ITCol. Tangible Interaction for Collaboration

Experiments Carried Out

Artola Verónica[1], Sanz Cecilia, Pesado Patricia
Instituto de Investigación en Informática LIDI,CONICET[1]
Facultad de Informática
La Plata, Buenos Aires, Argentina
{vartola, csanz, ppesado}@lidi.info.unlp.edu.ar

Baldassarri Sandra
GIGA- AffectiveLab
Departamento de Informática e Ingeniería de Sistemas
Zaragoza, España
sandra@unizar.es

***Abstract*—This article presents a collaborative game based on tangible interaction, called ITCol (Tangible Interaction for Collaboration). It has been developed to tackle a specific educational need in the context of a post-graduate course at a School of Computer Science. The purpose of the application is, through a detective game, to help adult students experience and experiment with collaborative work. ITCol proposes an interaction mode through tangible objects placed on a horizontal tabletop. In this article, we focus on describing how the use of this type of tangible interaction helps students to experience collaboration, considering characteristics such as individual responsibility, positive interdependence, developer interaction, among others. Additionally, the advances achieved in the evaluation process are described, as well as the initial results that have been obtained.**

Keywords- Educational Scenario; Collaborative Learning; Adults; Tangible interaction; Tabletops and collaborative activities

I. INTRODUCTION

Tangible User Interfaces (TUI) have represented a significant paradigm shift in the design of user interfaces and the interaction with computer systems [1]. TUIs are user interfaces that allow the user to interact with digital information through physical environments. In TUIs there is a strong coupling between digital information and its tangible representation. Through the physical manipulation of tangible representations, the digital representation is altered. Physical shapes are used both for representing and controlling their digitals counterparts.

While Graphic User Interfaces (GUIs) are useful as general purpose interfaces, TUIs– through the emulation of several tools that use the pixels on a screen – are used as specific purpose interfaces for a specific application, using explicit physical shapes that can perfectly fit in the physical environment of the users [2][3].

Active surfaces are one of the possibilities offered by systems based on tangible interaction; these can be either interactive boards [4] or horizontal tabletops [5]. In particular, this paper addresses an application using tabletops. On these surfaces, there are different methods that can be used to enter information: using the fingers or electronic pens to touch the surface; using gestures that are registered by cameras, so as to avoid contact with the surface; using standard input devices such as keyboard and mouse; and, finally, the method on which this paper focuses, which is using tangible objects that are identified when they are placed on the surface [6].

There are various tabletop models. In some cases, the radiofrequency (RFID) embedded in tangible objects is detected and the system reads object position and orientation; in other cases, the position of tangible objects is detected by means of a camera located above/below the tabletop surface, which requires the use of fiducial or reference markers. Fiducial markers are images that are attached to a physical object and allow identifying it by means of a visual detection system. These markers provide information such as identity, position, and orientation. In the case of visual detection, the infrared spectrum is usually used to differentiate the marker from the projection, so fiducial markers are built by grouping black- or white-colored areas. In any tabletop model, tangible objects can be figurative (e.g., miniature toys) or iconic or symbolic, e.g., to reference system operations. For instance, an object with an eraser label can be used to remove elements that are displayed on the interface.

According to [6], tabletops are implicitly pedagogically biased, which can be exploited considering the following aspects:

- Tabletops are designed for co-location. Most computer-supported collaborative learning environments have been based on online work. The impact of co-presence in collaboration is not only centered on the students being able to see each other, and exchange objects, but the organization of the physical space becomes a key issue as well.
- Tabletops are designed for multiple users. The tabletop is a social space, whereas the desktop is personal. Even though portable computers can be used collaboratively, they have been designed as "personal computers". The meaning of "multiple users" is not the same for tabletops and virtual learning environments. For the latter, each user has an identity (access credentials), while this is not usually the case with the former. It can be said that interactive tabletops are intrinsically "interpersonal computers" [7].
- Tabletops are designed for practical activities. The dominant model in an interactive tabletop is solving problems by moving physical objects placed on the surface

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or with the hands. Thus, tabletops seem to be more suitable for tasks in which specific handling movements are important for solving the problem, which explains why many of these applications are focused on children.

- Tabletops are designed for multimodal communication methods. Speech, gestures, eye contact, actions and posture are considered to be essential components of communication. This allows for a richer discourse in teaching and learning, research, and analysis [8][9].

In this paper, we present ITCol (Tangible Interaction for Collaboration), an application for experience-based learning and collaborative work. This application has been developed in the context of a specific didactic proposal and is based on the specific educational needs of a group of educators. ITCol integrates the benefits of TUIs, by offering and environment that is familiar to users, with the previously mentioned benefits of tabletops to carry out a collaborative activity in the form of a game that requires solving a detective case. The group of educators that presented the educational need participated in the design process, as well as in the subsequent assessment process, which will be detailed further on.

In Section II, background information specifically relevant for this work is presented. In Section III, the proposed system, called ITCol, is described in detail. Section IV details the experiments carried out with ITCol, and Section V presents the results obtained. Finally, Section VI discusses the conclusions.

II. Related Work

In this section, previous work related with collaborative learning and a series of experiences of tangible interaction in educative scenarios are presented.

A. Collaborative learning

Collaborative work implies a series of important advantages in different learning dimensions. As regards the execution of group tasks, it fosters the achievement of objectives that are qualitatively richer in content, since it collects proposals and solutions from the different members in the group; it facilitates appreciating the knowledge of the different members in the group; it promotes the development of critical thinking and open-mindedness; and it strengthens the sense of solidarity and mutual respect. Collaborative Learning can be defined as a set of didactic methods as well as strategies to facilitate the development of skills (learning and personal and social development), where each member of the group is responsible both for their own learning as well as that of the other members of the group [12][13].

The authors from [14] propose five main aspects for collaborative learning:

1) Individual responsibility: all members are responsible for their individual performance within the group.

2) Positive interdependence: the group must depend on each other to *achieve* a common goal.

3) Collaboration skills: the skills necessary for the group to work effectively such as teamwork, leadership and conflict resolution.

4) Developer interaction: group members interact to develop interpersonal relations, and establish effective learning strategies.

5) Process group: the group reflects on a regular basis and evaluates their work, making the necessary changes to increase their effectiveness.

Besides, in a collaborative learning activity it is necessary to [15]: a) Establish the didactic objectives of the collaborative work activity; b) Design the task: individual and group; c) Set the groups; d) Define the role of teachers and the role of technology (if corresponds); e) Define self-assessment of individual and group work; and f) Set up the closing, summary or final work of each group. Analyze student feedback.

In this article, ITCol, our collaborative tangible interaction game has been designed following the basis previously exposed and analyzing how this type of interaction impacts on collaborative learning process. The research is aimed to analyze if the students achieve a collaborative dynamics taking into account the 5 main aspects previously mentioned [14] and how the design of ITCol, based in tabletop tangible interaction, takes part in this process. Although there are studies about collaborative learning with TUIs, most of them are focused to early or midlevel students. No specific analyses in post-graduate students' level have been found.

B. Tangible interaction in education

A good TUI design can provide a familiar environment for the user, appropriate for collaborative learning [16]. Studies such as the one carried out by Carreras and Parés [17] show that tangible interfaces promote active participation, which helps the learning process. These interfaces are not intimidating to inexperienced users and foster exploratory, expressive and experimental activities [16]. From the standpoint of learning theory and cognition, the value of tangible interaction includes the possibility of using participation practices, building models, carrying out collaborative activity, and so forth [18]. Some of the various arguments that have been presented in favor of using applications based on tangible interaction include: increased flexibility, generation of metaphors, possibility of focusing attention on the task and generating actions, conception of an additional channel to pass information, reasoning the world through discovery and participation, memory enhancement through physical action, promotion of social interaction, and collaboration, to name a few [19][20].

There is a long history of use of physical objects in teaching. Some research projects have designed and developed tangible objects or environments that focus on various aspects of the learning activity, e.g., narrative, exploration, and construction [20][16]. Below, some collaborative tangible interaction applications designed for the educational scenario and are considered to be relevant for this work, are described.

Fernaeus *et al* [21] present a tangible programming space that allows groups of children (from 6 to 12) to collaboratively create dynamic systems that run on a computer screen. The analysis of this proposal is extremely interesting, since links to four central axes in the area of tangible interaction are found: coupling, manipulation, the concept of input and output, and physical objects as representations of digital information.

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Do-Lenh *et al.* [22] present a research related with the differences in learning outcomes at individual and group levels between students using traditional computer and augmented tabletop with tangible interaction in an expressive collaborative learning task. They found that the collaboration in the tangible condition seemed to be qualitatively better, but they also affirmed that single mouse interfaces still have benefits when the goal is to effectively transfer knowledge among group member in a high level task requiring comprehension skills, especially in groups with high discrepancy. Zufferey [23] have also worked on the TinkerLamp tabletop using blocks and other objects for collaboratively building a warehouse. In their results they highlight how students were motivated to explore more solution alternatives while the task was being carried out.

Antle *et al.* [24] present the results of a design-based research, which explore the design space of collaborative, multi-touch, tabletop games for learning. They present Youtopia, a multi-user system developed to investigate issues surrounding how to design and evaluate children's collaborative learning applications using tabletops. As they say, each child in a pair needs to take specific actions in order for the system to respond in the desired way. This strategy may support situations of positive interdependence in collaboration since the task requires the coordinated action of more than one child to enact the strategy.

All these projects provide the foundations and have opened the path for our ITCol proposal. One of the aspects that most of these projects share is that they are aimed at children or teenagers or compares different types of interaction. ITCol focuses on the need of exploring the use of tangible interaction for post-graduate education, which is specifically aimed at an adult audience. Besides it is based in a collaboration model which takes in account the five essential aspects of collaborative learning described in Section II.A.

III. ITCOL – TANGIBLE INTERACTION FOR COLLABORATION

ITCol (Tangible Interaction for Collaboration) is a detective game which goal is to find out the solution to an investigation case based on clues. The game requires players to work collaboratively in order to solve the case at hand. ITCol uses a tabletop to present the application interface and objects can be placed on its surface to achieve the corresponding interaction. The game was designed considering that each participant has an essential clue and knowledge of the problem to be solved. This is necessary to achieve the collaboration dynamics. Besides, we aim to contribute to the literature by considering the tangible objects, the tabletop and ITCol itself as essential elements in the collaboration process. Tangible objects give the possibility for each member of the group to become involved with the characters of the game, and the tabletop and ITCol give important information about the problem to be solved and help in group metacognition process. In the following section, the main goals of ITCol are presented.

A. Didactic Goals Proposed for ITCol

This activity is presented as a didactic strategy for tackling the concept of collaborative learning. As the game unfolds, a synchronous, face-to-face collaboration process takes place [25]. Through this experience, students are able to understand the significance of interaction, negotiation, communication and coordination, which are all characteristics of collaborative learning [14].

One possibility, in order to carry out the dynamic of ITCol, was to use a set of computers (mobile or desktop) connected to establish the interaction among people. However, the fact that everyone should work on a different device could hinder the dialogue, negotiation, debate, since students have different abilities in relation to the use of digital technology, since the goal of ITCol is to be use with adults. So, in this case, the work of students sitting around a table was weighted as the most consistent scenario in relation to the learning objective. On the other hand, if it were a single computer for a whole group, only one of the members could be using it. This situation does not encourage the collaborative process [22]. Besides, the use of tangible objects was considered a benefit in relation with the dynamic of the game because it can shorten the distance with the case presented to the group. It was considered that a collaborative dynamics supported on Tangible Interaction table would achieve the learning objectives proposed in a more natural way, offer additional information for the case resolution, and at the same time introduce the possibility of recording the session and registering the required interaction. These were the principal hypotheses that supported the design of ITCol.

B. ITCol Functionality - A Description

ITCol proposes going through 3 different stages. Initially, in the first stage, participants are presented with a narration that introduces an investigation case and they are given the questions to be solved. This is done by means of a video clip that they watch on the surface of the tabletop. Then each member of the team receives a number of objects (representing characters or places involved in the investigation case) that, through interaction with ITCol, represent unique clues on the case. Each student must analyze his/her clues individually. This is important to achieve "individual responsibility" and "positive interdependence" characteristics mentioned in section II. The clues are distributed strategically, in order to favor the participation of all the members of the group. Then, in the second stage, the team must collaboratively solve, by interacting with ITCol and the tabletop, the questions posed in relation to the case. During this stage, members dialogue, negotiate, and contribute their information.

Collaboration skills, developer interaction, and process group are the characteristics present in this stage. ITCol accompanies this phase through the use of objects that represent additional clues and the possibility of obtaining additional information about the relation between the characters (or places) that all the members have (objects used in the first stage). Besides each participant has a special object referred to as "token". These "token" objects list key aspects in relation to the clues. Finally, in the third stage, participants must reach a conclusion to solve the case. The team wins if they arrive at the correct conclusion, in which case they receive a qualification based on their performance. If the conclusion is not correct, they can either try again or see the expected solution.

The players have a limited amount of time to complete each stage. The time available is always visible so that the team can plan and, if they find that this time is not enough, they can request additional time. Any request for additional time degrades the final qualification of the team.

In the following paragraphs, each ITCol stage is described in detail:

- *First stage:* objects representing case clues/evidence are distributed to the players. Each of them then individually interacts with ITCol to gather the information provided by their objects through its interaction with ITCol. The information obtained by each player is unique. Thus, the knowledge each player has, and therefore his/her contribution to group work, is essential for solving the case. The information gathered during this stage cannot be reviewed later on, which means that it is highly important that the player tries and remember as much data as possible. This allows working on the individual responsibility of each student as well as positive interdependence [14].

  Interaction with the objects occurs within a delimited area on the tabletop. Fig. 1 (Left) shows a clue given by a character object, being displayed on the surface of the tabletop. The clue is formed by an image and/or a piece of text, and its design takes advantage of the entire tabletop surface.

  When displaying the information from the clue, the individual must try and remember it. For this purpose, ITCol allows selecting key phrases that appear at the bottom of the screen (Fig. 1, Right), and that the participant can select using a pen, as shown in Fig. 1 (Middle).

  The number of phrases that can be remembered is limited, and each player is responsible for selecting which he/she considers to be the key phrases for the case. During the second stage, the player will be able to access only these key phrases as memory joggers, using the "token" object (Fig. 2).

  The objects used for interaction are ad-hoc objects. We believe that these objects are essential for improve the collaboration process. The objects that represent clues are formed by an image that represents the character (or the place) about which information is given and a base to which a marker is added. Also, as already mentioned, a pen object is used by the players to select information (see Fig. 1, Right).

Figure 1. Left: Object with the image of one of the characters from the case with its marker on the base; Middle: pen used for selecting key phrases; Rignt: Player selecting information to be remembered

Figure 2. The interaction with an object that provides the clue.

- *Second stage:* participants gather to discuss the case and find answers to its questions. The team must work in such a manner that all participants are able to talk and listen to the others. During this stage, they will be able to learn new additional information by linking the "clue" objects they already have or by requesting new clues through new objects (e.g., new characters or locations). There is a limit to the amount of additional information that can be requested, which forces players to carefully consider and agree on which clues to request. In this stage, emphasis is placed on collaboration skills, promoting interaction and group process [14].

  Some of the key aspects of this stage are described below:

  - Three types of interaction take place: additional clues, relations and "tokens." For each type of interaction, there are different objects and different interaction areas (Fig. 3).
  - For the additional clues, new objects are added that are similar in appearance to those used during the first stage (characters or locations). In the case of relations, the objects used during the first stage are used, and the team must decide which characters might be related to each other, place them on the tabletop and receive from ITCol any additional information about that possible link (Fig. 3, Below and Left). When a player places its "token" object on the surface, ITCol displays the list of key phrases selected by the player during the previous stage (Fig. 3, Below and Middle). This list acts as a memory jogger for each player, and its orientation can be changed by rotating the "token" object. Thus, players from various positions around the tabletop can still read the text. The interaction area corresponds to the entire surface of the tabletop, and more than one "token" object can be placed on it simultaneously, so that the information recorded by various players can be compared.

- *Third stage*: during this stage of the game, the team is asked to solve the unknowns of the case, and is told if such answers were correct or not. Finally, the team must reflect on its performance and the end result of the game.

  Each question in ITCol is assigned an answer that is represented with one of the physical objects distributed at the beginning (questions are answered using a character and a location). At the end of the game session, ITCol informs the participants if the answers selected for each question were correct or not, and then assigns a grade. This

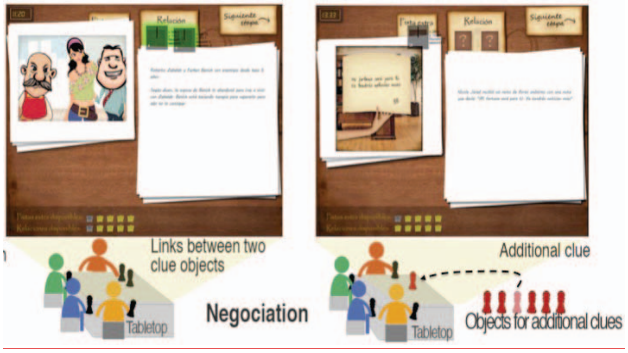

Figure 3. Information displayed when objects are placed on the correspondent area.

grade may be: Poor, Good, Very Good, or Excellent. It is calculated based on the additional elements used during the debating stage (additional clues or relations between objects) and any requests made for additional time. This grade is aimed at motivating the team to not only try and solve the case, but also try and do it with the best grade possible. ITCol displays each question of the game with an interaction area where the players must place the object they consider that correspond to the correct answer. Once the answers are confirmed, ITCol shows the result and the grade obtained.

C. *Technical aspects of ITCol*

The application prototype was developed on Adobe Flash Builder 4.5 and ActionScript 3.0 (AS3), with Adobe AIR as run environment. GIMP was used for graphics. For fiducial marker detection, the ReacTIVision library [26] was used.

For the configuration of the investigation case, an XML file was used whose schema was designed specially to allow the generation of new activities. Thus, the tool offers the possibility of allowing the creation of collaborative activities based on Tangible Interaction. The XML configuration file not only contains the case, but also allows setting some ITCol-specific parameters. For example: the time available for each stage, the maximum number of allowed additional clues and relations, the maximum amount of information that can be remembered by each player, etc.

In the context of the ITCol research project, a tabletop called VisionAR has been created [10]. For the framework of this tabletop, Medium Density Fiberboard (MDF) and acrylic were used. Its design facilitates assembly/disassembly operations, which is useful for moving the tabletop from one location to another. Fig. 4 shows the parts of the VisionAR framework, which is based on the NIKVision model [11]. The architecture of VisionAR includes the following:

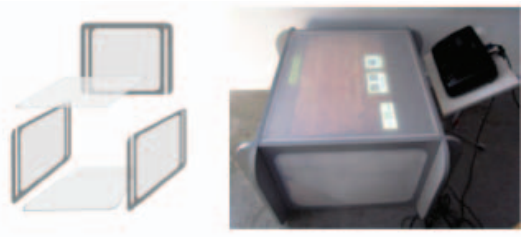

Figure 4. Left: VisionAR Framework; Right: VisionAR in use: the projector, on an adjustable stand, and the projection on the surface are shown.

- An infrared camera, located inside the tabletop that is used for registering the objects that are placed on the surface.
- Four infrared LED bars, which provide appropriate lighting for object detection.
- A projector that points to a mirror that is placed inside the tabletop and reflects on the tabletop surface, which is the interaction area for the users.
- A personal computer connected to the projector and the camera, running the tangible interaction application.

IV. EXPERIENCES

The assessment process for ITCol was organized into three well-defined phases: Phase 1. Detective game's dynamic assessment phase, without using any computer technology; Phase 2. Informal ITCol software and hardware testing phase; and Phase 3. Formal assessment phase to analyze ITCol's dynamic and the scope of its proposed objectives.

A. *Phase 1. Assessing Dynamics*

First, a pilot experiment was developed to test the dynamic of the game that was proposed for development, without using ITCol. To carry out this test, no computer technology was used, and it allowed confirming the initial proposal and defining new aspects for the game. The group was formed by 5 players and the coordinator. The players were invited considering their different profiles, with background in either Educational Sciences (in particular, Educational Technology) or Computer Science. The detective's game was played, in a first phase, using only paper clues and later arguing verbally for solving the case. The session lasts one hour and an observer takes notes in a semi-structured template paying special attention to which elements of a collaborative dynamics were followed and which not.

The main observations resulting from this session were:

- During the session, players were allowed to keep their clues throughout the duration of the game. During the first stage, players skimmed through the information and then, during the discussion stage, they kept on checking that information, which resulted in players occasionally not listening to their teammates. This led to the conclusion that there should be a specific period during which players can read their clues, after which they should not be allowed to go back to them. Thus, players are forced to individually process their information, promoting one of the key aspects of collaborative processes; namely, individual accountability. Additionally, it was observed that the volume of information to be handled by each player can become overwhelming, so it was decided that players should have the possibility of selecting key pieces of their information to be used as memory joggers during the discussion stage.
- Clue illustration is important to successfully relate to characters involved in the case. It was observed that the players could not remember the names of the characters

and did not get involved with the story. Because of this, character and places objects were designed for ITCol.

- Collaborative dynamics was achieved. Players communicated among them, discussed the case, negotiated, and finally reached a solution. This allowed validating the game proposed as appropriate to achieve the expected collaborative dynamics. But it was also discovered that some players do not process the clues received and do not take into account his own individual responsibility in the process.

- At some point, the team reached a stagnation point, so the possibility of ITCol providing additional information to help them move forward was considered. The provision of additional clues and information about character relations were proposed as possible types of additional information. Besides, in this way it is wondered if it is possible to consider the objects, the tabletop and ITCol itself as important elements in the collaboration process to help to group metacognition skills. In order to get the team to discuss before making any decisions, it was decided that a penalization should be applied for a number of additional information requested.

B. Phase 2. Informal Software and Hardware Assessment

After validating the game, and with the first version of ITCol already available, informal tests were carried out. These are labeled "informal" tests due to their lack of structure, absence of pre-set times and lack of definition of specific user profiles. However, these tests have a series of tasks to be done by the users: watch the first video, interact with the characters and the clues, register key phrases using the pen, try the relations between characters (or places), test the special token and try the third stage answering the questions of the investigation. Informal tests were repeated several times until a stable version of ITCol was obtained. For these tests, various users (a total of 10 users) were asked to interact with the system following the logics proposed by the application. A thinking aloud method was used, so that, along the session, users had to verbally express the difficulties and positive aspects of the tasks. Most participants did not have any prior experience with Tangible Interaction-based software. These sessions were aimed not only at testing application stability, but also at analyzing application ease of use and operation. Users participated individually and two persons coordinate each session. During the sessions, one of the coordinators registers all the commentaries that the users say in a document and the other film the session to posterior analysis. Some of the users had already participated in the previous assessment phase, which allowed them to make contributions in relation to the advantages of using this technology for game dynamics and of using the character and places objects.

Below, the changes made to ITCol after the informal test sessions are listed, together with a brief description of the situation that led to them.

- *Change 1*. The option to return to the previous stage was added. This option is equivalent to requesting additional time for the already finished stage. This was included at the beginning of each new stage, and it carries degradation in team performance. Thus, players are forced to commit to their work and not to waste time.

- *Change 2*. Ability to rotate the information remembered by each player. During the second stage, to help players sitting at the sides of the tabletop work more comfortably, the possibility of rotating the information displayed by the "token" objects was added. Thus, when the object is rotated, the orientation of the text accompanies such rotation, which means that users can move the objects to read the information from their position (see Fig.2).

- *Change 3*. Change in interaction method, from “Touch with fingers” to “Touch with pen”. Initially, the method for selecting key information from each clue during the first stage was based on using a finger to touch the desired piece of information to be remembered, which resulted in a checkmark added to the corresponding text. Throughout the tests, it was observed that finger detection efficacy was variable. It worked correctly for some users, while it was more unstable with others. This depended mainly on two variables: hand position (producing shadows) and finger size. Therefore, the decision was made to use a pen to ensure uniform size and make sure no shadow was cast on the screen due to hand position. This change drastically improved application stability. However, the possibility of using the hand instead of a pen is an aspect that will be furthered studied.

- *Change 4*. Adding the option to view the solution. In the first versions, the solution was shown by default when the game ended. One of the users mentioned that she wanted to try again instead of being presented with the answer. A change was therefore introduced to offer the option to either see the solution or try a different answer. The team can make this decision based on the rules defined by the educator coordinating the game session.

During the informal test stage, in addition of introducing improvements to the prototype based on user observations and feedback, operation errors were also addressed.

C. Phase 3. Formal Assessment Sessions

Once the system had been adjusted, formal test sessions were planned. For these sessions, five work groups of four persons were formed (20 participants), including educators of various ages and disciplines that are students of the post-graduate subject for which ITCol was designed. Groups were called on different days, and each session had an approximate

Figure 5. Players interacting with the tabletop during the second stage.

duration of 1 hour. They have five minutes after the initial video to organize the group. Some groups planned a strategy in order to communicate during the second stage and others only talked about the video. Three techniques were used to gather information: observation, surveys, and interviews. After the five sessions, all the data analysis took place. We analyzed the videos of each session, the annotations and the surveys. In the following subsections, the results obtained from observing and analyzing participant interaction with the system are presented, as well as the results related to collaborative work situations that occurred during the experiments.

V. RESULTS

The results obtained during the assessment process are following analyzed, taking into account those related with interaction in first place, and then those related with collaborative work. A descriptive analysis was followed based on the observations, surveys and interviews data.

A. Interaction-Related Results

The existence of the tabletop as tool to solve the case allowed for case characters to become alive. Players shared the information collected from their clues as if they had actually talked to the characters. All the groups manifest that ITCol with the tabletop seem to be another member of the group because of the additional information given in strategic moments as a result of interaction with the objects (relation between objects and additional clues during stage 2). In general, players agree that the tabletop helps them and it favors the organization of the physical space to communicate to each other. The possibility of seeing the key phrases of two players (through the token object) at the same time helps in the analysis process of the case.

The tabletop allows only four persons to participate in each session because of its dimensions. Some participants manifested that they would prefer a taller tabletop. However team members maintained their motivation throughout the session, and interaction with the tabletop was appealing and novel to them, as well as natural. No detailed use instructions were required. Individuals were able to work intuitively.

The use of the pen to select objects was successful. Participants did not require any explanations on how to use it.

B. Collaborative Work-Related Results

In the first stage, during which each player is asked to remember the information they considered most relevant for the case, participants successfully realized that individual accountability was important. Each participant felt like an essential member of the team and considered his/her knowledge to be equally important as that of their teammates. In this regard, all groups said that it is important for this game in particular to distribute the objects strategically so as to balance the information provided to each participant. Unlike the first evaluation of the game's dynamic (without ITCol), in this case stands out that all participants expressed to feel their individual responsibility for solving the problem, During the first stage, different behaviors were analyzed; some participants interacted first with all his characters (or places) object, and then selected key phrases. Other participants selected key phrases, as they were interacting with each object, without knowing all the information. It was noted that the two strategies were successful in the sense that, in general, were able to record the essential information for the case, however, it is considered that the first gave better results in terms of selecting more strategic key phrases to the case, and showed better information processing. In only two cases was observed that participants omitted key information relevant to the case, and then could not be retrieved, so influenced the result reached by the group. This served to deal with students, after the sessions, the importance of individual responsibility in the processing of initial information. It was observed that when the team met to work collaboratively (Fig. 5) and discuss the solution, two types of strategy were used: in one of them, when a player mentioned his/her information about a character, the other players who also had information about that character made their contribution without waiting for their turn to speak; in the other, players took turns to speak based on the position they had around the tabletop. Later on, when analyzing team performance, it was observed that the strategy used affected the end result of the team. The former had better results in terms of achieving a proper resolution of the case.

The game allowed generating the collaborative dynamics required for the objectives posed. Also, the use of this technology allowed carrying out game dynamics without distracting the team from their goal; session development was recorded in a log file. During the interviews, users highlighted the importance of the selected communication strategies in order to achieve the resolution of the problem (collaboration skills).

All users agreed to identify the components of a collaborative activity during the experienced processed. Some of the aspects pointed out by the participants during the interviews and inquiries are: individual responsibility related to the necessity of a suitable initial processing of the clues for arriving to the solution; the required contribution of all the members to achieve the solution (positive interdependence); the also required communication, the interchange of information about a case's character o place, the relationship between clues given by different characters (developer interaction); and the coordination of the team for communication and decision making. Regarding team coordination, it is important to highlight that the leader spontaneously emerged in each team and that in some cases, the leadership was shared by two persons.

Also, participants considered that the helps given by the relationship of two characters, or a character and a place, and the extra clues (when no agreement was possible), allowed the team to generate new hypothesis or to reject the wrong ones and to give up the stagnation. The work with physical objects was considered important in the collaborative process, since they allowed students to be involved in the case (this fact didn't happen during the assessment session without ITCol).

Finally, it must be said that all the participants would recommend this experience and would like to take part in similar sessions. The motivation was very high and the participants showed their interest in proposing new ideas for

the game. We are currently working on the design of an application that allows using the log file as input to obtain the information required by educators to review the session. There are still new questions to answer regarding when the participants decide to inquire about relationships between characters and / or places, how these requests relate to the collaborative process, what other metacognitive clues ITCol could offer to assist the development of collaborative group process, among others.

VI. CONCLUSIONS

We presented the design of an educational game that makes use of tangible interaction on a tabletop to solve a detective case. This work is part of a research project that studies the use of various human-computer interaction paradigms in educational contexts. In particular, the field of Tangible Interaction and Education is tackled. In this sense, ITCol, the game presented, achieves a positive contribution in:

- The use of tangible interaction in educational scenarios with adults, since available developments are in general oriented to children or teenagers.
- The possibilities offered by tangible interaction when using a tabletop for collaborative work and learning.
- The role of the objects, the tabletop and the application during the collaborative process.

On the other hand, this has been the first step to introduce tangible interaction to educators in a post-graduate course. This opened up a road of interest for this area and an authoring tool is now being developed for educators to be able to create their own tangible interaction-based activities. Meanwhile, a more rigorous and objective assessment is being carried out, either in methodology as in number of persons. We are currently working on these aspects, which will be the topic of future publications.

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