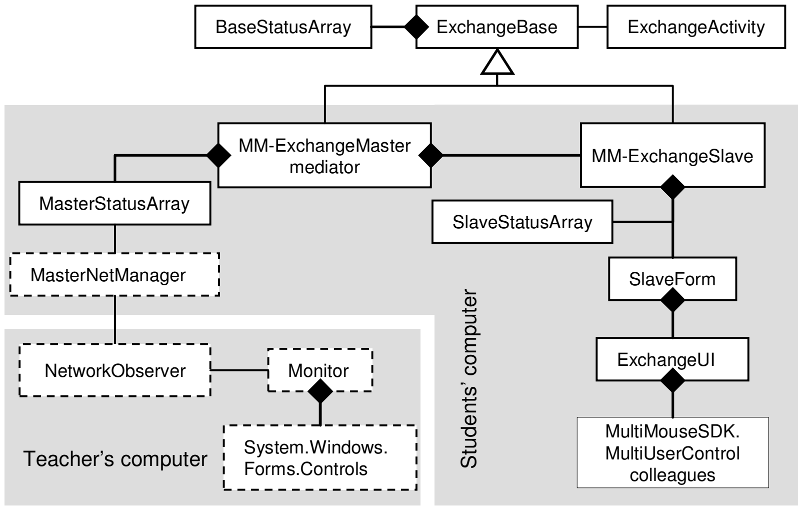

Fig. 6: Exchange-MM Architecture; classes in dashed lines correspond to proposed extensions of the current architecture.

The colleagues comprehend the set of extended controls (e.g. an extended button) that implement the *MultiMouseSDK.MultiUserControl* class (Pawar et al., 2006). Such extended controls can identify which one is the mouse whose events are listening. Events are propagated to the upper classes, up to the mediator so that communication between slaves (colleagues) and the master can occur, between the *MM-ExchangeMaster* and the *MM-ExchangeSlave* classes (Fig. 7).

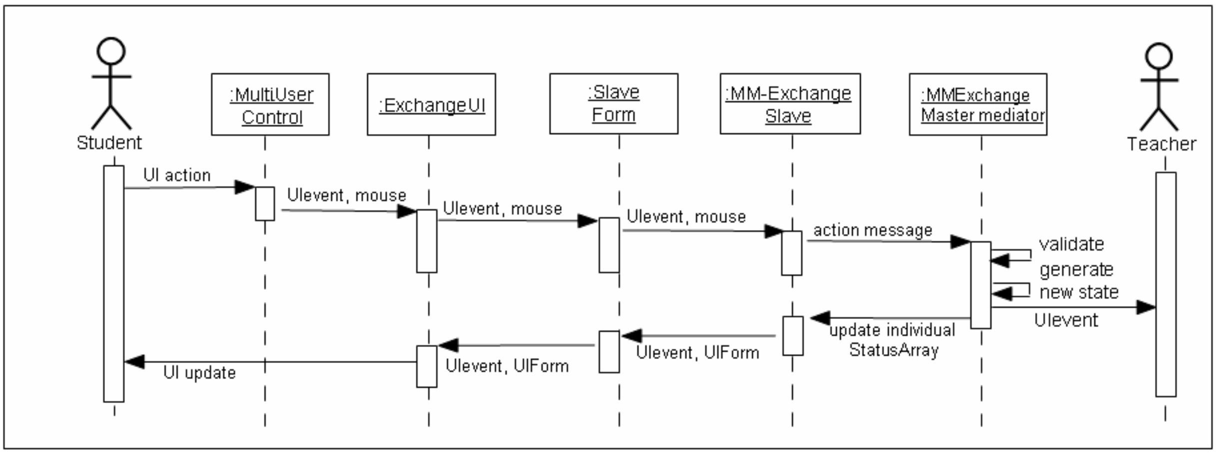

Fig. 7: Diagrama de secuencia del mecanismo de sincronización de Exchange-MM (SDG). Tanto la aplicación de los estudiantes como la del profesor comparten el mismo espacio de memoria.

Unlike the SISD version, Exchange-MM slaves are not distributed across various devices, but share the same memory space in a standalone PC. Because of this, the wireless network component is no longer required. However, the Master/Slave mechanism is still applied (*MM-ExchangeMaster* and *MM-ExchangeSlave*), as well as the mechanism for handling state vectors (*MasterStatusArray* and *SlaveStatusArray*). Es decir, el mecanismo de sincronización de Exchange-MM (SDG) también envía un mensaje con la acción realizada por el alumno desde la su parte de la aplicación (Slave), mediante invocación de métodos, a la aplicación del profesor (Master). La copia Master verifica la validez de la acción; de ser necesario genera un nuevo estado y envía un Array con el estado de todos los estudiantes a todos Esclavos. Cada esclavo acepta únicamente la información que le corresponde (Fig. 7).

The *MM-ExchangeMaster* holds instances of *MM-ExchangeSlave*, one for each peer (three in this case). The master copy is still able of updating slave's states when slaves inform about users' actions performed by the *MultiMouseSDK.MultiUserControl* colleagues through the *MM-ExchangeSlave* class. As the *MM-ExchangeMaster mediator* identifies the signal's source, it also determines which students' state vector needs to be updated.

State vector handling mechanism is the same of Exchange version; however, in this version we have implemented a model of one master controlling only one group. This self-imposed limitation can be easily overcome in order to support a scenario where various groups comprised of three students can be mediated by its own *MM-ExchangeMaster* component and a central computer is used to *monitor* the whole activity. This will require of a set of complementary classes denoted by the dashed lines on Fig. 6. This monitoring feature is important, since it allows teachers to track group's state and progress in real time. This monitoring functionality can be implemented using the Observer pattern (Gamma et al., 1995). The *observer* pattern defines an updating interface for objects that should be notified of changes in a *subject*. The pattern's subject corresponds to the *MasterStatusArray* as it holds the status for the entire application. The *NetworkObserver* is the observer to whom subjects' changes are reported. As patterns' subjects are distributed over a bunch of PCs, it is necessary that they support the *MasterNetManager* component. The Observer informs a teacher about activity changes, so the teacher can have real-time monitoring of the activity being run (Fig. 6).

4. Usability Analysis

Exchange-MM was used to exercise basic reading abilities collaboratively inside the classroom. A usability analysis was performed to observe the children relationship with the system and among group members.

4.1 Experimental Design

La usabilidad de Exchange MM fue testeada durante dos meses en forma semanal con 38 estudiantes de Segundo grado (ocho años de edad) de un colegio de Santiago de Chile que atiende a niños y niñas de bajos ingresos. Los 38 alumnos corresponden a un curso elegido al azar entre ocho cursos del primer ciclo de educación básica del colegio, el cual estuvo conformado por 22 niños y 16 niñas. Estos estudiantes, previo a esta experiencia, al igual que todos sus compañeros de escuela, habían asistido a la sala de computación del colegio en algunas oportunidades, por lo que estaban familiariarizados con el uso del mouse, movimiento del cursor, utilización de software educativo y uso de programas de dibujo, pero nunca habían trabajado en un ambiente de múltiples mouse.

En conformidad a las investigaciones de Zurita, Nussbaum & Salinas (2005) el trabajo se realizó en grupos conformados por tres alumnos. Estos tres alumnos compartían una misma pantalla pero cada uno disponía de su propio mouse. En cada una de las sesiones de trabajo los grupos de tres alumnos fueron formados al azar por un profesor que no los conocía. Así, los alumnos pudieron trabajar en las distintas sesiones con diferentes compañeros de curso. The activities included reading content for first and second grade students. These contents were displayed in increasing difficulty level. Researchers attended all the sessions and student's behavior was carefully observed. Notes of the observations were registered and discussed in periodic meetings throughout the experience.

During the experience, videos of groups making a complete activity were recorded. In addition, recordings of the complete class making the activity were made, in order to analyze the behavior of all the students. Altogether five groups were recorded: two in the first session, one in the third, and two in the seventh (last) session. The videos were observed and analyzed according to an observation guideline (Table 1). This process was complemented by observations made directly in the classroom, in order to analyze the videos within a suitable context.

Additionally, students were asked to state their opinion about the experience and were requested to draw it at the end of the experience. They were also interviewed by the teacher who led the activity and the School's Principal.

4.2 Observation Guideline

The observation guideline was based on the criteria of usability included in (Zurita & Nussbaum, 2004 a & b), and adapted according to the specific objective of this experience. The guideline is comprised by five categories:

1. Communication, to exchange information and to request and deliver help.
2. Negotiation, to solve conflicts within the group
3. Interactivity, to influence the cognitive process of the group members.
4. Coordination, to construct agreement to achieve common goals.
5. System appropriation.

The goal of the observation guideline is to establish, as it was done before with wirelessly interconnected Pocket PCs (Zurita & Nussbaum 2004b), if the technological network favors or obstructs communication, negotiation, interactivity, and coordination between members of the group when working collaboratively a group of 3 children in front of a PC with Multiple Mouse. Also, the observation guideline was an instrument to measure how easily the kids could make the system theirs' own.

The observation guideline is composed by categories and attributes and sub-attributes as shown in Table 1. These attributes are measured according to two pairs of criteria: Individual (I) or Collective (C) work and Quantitative (QN) or Qualitative (QL) observation. Independent of the previous, "Uttered Expressions" and "Provided Assistance" are attributes measured individually in a quantitative way. For each group member it is evaluated the number of occurrences the corresponding sub-attribute occurs during the experience. When attributes are collective, these are measured as the joint performance of the group. When the evaluation is quantitative, the number of occurrences is observed, while when it is qualitative a scale from 1 to 3 is used, where 1 considers that the attribute is not observed, 2 observed regularly and 3 when it is observed well above average.

Table 1

Observation Guideline. The first column corresponds to the category, the second to the attribute being measured, the third gives a brief description of the attribute, the fourth tells if the attribute is measured individually (I) or collectively (C) and if it is a quantitative (QN) or a qualitative (QL) measure. Fifth and sixth columns show the result for the same group in the first and the last session. Seventh column displays the significance level of the difference between the sessions.

Category	Attribute	Description	Measure	1st session	7th session[a]	p
Communication	Group Communication	Verbal exchange of information between students. The required behavior is to speak clearly at a correct pace and listening with visual contact.	C, QL	2.5	2.5	-
	Uttered expressions	Communication of a person to another person, or the person to the group.				
	Person to person		I, QN	16	11.3	0.412
	Person to Group		I, QN	15.5	4.3	0.060
	Provided assistance	Number of occurrence where a group member gives, receives or asks for support to another group member or to the whole group.				
	Give		I, QN	7.5	1.2	0.114
	Receive		I, QN	5.8	1.2	0.062
	Ask support		I, QN	1.7	0.2	0.139
Negotiation	Unsolved Conflicts	The number of unsolved divergent points of view (conflict) that occur within the group. When a conflict ends with an imposition of a member over the others, it's considered as unsolved.	C, QN	0.5	1	-
Interactivity	Positive interdependence	Students feel that they are responsible for their own learning and of their classmates.	C, QL	2.5	3.0	-
	Group work	Students share goals and each individual contribution is affected by the actions of the others. The individual activities facilitate the effort of the others to reach the goals of the group.	C, QL	2.5	3.0	-
	Attention and focus	Students focus in their work without interruptions or actions referred to other purposes.	C, QL	2.5	3.0	-
	Mutual trust	Students trust each other; they do not question the other group members' opinions' and feel comfortable to express their own opinion.	C, QL	3.0	2.5	-
	Acceptance and tolerance	Students are capable of accepting opinions of other group members with which they do not agree.	C, QL	2.5	2.5	-
	Anxiety	There is nervousness or confusion in the group facing the group work.	C, QL	2.0	2.0	-
	Motivation/interest	There is interest and motivation to work in group to solve the activities	C, QL	2.5	2.5	-
Coordination	Discipline	The established set of rules and roles are respected.	C, QL	3.0	2.5	-
	Coordinated group work	Students work within the group in a coordinated fashion.	C, QL	2.5	3.0	-
	Requested support	Support for the accomplishment of the individual or group activities is asked to persons outside the groupb	C, QL	1.0	2.0	-
Appropriation	Suitable handling of material	Students master the use of the system (Hardware and Software)	C, QL	3.0	3.0	-
	Simplicity to follow the instructions	Students understand how to apply the instructions to perform their work.	C, QL	3.0	3.0	-

[a]Data obtained from 2 groups of 3 students each.

b mayor puntaje mientras menor apoyo pedido a terceros fuera del grupo

We observe, even the differences are not significant ($p>0.05$) that the communication in all its individual attributes diminished, which is consistent with the qualitative observation that the kids work was more efficient and synchronized.

4.3 Qualitative Observations

4.3.1. Accomplishment

In the first session, it was observed that some children had difficulty to understand the activity dynamics. Some of them had problem using the mouse. This was easy to understand considering that most of them had no previous contact with PCs. Only three groups finished the activity the first day; the rest made progress but weren't able to accomplish the sessions' goal, since it was not easy to adapt themselves to this new methodology. In the third session these difficulties were overcome and all groups were able to finish the activity. At the end of the experience (seventh session) all the groups worked correctly, in a synchronous and efficient way and all the groups were able to finish the activity in less time than the planned one, without difficulties. We conclude that one mouse per child and one big shared screen facilitates the interaction, collaboration and group reflection.

4.3.2. Leadership

In the first session a pattern was observed in almost all the groups: one of the children took the leadership and gave instructions to the other two, who obeyed during the activity. Children who performed better gave aid to their less capable group mates. The later followed their advice without problems or discussions in each exercise. In the third session, there were cases where the leadership was shared by two group members. There were cases where the passive student also participated, although a little less than the other two. Finally, in the last session the leadership pattern was scattered; there were passive students but most participated in the discussions. We conclude that the application allows children who at the beginning do not exert a leadership, take an increasingly active role.

4.3.3. Motivation

Students were very motivated with the activity from the beginning to the end. Anxiety to begin before each session could be observed. In addition, they were excited when they made the activity, as observed by their behavior as by their commentaries. A level of competition between the different groups was observed; the members were attentive to the work of the other groups, which caused them to verbally motivate their group mates to engage in the activity. Throughout the experience it was observed that the students had a high level of concentration, motivation, and attention doing their tasks, while maintaining motivation and a remarkable group joy when successfully finishing an exercise and pass to the following one. The same was observed when accomplish the sessions' goal, which strengthened the group bonds and the common feeling to belong to a work team doing a shared task.

4.3.4. Group Work

It was observed from the first to the last session that the children gave a constant aid to their classmates in form of instructions "Give me..." or "Press there..." They used the screen of the computer like a board where they pointed with their fingers to indicate their peers some object (Fig. 2). In addition, they used the cursor corresponding to their mouse to give instructions to their classmates. There were doubts if the single screen could affect the reflection and collaboration process, which clearly did not happen. Students fixed their attention on the common screen, where individual resources were shared. The screen becomes a learning place where students discuss, collaborate and negotiate. They talk about objects on the screen and actions to perform. Discussion and mutual learning, without preventing individual work, was clearly observed. On the other hand, it was very unusual to see a boy/girl using the mouse of a peer. In fact, the only time it happened was in the first session when there still were children who did not handle the mouse accordingly. We clearly conclude that the students promptly feel they are part of a team.

4.3.5. Engagement

Participants were asked about their opinion on the activity. Students who participated in the activity emphasized that it was fun to play with their classmates. To have one mouse for each made them “not fight”. About working with other classmates it became sometimes difficult since some finished first and had to wait the others, and these claimed to be pushed to work quicker. Some would have liked to play alone, although all said that they would like to continue occupying this software. Fig. 8 is a drawing done by one of the children; we observe all the elements of the activity, with the screen divided in 3 parts, with a cursor for each participant (and the respective mouse that controls these, the 3 participants and the cameras used to record the group work.

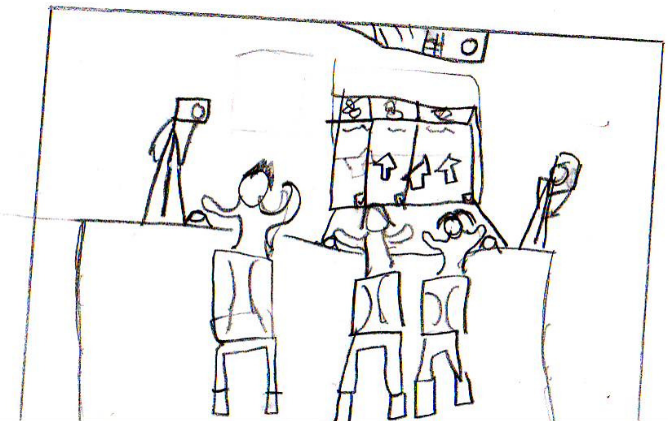

Fig. 8: Drawing about the activity done by a child.

4.4 Schools’ perspective

The teacher found positive that children were able to learn to work in group while playing forming social abilities. She stressed that generally these children don’t work in small groups, and when they do always there are groups, or students within a group, that do not work, which was clearly not the case in this experience. She also valued that children learned to use a mouse, ability that this kind of students usually have not acquired, developing motor abilities.

The school’s Principal declared his satisfaction facing two restrictions that were solved in a cheap and easy way through this application. First, the difficulty to achieve collaborative learning due to the teacher’s lack of knowledge about techniques of collaborative work, and by the difficulty to maintain the group of students concentrated in an activity. Second, the lack of computers: the school had only 20 computers for a 38-40 student classes; if there isn’t a suitable and organized way to share the resource it is not possible to use it. SDG allows using one machine per three students reducing the hardware requirements, with the only additional cost of two additional mice per computer.

5. Conclusions

In this paper there are several contributions.

First, we have shown a software architecture that with minimal changes supports a collaborative activity both with wirelessly interconnected handhelds (SISD) and with PCs using multiple mice (MISD or SDG). The architecture is based on a master/slave coordination schema, and is implemented using a mediator pattern. This architecture was originally developed for a SISD schema (Zurita & Nussbaum, 2004-b), and on a MISD schema, the architecture has the flexibility to be easily extended for monitoring the peers work from another machine.

This work was partially based on the use of a library that allows using MM (Pawar et al., 2006). This library provides only limited functionality, since it doesn't implement the traditional controls (i.e. buttons, radio buttons) and it can only emulate partial functionality of them. Since the library doesn't provide controls they have to be developed almost from scratch, making indispensable a library that allows the reuse of applications previously made.

Una forma alternativa de implementar la funcionalidad descrita en este paper es mediante un Multi Agent System (MAS). Un MAS es un sistema donde varios procesos de software independientes, autónomos y dotados de algún grado de inteligencia, llamados agentes, ejecutan acciones de manera proactiva (Wooldridge & Jennings, 1995). Bajo este paradigma, cada agente representaría a alguno de los *roles* involucrados (Exchange Master / Exchange Slave) actuando de acuerdo al patrón mediador. Cada agente podría reconocer la plataforma donde se esta ejecutando (SDG/SISD), y decidir cuál es el medio apropiado para propagar las acciones del usuario (invocación de métodos/WiFi). Este enfoque permitiría un mayor grado de flexibilidad, escalabilidad y extensibilidad dado que la funcionalidad estaría encapsulada en roles y agentes, permitiendo implementar modelos educativos más complejos.

Second, the usability analysis showed, as it was done before with wirelessly interconnected Pocket PCs (Zurita & Nussbaum 2004b), that the technological network (el sistema conformado por los tres mouse, los tres cursores, la pantalla compartida y la aplicación de software) favors communication, negotiation, interactivity, coordination and appropiability between group members' when working collaboratively in a group of 3 children in front of a PC with Multiple Mouse.

En efecto, puede apreciarse de los resultados de la pauta de observación (tabla 1) y de las entrevistas que:

1. El nivel de comunicación grupal fue alto desde el principio y se mantuvo hasta el final. Sin embargo, el número de asistencias solicitadas y dadas fue disminuyendo a medida que los estudiantes dominaban la lógica del sistema. Es decir, al dominar el sistema los alumnos disminuyeron sus necesidades de ayuda y se enfocaron a conversar sobre las materias de aprendizaje teniendo la pantalla como foco.

2. Es coherente con lo anterior que el nivel de coordinación también se mantuvo alto; especialmente disminuyó la petición de ayuda a terceros fuera del grupo, en especial, la profesora.

3. Respecto de la apropiación, all the groups quickly surpassed the technical barriers and promptly understood the activities' model. It's interesting to notice how the multiple mice concept is quickly grasped by the students, since they show no surprise to the fact of having multiple cursors on the screen.This can be explained by the familiarity that youngsters have using mice or the easiness they have to obtain this ability.

4. A nivel de interacción cabe destacar la interdependencia positiva, el trabajo grupal y la atención y el foco que se produjeron desde el principio y fueron mejorando en la medida que avanzaba la actividad. Es posible atribuir esta consecuencia al hecho que todos los estudiantes tenían un común foco de atención lo que los ayudaba a mantenerse concentrados en la actividad y lograr una interdependencia positiva física. The fact that everything happens in one screen that is in front of the children, where all have to simultaneously participate, stimulates the discussion and continuous verbal exchange.

5. Un elemento fundamental que favoreció la interactividad, en especial, la motivación entre los estudiantes fue el hecho que cada uno manejara su propio mouse. The fact that every kid controls a mouse gives him (her) a tangible object which forces him (her) to participate on the activity, making him (her) a protagonist of his (her) own learning generating a more shared leadership. Los alumnos tendían a proteger y apropiarse de su mouse el que les daba la posibilidad de participar en la discusión tanto marcando en la pantalla lo que querían con el cursor como haciéndolo con el dedo pero sin soltar el mouse que mantenían con la otra mano, como se aprecia en la figura 2.

6. Como es posible observar respecto de la coordinación del trabajo grupal y el requerimiento de ayuda externa, la simplicity of the software allowed that the technological network were not an obstacle for learning, but a suitable support to verbal exchange and mutual aid. Thus, the student's efforts were focused to learn and participate.

Third, the teacher and Principal interviews stress two important elements inside schools: First, how the application enforces that all children have to work, if not the activity can't be executed. It is important because usually many students don't work when collaborative work is done and many teachers don't have techniques to foster collaborative work. Second a practical benefit. SDG reduces the hardware requirements and so, allows schools which lack of computers make use of Computer Supported Collaborative Learning (CSCL).

Acknowledgements

This work was supported partially by FONDECYT # 1080100, and support of Microsoft Research India.

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