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Collaboration within large groups in the classroom

Eyal Szewkis · Miguel Nussbaum · Tal Rosen · Jose Abalos · Fernanda Denardin · Daniela Caballero · Arturo Tagle · Cristian Alcoholado

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Abstract The purpose of this paper is to show how a large group of students can work collaboratively in a synchronous way within the classroom using the cheapest possible technological support. Making use of the features of Single Display Groupware and of Multiple Mice we propose a computer-supported collaborative learning approach for big groups within the classroom. The approach uses a multiple classification matrix and our application was built for language-learning (in this case Spanish). The basic collaboration mechanism that the approach is based upon is “silent collaboration,” in which students—through suggestions and exchanges—must compare their ideas to those of their classmates. An exploratory experimental study was performed along with a quantitative and qualitative study that analyzed ease of use of the software, described how the conditions for collaborative learning were achieved, evaluated the achievements in learning under the defined language objectives, and analyzed the impact of silent and spoken collaboration. Our initial findings are that silent collaboration proved to be an effective mechanism to achieve learning in large groups in the classroom.

Keywords Collaborative learning in the classroom · Silent collaboration · Spoken collaboration · Multiple mice · Single display groupware · Multiple classification matrix

Introduction

Many authors have claimed that collaboration has become an important subject in the area of education (Johnson and Johnson 2002; Roschelle and Teasley 1995). It has been defined as an essential component of twenty-first century skills (Bruns 2007), and thus its adaptation to the classroom is crucial.

E. Szewkis · M. Nussbaum (✉) · T. Rosen · J. Abalos · F. Denardin · D. Caballero · A. Tagle · C. Alcoholado
Computer Science Department, School of Engineering, Pontificia Universidad Catolica de Chile, Vicuña Mackena 4860, Santiago, Chile
e-mail: mn@ing.puc.cl

Social interaction and the ability to share and consider other points of view add a component that is not present in individual learning. Vygotskian and Piagetian researchers have inferred that “development may occur when two participants differ in terms of initial level of competence about some skill or task, work collaboratively on it, and arrive at shared understanding” (Tudge 1992).Collaborative learning can be very effective and useful (Gokhale 1995), because it can develop generic communication, collaboration and team building skills, as well as assisting teachers in the management of the class (Allen et al. 2006).

Computer-supported collaborative learning (CSCL) studies how people can learn collaboratively while being mediated by a computer (Stahl et al. 2006). Several initiatives have been implemented in CSCL for the classroom and some examples of these experiences are described by Zurita and Nussbaum (2004) and Diggelen and Overdijk (2007) who performed small group collaborations; Hung et al. (2009) who developed a collaborative English vocabulary-acquisition-game system; and Zea et al. (2009) who made a collaborative video-game to teach vowels. In these cases, the research focused on small groups, where each participant had his own device.

We can also find examples of CSCL in large groups. An illustrative case is Wikipedia, a free online encyclopedia written collaboratively by thousands of contributors from around the world (Kittur and Kraut 2008). There are also experiments using Massively Multiplayer Online Games (MMOGs). Girvan and Savage (2010) used the virtual world *Second Life* in order to examine how communal constructivism could be an appropriate collaborative pedagogic tool, and Bennerstedt and Linderoth (2009) studied how collaborative interaction takes place among players in an MMOG game. A final example is Jara et al. (2009), who worked with virtual laboratories, a web-learning resource which incorporates collaborative learning practices through the Internet.

Wallace et al. (2009) argue that working in a common physical space can provide great benefits, such as “improved activity awareness and coordination, improve communication efficiency by enabling non-verbal communication such as gestures, and facilitate grounding via a shared visual reference.” A knowledge community, where students work with their peers and teachers on their goals in the same space makes all students accountable for their learning (Brown and Campione 1996). Beers et al. (2007) indicate that for collaborative learning to be effective, individual learners have to achieve a sufficiently common cognitive frame of reference that does not appear by itself, but has to be negotiated. Technology can support this process, and (Roschelle et al. 2004) indicate that CSCL influences learning, motivation, commitment and the development of mutual understanding, and that CSCL for large groups, such as a whole classroom, allows the development of more robust and more varied ideas.

Single Display Groupware (SDG) allows multiple collocated users, each with his own input device, to share a common screen (Moraveji et al. 2008), which is useful when developing a collaborative activity where interaction with each member of a large group within the classroom is desired (Pavlovych and Stuerzlinger 2008).It has also been shown that when several users, each with his own personal input device but with a shared screen, have to interact to complete an activity, there is greater participation and student engagement (Infante et al. 2009; Scott et al. 2003).

The quality of this engagement depends on the metacognitive awareness developed through a reciprocal process of exploring one another’s viewpoints in order to construct a shared understanding. The tasks chosen need to be appropriate to the capabilities of the learners’ requirements and to the collaboration process, and structured so that children must work together for successful completion (Nussbaum et al. 2009). Collaboration should occur among children with different skill levels or perspectives, which would create the socio-cognitive conflict necessary from a Piagetian perspective, and so providing the cognitive restructuring that underpins cognitive change (Fawcett and Garton 2005; Teasley 1995)

Besides the web-based collaborative approaches previously indicated, there have been a number of attempts at achieving CSCL with all students in the classroom. CollPad (Nussbaum et al. 2009) is an open-ended-question constructivist approach; students first solve the problem individually, then in small groups work collaboratively to reach a collective answer, based on their replies, and finally the teacher guides a classroom discussion founded in the small-group answers in order to reach the task aim. Group Scribbles (Roschelle et al. 2007) mainly uses the first and last phases of the previous method (individual work and teacher-mediated whole class discussion) and aims to support teachers in inventing and enacting new forms of collaboration and coordination in the classroom. Both approaches are characterized by the teachers' active mediation for student sequential participation in whole classroom synchronous discussion, each student having a personal device, which is wirelessly interconnected with the others. In this paper we will show that, working with one mouse per person and sharing a common screen, it is possible to get all students in a classroom to actively and collaboratively participate asynchronously in a task under teacher supervision, at a much lower cost than if each of them were using a personal device, thus making it an attractive technology, especially when resources are scarce (Pawar et al. 2006).

Making use of the features of SDG and of Multiple Mice we propose a CSCL approach for big groups within the classroom, with low hardware infrastructure costs. First, we will analyze the conditions for collaboration. Second, we will demonstrate an approach for silent collaboration using an interpersonal computer that makes use of large group collaboration in the classroom, and an application for language-learning concepts. Third, we will describe the experimental work performed as well as the qualitative and quantitative results of these experiments, and finally we will present the conclusions of this paper.

Conditions for collaborative learning

It is not easy to achieve learning through massive collaboration in the classroom as certain conditions must exist that allow such activities to be conducted successfully. These are: the existence of a common goal (Dillenbourg 1999), positive interdependence between peers (Johnson and Johnson 1999), coordination and communication between peers (Gutwin and Greenberg 2004), individual accountability (Slavin 1996), awareness of peers' work (Janssen et al. 2007) and joint rewards (Axelrod and Hamilton 1981). In what follows, we analyze the importance of each of these conditions.

Common goal To characterize a situation as collaborative, there must be a common goal (Dillenbourg 1999). Members of a group who make the effort to solve a problem together achieve learning through collaboration as a result of the social interactions that it generates (Zurita and Nussbaum 2004; Roschelle and Teasley 1995).

Positive interdependence Positive interdependence is defined as "the perception that we are linked with others in a way so that we cannot succeed unless they do" (Johnson and Johnson 1999). Even when there is a common goal that requires peer interdependence, its effect is greater when the group-mates interact amongst themselves, as opposed to working individually (Johnson and Johnson 2009). In positive goal interdependence, students realize they can be successful in achieving their goals only if all their peers are also successful (Brush 1998).

Coordination and communication Malone and Crowston (1990) define coordination as “the act of managing interdependencies between activities performed to achieve a goal”. Coordination ensures that interactions occur in the right order and at the right time, avoiding the loss of communication and cooperation efforts (Raposo et al. 2001; Gutwin and Greenberg 2004). Without proper communication, it is impossible to achieve successful collaboration (Spada et al. 2005).

Individual accountability When a group member performs an action and all the other members observe the consequences, they are accountable before their peers for this action (Janssen et al. 2007; Johnson and Johnson 1999). In this way the role of each individual is reinforced to ensure proper contribution to the joint work (Slavin 1996).

Awareness To carry out a collaborative activity successfully, there must be an awareness mechanism that allows group members to obtain information about the current state of their peers (Zurita and Nussbaum 2004). In this way, all participants receive common feedback, which supports their decision making processes (Gutwin and Greenberg 2004; Janssen et al. 2007).

Joint rewards When all group members receive either rewards or punishments, i.e., depending on the result all players win or lose alike, they will look to maximize their joint utility and so generate a scenario where collaboration will prevail (Zagal et al. 2006).

Silent collaboration with an interpersonal computer

Our aim was to make a large group of students work collaboratively in a synchronous way within the classroom using the cheapest possible technological support. To achieve this we used a PC, a projector and one mouse for each group member. In this way, we built an Interpersonal Computer (Kaplan et al. 2009) that allowed personal input and feedback for each student.

The task we worked with was a multiple classification matrix, which refers to “the ability to define a class [of objects] by two or more attributes simultaneously” (Parker et al. 1971) and is considered one of the most important research topics in Piagetian theory (Inhelder and Piaget 1964). In the activities, each student received an object (a word or image), initially positioned out of place in a cross-classification matrix. Through exchanges with other peers they must place the objects where they belong.

Game logic: Silent and spoken collaboration

Given that our goal is to make every student present in the classroom participate simultaneously using an Interpersonal Computer, we propose a “silent collaboration” approach, where students must compare their ideas to those of their classmates, through suggestions and exchanges.

The interpersonal computer presents students with a space for common interaction, where objects within across-classification matrix are initially distributed at random, Fig. 1. Each child is assigned one of these objects, and their task is to place it in the correct position, depending on the characteristics specified by the heading of the corresponding line and column. In order to move an object, the child must exchange it for one allocated to one of their peers.

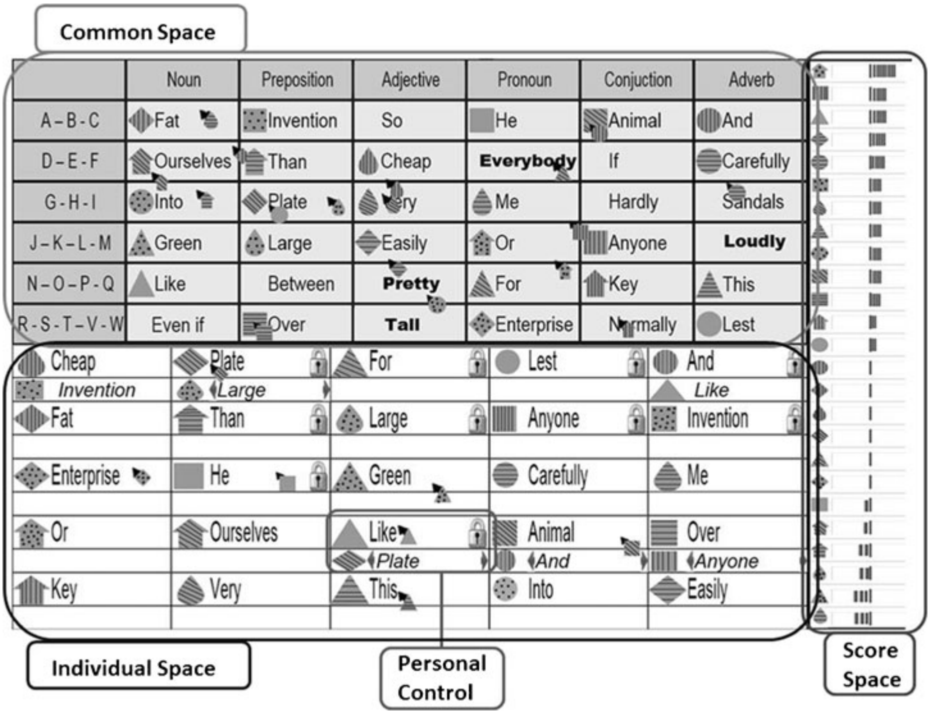


Fig. 1 Layout of the game

Considering that students who wish to exchange objects may not be sitting next to each other in the classroom, which would make verbal communication between them difficult, we have created a simple negotiation mechanism based on suggestions, that we have called silent collaboration. The silent-collaboration process can be complemented with verbal communication among students, which we will define as "spoken collaboration." It is important to stress that this last process is made difficult by the fact that in most cases children will have to work with a peer that is not physically close to them; e.g., in Fig. 2 the fourth face (from right to left) is addressing someone at a distance from him.

Fig. 2 Children interacting with the interpersonal computer

Silent collaboration occurs when a student who wishes to carry out an exchange of objects clicks on a classmate's object, within the cross-classification matrix, indicating a desire to swap. The student who is called upon to carry out this exchange can either accept or decline this proposal. The student who suggested the exchange can take back his offer, but only until his classmate makes a decision.

In this exchange process, it may occur that both objects are placed correctly, that neither of them is placed correctly, or that only one of them is placed correctly. Given that the first option isn't always possible, due to the activity's characteristics, and considering the conditions for collaborative learning—where each student must be responsible for his actions (individual accountability)and that rewards and punishments must be shared (joint rewards)-we defined a points mechanism that evaluates both players simultaneously. Thus, if one of the exchanged objects is placed in the correct position, both peers add one point to their score, and if not, they both lose the same number of points.

When one of the objects is placed correctly, it is fixed within the matrix until the end of the game, and a new object is assigned to the student who placed it, while the second player must continue with his object, until it is placed in the correct position. Once there are no more new objects available for allocation, or when a student successfully completes an exchange, a message appears in his personal space, inviting him to help those classmates who haven't yet finished (spoken collaboration).However, experimentally it was observed that spoken collaboration occurred independently of the students' completion of the activity.

When an iteration of the activity is completed, i.e., students have correctly placed all objects in the cross-classification matrix, the teacher explains this positioning to the entire group, answering questions and analyzing the main aspects of the activity. Because the assignment of objects to each student is random, the process should ideally be repeated, making students reposition objects a second, and even a third time, with the teacher reinforcing whatever aspects of the activity he finds most convenient at the end of each repetition.

Game mechanics

The first stage of the activity is the recognition stage—where the students identify themselves by assigning their names to their unique cursor icons.

In the next phase -the activity stage-the screen is divided in two, as in Fig. 1: the upper half is the common space, and the lower is the individual space, which is further divided into equally sized rectangular boxes, each one identified by the students' personal icons (determined in the recognition phase).In the individual space there is one box for each group member, who has personal control over this box. Each student's cursor can initially only move within his personal control box. By clicking the right button, they can move into the common space. For a projector resolution of $1{,}280 \times 1{,}024$ pixels, a maximum of 25 personal control boxes provide sufficient space to accommodate the needs of the Multiple Classification task for each of the 25 students working collaboratively.

As illustrated in Fig. 1, the common space represents the game board where students can suggest exchanges between one another, in order to locate the objects in their correct places, and receive points. In the personal control area, they have to decide whether or not to accept the suggestions they have received. Accordingly, the game actions are to suggest and receive objects.

Each personal control is composed of the elements shown in Fig. 3:

1. *Player's identifying symbol*: Zone 1, Fig. 3a, shows the student's icon. Once the player has made an exchange, the corresponding feedback is indicated in this Zone, as shown in Fig. 4.

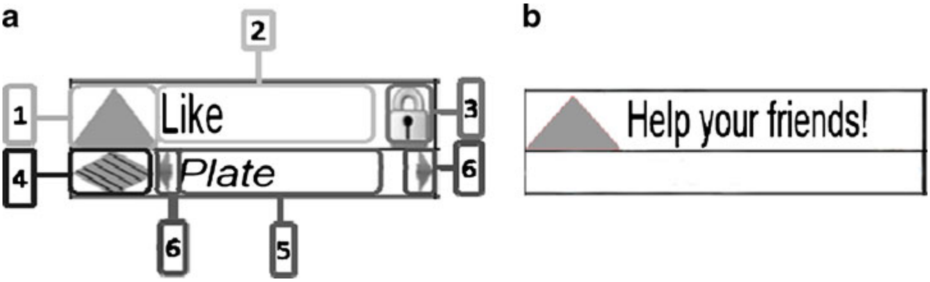


Fig. 3 Personal control

2. *Current object:* Zone 2, Fig. 3a, displays the object the student is responsible for in the common area.
3. *Committed object symbol:* Zone 3, Fig. 3a, A lock appears once the student suggests an exchange to a peer; therefore he cannot offer this object to another peer or accept an incoming suggestion unless he cancels his previous suggestion by clicking on the lock icon. This mechanism maintains consistency in the game.
4. *Suggester's symbol:* Zone 4, Fig. 3a, shows the icon of the peer that wants to exchange the object in Zone 5, Fig. 3a, with the object in Zone 2, Fig. 3a. The student can accept the exchange by clicking on this symbol,.
5. *Suggested Object:* Zone 5, Fig. 3a, displays the object offered for exchange by the user corresponding to the symbol in Zone 4, Fig. 3a.
6. *Next (previous) arrow:* Zone 6, Fig. 3a, shows the button which moves between suggestions, when there is more than one.

To perform an exchange the player has to either locate the object they own in its correct position, suggest an exchange to the current owner of that position, or accept suggestion that has been received. In Fig. 1, the player characterized by the vertical striped circle offers the object—"And"-for exchange to the student represented by the diagonal striped square, with the object "Animal". In this way the student with the vertical striped circle suggests a correct exchange ("And" is a conjunction), and if the student with the diagonal striped square accepts it, both receive a point. Simultaneously, the student with the vertical striped circle has received a suggestion from the student represented by the triangle (with no pattern)—the word "like". If accepted, each would lose a point, since "like" is not an adverb. However, the student with the vertical striped circle cannot accept this exchange, since he has already suggested one, indicated by the lock icon in his personal control box. At the same time, the student characterized by the triangle (with no pattern) has received several exchange suggestions, as evidenced by both arrows, which are present in his personal control box, but he cannot accept any of these since he has already suggested one, which is indicated by the lock icon.

When a student accepts an offered object, both objects are exchanged. We can see this by comparing Figs. 1 and 4, where the object "And" is placed where the object "Animal" used to be, and vice versa. If one of the exchanged objects is placed in its correct position, both students gain a point and the object changes in color (bold in Fig. 4) and cannot be moved from that position until the end of the game (Fig. 4). Otherwise, both students lose one point. This is shown in the Score Space (Fig. 4) where the points of each of the involved students are updated. Additionally, Fig. 4 shows the personal feedback given to

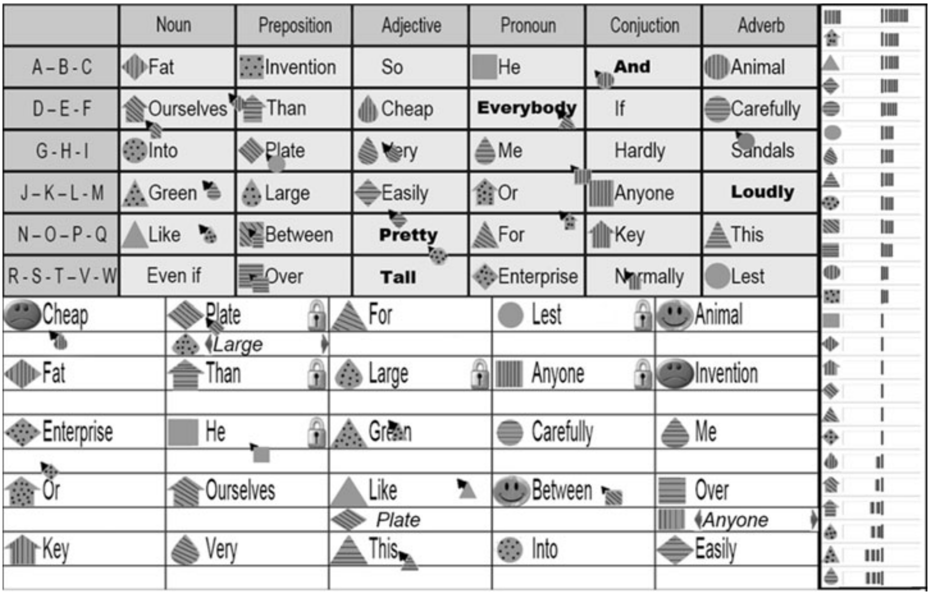


Fig. 4 Feedbacks after exchanges have been made

the students: both students receive a smile in the Personal Control box, when the exchange is correct and a sad face when incorrect. Finally, the student that receives the (correct) object ("And") now has a new object to process ("Between"), while the student that receives the exchanged object ("Animal") must now process this one. Also, in Fig. 4 we can see that the students represented by a drop with a vertical stripe and a square with a diagonal stripe (Fig. 1) have made a wrong exchange, keeping their objects, and each losing a point.

At a certain point in the game, towards the end of the activity, there will be no objects to be assigned to the players. At this point, a message will appear in their personal control box, encouraging the student to assist their classmates (spoken collaboration) (Fig. 3b).

When the game is over and all the objects are placed in their correct positions, the teacher explains to the students why each of them is classified in a certain way and what each category means, encouraging the students to participate and ask questions (especially those that have the lowest scores).Considering that the objects are assigned randomly at the beginning of the game, the activity can be played several times with the same students, reinforcing the concepts explained by the teacher. These iterations stop once the teacher notices that (most of) the students solve the activity (almost) flawlessly, or when time runs out.

Experimental work

Design of the intervention

An exploratory study took place in 2010 at a (low income) state-subsidized school in Santiago de Chile, over 6 sessions of 45 min each. 74 students from 6th grade

(43 boys and 31 girls, whose ages ranged between 11 and 12 years) were divided in to an Experimental Group (EG), of 42 students, and a Control Group (CG), of 32 students.

The study focused on language classes (Spanish), specifically on the subjects of accent rules, word classes (nouns, verbs, adjectives, prepositions, pronouns, adverbs and conjunctions), verb tenses and reading comprehension. A written pre-test covering all subjects, with a maximum score of 73 points, was administered to both groups (EG and CG) during the first session to assess the students' initial knowledge. This same test was repeated as a post-test in the final session.

During 5 weeks, six sessions were performed, each with one or more iterations per activity. The first session was devoted to familiarizing the students and teachers with the system's dynamics. Therefore, in Figs. 5, 6, 7a, b and c only the last 5 sessions are depicted. While all the sessions were of the same duration, not all the sessions involved the same number of iterations, with 2, 1, 2, 3 and 3 respectively over the 5 sessions. Furthermore, the number of objects available for exchange wasn't necessarily the same in all of the activities, and so in order to accurately compare the activities the total number of events (exchanges) per session was used, given that each session lasted approximately the same length of time.

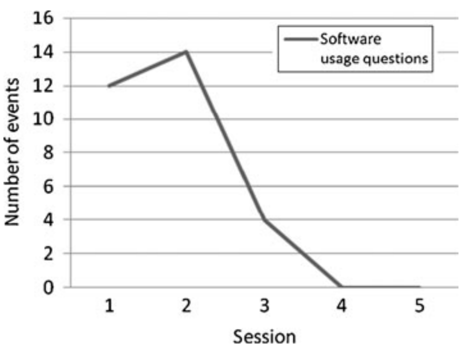
To assess the impact of our system we compared the CG, where the students worked only with conventional non-digital resources, with the EG that spent 60% of the time with the same conventional non-digital resources and 40% of the time with the CSCL system. In both the EG and CG the conventional non-digital resources consisted of guides for both teachers and students on the language contents to be assessed, with the aim of facilitating classes on these subjects and give both groups a similar theoretical background..

Since the system allows for up to 25 students to work simultaneously and the EG had 42 students, two randomly formed groups were defined, each monitored by a teacher as they worked simultaneously with their own hardware. This can be seen in Fig. 2 where we see some students facing the camera, (and a screen that isn't shown), and the others facing away towards the other screen(which is visible).

The objectives of this trial were to:

1. Study the ease of use of the Software
2. Analyze if the conditions for collaboration were achieved.
3. Evaluate the achievements in learning under the defined language objectives
4. Analyze the impact of silent and spoken collaboration.

Fig. 5 Software appropriation



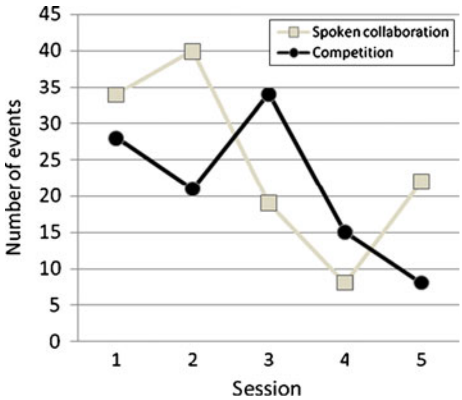


Fig. 6 Comparison between spoken collaboration and competition

The qualitative results were gathered by four in-classroom observers, two for each group. The study was supported by a Tablet PC with soft ware that registered the following events:

1. Competition: Number of occasions students compared themselves to their peers, by checking their position in the Score Space, or by commenting on their performance in the activity to others.
2. Spoken collaboration: Number of occasions where students verbally interacted with each other, in order to negotiate an exchange, or to decide whether it was convenient to carry out an action within the activity.
3. Software Usage Questions: Number of occasions students asked about an aspect related to use of the Software.

Each of the above points corresponds to a single student's action. Additionally, a system log monitored the following elements:

1. Cancellations: Number of times a student cancelled a suggestion.
2. Incorrect Exchanges: Number of incorrect exchanges carried out during the activity.

The number of correct answers was not registered because, since there are a finite number of objects to be placed in each activity, the number of correct answers will

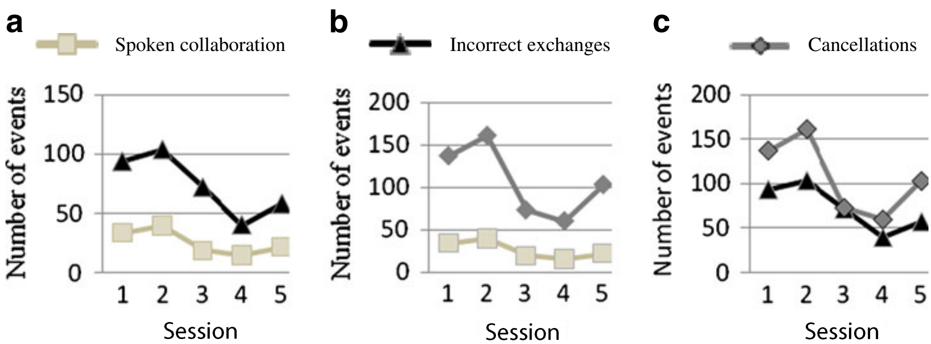


Fig. 7 **a** Comparison between spoken collaboration events and incorrect exchanges. **b** Comparison between spoken collaboration events and cancellations. **c** Comparison between cancellations and incorrect exchanges

always be the same unless an exchange allows two objects to be placed correctly simultaneously, which can be determined by the initial random distribution of objects.

Software ease of use

We began our analysis by studying whether the software presented the children with any difficulties, because these could influence other results. The children, with each passing session, proved to handle the software very well, as shown in Fig. 5, which illustrates the evolution of students' requests for help. We observed a peak of 14 events, for a total of 42 children -a very low figure—which would indicate that dedicating the first session to familiarizing the children with the system made it easier for them to properly interact with it in later sessions.

Achievement of conditions for collaboration

During the activity, we observed that the previously mentioned conditions to build a collaboration scenario within the classroom were met (analyzed in Table 1).

Evaluation of learning achievements

As a first analysis, we considered the EG students' performance on the previously mentioned written content test -both before and after the intervention -which showed a very large effect size (Table 2).

Secondly, we compared post-test results between the EG and CG, which showed a large effect size between both groups, as shown in Table 3.

Table 1 How the conditions for collaboration were achieved

Condition	Description
Common goal	The group had to collectively complete an activity based on a double entry chart. In order to do this, everyone had to place their object correctly so that, at the end of the activity all the elements were correctly classified.
Positive interdependence between peers	All group members actively participated in the game, as it was necessary to interact amongst each other in order to complete exchanges. Otherwise, it would have been impossible to achieve the group's goal.
Coordination and communication between peers	Students had to communicate and coordinate their actions, in order to negotiate object exchanges. For this they used silent and spoken collaboration. In the former, they communicated their suggestions and accepted or rejected those of their peers; in the latter, they verbally discussed those decisions.
Individual accountability	When a student made an incorrect suggestion, or refused a possible exchange, they were accountable for this action reflected in a loss of points, and therefore loss of credibility before their classmates.
Awareness of peers' work	Because of the Shared Display, group members had constant access to information about their classmates' situations: they knew what object others had, who they should ask to swap with, and how credible each one was, based on their score and the correct or incorrect exchanges they were making.
Joint rewards	When a correct/incorrect exchange took place, both parties gained/lost points equally.

Table 2 Comparison between pre-test and post-test results in the EG

	Number of students	Mean	Difference	Significance	Cohen's d
Pre test	42	31.369	11.345 (36.16%)	$p<0.001$	1.11
Post test	42	42.714			

The results shown in Tables 2 and 3 show the learning impact observed in the EG. Considering that both the EG and CG used the same non-digital resources and that the EG used the system for 40% of their available class time, we may conclude that the improvement in learning is due to the collaborative dynamic of the EG classes. However, further research should be conducted to analyze the effect of the teachers, which in this case was not controlled.

The impact of silent and spoken collaboration

Figure 6 shows the correlation between the number of spoken collaboration events and competition events, for each one of the activities. We can see that in sessions 1, 2 and 5, spoken collaboration prevails above competition events, while in sessions 3 and 4, the opposite occurs. During these last two sessions, where the most competition events were registered, completion time for the group was shorter (13:15 and 5:35 min respectively for the first iteration).Session 2 is where the difference between spoken collaboration and competition was most notable. Students perceived this activity as very difficult, a perception which was also reflected in their completion time (31:05 min for the only iteration), and the high number of registered reproaches, insults and signs of boredom (2, 22, 6, 5 and 2 respectively over the 5 sessions).

Table 4 shows the correlation values for the relationship between the total spoken collaboration events per session, and the total incorrect exchanges per session (Fig. 7a);the total spoken collaboration events per session and the total cancellations per session (Fig. 7b); and between the total cancellations per session and the total incorrect exchanges per sessions (Fig. 7c). From Figs. 5 and 7 we observe that from session 3 on, there were fewer requests for help, fewer cancellations and fewer incorrect exchanges, indicating that sessions 1 and 2 were, in some way, still part of the training period. Table 4 shows the correlation values including and excluding sessions 1 and 2; we observe that the only correlation that remains high is between the total spoken collaboration events per session and the total cancellations per session (Fig. 7b). This suggests that verbal discussion between classmates influenced the number of cancelled exchanges.

Given that incorrect exchanges and cancellations were registered through the system log, and spoken collaboration events were noted by in-class observers, it was impossible to retrieve whether cancellations due to collaboration were correct or incorrect. Nonetheless, the system did allow us to observe that when a greater number of spoken collaboration

Table 3 Post-test comparison between CG and EG

Student group	Number of students	Pre-test	Post-test	Difference	Significance	Cohen's d
Control group	32	31.219	32.703	10.011 (30.6%)	$p<0.001$	0.89
Experimental group	42	31.369	42.714			

Table 4 Correlation values for Fig. 7

Relation	Sessions 1–5	Sessions 3–5
Spoken collaboration- incorrect exchanges (Fig. 7a)	0.94	0.63
Spoken collaboration- cancelations (Fig. 7b)	0.99	0.95
Cancelations- incorrect exchanges (Fig. 7c)	0.89	0.36

events were recorded, despite an increase in the number of cancellations, the number of incorrect exchanges was not reduced (although the measured correlation was not even).

The above may us lead to conclude that there is no correlation between spoken collaboration and correct answers, which might make us think that silent collaboration was the mechanism that achieved increased learning. Further research must be done since it could be that the interpreted relationships among silent collaboration moves are not influencing one another as much as the task structure.

Conclusions

In this study, we have analyzed an application of Single Display Group ware with Multiple Mice and low hardware infrastructure costs—a computer, a projector, and one mouse per student- which makes large-group collaborative learning possible in the classroom. We showed how to create the conditions for collaborative learning, and our initial findings would suggest that we achieved the goals of learning and collaboration in large groups.

We determined experimentally that, in order to achieve collaboration in large groups, it is necessary to develop certain mechanisms, that we named silent collaboration. More research has to be done. We want to compare two silent collaboration mechanisms: the one presented in this paper with another that inhibits spoken collaboration, in order to fully understand the mechanisms of silent and spoken collaboration when all students collaborate inside a classroom. We also want to understand how the underlying pedagogical task affects silent and spoken collaboration by studying a second task besides the presented Multiple Classification matrix. Further research is also necessary to study how the difficulty of an activity affects the number of moves a student makes. The observation tools must be improved in order to establish the correctness of cancellations made as a result of spoken collaboration, and how the distance between peers affects the success rate of exchanges and the number of spoken collaboration events.

The EG and the CG used the same non-digital resources; the difference between them was that the EG used the presented CSCL approach for 40% of the available class time. Increases in student attainment are produced by quality content, pedagogical practices and commitment on the part of the students (Elmore et al. 1996). The determining factor in the learning process is the relationship between these, and not the individual attributes of each element on its own (Cohen et al. 2003). Further research is also lacking in order to compare our results with a CG that performs a similar non technology supported activity, to study the engagements of the students and to play with variables—such as the percentage of time assigned in the EG to the CSCL activity and the curricular topics that are covered (math, science, etc.).

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References

Allen, B., Crosky, A., McAlpine, I., Hoffman, M., Munroe, P. (2006). A blended approach to collaborative learning: Can it make large group teaching more student-centred. In *Proceedings of the 23rd Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education: Who's Learning* (pp. 33–41)

Axelrod, R., & Hamilton, W. D. (1981). The evolution of cooperation. *Science, 211*(4489), 1390.

Beers, P. J., Kirschner, P. A., BoshuizenH, P., & Gijselaers, W. H. (2007). ICT-support for grounding in the classroom. *Instructional Science, 35*, 535–556. doi:10.1007/s11251-007-9018-5.

Bennerstedt, U., & Linderoth, J. (2009). The spellbound ones: Illuminating everyday collaborative gaming practices in a MMORPG. In *Proceedings of the 9th International Conference on Computer Supported Collaborative Learning-Volume 1* (p. 404–413)

Brown, A., & Campione, J. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in learning: New environments for education* (pp. 289–325). Lawrence Erlbaum Associates

Bruns, A. (2007). Produsage: Towards a broader framework for user-led content creation. *Creativity and Cognition, 6*, 13–15.

Brush, T. (1998). Embedding cooperative learning into the design of integrated learning systems: Rationale and guidelines. *Educational Technology Research and Development, 46*(3), 5–18.

Cohen, D., Raudenbush, S., Ball, D. (2003). Resources, instruction and research. *Educational Evaluation and Policy Analysis*, *25*

Diggelen, W. V., & Overdijk, M. (2007). Small-group face-to-face discussions in the classroom: A new direction of CSCL research. *Proceedings of the 8th International Conference on Computer Supported Collaborative Learning* (pp. 727–736). New Brunswick, New Jersey, USA: International Society of the Learning Sciences

Dillenbourg, P. (1999). What do you mean by collaborative learning? In P. Dillenbourg (Ed.), *Collaborative-learning: Cognitive and computational approaches* (pp. 1–19). Oxford: Elsevier.

Elmore, R. F., Peterson, P. L., & McCarthey, S. J. (1996). *Restructuring in the classroom: Teaching, learning, and school organization*. San Francisco: Josssey-Bass Inc.

Fawcett, L. M., & Garton, A. F. (2005). The effect of peer collaboration on children's problem-solving ability. *The British Journal of Educational Psychology, 75*, 157–169.

Girvan, C., & Savage, T. (2010). Identifying an appropriate pedagogy for virtual worlds: A communal constructivism case study. *Computers & Education, 55*(1), 342–349.

Gokhale, A. A. (1995). Collaborative learning enhances critical thinking. *Journal of Technology Education, 7*, 22–30.

Gutwin, C., & Greenberg, S. (2004). The importance of awareness for team cognition in distributed collaboration. In E. Salas & S. M. Fiore (Eds.), *Team cognition: Understanding the factors that drive processes and performance* (pp. 177–201)

Hung, H., Young, S. S., Lin, C. (2009). Constructing the face-to-face collaborative game-based interacted environment for portable devices in English vocabulary acquisition. *Proceedings of the 9th International Conference on Computer Supported Collaborative Learning* (pp. 370–374). Rhodes, Greece: International Society of the Learning Sciences

Infante, C., Hidalgo, P., Nussbaum, M., Alarcón, R., & Gottlieb, A. (2009). Multiple mice based collaborative one-to-one learning. *Computers & Education, 53*(2), 393–401.

Inhelder, B., & Piaget, J. (1964). *The early growth of logic in the child: Classification and seriation*. Routledge and Kegan Paul

Janssen, J., Erkens, G., Kanselaar, G., & Jaspers, J. (2007). Visualization of participation: Does it contribute to successful computer-supported collaborative learning? *Computers & Education, 49*(4), 1037–1065.

Jara, C. A., Candelas, F. A., Torres, F., Dormido, S., Esquembre, F., & Reinoso, O. (2009). Real-time collaboration of virtual laboratories through the internet. *Computers & Education, 52*(1), 126–140.

Johnson, D. W., & Johnson, R. T. (1999). Making cooperative learning work. *Theory Into Practice, 38*(2), 67–73.

Johnson, D. W., & Johnson, R. T. (2002). Learning together and alone: Overview and meta-analysis. *Asia Pacific Journal of Education, 22*(1), 95–105.

Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher, 38*(5), 365.

Kaplan, F., DoLenh, S., Bachour, K., Yi-ing Kao, G., Gault, C., Dillenbourg, P. (2009). Interpersonal computers for higher education. In P. Dillenbourg et al. (Eds.), *Interactive artifacts and furniture supporting 129 collaborative work and learning, volume 10* (pp. 1–17)

Kittur, A., & Kraut, R. E. (2008). Harnessing the wisdom of crowds in wikipedia: Quality through coordination. *Proceedings of the 2008 ACM Conference on Computer Supported Cooperative Work* (pp. 37–46). San Diego, CA, USA: ACM

Malone, T. W., & Crowston, K. (1990). What is coordination theory and how can it help design cooperative work systems? *Proceedings of the Third Conference on Computer-Supported Cooperative Work* (pp. 350–370). New York, USA: ACM Press

Moraveji, N., Kim, T., Ge, J., Pawar, U. S., Mulcahy, K., Inkpen, K. (2008). Mischief: Supporting remote teaching in developing regions. *Proceeding of the Twenty-Sixth Annual Sigchi Conference on Human Factors in Computing Systems* (pp. 353–362). Florence, Italy: ACM

Nussbaum, M., Alvarez, C., McFarlane, A., Gomez, F., Claro, S., & Radovic, D. (2009). Technology as small group face-to-face collaborative scaffolding. *Computers & Education, 52*(1), 147–153.

Parker, R. K., Rieff, M. L., & Sperr, S. J. (1971). Teaching multiple classification to young children. *Child Development, 42*(6), 1779–1789.

Pavlovych, A., & Stuerzlinger, W. (2008). Effect of screen configuration and interaction devices in shared display groupware. *Proceeding of the 3rd ACM International Workshop on Human-Centered Computing* (pp. 49–56). Vancouver, British Columbia, Canada: ACM

Pawar, U. S., Pal, J., Toyama, K. (2006). Multiple mice for computers in education in developing countries. *Proceedings of IEEE/ACM ICTD 2006* (pp. 64–71). Piscataway, NJ: IEEE

Raposo, A. B., Magalhaes, L. P., Ricarte, I. L. M., Fuks, H. (2001). Coordination of collaborative activities: A framework for the definition of tasks interdependencies. *Proceeding of the 7th International Workshop on Groupware (CRIWG)* (pp. 170–179). IEE Computer Society

Roschelle, J., Abrahamson, L., & Penuel, W. (2004). *Integrating classroom network technology and learning theory to improve classroom science learning: A literature synthesis*. San Diego: Annual Meeting of the American Educational Research Association.

Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer supported collaborative learning* (pp. 69–100). Berlin: Springer-Verlag.

Roschelle, J., Tatar, D., Chaudbury, S. R., Dimitriadis, Y., Patton, C., & DiGiano, C. (2007). Ink, improvisation, and interactive engagement: Learning with tablets. *IEEE Computer, 40*(9), 38–44.

Scott, S. D., Mandryk, R. L., & Inkpen, K. M. (2003). Understanding children's collaborative interactions in shared environments. *Journal of Computer Assisted Learning, 19*(2), 220–228.

Slavin, R. E. (1996). Research on cooperative learning and achievement: What we know, what we need to know. *Contemporary Educational Psychology, 21*(1), 43–69.

Spada, H., Meier, A., Rummel, N., Hauser, S. (2005). A new method to assess the quality of collaborative process in CSCL. *Proceedings of the 2005 Conference on Computer Support for Collaborative Learning* (pp. 631)

Stahl, G., Koschmann, T., Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. *Cambridge handbook of the learning sciences*, 2006

Teasley, S. (1995). The role of talk in children's peer collaboration. *Developmental Psychology, 3*(2), 207–220.

Tudge, J. R. (1992). Processes and consequences of peer collaboration: A Vygotskian analysis. *Child Development, 63*(6), 1364–1379.

Wallace, J., Scott, S., Stutz, T., Enns, T., & Inkpen, K. (2009). Investigating teamwork and task work in single and multi-display groupware systems. *Personal and Ubiquitous Computing, 13*(8), 569–581.

Zagal, J. P., Rick, J., & Hsi, I. (2006). Collaborative games: Lessons learned from board games. *Simulation and Gaming, 37*(1), 24–40.

Zea, N. P., Sanchez, J. L. G., Gutierrez, F. L. (2009). Collaborative learning by means of video games: An entertainment system in the learning processes. *Proceedings of the 2009 Ninth IEEE International Conference on Advanced Learning Technologies* (pp. 215–217). IEEE Computer Society

Zurita, G., & Nussbaum, M. (2004). Computer supported collaborative learning using wirelessly interconnected handheld computers. *Computers & Education, 42*(3), 289–314.