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Co-located single display collaborative learning for early childhood education

Florencia Gómez · Miguel Nussbaum · Juan F. Weitz · Ximena Lopez · Javiera Mena · Alex Torres

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Abstract The benefits of collaborative learning are well documented. However, most of the research has been done with children beyond the ages of early childhood. This could be due to the common and erroneous belief that young children have not developed the capacity to work collaboratively toward a given aim. In this paper we show how small group co-located collaborative learning on a single display computer improves oral language, logical-mathematical and social skills in pre-school children. Considering that early childhood teachers have a responsibility to provide a supportive environment, teacher mediation is essential in order to achieve collaborative learning. Thus, teachers were trained in the use of the technology and strategies for effective collaborative learning. The study was implemented in 10 kindergarten classrooms with 268 children between the ages of 5 and 6 years old. A group of 5 kindergarten classrooms with equivalent characteristics participated as a comparison group. During the four-month intervention, children worked on collaborative activities at least twice a week. A quasi-experimental approach was used to assess the implementation, including pre- and post-testing. The data showed differences in the learning of oral language, logical-mathematical and social skills, with the experimental group demonstrating significantly greater achievement.

Keywords **Small group** Computer Supported Collaborative Learning · Co-located learning · Early childhood education · Single display collaborative learning

M. Nussbaum · J. F. Weitz · X. Lopez · J. Mena · A. Torres
School of Engineering, Computer Science Department, Pontificia Universidad Catolica de Chile, Vicuña Mackenna 4860 Santiago, Chile

M. Nussbaum
e-mail: mn@ing.puc.cl

F. Gómez (✉)
School of Education, Pontificia Universidad Catolica de Chile, Vicuña Mackenna 4860 Santiago, Chile
e-mail: fgomezz@uc.cl

Introduction

Collaboration among young children has not been widely studied in the context of cultural settings that influence learning (Callaghan et al. 2011), such as schools. Collaboration as a strategy to support learning in different areas of the curriculum seems to be a necessary component of preparing children for school (Lara-Cinisomo et al. 2004). Developing skills for collaboration requires providing support and guidance in order to help students and teachers work together. This support can be provided in highly structured activities; but controlling activities with small children can be very challenging. Moreover, if we understand collaborative skills such as those which enable learning from, and with, others at school, it seems positive that the development of these skills should be connected to different curricular areas. In this paper we argue that small-group co-located collaborative activities in a computer-supported environment, or what we call "co-located single-display collaborative-learning activities" can improve learning oral-language, logical-mathematical, and social skills in preschool children. In our view, this is possible in a setting that provides support for children to engage in activities that are mediated by computers, use specific software to motivate collaboration, and support teachers in working with the children to promote collaboration.

The concept of school-readiness skills refers to the prerequisites that children need to begin formal education (Astington and Pelletier 2005). These prerequisites are related to cognitive, physical and social abilities (Lara-Cinisomo et al. 2004), which enable them to develop specific skills in literacy, numeracy, and social understanding (Ziv et al. 2008). These skills will establish the groundwork for successful acquisition of more complex learning at higher levels of schooling (Dickinson and Neuman 2006). Therefore, it is at the pre-school level where the firm foundations necessary for acquiring different social skills have to be developed (Peisner-Feinberg et al. 1999).

At the early-childhood level, social understanding involves children's comprehension of their own and others' beliefs, emotions, and intentions, which directly affect their social interactions with others (Carpendale and Lewis 2006). When children have the opportunity to work collaboratively, they develop a common understanding of the world as they acquire verbal, cognitive and social skills, all of which influence their learning (Gillies 2006; Rogoff et al. 2001; Webb et al. 2008). In this type of learning environment, pupils attain a better understanding of their classmates' needs, their points of view, and a better perception of problems. That is why when children help a classmate they gain a greater understanding of their own perspective on the problem at hand (Gillies 2006). Children do, however, learn gradually through social interaction to conceive of a world existing independently of them and to take other points of view into consideration (DeVries 2002; Fawcett and Garton 2005; Rice 2001).

Even though the benefits of collaborative learning are well documented, most of the research has been done with children beyond the ages of early childhood (e.g., Vermette et al. 2004). This could be due to the common and erroneous belief that young children do not have a sufficient developmental capacity for collaboration (Battistich and Watson 2003; Tunnard and Sharp 2009). However, evidence shows that children in their early childhood can acquire the skills necessary to collaboratively interact with their peers if they are taught to do so (Gillies and Ashman 1998). A program that provides opportunities for children to participate at an early age in collaborative-learning activities, which require interaction among peers, promotes empathetic behavior and healthy interchange (Piercy et al. 2002; Vasileiadou 2009). Stevahn et al. (2000) compared pre-school children who were taught how to resolve conflicts with other children who were not. The study found that those who received the training correctly used the skills they acquired to deal with conflicts and solve them in a positive fashion. Moreover, Larkin (2006) in a case study of two 5 year-old students that engaged in cognitive acceleration through a science education program with collaborative work, observed that the collaborative interactions produced individual development of metacognition. Therefore, children in early childhood are capable of working in a collaborative way inside the classroom, but teachers must create the corresponding conditions.

To achieve collaborative learning, the mediation of the teacher is essential. The teacher provides the scaffolding that guides the child towards the Zone of Proximal Development (Vygotsky 1978) helping them to achieve autonomy, to collaborate and eventually learn from that process. This collaboration is not achieved naturally and there is no guarantee that learning will take place merely because individuals work together (Dillenbourg 2002). Some specific conditions necessary for efficient collaboration among members of a group are: individual responsibility, mutual support, and positive interdependence (Dillenbourg 1999; Hamm and Adams 2002; Johnson and Johnson 1991; Szewkis et al. 2011). In addition, the pedagogical intervention of the teacher plays an important role in the setting that helps to produce these conditions. Early childhood teachers have a responsibility to provide a supportive environment, be a model for the skills of collaborative work, and have a positive relationship with their young students in order to produce effective collaborative interactions between them (Battistich and Watson 2003).

The development of collaborative work among students can be facilitated through the use of technological tools (e.g., Roschelle et al. 2000). Computer-Supported Collaborative Learning (CSCL) can support collaboration, discussion of ideas and conflict resolution (Bricker et al. 1995). In a study conducted by Zurita and Nussbaum (2004) of collaborative activities for first-graders that compared the problems that emerged in an activity not mediated by technology with those encountered when a similar activity was mediated by mobile computer devices, it was found that the use of technology reduced the difficulties in areas such as coordination, communication, organization, negotiation, synchronism and interactivity. Technology provided an environment that supported interaction among children orienting their activities to collaboration. This required both intentionality and adequate support to develop childrens' collaboration for learning, which was provided by the mediation of technology.

Even when group work is included as strategy, children are rarely provided with formal training to collaborate (Kutnick et al. 2002), but rather develop these skills as a result of spontaneous teacher intervention in everyday situations and not as part of planned activities. In order to access the potential benefits of collaborative work, children need to be taught how to navigate group work (Tolmie et al. 2010). It is therefore relevant to study how young children can learn to collaborate with others in settings that are integrated into the learning of conventional skill sets, and where they are supported to work with others. Supported by computers in facilitating processes in collaboration (Zurita and Nussbaum 2004) and using computers as mediators for guiding children to learn with others can be a powerful option.

Integration of computers to develop collaborative learning has been done using different devices in different settings. This integration has been studied to determine the possibilities of the proposals that combine devices and settings to support collaborative interaction (e.g., Lipponen et al. 2003; Roschelle et al. 2007). These studies consider settings that are well equipped, which contrasts with the reality of schools in more deprived contexts. In developing countries, a recurring difficulty is the low availability of computers per student, which limits individual students' access to the devices and therefore their potential impact. Furthermore, most PC applications supporting collaborative work require students using a single computer to take turns with the mouse or keyboard . This reality of reduced access to technology in schools restricts the students' interaction with the devices, which could affect their engagement in activities that involve using computers. Using one-to-one devices in collaborative learning for face-to-face activities has had a positive effect on improving the conditions for collaboration (Nussbaum et al. 2010), and this improvement is maintained when the activity is on a single shared screen where individuals can use their own input device (Infante et al. 2009). The latter technology is called Single Display Groupware (SDG), which allows multiple co-located individuals, each with their own input device on the same machine, to interact simultaneously on a single communal display (Stewart et al. 1999). The information displayed is shared by a group of users who have a distributed control through multiple inputs, allowing several people to interact at the same time, in the same place (Kaplan et al. 2009). The use of multiple inputs at the same time and place has been studied by a number of researchers who have sought to demonstrate its effects when peers work with a single screen (e.g., Paek et al. 2004; Pawar et al. 2007). The results show that children controlling their own input device in a collaborative setting display less boredom and off-task behavior and are more active, suggesting greater engagement in the activity (Scott et al. 2003). A fundamental aspect that favors interactivity among the students, and particularly their level of motivation, is the fact that the activity makes each of the students work with their own objects: each student controls their own input device, allowing them to participate and engage in learning (Infante et al. 2009). In addition, co-located collaboration favors more direct interaction among students, allowing visibility of gestures and body expression that contributes to better communication (Bricker et al. 1995).

In this paper we present a study in which we sought to answer the following research question: Can small-group co-located collaborative learning on a single display computer improve oral language, logical-mathematical, and social skills learning for preschool children? The study we present involved the design of an intervention for computer-supported co-located collaborative activities using SDG for one computer (co-located single display collaborative learning activities) shared by three kindergarten-age children. We chose this technology because it creates an environment that has tasks that require children to collaborate in order to reach certain goals, supports the simultaneous visualization of elements involved in the tasks, and ensures equal access to technology in a context where 1:1 access cannot be guaranteed. The activities developed allowed for the use of three different dynamics implemented using the same technology system. Teachers participated in designing contents for the dynamics and were supported in implementing the activities with children. In the following sections we describe the tools used in the intervention, the method followed to assess the intervention, the measurements performed, the results gathered, and the discussion and conclusions.

Tool description

The technology used in this experience consisted of a Single Display Groupware application that supports co-located CSCL (Tse and Greenberg 2004) in which three children engage in co-present collaborative work at a single computer with one screen, each child with their own input device—a mouse (Fig. 1).

Three different software applications were implemented under the same technology. One of them, called RoleGame (Infante et al. 2010) has an interface similar to those used in video games with characters that can only be controlled by a corresponding mouse. The other two, known as Exchange (Infante et al. 2009) and Sort (Zurita et al. 2005), have a screen divided

Fig. 1 Small group co-located collaborative learning on a single display computer

into different-colored zones, one for each participant, while their mouse, that can move all over the screen, can only select objects belonging to their color.

To accomplish the conditions for collaboration the three applications are structured around the following features:

- A **common goal** is defined for the group (Dillenbourg 1999). The common goal is set by the application and must be achieved by all the children, working together. An example of a goal might be to find the beginning letter sound of a word or to sort numbers from lowest to highest.
- Only with **coordination and communication** (Malone and Crowston 1990) it is possible to achieve the common goal since the tasks are interdependent and require synchronization between the members of the small group. In the applications, children have to agree on what the goal is and what the steps to achieve it should be. Then they have to determine what each member must do and coordinate their efforts in order to, for example, exchange elements between members of the team and complete the task.
- **Positive interdependence** (Johnson and Johnson 1991) is achieved since each participant has a specific task and to successfully perform the activity the students must not only complete his or her own, but also ensure that their peers complete theirs. Success is only achieved when all members reach their goal, which also assures **joint rewards** (Zagal et al. 2006). In the applications, although the goal is common, intermediate goals for each member need to be achieved in order to accomplish the common goal. Therefore, members of a small group rely on each other and need individual actions to complete the task.
- Since the children share the same screen in the applications they can all see the actions their peers perform, therefore making **each group member accountable** for their work (Janssen et al. 2007), as can be seen in Fig. 1.
- Through the application's common screen, the children receive common feedback, which acts as an **awareness** mechanism (Zurita and Nussbaum 2004). In this way, all members in the small group know if the task was achieved or not and are provided opportunities to re-perform the task, as can be seen in Fig. 2.

Fig. 2 Feedback after completing a task. **a** If the team response was correct the application shows a happy face and children continue with the next task by clicking on the arrow button (*bottom of the working space*). **b** If the team response was not correct the application shows sad faces and children have to re-perform the task by clicking on the go back button (*bottom of the working space*)

The applications were created not only to favor collaboration between children but also to develop readiness skills. To this end, each application requires the design of contents that are integrated in the dynamic of the application allowing a broad range of content in different disciplines.

A summary of the main features of each application is given in Table 1.

Method

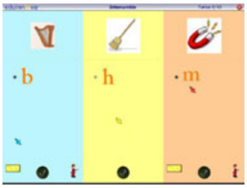
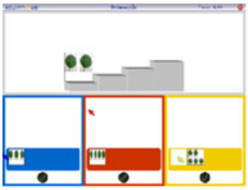
We utilized a quasi-experimental design with a control group to assess the intervention with kindergarten children from a densely populated, lower-middle income area in Chile's Metropolitan Region, where the capital, Santiago, is located. The schools participating in the study receive public funding and are administered by the municipal education department. Fourteen schools, including two special education schools and one adult school serve the area. The average school achievement in the national standards test for the district is significantly below the average regional and national scores. Schools in the district tend to work independently, but at the preschool level the municipal education department has motivated teachers to work together in periodic lesson planning that follows the national curriculum and is common to all kindergarten classrooms in the district's schools.

Participants

The intervention (experimental group) was conducted in five schools with two kindergarten classrooms each (N=268; 45.5 % female; 54.5 % male). Each classroom gathered children aged from 5 to 6, and one teacher. The control group consisted of four other schools in the same district with similar socioeconomic and teacher characteristics with a total of 5 classrooms (N=172; 43.5 % female; 56.5 % male). Both experimental and control groups were consistent in terms of socioeconomic level, age, and teachers' experience. All teachers taking part in the experimental and control groups were female, held a degree as preschool teachers, and had an average of 15 years of classroom experience.

The number of students per classroom differed between control and experimental groups (26.8 and 34.4 average size of the class respectively). In the past years, the public education

Table 1 Description of collaborative dynamics used in the intervention

Application	Dynamic	Contents
Exchange (Infante et al., 2009) 	**Matching and exchanging:** each participant must form pairs of elements within their assigned zone, such as a question in the upper part of the zone and the corresponding answer in the middle part of the zone. The three students must engage in face-to-face negotiation as they attempt to identify a matching question-answer pair, exchanging answers among themselves. In order to solve the problem, students must "send" their peers their individual answers when they believe that the letter in their screen does not correspond to the object shown above. Students "mail" their answers to their companions by clicking on the postman in the bottom right corner. An envelope with the color of that member's zone will appear automatically in the other members' zones, and when students believe that the letter shown in their zone matches the object shown above, they select their answer. There are only three questions and three matching answers that members can mail to each other. Once all the right pairs have been created, each member clicks on the confirmation button to see if all answers are correct. If so, they can continue to the next task, otherwise, they have to re-perform the task, making new exchanges.	Used to treat material from different disciplines where the concepts can be paired. For example, in mathematics, matching a number with its written or graphical form (e.g., fractions); or, in language, matching an image of an object with the first letter of the object's name (see figure).
Sort (Zurita et al., 2005) 	**Sorting and coordination:** the objective is to sort elements into logical sequences according to a given criterion (size, number, alphabetical order, or some other pattern). The screen is divided into separate boxes that contain the elements to be ordered belonging to each peer, plus a common zone where the ordering is performed collaboratively (upper part in the figure). The students must analyze the different elements, identify the ordering criterion (by size, by amount, by logical pattern, or logical order of letters if it's a word, etc.), apply the ordering criterion and co-ordinate efforts to choose and order them one by one. To do so, children have to select each element by clicking on it; the selected element will be automatically placed in the ordering zone (upper part). Once all the elements have been placed in the ordering zone each member must confirm the answer by clicking on the confirmation button. If it is correct they can continue to the next task. Otherwise, they must reorder the elements until the order is correct.	Used to treat material from disciplines where object sorting is required to complete a task. For example, sorting letters to form words; words to form sentences; figures into logical sequences; or, as in the figure, to sort numbers or objects according to the amount they represent.
RoleGame (Infante et al., 2010) 	**Roles to fulfill collaborative tasks**: in this video game every member of the team has a different role, both in the pedagogical and playful dimensions. The game moves the players through increasingly more complex levels in both dimensions independently. The objective of the game is to capture both ludic and pedagogical objects in order to achieve a given target. In the game, each peer is given a character (avatar), which has a certain role (or roles), whose different abilities make it necessary for the members of the group to come up with a collaborative strategy in order to achieve the ludic and pedagogical objectives. For example, the game area resembles a field where there may be rivers, mountains, and antagonist characters. The task that the three members of the group have to complete is to form a word with letters distributed across the field. All members have to go to the letters together, overcoming the obstacles on their way. Each member's avatar has a different role: one can climb mountains, the other can cross rivers, and the other can put enemies to sleep. In their distinctive roles, each avatar can help its peers to overcome the obstacles by using their special ability. In this way, the three members can collect the letters they need to form the word through direct collaboration. Once each letter has been captured and the right word formed, they can move on to the following level.	Used to treat material in different disciplines where the construction of objects is required, the same as in the previous game. The key difference from the previous game is the explicit introduction of a role-based, ludic dimension.

system in Chile has seen a decrease in student enrollment (Bellei, Valenzuela & Sevilla, 2009). This has led to the consolidation of classrooms, which in turn has resulted in the reduction of the number of classes offered for each level and in some cases in a higher number of students per classroom. Of the initial 268 children in the experimental group and 172 in the control group, only 145 and 87 children, respectively, attended both pre- and post-tests. The difference in attendance between pre- and post-tests may be explained by common absenteeism problems in young school children. This problem has not been systematically studied in Chile; however, it is widely recognized by educators, including the teachers in this study. Studies in other countries, like the United States and United Kingdom, have highlighted chronic absenteeism in kindergartens as being a problem (Broadhurst et al. 2005; Romero and Lee 2007), with children missing on average 12 to 18 days during the school year (Romero and Lee 2007). In our study, the absenteeism rate was similar on both the pre- and post-test days, mainly because the children who were absent on pre-test days were not necessarily the same ones who were absent on post-test days.

Implementation procedures

Preparing the intervention, conducting the intervention in the schools with children and teachers, and assessing the intervention in activities were not necessarily implemented in that same order. The *preparation of the intervention* followed different steps to setup conditions for the intervention with children. Besides logistics like contacting the participant schools, meeting administrative and teaching staff, and communicating relevant information about the intervention, our main activity was working with the teachers in a training program. Technology coordinators in each school also participated in the teacher training to become familiar with the applications and to provide basic support to teachers in using the computer lab where the intervention was carried out. The *intervention in the schools* lasted for 4 months and involved the activities described in section Tool description which used content developed by the teachers during training sessions. The *assessment of the intervention* comprised several activities that were conducted throughout the intervention in order to determine the level of success based on the students' achievements.

Children's activities

The implementation of experimental activities with children was conducted twice a week over the 4 months of the intervention in the participating schools. Experimental activities with children and teachers consisted in 45-min lessons that were wholly carried out in each school's computer lab. In each lesson students alternated between the Exchange, Sort and RoleGame applications that considered tasks aligned with curricular contents. According to the district schools lesson plan, teachers in the experimental group developed contents that were integrated in the applications used in the lessons carried out in the computer lab. This favored the integration of the computer mediated collaborative activities with the rest of activities developed in the regular classroom.

In order to provide a structure for the lessons and to make full use of the allocated computer lab time, we proposed a lesson organization in four phases. Therefore, every lesson had the same basic structure. The first phase lasted 7–10 min and was an initial motivation period dedicated to identifying the students' prior knowledge and giving them a motivational introduction to the content covered in the activity. Relevant relationships were established between each lesson's activities and previous activities developed in the regular classroom and/or the computer lab. Teachers in each classroom were responsible for creating these relationships with the purpose of introducing the children's previous knowledge and making connections between that past knowledge and the current lesson as scaffolding for future learning. In the second phase, which lasted about 5 min, the students were randomly distributed around the computers to ensure that they would work with different peers over the course of the four-month intervention. Children received individual identifiers with different designs (e.g., a fruit, an animal, or a color), and then proceeded to the computer displaying the same identifier. Although this phase basically just entailed splitting the children into groups, it was a relevant phase that ensured that the children worked with different classmates, allowing opportunities for heterogeneous group formation. In the third phase, the collaborative activity was performed for about 20 min. The educators' job in this phase was to support the groups, mediating their conversations and any conflicts that arose. Thus, the teachers were expected to provide feedback on the learning process taking place, as well as to point out and model certain collaborative behaviors that promote healthy co-existence and a context conducive to learning. The last phase was the wrap up, where the teacher briefly summarized and/or analyzed the session based on the learning acquired during the activity, linking topics with previous activities. This phase took roughly 10 min.

The control group underwent no intervention other than the usual planned activities. The lesson plans for the district were organized in coordination with all the schools and followed the national kindergarten curriculum in the areas considered for this study: oral language, logical-mathematical, and social skills. Hence, children in the control classroom performed activities following the same curriculum but without the use of the collaborative dynamics used in the intervention group.

Teachers' training

As part of preparation for the intervention, the ten teachers in the experimental group participated in training sessions to acquaint them with the collaborative model, work on lesson plans, design and create the activities, and learn how to support group work during the activities with the children. Training in teaching strategies was added to favor teachers' management of small group collaboration. The training was delivered by educators with backgrounds in classroom teaching and technology integration, and involved a review of the objectives and material for kindergarten as defined by the national curriculum. Efforts were focused on systematizing the implementation of the activities using technology as an integral component of the curriculum. In addition, there was consideration of the characteristics of collaborative work with small children and the variables to be taken into account when guiding these activities in the classroom. The training concentrated on issues of classroom activities management such as strategies to group the students, checking the readiness of resources (e.g., computers and applications), initiation of the activities, and handling of technical issues; guidance of collaborative work such as group supervision, support in group discussion, conflict mediation, feedback delivery, and integration of the computer lab activity with previous activities; and on general performance in structuring the lesson in the computer lab, and developing a positive classroom environment for small-group collaborative activities mediated by computers.

The teachers were also trained in the pedagogical design of content for the collaborative activities carried out in the computer applications. Teachers created content collectively, thus giving rise to a community in which material could be shared and revised. This resulted in promoting more creative exchanges between colleagues and leading to a greater variety of activities to be integrated in the software applications, and a better use of the time available for content design.

The training, which started 3 months prior to the beginning of activities with the children, also provided teachers with the skills needed to progressively increase their autonomy in implementing the activities. Thus, equipping them to develop an effective classroom integration of the computer applications and the pedagogical strategies consistent with the aims of the intervention. In order to inform training design decisions, the attitudes of the educators towards the introduction of the technology into their teaching practices were assessed through a survey of technology experience and use. Teachers were asked about their use of different technological tools that were needed for the preparation of the intervention, such as web browsing, e-mail, word processing, graphic editors and management of files. The responses collected were analyzed and findings used to adjust the teacher training in order to provide support that could cover the needs of the group of teachers participating in the intervention.

Changing a teacher's instruction model can be a source of anxiety, especially if the innovation includes the use of technology, and this can become a barrier to the success of the implementation. One way to address this is through coaching (Matthew et al. 2002) and the intervention therefore included in-classroom coaching performed by the same training instructors during the activities in the computer lab. The classroom accompaniment was aimed at breaking down activity management barriers and fears that tend to naturally arise when teachers are first confronted with the proposed technological innovation (e.g., Ertmer 2005; Pelgrum 2001). It also bolstered the practical side of the training, reinforcing the theoretical material while providing support for emerging difficulties and a sense of security during the experimental processes, as well as facilitating careful reflection on the collaborative experience. This coaching was delivered to each teacher involved in the implementation on a weekly basis during the first month, totaling on average four sessions. According to the level of confidence and competence that a teacher had reached, the coaching decreased in order to allow teachers to work autonomously.

Measurements

To determine the impact of the intervention on the children's learning, pre- and post-tests were applied to both the control and experimental groups using the same version of the tests for both evaluations. We used two tests for the assessment of learning outcomes: one for oral language and logical-mathematical rand quantification, and another for social skills. Both the oral language and logical-mathematical relationships and quantification test, and the social skills test were applied the week before the intervention started (the pre-test in August, at the beginning of the second academic semester in Chile) and the week after the intervention finished (the post-test in December, at the end of the second academic semester in Chile) with an interval of 4 months between evaluations. The oral language and logical-mathematical relationships and quantification tests were administered to small groups of no more than ten children by two external evaluators certified in preschool education. All the evaluators were trained to conduct the testing process according to a detailed protocol, the aim of which was to mitigate any potential misunderstandings that could arise during the evaluation process, and to achieve a general agreement among evaluators regarding how to conduct the test. The social skills test included observations that were conducted using a rubric. Both pre- and post-test observations used the same rubric, and the evaluators were trained to conduct the process as uniformly as possible for the different groups they observed. The training considered a pre-observation meeting with the evaluators that were oriented to thoroughly review the dimensions and descriptors of the rubric so as to achieve a shared understanding by all the observers. In order to achieve consistency among evaluators, the research team met with all the evaluators following the first observation to comment on the process and analyze their experience in piloting the rubric. The goal was to reach an agreement on how to organize the collaborative activity, how to complete the rubric, and how to interpret the rubric criteria to consistently register the children's behavior observed during the social skills test. Based on the pilot observation, the team worked on operationalizing the criteria by carefully recording aspects of the social skills test's activity that could provide information for modifications to the rubric. Therefore, some minor changes were made to the rubric afterwards, in the wording of descriptors and in instructions for the observers. This training was conducted during both the pre- and post- test process. The purpose of repeating the training was to ensure that all evaluators understood the procedures for conducting the evaluation and could use the evaluation materials properly. In total, six external evaluators participated in the evaluation process in both pre- and post-test. However, since the period between the pre- and post-test lasted 4 months, two of the evaluators who participated in the pre-test were not able to participate in the post-test for personal and job-related reasons. This prevented us from maintaining the same evaluators for both evaluation instances, which we addressed by conducting the thorough training described above with all evaluators involved in the pre- and post-tests.

The research team that created the tests included a pre-school specialist with a degree in psychology, a psychologist, and an elementary school teacher. The tests addressed topics included in the expected learning outcomes covered in the implementation. These outcomes were taken from Chile's official curriculum for oral language, logical-mathematical relationships and quantification, and social skills. The assessment was performed on basic skills associated with the students' readiness for the levels following kindergarten in these areas. The oral language and logical-mathematical relationships and quantification test, a pen and paper test, consisting of 16 items, eight for each area. The oral language section of the test comprised items that covered expected learning outcomes related to expanding the child's vocabulary by exploring the sounds and meanings of new words that are part of the child's experiences, developing phonological awareness, and associating phonemes with graphemes. The logical-mathematical relationships and quantification section of the test, on the other hand, assessed items that corresponded to learning outcomes such as time orientation using different concepts, like sequences (before-after, day-night, yesterday-today-tomorrow), duration (longer-shorter), and velocity (fast-slow). This part of the test also evaluated learning outcomes related to classification and sorting skills; using numbers to identify, count, classify, add, subtract; searching for information and sorting elements in a real context; and representing quantities using depictions (MINEDUC, 2005) (See sample items in Appendix 1). In order to determine the internal consistency of each test (oral language, logical-mathematical relationships and quantification) we measured using Cronbach's alpha. For the oral language test, the Cronbach's alpha was 0.70 at pre-test and 0.78 at post-test. For the logical-mathematical relationships and quantification test, the Cronbach's alpha was 0.74 at the pre-test and 0.84 at the post-test. These show moderate reliability of the assessment instruments used in this process.

The social skills test was oriented to assess children's success in learning skills that support peaceful coexistence and social interaction, as defined by the Chilean Ministry of Education. The skills considered in the test, based on the Ministry's definition, referred to "sharing with other children while playing, investigating, imagining, and co-constructing;

successfully organizing group activities with common goals and playing different roles in (…) collective activities while building cooperative norms" (MINEDUC, 2005). The test consisted of a non-technological collaborative activity that children performed in groups within each class while being observed by two external evaluators who focused on different groups of children. Since these skills were already considered by the experimental and control groups in their teaching and learning activities, our aim was to assess the impact of the proposed technology on the developed social skills after 4 months. Drawing on the social skills defined in the official curriculum, we developed an observation rubric that was used to record the behavior and interactions of the children during a collaborative activity inside the classroom. This social skills activity involved making a drawing about a well-known children's theme (the circus) using colored pencils on a single large piece of paper. The students were asked to do the drawings in groups of five, all of them drawing on the same large piece of paper. As with the testing in the other areas, the observation rubric was completed by two external evaluators who observed the different groups of students as they performed the collaborative activity. The observation rubric used a Likert scale to evaluate the child's willingness to share materials with other classmates, respect the rules of the activity, work in groups to achieve the goal of the activity, participate in the task, show willingness to exchange opinions, and show willingness to help other members of the group. As with the oral language and logical-mathematical relationships and quantification test, these elements were based on the expected learning outcomes set out in the peaceful coexistence plan included in Chile's official kindergarten curriculum.

A quasi-experimental design was used. Difference of means (repeated ANOVA measures, controlling for unequal cell size) and effect size tests (Cohen's *d*), when the differences were significant, were performed using the data obtained. Multi-level analyses relating children and teacher statistics were not performed given the small number of groups (<20) participating in this experiment and that data regarding the control group teachers were not collected.

Results

The analysis reveals a statistically significant increase in the students' results between the pre and post-tests for oral language learning for both the experimental and control groups ($F(1,223)=67.993$, $p<0.001$). There was no group effect ($F(1,223)=0.031$; df=1; $p=0.86$), i.e., neither of the groups had significantly better results in both assessments (pre-test and post-test) (Table 2). A significant interaction was observed between the two independent variables: groups (control and experimental) and time of measurement (pre-test and post-test) ($F(1,223)=15.885$, $p<0.001$), indicating that the performance of the groups varied in different ways between the pre-test and the post-test. It is worth noting that the experimental group had a performance inferior to that of the control group in the pre-test, and a superior performance to the control group in the post-test. The control group's improvement was 6.24 % while that of the experimental group was 17.90 %. In conclusion, although both groups progressed, the experimental group's performance was clearly better than that of the control group with large and medium effect sizes respectively (Cohen's d). The effect size of the intervention, which refers to the difference between improvement of the experimental and control groups, is 0.54.

Similarly, for the logic-mathematical relationships and quantification area (Table 3) the students in the control classrooms advanced by 6.09 % while those who participated in the

Table 2 Learning progress in oral language

Group	N	% Achievement pre-test Mean (SD)	% Achievement post-test Mean (SD)	Pre-post difference Mean (SD)	Effect size (Cohen's d)	Effect size (Cohen's d) of the difference
Experimental	144	51.39 (21.10)	69.30 (16.35)	17.90 (22.46)	0.95 (large)	0.54 (medium)
Control	81	56.86 (17.46)	63.10 (17.39)	6.24 (18.37)	0.36 (medium)	

project improved by 21.78 %. Once again, the difference between the test scores before and after the experiment was statistically significant ($F(1,222)=61.78$, $p<0.001$) and no group effect was identified ($F(1,222)=1.53$, $p<0.218$). However, a different performance of the groups (interaction effect) was detected between the pre-test and post-test ($F(1,222)=19.574$, $p<0.001$), reflecting that the experimental group performed better than the control group. Accordingly, the effect size for the control group was small ($d=0.26$), while the effect size for the experimental group was large ($d=0.87$). Cohen's d shows that the intervention had an effect size of 0.59.

The results for social skills summarized in Table 4, show that the group participating in the intervention improved by 10.09 % while the control group worsened by 8.19 %. We observed that in the lesson plans followed by all kindergartens in the district, there was little evidence of collaborative activities incorporated as intentional learning strategies. Moreover, a teacher indicated that kindergarten children rarely work collaboratively in groups, which could be seen as a belief that makes the introduction of collaborative dynamics in this teacher's classroom unlikely. This does not necessarily explain the decrease in achievement by the control group, and further exploration would be necessary for a better explanation. However, we know that children in the control group did not engage in collaborative activities during the period when the intervention group did. Additionally, the intervention considered supporting child conflict resolution, which has been shown to be a positive strategy for achieving collaboration among young children (e.g., Stevahn et al. 2000). Therefore, the 18.28 % difference between both groups may be explained by the intervention, considering that, unlike the experimental group, the control group did not conduct any activities related to the development of social skills that involved explicit collaboration. Effect size of the intervention is 0.51 (Cohen's d). Statistically, there was no significant trend towards higher averages between the pre-test and the post-test for the students as a whole ($F(1,230)=0.159$, $p=0.691$). In this case, the group effect was negligible, meaning that no group achieved a score consistently higher than the

Table 3 Learning progress in logic-mathematical relationships and quantification

Group	N	% Achievement, pre-test Mean (SD)	% Achievement, post-test Mean (SD)	Pre-post difference Mean (SD)	Effect size (Cohen's d)	Effect size (Cohen's d) of the difference
Experimental	144	59.20 (30.18)	80.99 (20.02)	21.78 (27.62)	0.87 (large)	0.59 (medium)
Control	80	70.73 (21.95)	76.82 (24.83)	6.09 (20.92)	0.26 (small)	

Table 4 Progress in social skills

Group	N	% Achievement, pre-test Mean (SD)	% Achievement, post-test Mean (SD)	Pre-post difference Mean (SD)	Effect size (Cohen's d)	Effect size (Cohen's d) of the difference
Experimental	145	62.16 (26.02)	72.24 (24.18)	10.09 (35.55)	0.40 (medium)	0.51 (medium)
Control	87	69.54 (30.00)	61.35 (29.39)	−8.19 (34.30)	−0.28 (small)	

other ($F(1,230)=0.401$, $p=0.527$). The only statistically significant effect was the interaction between the two variables ($F(1,230)=14.752$, $p<0.001$). This implies that the two groups initially behaved similarly, but in the post-test only the experimental group exhibited a positive effect on the social skills measure. As regards effect size, in both cases the effect was small but whereas the control group's effect was negative, for the experimental group it was positive.

Discussion

Finding evidence of the effectiveness of computer-mediated collaborative activities for early childhood has not been an easy task. Collaborative learning activities that use computers to mediate the interaction among children require certain features to effectively provide an environment that encourages learning with others (Zurita and Nussbaum 2004). In order to learn how to collaborate with others, children need to engage in activities that are designed to promote the achievement of a common goal, through a coordinated effort that is nurtured by communication, positive interdependence, and awareness mechanisms to understand how to improve performance for a determined task. We were aware that incorporating the mentioned features in children's activities could be very challenging; however, we also understood that computer mediation could provide an environment that supports collaboration.

In this study, we used computer mediation to support face-to-face interaction among children, and co-located distribution of small groups using a single computer to support joint attention to the task. Callaghan et al. (2011) points out that collaborative activities oriented towards a common goal require children to focus their attention on the task, monitoring each other's attention in order to comprehend and anticipate their partners' actions. The possibility of interacting with a single computer screen favors shared attention to the task, and contributes to reaching an agreement on the movements required to achieve the common goal. Therefore, during the children's interactions, the common visualization of task elements supported the mediation of social dynamics offered by the co-located single display collaborative activity (Infante et al. 2010). Achieving common goals through collaboration on co-located single displays with tasks that centered on curricular contents contributed to the children's achievements in the intervention group.

Mediation plays an important role in training children on how to collaborate to achieve their goals, as we observed during the activities carried out during this intervention. The application by itself is insufficient to make the children collaborate and thus the modeling that teachers provide becomes an important component in children learning how to collaborate. Through engagement in the co-located single display collaborative activities, children are exposed to mechanisms that make interacting with group members necessary for achieving the common goals, but the modeling of how to deal with conflicts and reach consensus is the teachers' responsibility as mediators.

Social skills are part of the skill set that children need to learn in school, and it is convenient to integrate these skills while learning regular curricular contents. We showed how collaboration can be introduced to preschool children while teaching them oral language and mathematical reasoning. Through careful and systematic implementation of computer-mediated collaborative tasks, active participation of teachers as student guides, and curricular integration of the activities with technology, we were able to provide an environment where children effectively achieved learning outcomes.

The fact that this was the first time that this intervention was implemented implied certain limitations on what could be accomplished. The needs of both the schools and the teachers had to be established as implementation proceeded, and elements that should have been included from the very beginning had to be integrated mid-process. Furthermore, it was especially difficult to gauge the time requirements a priori due to unforeseen difficulties that arose along the way, such as the educators' limited familiarity with the technology and weaknesses in certain pedagogical skills such as lesson planning.

Our goal was to study the effects of collaboration using a computer supported co-located single display in children's learning as compared to no use at all. Therefore, we worked with one group of children and their teachers to develop collaboration using computer supported co-located single display activities and we did not intervene in our comparison group. This decision was made on the basis of previous research that has shown the difficulties involved in working collaboratively with children in their early ages without mediation. First graders working collaboratively with no technological support have been observed to have the following problems (Zurita and Nussbaum 2004): coordination weakness, some members take control of the activities while others are left aside; communication shortcomings that considerably reduce social interaction between group members; negotiation problems, where peers impose their point of view and inhibit the activity's progress; and interactivity weaknesses, where peers do not respond to partners' requests due to social differences, lack of motivation and attention, or children lose track of the activity.

As a consequence, we did not conduct non-technological collaborative activities in any of the participating groups. This also implied not providing training to the teachers in the control group. It could be argued that the increase in achievement by the children in the experimental group, when compared to that of the control group, is explained by the fact that only the teachers in the experimental group were trained. However, all classrooms in the participating schools are expected to develop the same social skills that were considered in the intervention, and are part of Chile's official curriculum for pre-school children. In further research, it will be necessary to better isolate the training and software variables. Finally, the measurement conditions explained in Section Measurements were as coherent as possible, considering the real circumstances under which the experiment took place, which we believe were consistent enough to provide evaluation conditions that ensured validity in terms of the tests' internal consistency and observation procedures. In retrospect, future studies should attempt to maintain the same observers with the same children throughout the whole experience.

Conclusion

The purpose of the study was to determine if a particular configuration of technology for collaboration among young children was effective or not in achieving learning goals for oral language, logical-mathematical, and social skills. Consequently, we designed an intervention that used co-located single display collaborative activities that were conducted with kindergarten students on a weekly basis for 4 months. These activities included the teachers from the experimental classrooms as guides for the small groups of children during the learning process. The evaluation of the intervention used a quasi-experimental design with a control group and pre- and post-tests. The results of the evaluation gave a positive answer to our research question, "Can small-group co-located collaborative learning on a single display computer improve oral language, logical-mathematical, and social skills learning for preschool children?" Of particular interest was the positive effect that this learning had on the development of social skills, a factor that has consistently proven difficult to improve or even measure for early childhood. The analysis reveals that for the oral language test there was no significant difference between groups, but there was a significant difference favoring the experimental group for the logical-mathematical and social skills tests.

The implementation of the intervention highlighted the importance of offering settings where students in early childhood can share activities and develop collaboration while learning basic skills. It is also important to carefully provide teacher support for these activities in order to facilitate the collaborative interactions among children, and strengthen the role of the teacher. To this end, tools such as co-located single display collaborative learning have been shown to serve this purpose when used adequately by teachers, that is integrating them into their regular work and mediating accordingly with the children; thus achieving collaboration and learning.

For collaborative technology and enhanced learning environments to become common practice in schools, additional support is required. Schools need to be oriented towards the integration of computer-mediated collaborative activities in the general lesson plans, in conjunction with the curricular goals that children are expected to achieve in kindergarten. Also, teachers need additional support in order to use the corresponding authoring system to develop content, and to conduct activities with preschool children in the computer lab. Moreover, it is necessary that school management recognize the relevance of scheduling time for preschoolers to use the computer lab, which was a barrier for the schools participating in this study.

One limitation we faced came from the decision to only intervene in the experimental group, which meant that only teachers from the experimental group were trained. This feature was closely tied to the intervention, as we believe that training is a central aspect of working with technology in schools (Earle 2002) and follow the idea that technology itself will not suffice to create an environment that can support collaborative learning; thus this environment must be carefully structured and maintained by teacher mediation (Nussbaum et al. 2011). Since there was no intervention in the control group classrooms, we did not provide any training. We acknowledge potential threats that this decision could have on the validity of our results; therefore, we envision future studies where the training variable can be better controlled.

Future research should also focus on the observation of the interactions that emerge between preschool children participating in co-located small group collaborative learning and compare it with other dynamics in which collaborative learning is not necessarily the objective. Also of interest is to study to which extent this early childhood collaborative development influences the early years in schools.

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Appendix 1

Example 1:

Sample items of Oral Language and Logical-Mathematical Relationships and Quantification Test.

Item information (curricular area, specific content, and descriptor) was taken from the national curriculum for kindergarten (MINEDUC, 2005). Item images are presented in students' first language—Spanish.

Curricular area: Communication

Specific content: Oral Language

Descriptor: Children recognize words that correspond to their immediate surroundings.

Directions:

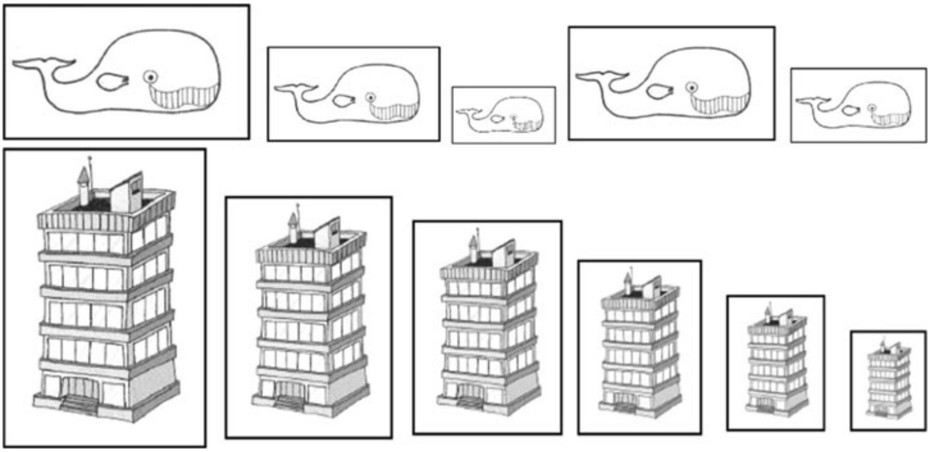
Paint the element that corresponds to the word.

Example 2:

Curricular area: Relations with natural and cultural environment

Specific content: Logical mathematical relationships and quantification

Descriptor: Sort at least six elements according to different criteria.
Directions:
Circle the series that is sorted in descending order.



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