Dynamic Grouping in Collaborative Learning Supported by Wireless Handhelds

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ABSTRACT

One of the most important decisions to be made in a face-to-face collaborative learning activity is how the participating groups are composed. These compositions produce different learning and social interaction results. The ability to change the group member composition in real time and dynamically enables the leveling up of learning results and improvements in the participants' social relationships. Changes in composition also facilitate the analysis of the best criteria to be used in a determined activity. We propose a face-to-face collaborative environment supported by wireless handhelds that allows for dynamic changes in the composition of groups while an activity is underway. Three different group composition changes were carried out in one environment and the outcomes were compared with another, similar environment where no such group composition changes were performed. The results obtained showed significant improvements, both qualitative and quantitative, in the environment where dynamic grouping was used. Moreover, the criteria for group composition that produce different social interaction outcomes were identified.

Keywords

Computer supported collaborative learning, Handhelds, Composition of collaborative groups, Collaborative learning with children, Dynamic grouping

1. Collaborative learning

Collaboration may be described as the mutual commitment of members of a small group to coordinate their efforts in order to solve a problem (Roschelle & Teasley, 1991). It has been demonstrated that a collaborative learning (CL) environment confers benefits in the achievement of learning objectives (Johnson & Johnson, 1999; Slavin, 1987), social results (group communication, problem-solving, and consensus), and positive interdependence and motivation (Chambers & Abrami, 1991; Newcomb & Turner, 1965). Furthermore, in such an environment students can acquire new skills, ideas and knowledge by working together to build solutions to educative problems (Webb, 1995; Webb & Farivar, 1999; Webb & Palincsar, 1996). Small-group CL activities are an integral part of classroom instruction in elementary schools (Macintyre & Ireson, 2002). These activities are varied in nature and are employed particularly in mathematics and language tasks aimed at attaining specific

limited or simple objectives that require social interaction of all the participants in a group to arrive at jointly agreed responses.

CL supported by computer technology, referred to as Computer Supported Collaborative Learning (CSCL), provides the members of a collaborative group with different environments and mediation elements for social interaction and learning support (Silverman, 1995). When CSCL is used with group members present in the same space (MCSCL), wirelessly interconnected handhelds enable mobility and face-to-face interaction (Danesh, Inkpen, Lau, Shu & Booth, 2001; Mandryk, Inkpen, Bilezikjian, Klemmer & Landay, 2001). One particular study of CSCL, published by Zurita, Nussbaum and Sharples (2003), will be used throughout this paper. Using a small group MCSCL activity for teaching first graders how to order numbers from 1 to 99, they showed that it is possible to build a technological framework that changes classroom practices by (a) organizing the necessary materials (boards, pieces, etc.); (b) providing a negotiation space; (c) stimulating coordination; (d) providing communication channels that promote and mediate group members' social interaction; (e) achieving higher and significant levels of learning; and (f) enabling mobility of group members.

Although the benefits of learning in small groups are apparent, how to group the students is not. Typically, students may self-select or be randomly assigned to groups (Lou, Abrami, Spence, Poulsen, Chambers & d'Apollonia, 1996), criterion used in Zurita, Nussbaum & Sharples (2003). Little research has so far been done on group composition (grouping), although it has been shown that different groupings produce different results in learning and social skills (Dalton, Hannafin & Hooper, 1989; Beane & Lemke, 1971; Hooper & Hannafin, 1988; Webb 1982; Leonard, 2001; Webb, Baxter & Thompson, 1997; Blatchford, Baines, Kutnick, & Martin, 2001) and may reduce heterogeneity in CL activities (Slavin, 1987; Cohen, 1994).

Whether and to what extent greater possibilities for improving equity, homogenous global learning and social behavior results of small groups in a classroom can be achieved by focusing on their composition is therefore an issue that merits further study. In this article we analyze: (a) how real time grouping, in a two-week MCSCL math activity involving first graders, improves learning and social behavior when compared with the same activity without grouping, and b) which group compositions produce better social interaction results. Our analysis is based on a previously evaluated collaborative learning math activity for six- and seven-year-old children (Zurita, Nussbaum & Sharples, 2003) that allows reconfiguration of groups under different composition criteria.

2. Grouping in Collaborative Learning

The criteria for in-classroom grouping has been an issue. Various authors (Dalton, et al., 1989; Beane & Lemke, 1971; Hooper & Hannafin, 1988; Webb, 1982) have shown that different grouping criteria for small groups affect the learning performance and social behavior of the activity members. According to Dalton et al. (1989), there is a need for further research on the relationship between the composition of a group and its functioning and performance, depending on the type of activity and the group's characteristics, knowledge, and skills. Web, Baxter & Thompson (1997) have raised the matter of equity in learning and social behavior in heterogeneous groups and the opportunity to learn from others, pointing out that all children should participate and learn irrespective of race, gender, preferences, or achievement level.

According to Macintyre & Ireson (2002), grouping has generally been determined by student achievement, with students placed in heterogeneous (mixed ability) or homogeneous (same ability) groups with a view to reducing the heterogeneity of learning and social behavior in the classroom (Gregory, 1984). Teachers generally decide on the groupings to be used based on research findings regarding the most successful grouping strategies. This has been a major issue in the debate about how to raise grouping standards in education (Budge, 1998a, 1998b; Evans, 1998).

There is substantial evidence that CL may promote equity in learning and acquisition of social skills. Slavin (1987) found that assigning students of different ethnic backgrounds to work together was consistently related to positive racial attitudes and behaviors, and also reduced the academic achievement gap between minority and majority students. The CSOS Report of 1983 confirms that collaborative education enhances educational equity.

Nevertheless, little is known about how group composition actually influences the performance and processes of CL groups (Leonard, 2001; Webb, Baxter & Thompson, 1997). Some combinations of students may have advantages over others in terms of students' learning. Most empirical research on group composition has focused on the mixture of achievement levels, and it is widely believed that heterogeneous groups benefit lower-

achieving students by giving them access to the intellectual resources of higher-achievers. According to Webb et al. (1997), studies show that low-achieving students learn more in heterogeneous than in homogeneous groups. While the use of heterogeneous groups for low-achievers is generally not controversial, Webb et al. (1997) and Johnson & Johnson (1999) indicate that high-achieving students show equally strong learning outcomes in heterogeneous and homogeneous groups.

Existing research on the effects of group composition on social and learning performance yields complex results. Most of this work was carried out over long periods of time and does not allow for simple predictions (Leonard, 2001; Macintyre & Ireson, 2002). However, Webb, Baxter & Thompson (1997) found that group composition introduces a possible source of inequity in that its impact on learning will vary even among students of similar performance levels. It is therefore necessary to be flexible when assigning members to groups and to monitor their evolution. In a study by Mulryan (1995), the students' social interactions and learning results improved when changes were made in group composition.

Face-to-face CSCL environments generally use Personal Computers (PC). This means that members must sit in a fixed position with no possibility of movement and restricted social interactions (Inkpen, Ho-Ching, Kuderle, Scott & Shoemaker, 1999).

Various studies (Danesh, Inkpen, Lau, Shu & Booth 2001, Inkpen 1991; Mandryk, Inkpen, Bilezikjian, Klemmer & Landay, 2001) show the potential for bringing mobility, and portability to face-to-face CSCL environments when students are wirelessly interconnected by handheld devices (MCSCL). This technology permits the creation of natural collaborative environments (Inkpen, 1991; Mandryk et al., 2001, Imielinsky & Bradinath, 1994; Zurita & Nussbaum, 2004). In MCSCL environments using handhelds, group members can move freely, allowing flexibility in social interactions and the formation of groups.

3. Dynamic Grouping supported by handhelds

We define dynamic grouping (DG) as the recomposition of group members during a collaborative activity for reaching a given educational objective. Dynamic grouping allows the composition of groups to be adapted to the social and learning needs of the students taking part in a collaborative activity.

Table 1. Criteria used in this study

Grouping criteria	**Description**	**Objective**
Random	Students are grouped according to the course attendance list (Race, 2000). This criterion is used at the start of the activities as a base criterion for the experimental group, and the sole criterion for the control group.	To achieve social and academic heterogeneity.
Preference	Students are grouped according to affinity with their classmates	That students work comfortable by reducing the students' choice heterogeneity.
Achievement	Students are grouped according to their academic performance. The two best (worst) students are grouped with the worst (best) one.	Academic heterogeneity to foster learning within the group.
Sociability	Students are grouped according to an affinity scale defined by the teacher.	Reducing social heterogeneity aims to encourage poorly evaluated students' social skills.

Table 1 shows the different criteria used in the recomposition of groups, as adapted from Johnson & Johnson (1999) and Race (2000). Other criteria such as gender and ethnic/cultural background can be used, but for purposes of comparing the experimental group with dynamic grouping to a control group without it, we opted to employ the criteria cited in the studies listed in the bibliography. The random criterion assumes by its very nature a combination of groups with a heterogeneous distribution. The preference, achievement, and sociability criteria depart from the principle of heterogeneity by grouping students whose levels on these criteria are homogeneous or similar. More than one grouping criterion is used because, as pointed out by Macintyre & Ireson (2002), the use of just one may limit students' learning potential, particularly given the self-concept of students with low skill levels.

The MCSCL activity we will use in this study involves the ordering of numbers (Zurita, Nussbaum & Sharples, 2003). Its objective is that first graders learn to order three numbers between 1 and 99 while working collaboratively in groups of three with dynamic grouping. A group is blocked once it has successfully ordered sequence "i", and must wait for all the other groups to complete the task before starting to order sequence "i+1". This allows the teacher to redefine the group composition on his or her machine depending on the children's social and academic performance. The blocking mechanism can be regulated for one or more tasks in accordance with the teachers needs.

3.1. Description of the Ordering Activity and the students' role

Each group member is assigned a number that appears on a cloud-shaped button located on the screen of their handheld. In the example illustrated in Figure 1, the numbers 54, 78 and 15 have been assigned to Miguel (Figure 1a), Gustavo (Figure 1b) and Rodrigo (Figure 1c), respectively. Each of them must read their number aloud to the other members.

The group's task is to order the three numbers. The ascending ladder (Figure 1) indicates that the numbers must be organized in ascending order; a descending ladder would mean that a reverse ordering was required. The group members engage in discussion with each other to determine the correct order of the numbers in the sequence. Each member presses the cloud button when its turn corresponds, making their number appear on the ladder displayed on the screens of all group members. In the example shown, Rodrigo selects his number first, making it appear on the first step of the ascending ladder on each group member's screen (Figure 1d, e, f). Then Miguel and later Gustavo select their numbers to complete the sequence (Figure 1g, h, i). Once the sequence is ordered, the group members must agree that the order is correct before proceeding to the following sequence. They do this by selecting one of the two buttons that appear at the bottom of the screen (Figure 1g). If the participants do not all select the same button – for example, if Gustavo agrees (as shown in Figure 1h) while Rodrigo does not ("X" in Figure 1i) – they will all be reminded by a text and voice message that they must come to an agreement (Figure 1j, k, l).

Figure 1. Screenshots of the Student-MCSCL application interfaces for three members. The screenshots 1a-1c, 1d-1f, 1j-1l, 1m-1o, 1p-1r are simultaneous views of the members at three different stages. Each participant has a number. The messages request decisions or display information

Once the group members have agreed on an answer (Figures 1m,1n and 1o) and the answer turns out to be correct, the group is awarded one point, supported by a congratulations message and a clapping sound produced by the handheld. Figures 1m, 1n, and 1o show that the group has two points because they have correctly ordered two sequences. A text and voice message will then ask the children if they want to continue with the activity. If they all answer "YES" ("SI"), another series of numbers to be ordered will be displayed on their screens. If they all answer "NO" ("NO"), the activity ends. If the students do not agree on an answer, the screen shown in Figure 1j will appear on each of their handhelds.

When the group members agree on a wrong answer the score of the group remains unchanged (Figure 1p, q, r). A voice and text message is sent to all of them asking if they would like to try again, with "YES" ("SI") and "NO" ("NO") buttons appearing at the bottom of their screens. (Figure 1g). If they all answer "YES" ("SI"), their screens go back to the states shown in Figures 1a, 1b, and 1c. If they all answer "no", a new series of numbers will be displayed.

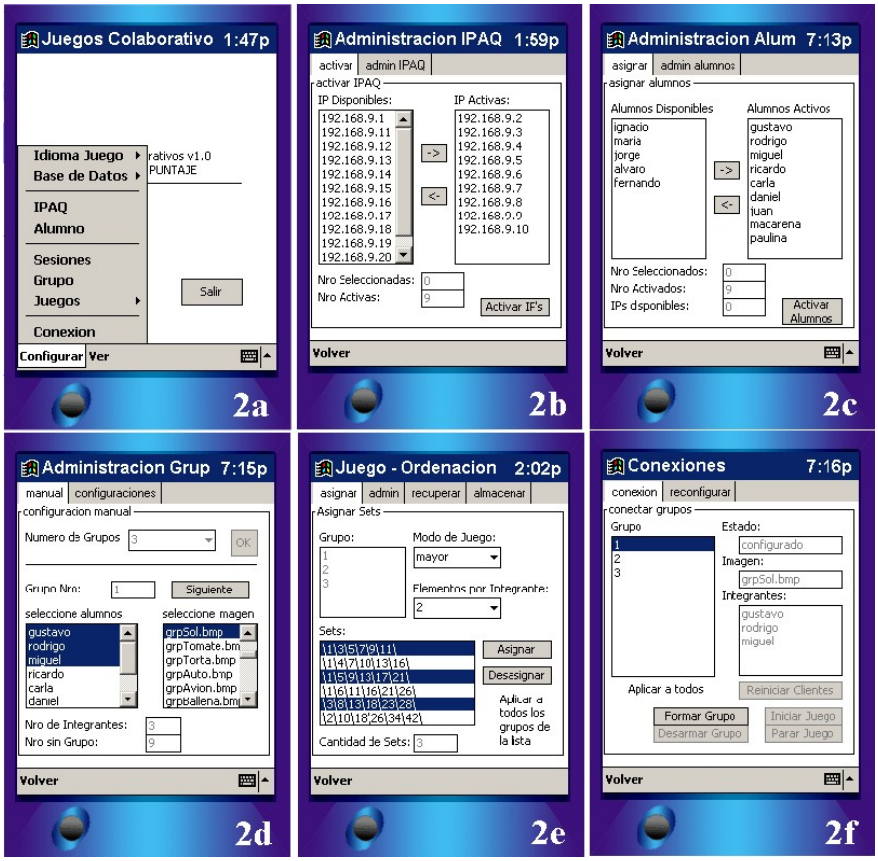

Figure 2. Interface of the Teacher-MCSCL application. The screens shows the different configurations required for starting a Student-MCSCL activity

3.2. Description of the Teacher's Role

The role of the teacher is to configure and manage the ordering activity and carry out dynamic grouping. Figure 2 shows the main interface of the teacher's application. The design of the interface incorporates menus (Figure 2a) and frames as recommended by (Grattan, 2001) to ensure that information can be displayed in an orderly fashion within the space restrictions imposed by the small size of the handhelds.

On the teacher's screen, each participant's machine is indicated by an IP address. In Figure 2b, nine student IPs have been selected to form three groups of three members each (right hand side of the screen). Figure 2c shows the nine selected students (right side of the screen) and the five students not included in the activity (left hand side of the screen). To organize the participating students into groups, the names of three students for each group plus a group identifying icon are chosen. In Figure 2d, Rodrigo, Carla and Macarena have been selected to form Group 1, with the image "grpSol.bmp" (a sun) as its icon.

The sequences of numbers and level of difficulty are then configured. In Figure 2e, three sequences (bottom left of screen) for assignment to the three groups have been selected (checkbox "Assign – Apply to all groups on the list"/"Asignar – Aplicar a todos los grupos de la lista"). A descending order is specified, with two elements per member for each sequence (combo-box "game mode"/"modo juego" and "elements per member/elementos por integrante"). Once the configuration of the groups and the activity is completed, the teacher's machine sends the activity information to the group members and the group task begins.

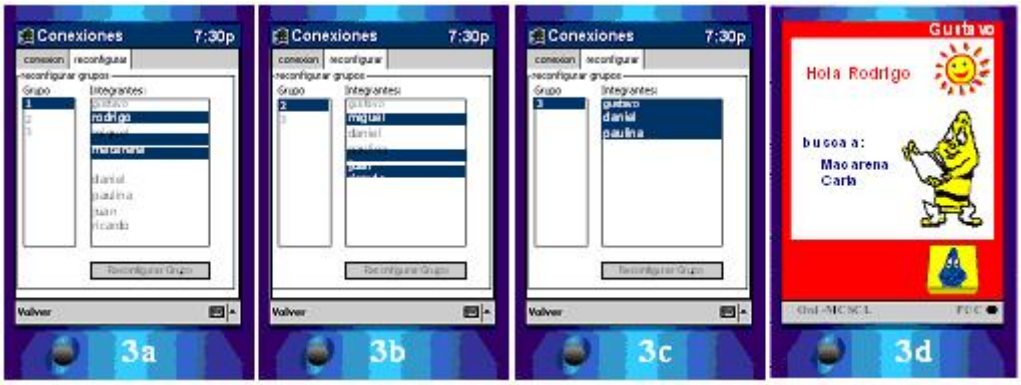

Figure 3. Interfaces to perform a DG with the teacher-MCSCL application (3a, 3b, 3c). One member of the group's interface (Rodrigo) in the Student-MCSCL activity is shown in 3d after all the collaborative groups have been formed through a new DG

To carry out a dynamic grouping operation, the teacher first stops an activity and dismantles all or a subset of the groups ("stop game/parar juego" and "dismantle group/desarmar grupo" buttons, Figure 2f). The groups are then reconfigured in accordance with the chosen grouping criterion. In Figure 3a, the first group is reconfigured to include Rodrigo, Macarena, and Carla. In Figure 3b there are six students remaining, from which Miguel, Ricardo and Juan are chosen to be placed in the second group. Finally, in Figure 3c the last three students – Gustavo, Daniel and Paulina – are assigned to the third group. The new groups are now ready to be created. The students' screens ask each of them to search for their two new partners and indicate their names (Figure 3d). Once each member finds the other two members, he or she presses the lower right button (showing a face) and the activity begins.

4. Design and Implementation of the Collaborative Applications

The system just described in Section 3 was developed for the Pocket-PC 2002 platform, using Microsoft embedded Visual Basic, Microsoft CE WinSocket 3.0 and SQL Server CE 2.0 for permanent storage of the configurations and results. The handhelds were Compaq iPAQ H3700 Pocket PCs with touch screens, a resolution of 240x320 pixels and Wi-Fi operating in peer-to-peer mode.

4.1. Communication among Handhelds

Communication among the handhelds is implemented at two levels in a Client-Server model. Figure 4 shows an example of the communication between the teacher and two collaborative groups as well as the intra-group communication. Each group has a server, called a Group Server, assigned by the teacher's machine. In this example Clients 3 and 1 have been appointed as Group Servers for Collaborative Groups 1 and 2, respectively. These servers create the necessary sockets for all clients in their group and establish communication among them.

Communication both within the group and with the teacher is managed by the appointed Group Server. In Figure 4, intra-group communication occurs when a student – for example, User 3 (that is, group client 3, MCSL 2) – selects his or her number from the sequence to be organized as explained in Section 3.1 (Figure 1f). This generates a message for the Group Server, which processes the data and sends it to all the clients in the group so that it is displayed on their screens (Figure 1d, 1e, and 1f; see Section 3.1). Communication with the teacher takes place when the game is started ("Start Game/Iniciar Juego" button, Figure 2f; see Section 3.2). A message

with the information is sent to the Group Server, which sends it to the other clients in the group, thus enabling the activity to begin.

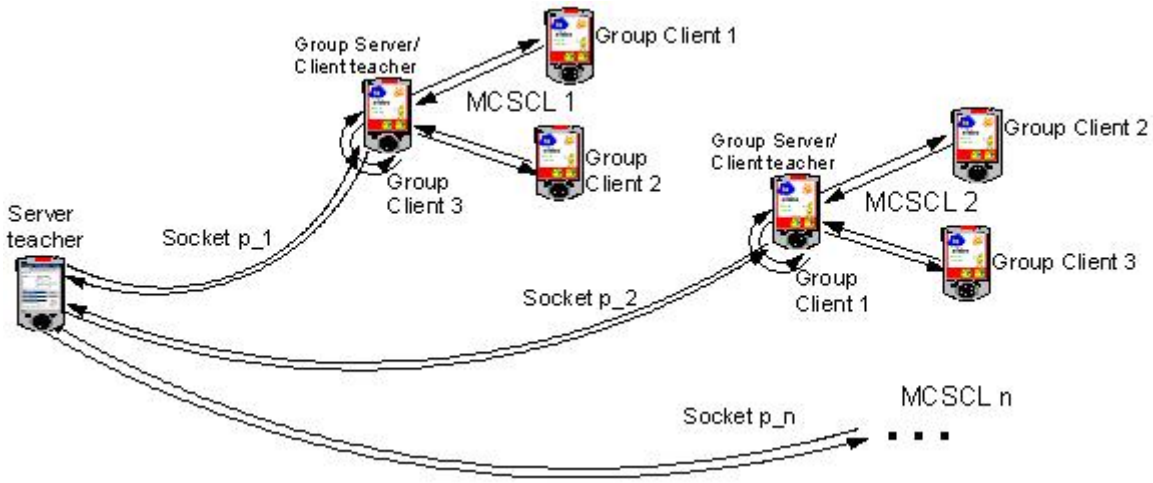

Figure 4. Diagram of the Client-Server Model used in this study showing teacher-group and intra-group communication during an MCSCL activity

4.2. Application Design

The student and teacher applications were designed and implemented as two independent tasks, each composed of layers. The layers making up the student application (Figure 5, right hand side) are built on the TCP/IP layer, which is responsible for sending and receiving the messages generated or sent by the layer above it. The first layer displays the interfaces for the different stages of the student activity; the second layer processes the data sent by the Group Server to be displayed by the Interface; and the last layer processes the configuration of the student and the items related to the group.

In similar fashion to the student application, the teacher's application (Figure 5, left hand side) is built on the TCP/IP layer. The server layer above TCP/IP serves as the sender/receiver of the messages generated/sent by the Group Servers. The database layer stores and recovers the information requested by the layer above it, which is composed of IP machines (IP), participants (ALUM), the selected activity (ACT), and the statistics (EST) involved in the collaborative activity that is received from each Group Server. The information is shown and entered through the interface with which the user interacts.

Our implementation of this model allows the teacher application to provide services for up to fifty handhelds simultaneously, organized in groups of one to five members.

Figure 5. Layer structure of the Teacher-MCSCL (left) and Student-MCSCL (right) applications

4.3. Network Services

The level of communication between the teacher and the collaborative group depends on basic services implemented in the teacher application. This application facilitates the development of the collaborative activity and the eventual reconfiguration of groups. The basic services it provides are:

- Group formation: The Teacher application sends a message through the network with the data specifying which machine will act as the Group Server and which ones will be clients. Once the group has been

formed, this Group Server sends a confirmation message to the teacher's machine, thus allowing the activity to start.

- Starting an activity: Once the group is formed, the Server Teacher application starts the activity on the clients' machines (student client application). This is done by sending the configuration of the game to the Group Server, which is client of the Server Teacher (Client Teacher). The Group Server then sends the received information from the Server Teacher to the machines of the other group members, configuring and displaying the interface of the selected activity. Through this interface the students begin playing and interacting with each other.
- Ending an activity: This service allows the current activity of a group to be ended at any time. This is done by sending a message to the Group Server, which then sends a stop message to all of its clients. The clients terminate the activity, and the Group Server then closes the open sockets and deletes the group information.
- Group disconnection: Enables groups to be disconnected. The teacher application sends a message to the Group Server, which then sends a message to all clients' handhelds to close their sockets and delete the group information from their memories. The Group Server in turn does the same, thus completing its task and returning to its status as a Client waiting to be connected to a new Group Server assigned by the teacher application as part of a new group.
- Recuperation after failure: If a network or connection problem occurs between client machines or between a Group Server and the teacher, the teacher application detects the failure and returns the group to the status of one that has just been configured, deleting the communication socket with the Group Server in order to set it up again and restart the activity.

The order in which these net services are provided is as follows:

1. The current activity for the selected groups is stopped ("stop game/Parar Juego" button, Figure 2f).
2. The selected groups are disconnected ("dismantle group/Desarmar Grupo" button, Figure 2f).
3. Once the selected groups are disconnected, they are reconfigured by selecting new members (Figures 3a, 3b, 3c).
4. New groups are formed ("form group/Formar Grupo" button, Figure 2f).
5. The activity is restarted ("start game/Iniciar Juego" button, Figure 2f).

Figure 6. A DG during a session of the experiment. The DG begins in 6a, continues in 6b and 6c, and ends in 6d

5. Experimental Design

The experimental design is based on a pre-test/post-test with a control group. In the experimental group, dynamic grouping was applied to five three-member collaborative groups using the criteria shown in Table 1.

The initial composition used the random grouping criterion. The control group, also consisting of five three-member collaborative groups, was composed of randomly selected members.

The learning process was measured using the same individual written exam at the beginning and the end (pre-test and post-test) of both the control and the experimental group activities. Statistical analysis of covariance was carried out on the pre-test results of the experimental and control groups to establish any significant learning difference between them. The exam consisted of 10 questions requiring that five sets of numbers from 1 to 99 be arranged in ascending or descending order.

Both groups were chosen from first grade classes (six- and seven-year-olds) at a public elementary school attended by children of a low socio-economic level in Santiago, Chile. The size of the sample was 15 students for each group (8 boys and 7 girls). All of the students had the same knowledge of number ordering and had been attending school for 8 months when the study began. The experiment was carried out over fifteen days. In each session, which lasted 35 minutes for both groups, the children were required to order fourteen sequences of three numbers each.

During the first three days, the experimental group was formed using the random grouping criterion to ensure the attainment of a certain initial maturity in the conduct of the collaborative activity and the use of the handhelds. Over the following 12 days, the three other dynamic grouping criteria in Table 1 (achievement, preference and sociability) were employed for four days each. The activity always began with random composition of groups, and then the group was reconfigured using the criteria chosen for that day. This was done to achieve a common point of comparison for analyzing the socio-motivational effects of applying dynamic grouping. Figure 6 is a sequence of photos showing children reconfiguring groups. This is easily accomplished thanks to the mobility made possible by the portability of the handhelds and the wireless nature of the network.

Table 2. Socio-motivational aspects

Aspect	Definition
Communication	Verbal information exchange among students.
Interaction	Not defined by the frequency of interactions, but rather by the extent to which they influence cognitive processes. Refers to the various situations created by the students for achieving their objective.
Conflicts	Occurrence of divergent points of view among the group members.
Negotiation	Negotiation of differences through communication and interactions aimed at reaching a consensus.
Positive Interdependence	Participants must feel responsible for their own learning as well as that of their classmates.
Help	Degree of mutual support among the members of a group.
Coordinated Group Work	Combining of efforts of some participants in order to reach common goals.
Acceptance and Tolerance	Degree to which the students tolerate and accept each other.
Interest	Degree of interest shown by the students.

The socio-motivational aspects most commonly used to evaluate CL activities are: Communication, Interaction, Conflicts, Negotiation, Positive Interdependence, Help, Coordinated Group Work, Acceptance and Tolerance, and Interest, as defined in Table 2 (Johnson & Johnson, 1999; Silverman, 1995). During the 7th, 11th and 15th sessions, the socio-motivational aspects of the experimental group were evaluated by three CL experts who observed the classroom activities using predefined guidelines based on the aspects listed in Table 2. The different levels of qualitative observations were ranked for each group on a scale of 1 to 7 according to the degree of accomplishment for each aspect (1 = none, 2 = very low, 3 = low, 4 = acceptable, 5 = high; 6 = very high; 7 = maximum). All experimental and control groups were videotaped. Triangulation techniques were used to corroborate the experts' evaluations.

6. Analysis of Results

The learning results of the individual pre-tests and post-tests administered to both experimental and control group are shown in Table 3.

Table 3. Mean and standard deviation of the pre- and post-tests administered to all the students in the experimental and control groups

	Control group		**Experimental group**	
	Pre-test	Post-test	Pre-test	Post-test
Mean	2.400	4.933	2.700	6.300
Standard deviation	1.961	1.651	1.538	1.078

A test of covariance was performed to measure the learning outcome. The pre-tests of the experimental and control groups were used as the covariance for the control of the initial level of learning. As can be seen in Table 4, the experimental intervention had a significant effect on the post-test results. The comparison shows that there was a significant difference of 95% between the means of both groups. The standard deviation for the experimental group (1.078) is lower than that of the control group (1.651), meaning that the results for the experimental group show less dispersion, and therefore a reduction in learning heterogeneity in the classroom.

Table 4. Analysis of covariance between the control and experimental groups

Square summing type III	**df**	**Quadratic average**	**F**	**Significance**
42.744	2	21.372	22.433	,000
159.446	1	159.446	167.363	,000
28.736	1	28.736	30.163	,000
10.614	1	10.614	11.142	,002
25.723	27	0.953		
1014.875	30			
68.467	29			
R quadratic = .624 (R adjusted quadratic = .596)				

As for the socio-motivational aspects, we obtained 20 measurements on each one for the groups formed under the random grouping criterion applied after the initial 15 minutes (five groups for four sessions: 4^{th}, 7^{th}, 11^{th}, and 15^{th} sessions). Another 20 measurements on the same aspects were obtained for the second part of the activity, using the three different reconfiguration criteria (4^{th} session using random, 7^{th} session using achievement, 11^{th} session using preference, 15^{th} session using sociability). These measurements were then processed with the SPSS statistic package in order to obtain the average and standard deviation for each aspect, and the results were compared using the random criterion as a base. The *Independent Samples T-Test* was performed to analyze the differences displayed by the variables as between the random criterion and the reconfiguration criteria at a significance level of 95% ($p<0.05$).

These results are shown in Table 5. The averages, standard deviations, and significance level data are given for each criterion. From these results we can conclude the following:

When the Reconfiguration criterion was **Achievement**, significant improvements were observed in Positive Interdependence, Negotiation and Conflicts. The students worked coordinately and solved their conflicts satisfactorily in the few social interactions they had. In groups with homogenous achievement it is interesting to observe that there is no much difference with the Random criteria in the degree of interest shown by the students and their verbal information exchange (Communication), which is consistent with the above.

With **Preference** as the reconfiguration criterion, the Communication, Interaction, Coordinated Group Work, Conflicts, Acceptance and Tolerance, and Help aspects exhibited significant differences. This shows that when kids select their group members there is a significant difference with the Random criterion in most of the aspects but in Negotiation (positive interdependence has $p=0.08$, close to significance).

Finally, using the **Sociability** criterion, significant differences were observed in Positive Interdependence, Interest, Interaction and Coordinated Group Work. When comparing a group formed by the students affinity (Preference) with a group according to the teachers' criteria (Sociability), Positive Interdependence and Interest only appears when the teacher selects, while Communication, Conflicts, Acceptance and Tolerance, and Help when the students select; Interaction and Coordinated Group Work shows in both. These findings are consistent, since the teacher seeks to form groups that share a common interest and have a similar sociability pattern, while the children just look for their friends. It is also interesting to observe that as with the Preference criterion, Negotiation has no significant difference with the Random criterion, and was an aspect that only in homogenous achievement groups (Achievement) was observed.

In summary, we conclude that when the children select their group mates (Preference criterion) more social behavior aspects with significant improvement can be observed, i.e., six compared with four of sociability and three of achievement.

It is important to note that these results were obtained for a given social and educational context and the conclusions we reach can vary in a different reality. Dynamic grouping allows a teacher to study group collaboration under a specific social and educational condition to determine which group configuration best satisfies the given setting.

Table 5. Socio-motivational results for the three types of dynamic grouping analyzed (achievement, preference, sociability), compared with the base criteria (random). M = Mean, SD = standard deviation, F = factor, Sig = significance (7^{th} with achievement, 11^{th} with preference, 15^{th} with sociability)

		Communication				**Positive interdependence**				**Interest**			
Day		Random	Achiev.	F	Sig	Random	Achiev.	F	Sig	Random	Achiev.	F	Sig
7^{th}	M	5.00	5.70	0.221	0.641	4.40	4.70	6.796	0.013	5.10	5.70	0.031	0.860
	SD	1.30	0.98			1.60	0.98			1.37	0.98		
		Random	Prefer.			Random	Prefer.			Random	Prefer.		
11^{th}	M	5.27	6.60	8.643	0.007	4.07	6.07	3.310	0.080	5.13	6.20	0.257	0.616
	SD	1.67	0.83			1.98	1.28			1.77	1.26		
		Random	Sociab.			Random	Sociab.			Random	Sociab.		
15^{th}	M	5.40	6.20	2.240	0.146	3.93	5.13	5.102	0.032	4.33	5.80	9.684	0.004
	SD	1.55	1.01			1.83	1.19			2.09	1.01		
		Interaction				**Coordinated Group Work**				**Negotiation**			
Day		Random	Achiev.	F	Sig	Randon	Achiev.	F	Sig	Random	Achiev.	F	Sig
7^{th}	M	4.50	5.70	0.835	0.367	4.60	4.20	0.112	0.740	3.20	2.90	5.993	0.019
	SD	1.43	0.98			1.54	1.20			1.82	1.37		
		Random	Prefer.			Random	Prefer.			Random	Prefer.		
11^{th}	M	4.60	6.47	4.180	0.050	4.20	6.20	4.416	0.045	3.13	3.40	0.315	0.579
	SD	2.03	1.19			1.82	1.01			1.60	1.35		
		Random	Sociab.			Random	Sociab.			Random	Sociab.		
15^{th}	M	4.20	5.27	7.155	0.012	4.47	5.53	5.500	0.026	3.00	2.47	0.263	0.612
	SD	2.11	1.28			2.07	1.41			1.69	1.41		
		Conflicts				**Acceptance and Tolerance**				**Help**			
Day		Random	Achiev.	F	Sig	Randon	Achiev.	F	Sig	Random	Achiev.	F	Sig
7^{th}	M	2.00	1.40	10.688	0.002	5.10	5.50	0.002	0.965	4.10	3.10	1.222	0.276
	SD	1.03	0.82			1.21	0.89			1.02	1.21		
		Random	Prefer.			Random	Prefer.			Random	Prefer.		
11^{th}	M	2.47	1.27	6.120	0.020	5.67	7.00	112.00	0.000	4.07	3.67	4.497	0.043
	SD	1.19	0.70			0.98	0.00			1.67	0.98		
		Random	Sociab.			Random	Sociab.			Random	Sociab.		
15^{th}	M	2.07	1.53	3.646	0.067	5.53	6.07	0.928	0.344	4.07	5.40	0.004	0.949
	SD	1.03	0.92			1.41	1.03			1.49	1.55		

7. Conclusions

Studying grouping, for a given activity in first graders, yielded significant results when comparing three types of reconfiguration criteria with random assignment as regards their impact on learning and several aspects of social behavior. These results permits to understand which group composition should be favored in a given set of circumstances. The system and methodology presented in this work, not restricted to the presented contents, can therefore be used as a tool to discover which group composition should be preferred for a given collaborative activity.

Activities should be kept short and a series of them should occupy no more than half of a class period in order to assure continuity after reconfiguration of new group members. Also, the handhelds generates on line reports of the various groups' outcomes, which constitutes valuable information for the teacher when assigning a new group configuration. All of the preceding is relevant given that the grouping of students in a collaborative activity involves many variables (skills, social factors, ethnic background, type of activity, educational objectives, etc.) which are difficult to isolate in such a way that precise grouping rules can be made.

The value of our work is that by using wirelessly interconnected handhelds, the impact of different group reconfigurations on collaborative activities can be studied and their learning outcomes and various social aspects of their behavior during the activities can be analyzed. The application of the work lies in the simple and fast way dynamic grouping can be applied with wirelessly interconnected handheld support, reconfiguring participants in groups of different size chosen from a given set of students.

Future research, with the support of this technology, could be directed towards the effects of applying a sequence of group reconfigurations within the same class of students using different criteria for the sequence, group size differences, etc.

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