Pupils' Collaboration around a Large Display

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Abstract— **Collaboration is acknowledged as a key element of learning. Thus, it is valuable to develop Information and Communication Technology applications that, being implemented on proper devices, can support collaborative learning. Large multi-touch displays appear to encourage collaboration by offering users a shared environment to act upon. However, little knowledge is available on the actual influence of this technology on human behavior and more empirical evidence is needed to better understand its capability to foster collaboration. This paper provides a contribution in this direction by presenting a field study that helps understand collaborative practices of pupils playing an educational game that runs on a multi-touch large display. This study involved 98 fifth-graders at a primary school (average age 10 years old). Results confirmed the potential of large displays as useful devices for collaborative learning.**

***Keywords*—Technology-enhanced learning; large multi-touch display; educational game; field study.**

I. Introduction

In the last few years, several publications reported and discussed studies investigating how Information and Communication Technology (ICT) can support children learning (e.g. [1-3]). Along this direction, we focused on primary school education in ancient history, especially because Italy has a rich source of cultural heritage, with historical sites dating back to centuries B.C. Our approach extends formal learning activities (classroom activities), with field visits and games to be played in situ [4] or in the school [5]. We focused on collaborative games, which are considered a valuable form of informal and collaborative learning, able to capture pupils' attention and engage them (e.g., [1]). Numerous benefits have been identified for collaborative learning. In particular, it helps developing a social support for learners and creating learning communities (*social benefits*); it generates positive attitude towards teachers and reduce anxiety (*psychological benefits*); it actively involves students in the learning process and improves classroom results (*academic benefits*) [6]. Specifically, collaborative games require different skills at the same time and each player can practice those ones felt to be the most congenial. By acting together, pupils can solve problems, overcoming difficulties thanks to their joint efforts. In addition, games create a pleasant learning environment, in which pupils learn with fun. Innovative technologies, such as mobile devices, interactive large displays and multimodal interfaces, can make the environment more engaging [1]. For example, the excursion-game technique discussed in [4] uses mobile devices and permits the development of educational pervasive games to be played by groups of young visitors, exploring sites of cultural interest, such as archaeological parks.

Literature reports examples of applications of large displays that foster synchronous and co-located collaboration [7]. Their size has the potential to accommodate more people in front or around the display. Thus, they can stimulate simultaneous participation in learning activities, promote engagement, allow to share control and responsibility over the manipulation of learning material [8]. However, more empirical evidence is needed to better understand the collaborative practices of learners around a large display and how such practices are organised and managed by learners. This paper gives a contribution to this issue by presenting a field study, whose goal was to investigate how pupils behave around multi-touch large displays. Small groups of pupils were observed while playing an educational game on a multi-touch vertical display installed in their school laboratory. The study involved a total of 98 pupils of six different fifth-grade classes at a primary school. We also compare and contrast our results with related work, analyzing how display features may affect pupils' collaboration.

The paper is organized as it follows. Section II discusses related work. The motivation for developing the educational game is presented in Section III. Section IV describes the study and discusses its results. Finally, Section V concludes the paper.

II. Display Features Affecting Collaboration

Large interactive displays are increasingly used; a comprehensive review is reported in [7]. By analyzing the literature, features of such displays that affect people collaboration are briefly discussed in this section.

A. Simultaneous use actions

Over a decade ago, Scott and his colleagues proposed a set of guidelines for co-located collaboration around a tabletop display [9]. A guideline that clearly emerges from users' feedback and is relevant for any type of large display is "support simultaneous use actions". This is a primary requirement, since people collaborating in a task want to interact simultaneously with artifacts on the display. It affects both hardware and software. The hardware must provide either multiple input devices or touch screens capable to detect multiple touches occurring at the same time. The software must support the interactions with

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multiple components at the same time. A notable example is *DiamondTouch*, a tabletop display that, beside allowing multiple concurrent users, is capable of identifying the touches of a specific user [10].

Another system that permits multi-user simultaneous interaction is *CityWall*: it detects more finger touches at the same time as well as hand touches. For example, in order to rotate a picture shown on the display, the user puts his hand on top of the picture and rotates his hand. The large display of CityWall allows people to browse photos and videos downloaded from social networks like YouTube and FlickR [11]. A study was performed with the system installed in a shop window next to a café in the center of Helsinki, Finland [12]. Data on 1199 people were collected. They showed that the large display enabled collaborative activities of different groups, who used the system in parallel, possibly for different tasks. In several cases, groups of strangers ended up socializing and having fun together, even if they started interacting separately. Several other studies performed in the last years show that the multi-user interaction possibilities offered by large display allow different people to work in parallel [7].

B. Display set-up

A feature that has a considerable influence on people collaboration is the display set-up, which refers to the physical installation of the display, characterized by size, orientation and shape [7]. Vertical flat displays are the most used so far. The horizontal orientation, i.e., a tabletop display, is frequent in locations like offices and museums, since users can interact for a long time while comfortably sitting around the display. Thus, it appears especially appropriate for collaborative tasks [13]. However, it also presents some inconveniences, because two users sitting on the opposite sides of a tabletop display see contents reversed with respect to each other. An interesting proposal for overcoming this problem has been recently presented in [14]: by wearing active shutter glasses, each user can see her/his private view, while the shared view is visible to everybody. Thus, users can collaborate in the manipulation of the shared information. Rogers and Lindley studied collaboration around vertical and horizontal large interactive displays [15]. They found that horizontal surfaces better support collaborative activities that closely couple the resources used and/or created during the various activities. On the other hand, vertical displays are better at providing a shared surface that allows a group of people to view and annotate information to be talked about and referred to. The vertical display gives all viewers the same perspective of the task and provides a holistic view of the data. A more recent study challenged this view [16]: by analyzing the users' performance and their satisfaction with vertical and horizontal set-ups, the authors reported a strong preference for the horizontal set-up (probably due to decreased fatigue). People who preferred the vertical surface appreciated that it provides a better overview and that hands less likely occlude objects on the screen.

Other studies experimented displays with diagonal orientation, showing that they improve the interaction of the user(s) placed at the lowest side, since the display provides a better viewing angle, but greatly limits the collaboration with users standing at the other sides, even if they have a common task to perform [13] [17].

Systems with spherical or cylindrical displays have also been proposed; they were compared in [18]. With both spherical and cylindrical displays, each user can see at most one half of the display. Thus, these displays, rather than fostering collaboration, allow different users to interact without disturbing each other and preserving their privacy.

C. Application purpose

The effect on collaboration determined by the purpose of the application running on a large display, i.e. related to the tasks users perform, is evident in the field study reported in [19]; it investigated the use of *Tourist Planner*, an application on a tabletop display, installed in the tourist information center in Cambridge (UK), which supported groups of people planning their trips The study showed that the system acted as an aggregator for a group of people coming together in the information center. They interacted together with Tourist Planner, collaborating to define their itinerary, rather than being dispersed in the environment, as usually occurred.

Some applications were designed to foster classroom collaborative activities through multi-touch tables. Piper and Hollan, for example, compared the use of the digital material through the tabletop with the use of paper material, in order to investigate how the study practices are influenced, including student participation and cooperation, in a neuroscience class of 20 undergraduates at the University of California [20]. Results revealed that the large, shared nature of the tabletop display allows student to have equal access to material and engage in parallel activities. Moreover, the use of the digital material on the tabletop provided greater playfulness and enjoyment were noticed.

TablePortal is a system that allowed teachers to manage and monitor collaborative learning of students working with multi-touch tables [21]. The teacher used a separate table to communicate with the students' tables; in this way, teachers and students could work together on their multi-touch tables and collaborate on learning tasks. Observations in a real context showed an enhanced level of teacher's awareness, flexible monitoring, and a positive impact on social interactions in the classroom.

Another example of successfully use of multi-touch technology for learning is reported in [22]. Comparing pair-programming learning through multi-touch technology with learning using a desktop, this study revealed that students performed better working at the multi-touch table, because it encouraged collaboration and helped people expressing their potential.

D. Location

Nowadays, large displays are installed in different locations, either public (a city street, a museum, a university campus, etc.) or semi-public (an office, a school, etc.). The location strongly affects the behavior of people in the environment around the display. In semi-public locations, most people know each other and could thus be less inhibited to work together [23]. If the display is installed in a location where people do not know each other, an initial time span is observed in which people are a bit reluctant to approach the display [24], but, once they start interacting, in most cases they soon socialize and collaborate with each other.

III. THE EDUCATIONAL GAME

The value of games for learning purposes is predicted by several pedagogical theories and confirmed by some studies showing how ICT can be used to engage learners with e-games (e.g., [2]). In her recent book, Oviatt reports an in-depth review of educational technology [1]. She provides evidence that interactive games lead to learning improvements of about 10–40% when compared with traditional lessons.

In our research, we built upon the Discovery Learning technique, defined by Bruner in his Constructivism theory [25], to propose an educational format that integrates formal learning (classroom lessons) with informal and technology-based learning [5]. The educational format organizes learning activities in three phases, in which pupils acquire new information: 1) attending the lesson(s) by their teacher in the classroom (*symbolic phase*), 2) acting in a real context (*active phase*); and 3) interacting with technological tools to manipulate visual images or tactile objects (*iconic phase*).

The format was experimented with pupils aged 10 years old. The goal was to foster history learning, stimulating pupils' interest in cultural heritage. The three learning activities were the following: 1) pupils attended a classroom lesson, in which the teacher provided basic notions on the history of Egnathia, an ancient Roman city in Southern Italy (symbolic phase); 2) pupils visited the archaeological park of Egnathia, in which they observed its ancient monuments and objects (active phase); 3) pupils played an educational game, called *History Puzzle*, implemented on a large multi-touch display available in the school laboratory (iconic phase).

In collaboration with teachers and pedagogues, we decided to adopt a collaborative learning approach, whose benefits are discussed by many researchers (e.g., see [6]). Specifically, collaborative learning refers to an educational method that involves groups of individuals, acting together in small groups to achieve a common learning goal. Consequently, we implemented History-Puzzle on a large interactive display, in order to allow small groups of pupils to play together. According to the simultaneous use actions requirement, our system recognizes the gestures performed simultaneously by the hands of multiple pupils.

The game proposes puzzles that pupils have to solve in order to discover monuments and/or other objects, which were presented by the teacher during the lesson and that pupils had seen during a visit to the archaeological park of Egnathia. The puzzles show the 3D reconstruction of the points of interest in Egnathia, allowing pupils to appreciate the original look-and-feel of archaeological ruins. The figure to be discovered by solving the puzzle is shown at the center of the screen. The nine square tiles of the puzzle contain incomplete sentences reporting historical notions about the selected place. For each tile of the puzzle, the players choose the tile with the rest of the sentence among those displayed on the left and right sides of the puzzle, and drag it onto the puzzle tile. In the example of Figure 1, which refers to the puzzle of the "Basilica Episcopale" ("Civil Basilica"), the tile with the sentence "Era un edificio con …" ("It was a building composed of…") is associated to the tile "… tre navate" ("three naves"), located at the top right corner of the display, which correctly completes the sentence. If the selected association is the right one, the tile reveals one ninth of the 3D reconstruction of the original place.

A score of 5 points is awarded if the tiles are correctly associated, while the current score is reduced by 2 points every time the pupils move a tile onto the wrong one. This score mechanism stimulates pupils to reflect upon their actions and leads them to discuss together the tiles they have to associate. The current score is permanently displayed at the bottom of the screen, just under the puzzle (e.g., "Punteggio: 30" in Figure 1). In order to make the game more challenging, some tiles report false answers or answers that do not match any of the nine incomplete sentences in the puzzle. When the puzzle is completed, a new screen proposes various multimedia contents related to the building, such as sounds, videos, images and texts. Then, the system returns to a screen showing the map of the park, where participants can choose the next puzzle. Once the game is over, the final score is displayed. History-Puzzle was deployed on a MultiTouch Ltd 46-inch large Full HD LCD display, with vertical orientation.

Figure 1. The "Basilica Episcopale" puzzle.

IV. FIELD STUDY

The data presented in this paper were collected as part of a wider study, conducted from November 2011 to January 2012, whose main goal was to evaluate the learning effectiveness of the educational format described at the beginning of the previous section. As reported in [5], the study showed that pupils were actively engaged in all educational activities and that the game was a valid means for consolidating the acquired knowledge. In this paper we concentrate specifically on the iconic phase, in which groups of pupils interacted with History-Puzzle. This analysis had another specific goal, namely to investigate how pupils behave around the multi-touch large display. This analysis was not reported in [5] and it is described in this paper. From now on, the study we refer to is about pupils playing with History-Puzzle, addressing the latter specific goal.

A. *Participants and procedure*

The study involved six classes of fifth-graders at the primary school "Clementina Perone" in Bari, Italy. A total of 98 pupils (50 girls, average age 10 years old) participated in the study, as part of their school activities. The overall study described in [5] involved a total of 107 pupils, but 9 of them did not participate in the iconic phase, since they were not at school when this phase was performed.. The participants were divided into 22 groups (12 groups of four and 10 of five pupils). The groups were decided by the schoolteachers, who also aimed to guarantee homogeneity in terms of the pupils' cognitive and social development. Parental consensus was obtained prior to the study.

On November 24th and 25th, the groups took turns to go to the school laboratory to play History-Puzzle, 10 groups the first day, the remaining 12 groups the day after. Three researchers were involved in the study. One of them interacted with the pupils, explaining how to interact by hand gestures and the task objectives. The other two observed and provided technical support if needed. Each group had to solve three puzzles. The interaction with the multi-touch display was videotaped by two cameras. Camera 1 was installed on a tripod about two meters away from the display to film the pupils' behaviour. Camera 2 was placed on top of the display to film the pupils' faces while they interacted with the system. Pupils' comments and utterances were captured by an audio recorder next to Camera 2. Moreover, two research assistants noted down the main events and provided help when explicitly requested or when pupils were not able to continue playing.

B. *Data analysis*

The collected data included videotaping of the groups' interactions and notes from observation in the laboratory. In order to better analyze pupils' behavior, three researchers transcribed the videos, literally noting down all intelligible speech and details of all instances of their interaction with the multi-touch display. Moreover, contextual information was coded: for each group member the level of involvement in the game and his/her position in front of the display were considered. The transcripts were analyzed by a thematic analysis following a semantic approach: themes were identified within the explicit or surface meaning of the data, based on what participants said or did during the game [26]. Each researcher independently produced the transcripts, and 60% of the results were double-checked for reliability, leading to an initial value of 85% for all measures reported in this article. Discrepancies were solved by discussion.

The analysis highlighted two important themes related to group strategy and anti-social behavior. Group strategy addresses the pupils' behavior while playing together as a group, showing common patterns and reflecting on their causes and consequences. The anti-social behavior theme provides an overview of the cases when pupils did not directly contribute to the game, either because they chose not to or because they were hampered by the others. This theme also investigates the causes of conflicts during playing or deliberate attempts to disrupt the game.

C. *Results*

Three researchers analyzed a total of 5 hours 46 minutes of videos recorded during the study. This included the arrival of the groups, game presentation, time each group interacted with the display to play the game, i.e., to solve the puzzles, look at the multimedia shown at the end of each puzzle and see their final score. In particular, the 22 groups took 3 hours 58 minutes to reassemble 65 puzzles (3 puzzles per 21 groups, plus 2 puzzles for a group who experienced technological problems). On average, a group spent 4,15 minutes to reassemble the first puzzle, 3,37 minutes to reassemble the second puzzle, 2,6 minutes for the third one.

Group strategy

The game was composed of two consecutive activities: *tile association* and *tile positioning*. Tile association was a problem-solving activity: pupils looked at the display discussing within the group the solution of the riddle, which would identify the correct association between tiles. Tile positioning was the physical action performed to overlap the tiles. Tile association required reading information from the display and identifying the correct answer; positioning required pointing and dragging.

Generally, the groups were well organized in performing the game. They mainly applied the following strategy. For each individual tile, they first read the riddle and discussed the answers. Positioning tended to occur only after reaching group agreement. Only 3 groups experienced some problems when solving the first puzzle. They appeared disorganized and unable to choose how to analyze tiles, which tiles to associate and who should move them. At the beginning, these pupils mainly played individually, reading and moving different tiles of the puzzle with little or no group interaction. Yet this state of affairs tended to disappear quickly and, afterwards, these groups identified a better strategy for solving the remaining two puzzles.

Tile association was a clear collaborative activity, articulated as follows: 1) as soon as a pupil started to read the text in a puzzle tile, the whole group read it in unison; 2) a pupil proposed an external tile to be associated; 3) pupils discussed together if they confirmed the proposal, 4) the tile to be moved was chosen; otherwise, they went back to step 2). Excerpt 1 reports a discussion occurring in Group 20.

Each pupil is denoted by a capital letter.

EXCERPT 1 - Group 20
A reads the text in a puzzle tile: “The Amphitheatre was…”. Then A reads the text of a tile to be associated “Rectangular”.
C: "Do you know the Amphitheatre? It was elliptical! It was not rectangular, as you said! So the right tile is this! [indicating a specific tile].

Generally, tile association was performed by the whole group without touching the display. If a pupil moved a tile without the permission of his/her classmates, he/she was scolded by the group, especially if the tile was wrong. Only in 6% of the cases (i.e. to solve 4 puzzles), a group split into two sub-groups, each of which took care of associating half of the tiles. Specifically, pupils divided the display space into two parts and each sub-group concentrated on the tiles displayed in front of them. The pupil behavior in each sub-group was the same. According to [27], this strategy is defined cooperative (pupils cooperate): group members split the work, solve sub-tasks either individually or in subgroups and then assemble the partial results into the final output. Instead, the strategy is collaborative (pupils collaborate) if group members do the work 'together'.

Tile positioning was performed by one pupil on behalf of the group. Two behaviors were observed: *spontaneous* and *organized*. The spontaneous behavior refers to the situation in which tile positioning was not defined a priori and a child naturally moved it. Thus, after tile association, either the pupil who identified the tile would move and overlap it on the puzzle tile or any pupil would move the identified tile because he/she was the closest to the display or the fastest to act (see Excerpt 2). This behavior was observed in solving 31% (i.e. 19 puzzles) of the puzzles. It is worth mentioning that this spontaneous behavior did not generate any confusion or disturbance in the group; instead, it was a sign that the group actually collaborated in harmony.

EXCERPT 2 - Group 7
The group discusses tile association, selecting the correct tile to be moved, as indicated by child C who reads the tile text: C: “Curbstone!”
D is the closest to the tile with text “Curbstone”.
C tells D: “Give me “Curbstone”.”
D takes the tile and moves it closer to C.
C completes the tile positioning.

Excerpt 3 shows a situation in which a child complained because he/she was not allowed to position a tile.

EXCERPT 3 - Group 15
The group reads a puzzle tile in unison.
A selects an external tile and reads its text.
B moves another tile and the association is not accepted.
C moves the same tile of B and again the association is not accepted.
D identifies another tile.
B, who is the closest to this tile, moves it
D exclaims: “Oh, nooo. I should move it!”

To avoid complaints, pupils turned to an explicitly organized behaviour, taking turns in positioning a selected tile. This often occurred around 60% (i.e. 37 puzzles) of the puzzles. Excerpt 4 illustrates a typical case.

EXCERPT 4 - Group 15
The group is discussing a tile association.
D autonomously positions a tile.
B to D: “Please do not do that again!”
A: “Let's take turns!”
D: “That’s right!”
A: “OK. The order is: me, Francesco, Giovanna and Vito.”

In 10% (i.e. 6 puzzles) of the puzzles, a different turn-taking was observed. Specifically, a pupil selected a puzzle tile to be associated. The discussion began and the group selected the external tile providing the correct association. The pupil moved the selected tile. Excerpt 5 illustrates this behavior.

EXCERPT 5 - Group 18
C: “Francesco [i.e. D] is the first: he must read and move the tile. Then, Giulia, …”
D: “They could go in through two different entrances…”
A: “Rectangular!” [pointing to the tile]
C: “Nooo, Symmetrical!!” [pointing to the tile]
B: “Yes, symmetrical!”
D moves the tile.

In some cases, pupils had to solve technological problems. The display used during the study is less sensitive at the borders and in a central strip about two centimeters wide. This makes the interaction with the displayed objects more difficult at these points. Once they understood how solving such problems, pupils collaborated to overcome them. Figure 2 illustrates an example in which two girls moved the tile together to overcome the less sensitive central strip.

Figure 2. Girls move together a tile to overcome a technological problem.

Anti-social behavior

Generally, all pupils participated in the game, collaborating with the others in the group. However, a careful analysis of group dynamics revealed some episodes when pupils appeared not to be collaborating for a short time, but soon they were stimulated by the other group members to be more active. The following three different behaviors were identified: 1) *hindered*, i.e., a pupil tried to interact with the display, but the others hampered her/him; 1) *disturbing*, i.e. a pupil bothered the group or encumbered the game activities, especially because he/she wanted to be the only one to interact with the display; 3) *onlooking*, i.e. a pupil watched the others playing (discussing and interacting with the display) without contributing. Table I reports the number and the percentage of the episodes in which such behaviors were observed.

TABLE I. NUMBER AND PERCENTAGE OF EPISODES REVEALING NOT COLLABORATING BEHAVIORS.

	Episodes	
Pupil behavior	***N***	***%***
Hindered	5	19%
Disturbing	10	37%
Onlooking	12	44%
Total	***27***	***100%***

A hindered pupil was observed only in 19% of the not collaborating behavior episodes. Figure 3 shows a girl who would like to interact with the display, but her classmates do not allow her to reach a better position to touch the display. However, she was active in tile association providing suggestions for selecting the tile.

Figure 3. The girl at the back is hindered by her classmates.

A disturbing behavior emerged in 37% of the not collaborating episodes. The disturbing pupil tried to prevail over his/her classmates with gestures like blocking the others to prevent them from touching the display (Figure 4). However, he/she was always scolded by his/her classmates and went back to a more collaborative behavior.

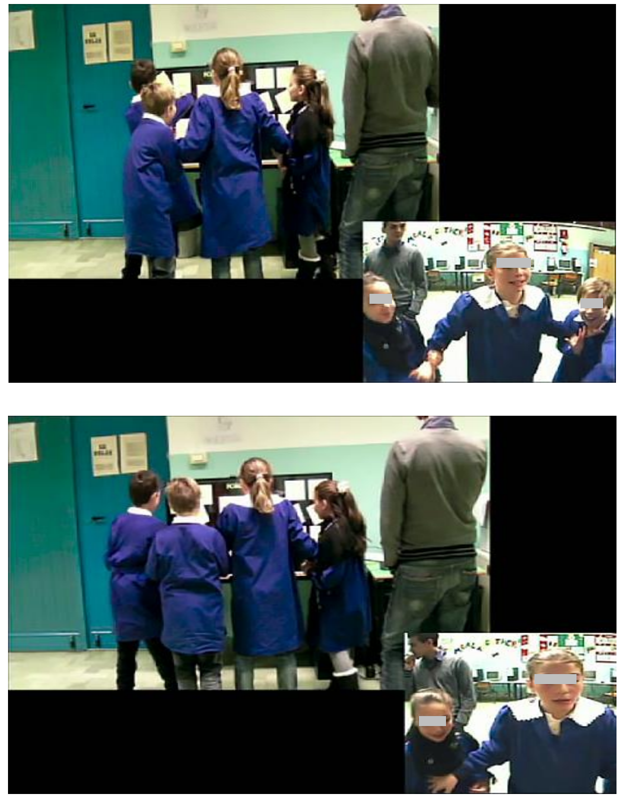

Figure 4. The girl at the center pushes away her classmates in order to interact with the display.

Finally, an onlooking behavior was noticed in remaining 44% of the episodes. Typical behavior of the onlooking pupil is having his/her hands behind his/her back (as in Figure 5) or in his/her pockets. Soon classmates tried to stimulate the onlooking child to be more active. In all cases, he/she returned to actively participate in the game.

Other episodes of anti-social behaviors occurred when pupils quarreled during the game. We observed only 15 episodes of conflicts among pupils. Specifically, 10 conflicts were related to social interaction and arose when a pupil did not observe his/her turn in interacting with the display, for example, because he/she was closer to the tile to be moved than the pupil whose turn it was. However, the other group members scolded him/her and re-established the right order, as illustrated in Excerpt 7.

EXCERPT 7 - Group 23
B: “Please, we have to go slowly!”
C: “We have to take turns! Simona starts!”
E tries to move a tile.
C to A: “Oh, Diego it isn’t your turn! You must not touch the display! Simona has to move the tile!”

Figure 5. An onlooker attitude of the boy with his hands behind his back.

The remaining 5 conflicts arose because of the pupils' position in front of the display (physical space). Such conflicts occurred more in groups of 5 (4 conflicts in 2 groups of 5, 1 conflict in 1 group of 4), also because the display was not large enough to comfortably accommodate all pupils in front of the display. Specifically, in the groups of 4, pupils were well positioned in front of the 46-inch display next to each other. Thus, they maintained their position since they could read the tiles and interact with all the objects shown on the display. Rarely, a pupil at the side of the display moved towards the center.

In groups of 5, it happened that a pupil was forced to stand behind the others or in a peripheral position, not convenient for interacting with the display, thus he/she tried to reach a better position by pushing the other pupils. In fact, it was observed that pupils being at the center were more active, since they could easily read the text in the tiles and reach them. Figure 6 shows a sequence of images in which a girl initially behind her classmates tries to acquire a better position to be able to interact with the display. However, pupils were able to manage such conflicts autonomously: the teacher intervened just twice to deal with physical space conflicts.

D. Discussion

The analysis of the data collected during the study confirmed what other authors report in the literature (e.g., [20-22]), namely that educational applications running on large multi-touch displays provide a shared experience for learners by facilitating social interaction and collaboration among them. In order to play the game, pupils worked together, solved problems emerging during the game, and exchanged information among themselves. Thus, with respect to the objective of our study, which intended to investigate about pupils' collaboration behavior, we can conclude that the educational game implemented on the large display fostered collaboration, particularly in the problem solving activities related to tile association.

The obtained results also permit further comparisons with related literature, by analyzing in more details which display features primarily acted as collaboration promoters. Table II summarizes these findings. As discussed in Section II, support for simultaneous use actions is considered as a primary requirement for allowing people to collaborate in the interaction with the display. In our study, however, students spontaneously swapped to a sequential use pattern in the interaction with the technology, thus showing that the simultaneous use actions requirement was marginal. Several factors can explain this behavior, including the task at hand, but we believe that the technology by itself could have afforded this behavior [28].

TABLE II. DISPLAY FEATURES FAVOURING COLLABORATION.

Display feature	***Collaboration promoter***
Simultaneous use actions	Marginal at this stage
Display orientation	Yes
Display size	Yes
Application purpose	Yes
Location	No evidence

Pupils appeared to be very excited by the multi-touch technology and all of them were keen on moving the tiles. They spontaneously adopted a sequential approach only to avoid conflict and to equally interact with the display. The group collaborated in the identification of the right answer, and then a designated "user" mediated the interaction with the display. Another reason for the sequential tile positioning was related to group performance. If a tile was improperly moved, the group score decreased. Indeed, the group required the control of tile positioning. If a member moved a tile without the group consensus, the others members scolded him/her. Nevertheless, the possibility of performing simultaneous actions was exploited to overcome technological issues: children effectively collaborated to overcome a problem, as in the case of pupils moving the tile together in Figure 2.

Concerning the display set-up, orientation and size revealed as collaboration promoters (see Table II). The vertically positioned display favored the view of the visualized elements to the players, who were all able to read the tile contents and collaborate in tile association. The display used in the study was of 46-inch size; it worked very well for groups of 4 pupils, since they could stand in front of the display very comfortably. In groups of 5, pupils moved more frequently to obtain a better position to interact with the display. Indeed, more conflicts about physical space occurred in groups of five.

History-Puzzle was designed with the purpose of promoting pupils' collaboration. It succeeded in this, since the results showed that pupils strongly collaborated, primarily in tile association. Moreover, as reported in [5], teachers highlighted that the multi-touch display favored pupils' inclusion (i.e. the involvement in the school activities of all pupils, regardless of social, cultural and personal differences [29]). Teachers remarked that even those pupils, who in class seem disinterested and tend to distract, actively participated in the game, provided appropriate answers and collaborated in the group activities with enthusiasm.

Figure 6. A girl trying to acquire a better position to interact with the display.

Based on our study, there is not evidence that the location influenced pupils' collaboration, because no comparison between different locations was carried out. However, teachers commented that, when working in the laboratory with desktop computers, usually pupils work individually or, sometimes, in pairs [5]. Once the large display was available in in the laboratory, they enjoyed working in larger groups and collaborating with their peers.

V. CONCLUSIONS

This paper has presented the results of a field study whose aim was to investigate collaborative practices of pupils playing an educational game implemented on a multi-touch large display. The study confirmed that such displays encourage collaborative activities. It also showed that size and orientation of the display and purpose of the application running on it were the features that most affected pupils' collaboration.

The performed study was based on qualitative data. Some researchers claim that quantitative methods are better than qualitative ones, since the former provide objective measurements and enable replication of studies, while the latter build on subjective interpretation. This is not true if qualitative data are analysed with methods that ensure the necessary objectivity and soundness [30], as done in the presented study. It is actually suggested to first perform qualitative research when the objective is to explore a new area of interest and to possibly discover diversity and variety [31]. Once enough insight is gained, it is possible to frame the design and analysis of a quantitative study to provide better indications of the magnitude of the researched phenomenon. We are confident that the research presented in this paper will stimulate further work toward a deeper understanding of the influence of large display on collaboration activities.

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