Learning to collaborate by collaborating: a face-to-face collaborative activity for measuring and learning basics about teamwork

C. Cortez,* M. Nussbaum,† G. Woywood‡ & R. Aravena§

*Center for Innovation on Education, Universidad Tecnológica de Chile INACAP, Santiago, Chile
†Department of Computer Science, Faculty of Engineering, Pontificia Universidad Católica de Chile, Santiago, Chile
‡SelCap S.A., Santiago, Chile
§Department of Statistics, Faculty of Mathematics, Pontificia Universidad Católica de Chile, Santiago, Chile

Abstract

In today’s fast-changing business environment, teams have emerged as a requirement for business success. However, in schools and universities, students are usually not taught teamwork skills. In this paper, we introduce learning to collaborate by collaborating, a process that enables collaboration and teamwork skills to be taught and measured through face-to-face collaborative work and class-wide activities supported by wirelessly connected hand-held devices. Following a description of learning to collaborate by collaborating, we present an experimental study whose results demonstrate that participants in the process displayed improved teamwork performance. We conclude that it is possible to effectively teach collaboration skills through the use of immediate feedback provided by a supporting technology.

Keywords

collaboration, experiential learning, face-to-face collaborative learning, teamwork.

Introduction

Although creative people are often imagined to be individuals working in isolation, the role of interaction and collaboration with others is in fact critical (Fischer 2005). In today’s fast-changing business environment, teams have emerged as a requirement for business success, particularly because of their ability to achieve larger goals than an individual working alone. Without adequate support, however, collaborating partners often fail to complete their joint task or find that it requires too much time and effort (Rummel & Spada 2005). New opportunities made possible by advances in communication technology have led to the emergence of related areas of research that are providing the needed support for collaborative work.

The field of computer-supported collaboration (CSC) classifies collaborative systems into orthogonal taxonomies based on the physical location of users and the simultaneity of interactions (Ellis et al. 1991; Palmer & Fields 1994). CSC research has concentrated mainly on distance collaboration and has led to the emergence of two further areas of investigation. In one of these, known as computer-supported cooperative work, computer-based network systems are created to support group work on a common task (Ellis et al. 1991), providing a shared interface typically using computational tools such as email, notification and awareness systems, video conferences and chat. The focus is primarily on distance collaborative activities.

The second area of research stemming from CSC is computer-supported collaborative learning (CSCL) (Silverman 1995), which aims at enhancing the learning process and improving students’ academic results with the help of technology. It allows peer interaction.
and group work while facilitating knowledge sharing and distribution (Liponen 2002). CSCL systems use technology to control and monitor interactions, to regulate tasks, rules and roles and to mediate the acquisition of new knowledge (Jermann et al. 2001; Zurita & Nussbaum 2004b). However, CSCL applications are commonly implemented for personal computers (PCs) and thus require that participants to be physically located in front of the computer screen (Inken et al. 1999). This hinders or prevents face-to-face interactions, which Johnson and Johnson (1999) describe as one of the key factors for attaining good results in a collaborative work group (Zurita & Nussbaum 2004a,b).

Advances in mobile computing are opening up new possibilities for supporting face-to-face collaboration. Wirelessly interconnected hand-holds provide a unique opportunity to create a learning environment where technology functions as a transparent, non-invasive support for group learning (Cortez et al. 2005). But with face-to-face collaborative activities, we must consider not only the actual task involved but also the social interaction dimension, described by Pinelle et al. (2003) as ‘the work of working together’. Baron (2003) has also conceived collaboration as a two-dimensional problem, defining it as a dual-problem space: a content space consisting of the problem to be solved and a relational space comprising the interactional challenges and opportunities. The author further discusses how the variability of success between groups that are matched for prior achievement can be attributed to the different types of interactions occurring within each group, and emphasizes the importance of understanding the nature of productive collaboration. This suggests that to truly support collaborative-learning environments, collaboration should be analysed and the resulting information made available to the participants (Fessakis et al. 2004).

In this paper, we propose a process for teaching and measuring teamwork skills using technologically supported, face-to-face collaborative activities. We show that:

- individuals who participate in this process improve their teamwork skills; and
- technological support can be used to measure teamwork skills and, therefore, provide immediate feedback.

We begin by describing the learning-to-collaborate-by-collaborating (LCC) process and its associated models and then examine a particular case of the process using a specific LCC face-to-face collaborative activity as part of the process. This is followed by the presentation of an experimental study based on this case. We conclude with a discussion of the results of the experiment and the implications of mobile technology for face-to-face collaboration.

### LCC: general description and associated models

The LCC process, presented in this paper, is a learning process guided by a teacher with teamwork knowledge. The process is organized in eight phases, principally based in the two models that we described next.

David Kolb (1984) has written that ‘learning is the process whereby knowledge is created through the transformation of experience’. On this approach, participants’ own experience and their reflections on it rather than theory and formal lectures are the means of generating understanding and transferring skills and knowledge. Kolb introduced an experiential learning model called the Learning Cycle (Fig 1), according to which a complete learning process must include each of the four stages shown in Table 1.

![Kolb's learning cycle.](image)

The LCC process is based on Kolb’s model as just described. In the concrete experience stage, participants work in teams. By taking part in a face-to-face collaborative activity, participants experience the interactions and processes involved in teamwork.

In the reflective observation stage, participants must assimilate, reflect and discuss the main processes they have just experienced in the previous stage, i.e. during the tasks performed in the concrete experience.
stage. This reflection is guided by a teacher who is knowledgeable in teamwork. In order for this to be effective, immediate feedback must be provided to both teacher and participants indicating the values of the variables in the processes performed during the collaborative activity.

During the abstract conceptualization stage, a conceptual model of teamwork is presented to participants in order to help them logically organize ideas and think about teamwork. Many studies have been performed of team performance (McIntyre et al. 1990; Dickinson et al. 1992; Salas et al. 1992), and, based on the core components of teamwork and identified by Dickinson and McIntyre (1997), they proposed a teamwork model that is used in this stage. The model consists of a learning loop of seven basic teamwork components: communication, team orientation, team leadership, monitoring, feedback, back-up and coordination (Fig 2).

There is much research on modeling teamwork for teams of robots and multi-agent systems (Tambe 1997; Kaminka et al., 2004; Schurr et al. 2004). However, when modeling teamwork for humans as said in Salas et al.’s (2005) study: ‘On closer inspection of most team effectiveness models, it is apparent that none of these models specify exactly what teamwork is, nor provide consistent tests of the various influences on teamwork. Instead, these models provide discussions of various factors that promote or detract from effective teamwork.’
We selected the Dickinson and McIntyre teamwork model because of the following:

1. It is specific on what teamwork skills should be observed as the model is presented associated with a conceptual framework for developing teamwork measures that can ensure effective individual and team performance (Dickinson & McIntyre, 1997, pp.19).

2. It considers the teamwork process as a learning loop characterizing teams as adaptable and dynamically changing over time. These characteristics are important to consider because as said in studies by McGrath et al. (2000) and Ilgen et al. (2005): conceptually, team researchers have converged on a view of teams as complex, adaptive, dynamic systems.

3. It includes most common elements considered in most research on teamwork process (Marks & Panzer 2004; Ilgen et al. 2005; Salas et al. 2005; Rousseau et al. 2006) as it can be seen in Fig. 2.

The central characteristic of the Dickinson and McIntyre teamwork model is its inclusion of teamwork skills in a loop, simplifying and classifying the teamwork process. Each model component is explained in Table 2. According to the authors, team leadership and team orientation are ‘input’ components of teamwork because at least one of these attitudes are required for an individual to participate in a team task. Intermediate processes for ensuring effective teamwork behaviour are monitoring, feedback and back-up. Finally, the ‘output’ component is coordination because it defines the performance of the team. Communication is a transversal component of particular importance given that it links the other components.

The Dickinson and McIntyre model not only is present in the abstract conceptualization stage but also forms the underlying philosophy of the collaborative activity. Because feedback on the results and processes of the activity must be given in the reflective observation stage, it is essential that the activity provides users with the requisite tools and the option to interact, perform and understand the Dickinson and McIntyre loop of teamwork skills.

In the last stage (active experimentation), participants put into practice the teamwork content they have learned. This is carried out through a second collaborative activity in which they once more have the opportunity to engage in real collaboration.

To ensure a complete and effective collaborative learning process, there are certain complementary activities that should be included before and after the Kolb learning cycle stages. Before starting the Kolb cycle, participants need to be motivated. Indeed, motivation is considered to be one of the instructional strategies for making learning durable (Hacker &

---

**Table 2.** Description of the teamwork components in the Dickinson and McIntyre model (1997).

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team Orientation</td>
<td>Refers to the team tasks and the attitudes that team members have towards one another. It reflects acceptance of team norms, level of group cohesiveness and importance of team membership.</td>
</tr>
<tr>
<td>Team Leadership</td>
<td>Involves providing direction, structure and support for other team members. It does not necessarily refer to a single individual with formal authority over others. Team leadership can be shown by several team members.</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Refers to observing the activities and performance of other team members and recognizing when a team member performs correctly. It implies that team members are individually competent and that they may subsequently provide feedback and back-up behaviour.</td>
</tr>
<tr>
<td>Feedback</td>
<td>Involves the giving, seeking and receiving of information among team members. Giving feedback refers to providing information regarding other members’ performance. Seeking feedback refers to requesting input or guidance regarding performance and to accepting positive and negative information regarding performance.</td>
</tr>
<tr>
<td>Back-up Behaviour</td>
<td>Involves assisting the performance of other team members. This implies that members have an understanding of other members’ tasks. It also implies that team members are willing and able to provide and seek assistance when needed.</td>
</tr>
<tr>
<td>Coordination</td>
<td>Refers to team members executing their activities in a timely and integrated manner. It implies that performance of some team members influences the performance of others. This may involve an exchange of information that subsequently influences another member’s performance. Coordination represents the output of the model and reflects the execution of team activities such that members respond as a function of the behaviour of others.</td>
</tr>
<tr>
<td>Communication</td>
<td>Involves the exchange of information between two or more team members in the prescribed manner and by using proper terminology. Often, the purpose of communication is to clarify or acknowledge the receipt of information.</td>
</tr>
</tbody>
</table>

© 2008 The Authors. Journal compilation © 2008 Blackwell Publishing Ltd
It is also important to ensure that participants have a social context in which to combine positions and beliefs [in terms of social constructivism theory, as per Vygotsky (1978)] and socially define objectives, tasks, roles and rules (Dillenbourg 1999). Consequently, the first phase of the LCC model, denominated ‘motivation and set-up’, is an introductory one in which students are motivated and a context is established for the activities to follow.

As noted by Margaritis et al. (2006), who observed that ‘during computer-mediated synchronous collaboration there is a need for supporting reflection of the partners involved’, a final reflection on the knowledge participants have gained about teamwork is also important. This in turn requires that we know participants’ level of teamwork knowledge both before and after the experience. With such data, the teacher can focus on those areas of the teamwork model that were shown to be weak and also demonstrate what progress has been made.

Altogether, the LCC process is composed of eight phases, including individual, group and class-wide ones (Fig 3). In order to guide the class-wide activities, receive feedback and transmit it to the participants, all phases are supported by technology and mediated by a person who has teamwork knowledge. The teacher orients the discussions and is responsible for effectively presenting and explaining the Dickinson and McIntyre (1997) model and communicating team performance results to participants.

**Implementation of the LCC process: an experimental application**

Because LCC is a general theoretical process, a particular case or application must be implemented before it can be tested, reflected by Collaborative Activities I and II corresponding to LCC phases III and VI, respectively. In order to effectively reproduce the different phases of the process, including measurement of teamwork performance and instant feedback provision for both teacher and participants, we decided to support the test application with wirelessly connected hand-held devices [Pocket PCs (Hewlett-Packard Company, 1999)].
Palo Alto, CA, USA). This technology was chosen because:

- it is transparent and non-invasive (Cortez et al. 2005);
- it allows dynamic representation (Roschelle et al. 2000; Tinker & Krajcik 2001); and
- it permits classroom-area networking (Roschelle 2003).

Thus, the experimental design supplies each participant with a wirelessly connected Pocket PC for carrying out the various LCC process activities. The technology guarantees a seamless network infrastructure simultaneously with a face-to-face social network (Fig 4a), (Zurita et al. 2003). During the LCC process, participants are located in groups facing the teacher and wirelessly connected to the teacher and to each other, as shown in Fig. 4b.

As noted in the introduction, one of the goals of the LCC process is to measure teamwork skills so that participants can be given immediate feedback. During the process, different data elements are captured by using the technology and displayed to the teacher. These data are of two types. The first type is participants’ declarative teamwork knowledge, which is evaluated through pre- and post-test questionnaires. The second type consists of the teamwork variable measurements captured during the collaborative activities (Fig 5). These measurements furnish immediate feedback to the teacher and complement his/her observations, allowing him/her to conduct the ‘Guided Reflection’ (phase IV),
‘Underlying Model and Results’ (phase V) and ‘Final Reflection’ (phase VIII) personally and effectively.

**Description of the collaborative test activity for LCC’s phases III and VI**

It is important when setting up an LCC process that the face-to-face collaborative activities of phase III (Collaborative Activity I) and phase VI (Collaborative Activity II) are well defined and implemented. Our goal was to create a general group activity independent of a specific domain that allows to measure and observe Dickinson and McIntyre teamwork skills. The collaborative activity we implemented was a group game that requires participants to interact in order to succeed.

Each individual participant receives two lists of elements on his/her Pocket PC that must be matched to increment both personal and team scores (Fig 6). The first list, ‘Own Guessing Game Images list’, is a set of riddles that the participant must answer by matching them with elements of the second list called ‘Interchangeable Solutions list’ that corresponds to the set of solution texts. Participants may interchange solutions within their teams as they attempt to find the ones that correctly match the riddles of the Own Guessing Game Images list. Each element of each team member’s list is unique, meaning that none of the elements on any given player’s lists are found on the lists of any other player on the team. The riddles are guessing games that anyone knowing how to read and handle a computer device is able to play. This ensures that the activity does not demand any specialized or technical knowledge.

The user interface for the collaborative activity, shown in Fig. 6, provides various options for supporting the game’s basic actions (Table 3) as well as the collaboration actions that allow participants to interact collaboratively in a more effective manner (Table 4). Participants’ use of these options enables us to evaluate and measure their Dickinson and McIntyre teamwork skills. Although they may engage in an efficient teamwork and collaboration, this might not occur because participants have the option to complete the entire game without obligation to interact, given that participants may match their riddles with their own solution list.
The LCC Collaborative Activity software that we developed, allows measuring seven variables grouped as follows:

1. Activity score. Corresponds to the average number of correct and incorrect matches (riddles solved) scored by each team. It reflects the team’s efficiency in performing the task assigned, i.e. their final performance.

2. Teamwork variables. As stated in Dickinson and McIntyre teamwork model (1997) (Fig 2 and Table 2), these variables correspond to core components (skills) of teamwork: team orientation (TO), team leadership (TL), monitoring (MO),

Table 3. System’s basic functionality used in the Collaborative Activities I and II.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Match</td>
<td>Matches solutions to riddles. This is an individual action and impacts directly on both the individual and team scores. The final individual score is calculated by first subtracting the incorrect answers from the correct ones to obtain the raw score, which is then weighted by 30% and combined with the team score weighted by 70%. This formula favours collaborative work while still encouraging individual effort.</td>
</tr>
<tr>
<td>See Image</td>
<td>Displays a riddle using the entire hand-held screen. This action is both individual and restricted because a given image can only be displayed by the owner a certain number of times (defined by the teacher, with default value of 3). This restriction is designed to speed up the activity and create situations where participants need other members’ help to solve the riddle. After seeing an image, the owner may decide to match it with one of the solutions on his/her list, to look for a solution among the other members, or, if he/she does not know the answer or is no longer able to see the image, to use the Ask for Help option.</td>
</tr>
<tr>
<td>Interchange</td>
<td>Interchanges a solution with another participant. This implies face-to-face and/or software interactions considering that, to perform an interchange, two members must agree and coordinate on which solutions they are giving and receiving. If no face-to-face communication is undertaken before using this option, it is highly probable that one of the participants in the interchange will cancel the interaction by not accepting the solution sent by the other member or by refusing to give a solution away to the other.</td>
</tr>
<tr>
<td>See Notification</td>
<td>This icon appears (blinks) on a team member’s screen when another player wants to contact him/her. Clicking on the icon displays a pop-up message indicating who wants to make contact and why, i.e. when the other participant wants to interchange a solution. This action permits the initiation of information and object flows between two team members.</td>
</tr>
</tbody>
</table>

Table 4. Collaboration options of the system’s functionality used in the Collaborative Activities I and II.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor</td>
<td>Displays team performance in terms of percentages of correct/incorrect answers (matches) scored by all other team members (excluding own scores). This option enables participants to be informed of the team’s overall performance. Individual scores have to be complemented by face-to-face communication to comprehend performance details.</td>
</tr>
<tr>
<td>Correct</td>
<td>Deletes matches made by another team member. One member cannot correct himself because similar as day-to-day situations, people cannot know when they are wrong unless someone points out the error. When this option is selected, the ‘corrector’ is able to see all of the matches made by the participant being corrected and deletes them, thereby freeing up the image (i.e. the riddle) and the solution to be used again. To ensure that the use of this tool is efficient and well coordinated, previous face-to-face communication between participants is necessary. This is so because for a correction to be undertaken, a team member must first discover that another member needs help, the latter must recognize that he/she might be wrong in some of his/her answers and both must agree on the corrected matches.</td>
</tr>
<tr>
<td>Ask for Help</td>
<td>Allows the participant to ask another team member to solve one of his/her riddles. This option implies giving away a riddle and losing the associated individual score. It permits participants to request back-up when they cannot solve their own riddles.</td>
</tr>
</tbody>
</table>
feedback (FE), back-up (BA) and coordination (CO). Communication has not been included in the measurable variables, as explained next.

These variables are evaluated during the collaborative activity because the use of the software options by the participants enables their measurement. All of the measured variables except team leadership are calculated via actions performed by each team member with the software and have individual scores that reflect players’ teamwork skills (behaviours). A detailed description of how the teamwork variables are evaluated by the software is presented in Table 5. The team leadership variable, although also measured in terms of actions, does not have an individual score by its very nature; its role is to report the number of leaders who appeared within each team during the LCC activity. All these variables are used by the teacher during the class-wide activities.

The communication component of the teamwork model was not measured by the software because, as is evident in Fig 2, it is the basis for all of the other processes. And, therefore, if the other processes effectively took place and were measured by the software, we can affirm that communication was also present. Furthermore, because the software implements a face-to-face collaborative activity, it is expected that most communication between participants occurs face to face, which cannot be measured through. Therefore, any attempt of measuring communication would not accurately reflect what actually occurred.

**Experimental design**

As we stated in the Introduction, this study proposes a process for teaching and measuring teamwork skills through face-to-face collaborative process using wirelessly connected Pocket PCs. To gauge our success, we must prove empirically, through an evaluation of the LCC process, the following hypotheses:

\[ \text{H1. Individuals who participate in the LCC process improve their teamwork skills.} \]

\[ \text{H2. Teamwork skills can be measured by using technological support.} \]

For demonstrating our hypotheses, we present four complementary studies.

**First study**

In order to obtain empirical data to observe if individuals who participate in the LCC process improve their teamwork skills (H1), we decided to measure the teamwork competence through the LCC software to an experimental and a control group, with similar subjects.

Hence, we organize a 2-h activity with six groups of undergraduate students for them to participate in the LCC process. In addition, in a different day, we organize a 40-min activity for the control group, also formed by six groups of undergraduate students.

Thus, in order to measure the defined teamwork competences, we organize the following groups and sessions:

- An experimental group that was exposed to the LCC process composed by six teams of students in an undergraduate human–computer interaction class at the Catholic University of Chile’s School of Engineering. The students participated simultaneously in the LCC process as part of one of the activities of the class. Each group had between four and six members, the average being five participants. The LCC process, including all eight phases (Fig. 3), was conducted over a 2-h session and was guided by a teacher who mastered teamwork theory and the Dickinson and McIntyre model.

- A control group that was not exposed to the LCC process but did take part in the same collaborative activities so that their teamwork performance variables could be measured. Therefore, the control group participated only in phases III (Collaborative Activity I) and VI (Collaborative Activity II) and thus received no context, teamwork feedback, analysis, orientation, or reinforcement. The control group was formed by seven teams, all of whose members were students in a human–computer interaction class. Here, too, each team varied between four and six members, with an average of five. The groups attended in a separated session from the experimental group and participated only in phases III and VI of the LCC process, in a 40-min session.

When analysing the data obtained through the software during phases III and VI (Activity Score and the
Team orientation (TO)  
This variable is measured through actions executed by the team. It increases for each individual when:
- two players successfully use the Ask for Help option, i.e. when the help request is accepted, meaning that a player is willing to help another player in order to help the team as a whole;
- a player uses the Correct option, i.e. when a player is willing to devote time to correct another player, thereby helping the team; or
- a player uses the Monitor option, thus showing an interest in the performance of the team.

Team leadership (TL)  
This variable is measured by a two-item questionnaire upon completion of the collaborative activity, asking each participant which team member they consider to have been the most influential person in the decision and coordination process.

Monitoring (MO)  
This variable is measured through actions executed by the team. The variable decreases for each individual when:
- a player initiates an interchange with another but the gesture is declined;
- a player initiates a Help process with another but the request is rejected; or
- a player offers to correct another player but the offer is rejected.

The three actions cause a decrease in the variable because when an action initiated by another is declined, it implies that the declining player’s situation was not properly observed. Acceptance of the action has the opposite effect.

The variable increases for each individual when:
- a player initiates a Help process with another and the request is accepted;
- a player offers to correct another player and the offer is accepted;
- a player starts an interchange with another and the gesture is accepted; or
- a player uses the Monitor option, showing an interest in the performance of the rest of the team.

Feedback (FE)  
This variable is measured through actions executed by the team. The variable increases for each individual when:
- a player agrees to be corrected because this means accepting negative information about his/her performance; or
- in a correction process, a player declines to eliminate a correct match because by acting thus, he/she is telling the ‘corrector’ that the suggested action is incorrect.

The variable decreases for each individual when:
- in a correction process, a player agrees to eliminate a correct match; or
- a player does not agree to be corrected because he/she does not receive feedback about his/her performance.

Back-up (BA)  
This variable is measured through actions executed by the team. The variable increases for each individual when:
- a player asks for help, because he/she is asking for back-up.
- A player offers to correct another player, because he/she is trying to provide help.

Coordination (CO)  
This variable is measured through actions executed by the team. The variable increases for each individual when a player makes a correct match because he/she is contributing to team performance.

The variable decreases for each individual when a player makes an incorrect match because he/she is hurting team performance.

Teamwork Variables, Table 5) of the experimental group versus the data of the control group, we can analyse if both groups are comparable and if they show differences between the measurements of their teamwork variables.

Second study
In addition, to determine whether the knowledge gained during the LCC process lasted over time and was not merely transitory, we held a second session of
teamwork variable measurement with the experimental group 2 months after the first study. In this occasion, the experimental groups participated in a collaborative activity, which we called Collaborative Activity III. This third collaborative activity was similar and can be considered as a repetition of phase VI (Collaborative Activity II) because the LCC instructional process was performed (2 months) before. Also, no refreshment of the teamwork competences was performed to the experimental group before Collaborative Activity III.

**Third study**

In order to observe the generality of the LCC process, it was tested in a working environment to a team of seven engineers (who regularly worked together) of a retail firm in the Information Technology department, in a 2-h session.

**Fourth study**

To demonstrate H2 and so the possibility of effectively measuring teamwork skills using technological support, we used expert observation to validate the data obtained from the software. A psychologist specializing in teamwork and familiar with the Dickinson and McIntyre model personally attended the first study. Complementary, a second teamwork expert joined the psychologist in viewing videos of the other studies. The two experts analysed and measured the teamwork variables from the obtained qualitative data, following a guideline for expert observation, which was previously prepared by the psychologist. The data generated by the experts were afterwards compared with the systems’ generated data.

**Results**

As regards H1, the obtained scores and teamwork variables (team orientation, monitoring, back-up, feedback and coordination) for Collaborative Activities I and II (phases III and VI) of Study I were analysed by using repeated measures analysis of variance, a generalization of students’ t-test for paired samples with two or more measurements of the same type. The team leadership variable was included in the analysis as a covariant in order to eliminate the variance due to the presence (or absence) of leaders from the results of the rest of the teamwork variables. Our findings, presented in Table 6 and Table 7, may be summarized as follows:

1. **Comparison of experimental and control groups for LCC Activity I:** No statistically significant differences between the two groups were found for any of the variables measured with the exception of the back-up variable, which is discussed at the end of this section. We therefore conclude that the groups are very similar and, thus, statistically comparable in all measured variables other than back-up.

2. **Comparison of experimental and control groups for LCC Activity II:** Statistically significant differences between the two groups were found for all variables measured. The experimental group obtained significantly better averages on all variables during the second activity.

---

Table 6. Comparative analysis between groups (between-subject effects): control group vs. experimental group. Repeated measures analysis with team leadership as covariant for the variables measured by the software in Collaborative Activities I and II.

<table>
<thead>
<tr>
<th>Collaborative Activity</th>
<th>Control group</th>
<th>Experimental group</th>
<th>Pairwise comparison</th>
<th>Control group</th>
<th>Experimental group</th>
<th>Pairwise comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaborative Activity I</td>
<td>Mean</td>
<td>Mean</td>
<td>Sig. (p)</td>
<td>Mean</td>
<td>Mean</td>
<td>Sig. (p)</td>
</tr>
<tr>
<td>Score</td>
<td>0.754</td>
<td>0.167</td>
<td>0.354</td>
<td>0.993</td>
<td>3.300</td>
<td>0.003*</td>
</tr>
<tr>
<td>Team orientation</td>
<td>1.443</td>
<td>0.033</td>
<td>0.336</td>
<td>2.114</td>
<td>9.683</td>
<td>0.001*</td>
</tr>
<tr>
<td>Monitoring</td>
<td>3.414</td>
<td>2.967</td>
<td>0.778</td>
<td>4.086</td>
<td>11.800</td>
<td>0.001*</td>
</tr>
<tr>
<td>Feedback</td>
<td>2.786</td>
<td>2.583</td>
<td>0.836</td>
<td>4.743</td>
<td>10.417</td>
<td>0.001*</td>
</tr>
<tr>
<td>Back-up</td>
<td>0.000</td>
<td>2.383</td>
<td>0.000*</td>
<td>0.029</td>
<td>6.250</td>
<td>0.000*</td>
</tr>
<tr>
<td>Coordination</td>
<td>1.329</td>
<td>0.567</td>
<td>0.144</td>
<td>2.471</td>
<td>7.750</td>
<td>0.001*</td>
</tr>
</tbody>
</table>

*Significant difference.
Comparison of LCC activities I and II for control group: No statistically significant differences were found between the data on the two activities for all variables measured by the software. We therefore conclude that the control group did not present significant improvements in its performance during the second collaborative activity.

Comparison of factors in LCC Activities I and II for experimental group: Statistically significant differences between the measurements of the two activities were found for all variable measures by the software. We therefore conclude that the experimental group presented a significant improvement in its performance during the second collaborative activity.

Because the experimental group shows a significant improvement of the teamwork variables when comparing measurements of phase III (Collaborative Activity I) and phase VI (Collaborative Activity II) while the control group does not, we can conclude that the improvement of the measurement detected for the experimental group is caused by the LCC process and is not a consequence of participants’ memorizing techniques and learning how to use the software. Therefore, we may conclude that the experimental group improved its performance in teamwork skills and that this increase is a consequence of the application of the LCC process (H1).

To complement these results, we calculated the correlations between teamwork and the score variables with each other (i.e. TO&Mo, TO&Fe, TO&Ba, TO&Co, TO&Score, Mo&Fe, Mo&Ba, Mo&Co, Mo&Score, Fe&Ba, Fe&Co, Fe&Score, Ba&Co, Ba&Score, Co&Score). We observed that all these correlations are significant at the 0.001 level. Furthermore, when doing a factor analysis of the teamwork variables, we obtained just one extracted component (Table 8). Therefore, we can conclude that all the variables are in fact measuring teamwork and are dependent of each other. This corroborates the Dickinson and McIntyre model, which describes a learning flow of basic teamwork components because, if one of the teamwork components is not effectively achieved, the flow is interrupted; consequently, the other components are affected as well as the global teamwork component.

When analysing how the variables are structured in the factor analysis (Table 8), we observed that all the variables equally generate the teamwork component (>0.95), in exception of the back-up variable. As the
data show, in order to predict the overall teamwork behaviour, it is enough to measure just one variable (e.g. Team Orientation). However, when focusing in the comparison of different groups’ and individuals’ teamwork performance, it is no longer sufficient to just measure one component because, as seen in the studies, the different scores of the variables are an important source of information for the teacher who guides the discussions of the LCC process in phases IV (Guided Reflection) and VIII (Final Reflection).

In the second study, the same experimental group performed the Collaborative Activity III and not the whole LCC process. The purpose was to determine whether the knowledge gained during the LCC process, performed 2 months earlier, lasted over time and was not merely transitory. The results, Table 9, show that both the teamwork variables and the final group scores on the application for Collaborative Activity II do not display statistically significant differences from those obtained on the Collaborative Activity II. Thus, the teamwork knowledge they reflect persisted over time, enabling us to affirm that the learning that occurred during the LCC process was not merely transitory knowledge but, in fact, was durable.

During the experiments, we were also able to observe the results in their qualitative dimension. Many differences were apparent in participants’ behaviour between Collaborative Activity I and Collaborative Activities II and III. In Activity I, they focused principally on their own individual work, interacting only after a considerable amount of time had passed, at which point they realized they could not proceed any further. They also showed little interest in group performance. By contrast, in Collaborative Activities II and III, the participants evinced much more team consciousness, which they manifested in a concern for team performance and the negotiation of strategies to efficiently carry out collaborative tasks, putting team performance before their own. These performance improvements were not observed in the control group. For them, behaviour on Collaborative Activities I and II was very similar, with participants for the most part displaying individualistic attitudes. We also observed that the wirelessly connected Pocket PCs did not obstruct social interactions and face-to-face communication, proving, on the contrary, to be useful in generating an environment where social interactions were a key element in efficiently accomplishing team tasks.

In the third study, Table 10, with the group composed by engineers of a retail firm, we observed significant advances between the Collaborative Activities I and II (LCC phases III and VI). The results of the table also show that the engineers’ performance was similar to the one observed for the students during the first study. In addition, it was remarkable that during the engineers’ group discussion and especially during the Final Reflection phase (LCC phase VIII), the discussions led to contextualization and examples of real, routine work.

The appreciations of the LCC process recollected through an individual questionnaire after the experience were similar for the engineers and the students. The engineers also indicated that the LCC process allowed them to meet their co-workers in a different and deeper
Regarding working methodology and the form of confronting new challenges (as was for instance the LCC process), in addition to their individual form of working as part of a team. These statements were also reflected in that participants evaluated the LCC process as very useful for their future group work in the IT department.

As regards H2, upon comparing the results obtained by the psychologist who personally attended the LCC process with those generated by the LCC software (first and fourth studies data), it was observed that, using the scale defined in Table 11a, the two reached the same conclusions with respect to teamwork variables for five of the six teamwork skills (Tables 11b and c). Furthermore, when the data obtained from the video analysis of the experimental groups by the two experts (forth study) were compared with the software results (first study), there was agreement in 92% (33 of 36) of the measurements (Table 11b). The measurement of the back-up variable was the only one where not always there was an agreement between the experts and the software data. Also, comparisons of the experimental group and the

<table>
<thead>
<tr>
<th>Pair</th>
<th>LCC Collaborative Activity I</th>
<th>LCC Collaborative Activity II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Engineers’ group</td>
<td>Students’ group’s mean</td>
</tr>
<tr>
<td></td>
<td>N = 7</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Score1–Score2</td>
<td>2.0</td>
</tr>
<tr>
<td>2</td>
<td>TO1–TO2</td>
<td>3.7</td>
</tr>
<tr>
<td>3</td>
<td>MO1–MO2</td>
<td>5.4</td>
</tr>
<tr>
<td>4</td>
<td>FE1–FE2</td>
<td>5.1</td>
</tr>
<tr>
<td>5</td>
<td>BA1–BA2</td>
<td>*</td>
</tr>
<tr>
<td>6</td>
<td>CO1–CO2</td>
<td>1.4</td>
</tr>
</tbody>
</table>

*Variable was not measured.

LCC, learning to collaborate by collaborating; TO, team orientation; MO, monitoring; FE, feedback; BA, back-up behaviour; CO, coordination.

Table 11a. Scale used by psychology experts and software in comparison.

<table>
<thead>
<tr>
<th>Value</th>
<th>Expert</th>
<th>Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low increase</td>
<td>Between 0% and 33%</td>
</tr>
<tr>
<td>2</td>
<td>Medium increase</td>
<td>Between 34% and 66%</td>
</tr>
<tr>
<td>3</td>
<td>High increase</td>
<td>Between 67% and 100%</td>
</tr>
</tbody>
</table>

Table 11b. Comparison between expert analysis by video and software measurements.

<table>
<thead>
<tr>
<th>Differences between Collaborative Activities I and II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
</tr>
<tr>
<td>Software</td>
</tr>
<tr>
<td>Group 2</td>
</tr>
<tr>
<td>Software</td>
</tr>
<tr>
<td>Group 3</td>
</tr>
<tr>
<td>Software</td>
</tr>
<tr>
<td>Group 4</td>
</tr>
<tr>
<td>Software</td>
</tr>
<tr>
<td>Group 5</td>
</tr>
<tr>
<td>Software</td>
</tr>
<tr>
<td>Group 6</td>
</tr>
<tr>
<td>Software</td>
</tr>
</tbody>
</table>

TL, leadership; TO, team orientation; MO, monitoring; FE, feedback; BA, back-up behaviour; CO, coordination.

Table 11c. Comparison between in-person expert analysis of one LCC process application and software measurements.

| Difference between Collaborative Activities I and II for group 7 (Retail) |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Expert | 1 | 2 | 2 | 2 | 2 | 3 |
| Software | 1 | 2 | 2 | 2 | 1 | 3 |

LCC, learning to collaborate by collaborating; TL, leadership; TO, team orientation; MO, monitoring; FE, feedback; BA, back-up behaviour; CO, coordination.
control group during Activity I revealed significant statistical differences for this teamwork component. According to the psychologist, this disparity may be explained by the fact that much of participants’ back-up behaviour was performed face to face and was therefore not captured by the software.

Overall, however, because there are almost no differences between the software results and those arrived at by the psychology experts, we may conclude that the software and technology used in the LCC process provided correct measurements for the various teamwork skills chosen for analysis.

Conclusions

This paper has presented a process for learning to collaborate called LCC process. Group work is inherently variable in that the performance of a team depends, among other things, on the abilities and attitudes of each team member and the group’s cohesiveness. The LCC process we have proposed facilitates individual teamwork skills to be learned by encouraging participants to interact collaboratively and then measuring their performance to provide immediate feedback and guidance to the learning experience.

We have demonstrated empirically that it is possible to create a technologically supported process that measures teamwork skills in real time and produces instant assessment of collaboration skills. Thanks to their involvement in the LCC process, participants were able to improve their teamwork performance and experienced a change in attitudes, emerging from the experience with greater willingness to work in a team.

Additionally, an important characteristic of the LCC process is that it is content independent and, therefore, possible to apply to any reality. Because participants do not require previous knowledge of any particular domain to participate in the LCC process, it may be used for teaching any person who has sufficient cognitive maturity to engage in reflection, which would generally include students or professionals in all areas of knowledge. However, the obtained results in this paper do not allow to directly conclude if the teamwork skills acquired by the participants of the LCC process are in fact transferable to other situations (different tasks) or dependent of the used technological support, i.e. handhelds. We might conclude that the skills are transferable, considering the retail firm exercise results, where real work activities were considered. However, further research is required to generalize these results.

The technology in the LCC process played a key role. The experiment undertaken here used small, wirelessly connected hand-holds to test the LCC process because of their ability to support face-to-face social interactions. These devices enable the creation of a seamless technological network that supports the social one (Zurita et al. 2003). The LCC process can thus incorporate face-to-face interactions without sacrificing the technological support needed to provide immediate feedback. The hardware and software used in the LCC activities supply participants with mediation mechanisms in the form of a data display, a means for sharing data and a negotiation space. The hand-held technology also makes it possible for learning to take place in different spaces and configurations. In particular, because of the device’s mobility and small size, students can easily be moved from class-wide activities to individual ones or organized into small groups. This allows performance information to be obtained and wirelessly transmitted during any phase of an activity and in any configuration. Nevertheless, although the LCC process presented here makes use of technology to improve collaborative learning, it is only the medium, not the goal, being employed principally to furnish support and provide feedback to the teacher-guided process.

Note

1This paper was partially funded by the Programa MECE Educación Superior, DIPEI and DIPUC of the Pontificia Universidad Católica de Chile and FONDECYT 1060712 and 1080100.

References


Learning to collaborate by collaborating

Decision-Making Performance (Final Report). Naval Training System Center, Orlando, FL.