

Stimulating cooperative and participative learning to match digital natives' needs

Large multi-touch-screens as cornerstone of pervasive classrooms

Alessandra Agostini, Elisa Di Biase, Marco Loregian

DISCo

University of Milano Bicocca

Milano, Italy

e-mail: {alessandra.agostini, marco.loregian}@unimib.it; e.dibiase@campus.unimib.it

Abstract—The school system suffers for being largely based on the concept of teaching as mere transmission of knowledge, with little active participation of students in the educational process. Moreover, children of the 21st century are born in a multi-media digital world and ask for adopting new technology-enhanced tools in the classrooms, in order to be engaged and motivated to learn. Our research moves the first steps towards a pervasive classroom allowing cooperative and participative learning, which could increase students' engagement and attainments. We start our work by designing applications suited for large interactive (touch sensitive) screens, aiming to stimulate new cooperative learning opportunities in classrooms.

Keywords: *single-display groupware; cooperative learning; collaborative learning; participative learning; multi-touch technology*

I. INTRODUCTION AND MOTIVATION

Cooperative and social learning (i.e., participative learning) have been a matter of discussion and experience for many years now [2, 9]. Despite research demonstrating the benefits of participative learning, still the educational world is permeated with the misleading concept that teaching means only to transfer notions and capabilities as well as cultural and moral values from teachers to students. This conception has been generating a sharp dichotomy between teachers and students, as the knowledge flow is strictly unidirectional: from teachers to students, who are accustomed to passively assimilating the lessons. On the contrary, participative or social learning approaches shift the focus “from the content of a subject to the learning activities and human interactions around which that content is situated.” [2]

Moreover, children of the 21st century have been part of a multi-media digital world from birth. As digital immigrants are used to electricity power, the digital natives' generation is comfortable with technologies [13]. Digital natives are accustomed to communicate by using simultaneously various media (e.g., chatting on PC, texting on mobile phone, etc.). They collect information and build their own knowledge exploiting multiple sources: not only family, school, and books but also TV, DVD, and the Internet. Even preliminary neurological studies show that they are able to handle multiple stimuli concurrently better than digital immigrants

are. The day-by-day world of digital natives is multimedia and permeated of digital technologies while, in some way, school is still mostly clung to chalks and blackboards.

The gap between digital natives' generation and the actual out-of-date school asks for adopting new technology-enhanced tools in the classrooms. Tools that support new ways of teaching, engage students, and stimulate their active participation to the lessons. In order to penetrate the digital world of the new generations, which are nourished of clicks and buttons [3], a complete redesign of the classroom and its educational tools is needed. In this new learning environment technology —permeating all the activities— disappears within school desks, walls, and all objects of the classroom.

Our research attempts to move the first steps towards a pervasive classroom, stimulating new pedagogical practices and, more specifically, allowing a cooperative and participative learning, which could increase students' engagement and attainments. We start our work by focusing on applications suited for large interactive screens, or Interactive WhiteBoards (IWBs), with multi-touch technology. In fact, in recent years, the usage of large interactive screens is considerably increased thanks to the consolidation of equipments as well as the reduction of their cost. Large interactive screens are used in different situations for a wide range of purposes: organizations adopt large screens to facilitate group activities and circulation of knowledge (e.g., [5, 18]); interactive walls begin to populate our cities (e.g., [11]); finally, school buildings and classrooms are equipped with large screens for enhancing the social and learning experiences of students (e.g., [10, 15]).

From the teachers' viewpoint, the use of IWBs in the classroom provides new opportunities to both *teach creatively*,—e.g., thanks to the multimedia content— and *teach creativity* [20]. From the students' point of view, children of the 21st century are comfortable with technologies and their experience must be exploited in the learning environment [7].

IWBs seem to stimulate a more decentralized role for the teacher as facilitator and knowledgeable guide. These tools facilitate a co-learning approach to education, where teacher and pupils work together, rather than adopting the usual formal roles. This can induce more independent and self-directed learning [7]. IWBs, by nature, support a beneficial knowledge sharing across the whole class. Collaboration in building this knowledge could be stimulated by adopting

multi-touch technology, which allows a simultaneous use of the tool by small groups of students.

Taking into account these considerations, the main goal of our project is exploiting at best the affordances of multi-touch technology, which allows new cooperative learning opportunities in classrooms, while consolidating the verified benefits of using IWB with single-touch technology.

II. BACKGROUND WORKS ON LARGE INTERACTIVE DISPLAYS

A. *Impacts of Multi-touch Technology on Interaction and Collaboration*

Large multi-touch surfaces have several natural affordances, which can simplify small group collaborative work, establishing new ways of interacting. First of all this kind of devices allows multiple-user interaction, involving all group members to interact with the display at the same time. Then it is possible to support natural gesturing, helping users to notice their partner's actions, providing rich interpersonal interactions, enabling users to both impart and understand each other's intention seamlessly. The naturalness of these interactions allows exploiting our existing capabilities for interaction in the physical world in the digital domain [6].

For example, the multi-touch features of CityWall [11]—a large interactive vertical display installed in Helsinki—were central for supporting expressive gestures, that helped participants in coordinating and communicating. The size of the surface and its multi-touch features support bodily interactions with the display, allowing to be expressive towards other participants, and helping them to take up roles and to negotiate turn-taking as well as different kinds of collaborative activities [11].

A larger display area gives the opportunity to organize objects spatially. In addition, multi-touch input may be a more appealing and natural means of input as users manipulate objects directly and easily with their fingers [8]. However, for text insertion tasks, it is uncertain whether, or how much a pure touch-based input—i.e., without devices such as pens or styli—can really be effective. On multi-touch tabletops, people point and touch virtual artifacts on a table in the same way as if they were physical objects, often using both hands [6], while this is not possible in the single-touch condition, which simulates a mouse-based interaction.

A study on university undergraduate students examines their interactions with a multi-touch digital tabletop [12]. This study confirms that tabletop UIs are well suited for displaying highly visual information (diagrams for labeling, graphs to draw). In this case, the activity content is a static diagram, to be rotated, resized, and moved by pairs of students. Each student sits side-by-side to share text-based material, which can be marked with fingers. Discussing and repeating the activity together, for memorizing it, required students to erase previous answers, and this is more easily done in a multi-touch condition. Digital tables can also enable a more dynamic and immersive experiences while reasoning about abstract concepts, as suggested by theories of embodied cognition [12].

In another study [8], the system supported both multi-touch and single-touch interaction. In the multi-touch condition, various children could interact with the digital content simultaneously, talking more about the task, while in the single-touch condition they talked more about turn taking. The multi-touch mode supports better collaboration by allowing more equitable participation at the tabletop, because everybody can interact whenever they want. Their discussions involved explicit reasoning and justifications, while they can work in parallel way on the same task: this interaction was more collaborative in nature.

B. *Impacts of IWBs on Learning and Teaching*

Student engagement is one of the most important factors, which affects teaching and student motivation to learn. The more students are motivated, the more likely they will be successful in their efforts [1]. A project investigating the impact of using IWBs for literacy and mathematics in primary schools underlines that students are more motivated in lessons with IWB because of the high level of interaction and discussion [15]. Students enjoy interacting physically with the board, manipulating text and images.

Literature relates the unique physical and tactile nature of the boards with the reinforcement of pupil's learning, especially when they can interact directly with the board. Actually, the single-touch feature of the adopted IWBs limits the number of pupils interacting during the lesson. Moreover, not all the teachers let their students interact with the IWB most of the time, because lessons are still planned in a traditional way, even if supported by a new device. The amount of time pupils had been taught with an IWB proved to be a key factor in the learning process [10]. The uniqueness of IWB technology lies in the possibility of an intersection between technical and pedagogic interactivity; in other words, in the opportunities this technology holds for collective meaning making through both dialogic interaction with one another and physical interaction with the board [15]. Using a single-touch IWB, the teacher has to concentrate on developing new practical strategies to keep the rest of the class mentally engaged while one child is working at the IWB [10]. The students that are not interacting with the device may lose involvement during the lesson.

By introducing an IWB with multi-touch technology, the teacher and students, or groups of students, can really work at the screen at the same time and interact more often with the device. A multi-touch IWB maximize these kinds of interaction during the activities within the classroom, offering new ways to think, plan and develop the lesson from the point of view of cooperative work.

Significant researches of the UK government [10] and of the British Educational Communication and Technology Agency (BECTA) [17] confirm that when teachers have had sustained experience (of about 2 years) of using interactive whiteboard, they are able to change their teaching practices to make best use of its facilities. Many teachers adjusted their style to be more inclusive and cooperative in supporting learning, to manage a well planned and conducted lesson, that was centrally based on her/his enabling pupil's

interactivity with the IWB. The use of the IWB became embedded in their pedagogy as a mediating artifact for their interactions with their pupils, and pupils' interaction with one another [17]. Moreover, other researches on using IWBs for creative teaching and learning in literacy and mathematics [20] indicates that rules, procedures, and basic skills—rather than being the main learning goal—could be seen as tools to be used creatively in solving problems and developing new ideas, which is critical to the enhancement of the whole class learning process. Another study investigating pedagogic practices in British primary classrooms [4] shows that teaching with IWBs is really flexible: the IWB involves striking a balance between providing a clear structure for a well-resourced lesson and retaining the capacity for more spontaneous or provisional adaptation of the lesson as it proceeds.

Even if in the above-mentioned experiences, single-touch IWBs have been used to deliver lessons in a variety of ways [1], teachers' effort to develop new pedagogical practices may not be enough to go beyond interaction bounds of single-touch IWB. Considering all the multimedia and multimodal opportunities offered by the IWBs, the adoption of multi-touch technology can really bridge the gap, enabling more students to work and interact together on the display, increasing the number of interactions and the level of participation of the whole classroom. These new possibilities can lead to a different learning approach where knowledge is really built through group cooperative activities.

III. PROPOSED APPLICATIONS

A. Background

As outlined before, various studies made in primary (elementary) schools report that IWB enhances students' interaction and engagement while it is still a controversial point if similar benefits are achieved with students of higher schools [19]. Therefore, we focus our efforts in designing applications devoted to primary schools (pupils aged 7–10 years).

We suppose an appropriate expertise of teachers on the use of ICT. In the long term, this constraint on teachers' expertise should not be too limitative if the actual trend of introducing ICT within the classrooms continues and the use of technologies is not confined in laboratories. For example, Lewin reported that: "As teachers had technology (IWB and a laptop or desktop computer) in the classroom, available to use whenever they wished to do so, there was a huge increase in teachers' ICT skills over a 2 year period." [10]

B. Scenarios of Use

By following a user-centered approach to design, we are starting our research with scenario-based methodology. The designed scenarios regard ordinary lesson activities involving the use of a large interactive screen with multi-touch technology. We designed three scenarios and developed three beta prototypes supporting them. Two prototypes are suitable for literacy lessons, and the last implements the Tangram game. This game could be

profitable while studying plane geometry, but also for introducing the use of IWBs in the class in a playful way.

In the prototypes devoted to literacy lessons, we involve pupils in decomposing or assembling stories. Using words and pictures to build sentences should stimulate creativity, doing it together should make it more entertaining. Depending on teachers' purposes and needs, pupils can manipulate every literary genre.

For space reasons, we present in depth only the scenario of creation of a story, while the other two scenarios are summarized.

1) Scenario 1: The fairytale box

After the break, as the bell rings, pupils rush into the classroom.

"What's going on?" asks the math teacher leaving the classroom.

"We've got the literacy lesson with the IWB!" answers Alex enthusiastic.

"Please, sit down! Today we are using the IWB to create a fairytale." explains Ms. Melman—the literacy teacher.

"First of all, we have to decide who will participate into our tale. We have to choose *who* the main characters are, *where* the tale takes place, and *when* it happens. Later on, we will focus on the actions they will do." says Ms. Melman pointing to the IWB screen containing four areas filled with words and images and labeled Who, Where, When, and What. The bottom of the screen is empty. It will be used for writing the parts composing the fairytale: Preface, Development, and Conclusion.

Ms. Melman divides the class in groups. She leaves out the What area and assigns the other areas to three groups.

"One from each group can come to the board. Don't worry: we've got plenty of time for all of you." remarks Ms. Melman. Actually, three pupils could comfortably interact with the IWB at the same time. During the lesson, other trios will be able to interact with the IWB.

"Each group has to choose, from its own set, what to use in the fairytale. You can even look in the folder for finding more stuff." explains Ms. Melman.

Immediately, Alex and Gloria are ready in front of the IWB. Ms. Melman tries to convince the shy Martina to come to the whiteboard. Impressed by the engaging images on the screen, the girl accepts.

"Now, we're going to draw, in the middle of the screen, a new area to contain the chosen objects: the Fairytale box. Then we'll write together the story within the textual area, obviously, starting from its beginning. That part of a story is called Preface." continues Ms. Melman.

While Alex and Gloria resize and arrange the sets, Martina writes the heading Preface in the text area. Then the trio collaborates on drawing and labeling the Fairytale container (see Fig. 1).

Every delegate of the groups discusses with her/his group for deciding which items to move into the Fairytale box. Martina is the first one coming back to the IWB, followed immediately by Alex and Gloria. Surprisingly, the shy girl now looks quite confident, passing words and images to the others. We can notice how pupils naturally helped each other without any teacher's intervention.

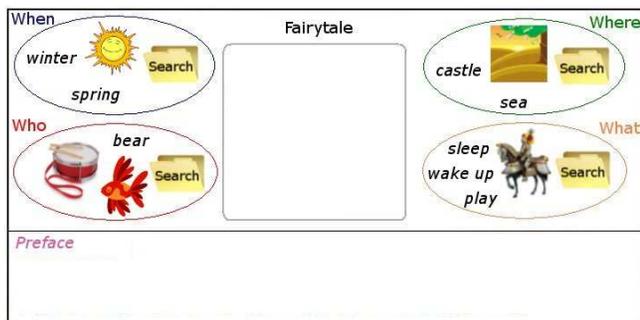


Figure 1. The IWB after the initial setup.

“Now look at the objects within the What set! Altogether, we can choose the actions that main characters can do.”

Each delegate again discusses with her/his group for choosing the preferred verbs, then they run to the IWB. “Take your time, isn’t a competition!” remarks Ms. Melman.

After dragging and dropping verbs, each pupil writes a sentence to build the Preface (see Fig. 2), alternating at the IWB.

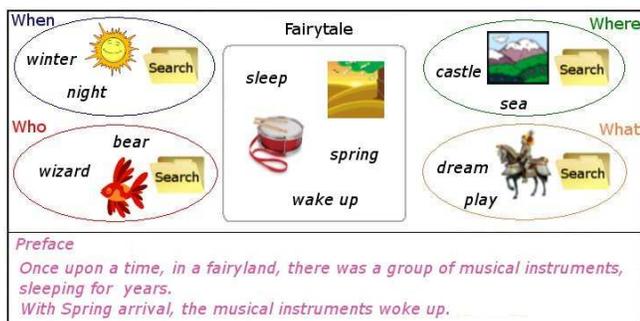


Figure 2. The IWB while developing the preface of the tale.

“Now that we finished the Preface, we have to be careful in organizing the plot. We are in the core of the story, called Development. Why don’t you think about what it may happen if we add another character, or a magic object to our tale?” Ms. Melman suggests while three other kids (Carl, Russell, and Kevin) are ready to write.

This continuous turn taking on using the IWB allows for an active participation of more pupils. This approach should also promote the attention and involvement of the whole class. However, the teacher has to manage and coordinate students’ turn taking and movements in a profitable way.

Carl and Kevin, following Ms. Melman’s suggestions, decide to enlarge the Fairytale box for accommodating more elements on it. Russell creates and labels a new textual area, replacing the Preface area, for containing the Development. The trio continually goes back and forth from their groups to the IWB, because pupils have many ideas, giving free rein to their imagination.

“Why don’t you select only few elements at a time and write down a sentence immediately?” says Ms. Melman.

The activities to do are the same of the Preface, so the lesson flows smoothly: pupils learn fast by watching their classmates. The Fairytale box continues to grow until the end

of the lesson, with new elements taken from the four sets and their folders. For the sake of clarity, the objects in these folders are automatically ordered and filtered by the system, taking into account the items contained in the Fairytale box.

Every now and then Ms. Melman, by posing careful questions, asks to the groups for controlling the consistency of the plot. Whenever necessary, appropriate revisions are made with the collaboration of the whole class.

Further delegates work out the Conclusion, the most difficult step. Everyone would say her/his personal ending. Pupils are excited and Ms. Melman has to coordinate pupils to reach a shared conclusion. Finally, the plot is complete and Preface, Development and Conclusion appear as a textual sequence on the IWB. Even if the fairytale looks finished, Ms. Melman calls a last trio (Giulia, Stefano, and Anna), which, puzzled, comes to the IWB.

“What is missing?” asks Ms. Melman to the class.

“The title!” Giulia bursts out.

“Well done Giulia! Underline your preferred places and main characters to imagine an original title for our tale.”

Giulia writes down the proposed titles, while Stefano and Anna discuss and collect groups’ suggestions.

“That’s beautiful!” says Ms. Melman as soon as pupils agree on a title; “As homework, please write your personal ending of the tale. Next time, we’ll read them in class.”

2) *Synthesys of the other scenarios*

In the second scenario, pupils are stimulated to work on decomposing a well-known fairytale, to play with grammatical structures. As before, the class is split into groups and groups’ delegates alternate at the IWB.

The lesson starts with a brainstorming activity with the teacher asking questions about the selected tale shown on the screen. Later, the pupils at the IWB—following classmates’ suggestions—underline names of the main characters, action verbs, significant places, and time expressions contained in the text area on the bottom of the screen. Pupils draw four-colored set and label them (see Fig. 3a): When, Where, Who, What. Later on, a fifth set (the Why set) will be added.

Each child at the IWB is in charge of filling one set with the appropriate words and sentences, after discussing with her/his group. The quartet has to collaborate while dragging and dropping stuff inside the appropriate sets. It is not so easy: sometimes more than one pupil chooses the same word and wants to drop it inside her/his set. The teacher has to coordinate carefully the class for stimulating collaboration among pupils. The appropriate correction of possible mistakes is made with the active participation of the whole class.

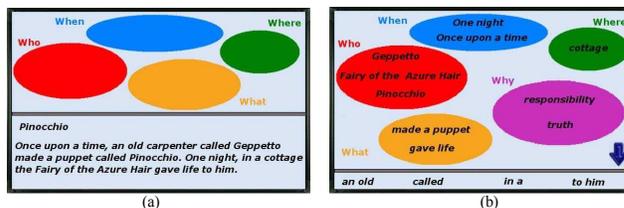


Figure 3. The IWB after initial setup (a) and at the end of the lesson (b).

After this phase, the teacher emphasizes that some ‘useless’ words (prepositions, pronouns, articles, etc ...) are still in the text area and takes the occasion for recalling some notion of syntactical structures.

At this point, the teacher asks pupils to focus their attention on the purposes behind the actions of the main characters: this is an arduous task, because students discuss a lot on the motivations.

As soon as they reach an agreement, one pupil makes smaller the text area to obtain some room for accommodating the Why set. The others rearrange the four sets, add the Why set, and write inside it the motivations of the tale. Finally, the tale appears on the IWB broken down in its main grammatical structures (see Fig. 3b).

The third prototype, implementing the Tangram game, supports a competition among groups of pupils.

The IWB shows a black and white scheme together with seven geometrical figures (see Fig. 4a). The teacher divides the class into groups composed by three pupils. The groups are in competition in a time-limit task.

Each group has to fill a different schema and has to guess the object that will appear. Each trio collaborates in trying to wedge the geometrical figures inside the proposed scheme.

At the beginning of a session at the IWB, the group must describe the geometrical properties of one figure. Then the group can start the timed race. Even if the scheme is not completed, one pupil can stop the clock and guess the object (see Fig. 4b).

At the end of each session, a table appears summarizing: the name of the group, the elapsed time, the guessed object and its correctness or not. When all groups have finished, the IWB shows the results.

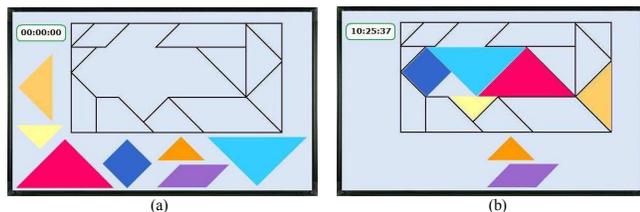


Figure 4. The IWB at the beginning (a) and at the end of the game (b).

C. Implication for Design

Our scenarios lead us to formulate a set of design guidelines, which we adopted while developing our experimental prototypes.

The organization of the activities of the lesson should allow as many students as possible to use of the IWB. The multi-touch technology already enables a simultaneous use by several students; moreover, the lesson should be organized in order to accommodate the rotation of the students actively using the IWB (e.g., decomposing the learning process in steps or phases).

The learning process should be based on tasks involving pupils’ collaboration and/or competition. Both the kind of tasks and the arrangement of pupils (e.g., their role in a task) should stimulate a continuous and active involvement of

students, especially when they are not interacting with the IWB.

Teachers should rarely interact in person with the technology. From our viewpoint, quite unlike other classroom’s experiences using IWB, the teacher should act as a mediator between the technology and the class as well as a facilitator of the pupils’ cooperation. It is of paramount importance that the teacher—exploiting his/her consolidated experience with *traditional* classrooms—limits its role to supervise, coordinate, and ensure pupils’ participation.

Teachers need to be engaged with ICT not only at the level of consumer, but also at the point of design and development [20]. In particular, the teacher should be able to create, or at least to personalize, the content of the lessons instead of receiving complete pre-defined lessons in specific subjects provided by the vendors.

With respect to the technical features, we only report some distinctive aspects. In particular, it is out of the scope of this paper to deepen the issues of usability and efficacy of the interaction. There are ample debates regarding the possible modalities of interaction with large screens or tabletops and a vast literature reporting on the pros and cons of the various alternatives. It is fundamental that, by exploiting the outcomes of those previous researches, IWB applications support a natural and easy to use modality of interaction. Moreover, it is worth recalling that the multimedia and multi-sensory characteristic of IWBs should be exploited as much as possible. In fact, presenting information in sharp colors, the possibility of annotating, manipulating, moving, and focusing on images or text can enhance the learning process. However, it is uncertain if verbal and visual information are always best presented together as well as if dynamic visuals are always better in promoting understanding than static visuals.

In designing the interaction of IWB applications, users (i.e., teachers and students) must have an ample freedom of interaction. This approach is aligned with the principles for a good design expressed in [14]. Firstly, the flow of the activities involved in the learning process must not be predefined. In this way, the development of the lesson could freely adapt to the actual requirements. Secondly, the possible students’ interactions with the screen and its objects (e.g. images, words, and phrases) must not be bound to their roles, if any. In other words, all students should have the same access rights. In case the accomplishment of a task asks for establishing roles, these roles must be defined only from a strategic viewpoint, not to impose different rights and behaviors to pupils. This choice allows the children to help each other as well as to exchange their responsibilities.

Obviously, a side effect of such freedom is that the teacher has no support in the management of the class or in reinforcing assigned roles and responsibilities. In fact, we retain that rigid workflows or role hierarchies are unsuitable for cooperative and participative learning.

Finally, applications should not automatically correct pupils’ mistakes. The automatic correction could be useful in those applications devoted to support individual activities (e.g., automatic correction of typos in text-editors); on the contrary, in those applications aiming to support participative

learning processes, it is preferable that the whole class can act as a reviewer.

IV. CONCLUSION AND FUTURE WORKS

In this paper, we have summarized the design guidelines and approach we are adopting in a new project involving some Italian elementary schools – populated by the so-called digital natives. By starting from previous research on the social impact of interactive screen technologies, we aim at maximizing the benefits of IWBs on how teachers and students deal with education and its practice.

By using IWBs, teachers can involve children more easily, and keep them engaged with lessons while stimulating learning. This can happen both because of the appeal technology naturally has on children (i.e., playfulness) and because of the cooperative mechanisms touch-based interaction is able to trigger. Single-touch input helps learning turn-taking, while multi-touch stimulates working together simultaneously.

Comparing “old and new devices” in order to understand what is the best buy is therefore not the best way to proceed at this time, and we have designed basic scenarios to drive the development of sample cooperative applications for lower education. We are now at a preliminary stage, but previous research will provide guidelines for experimental evaluation, with which we will assess (for example) if our applications will reinforce learning, distract or keep children focused.

REFERENCES

- [1] W. D. Beeland, “Student engagement, visual learning and technology: can interactive whiteboards help?,” Proc. Annual Conference of the Association of Information Technology for Teaching Education (ITTE 02), Trinity College, Dublin, Jul. 2002, pp. 1-7.
- [2] J. S. Brown and R. P. Adler, “Minds on fire: open education, the long tail, and learning 2.0,” *EDUCAUSE Review*, vol. 43, Jan./Feb. 2008, pp. 16-32.
- [3] M. Castells, *The Rise of the Network Society*, in *The Information Age: Economy, Society and Culture*, 2nd ed., vol. I. Oxford, UK: Blackwell, 2000.
- [4] J. Gillen, J. K. Staarman, K. Littleton, N. Mercer, and A. Twiner, “A “Learning Revolution”? Investigating pedagogic practices around interactive whiteboards in British primary classrooms,” Proc. American Educational Research Association Conference (AERA 06), San Francisco, Apr. 2006, pp.1-11.
- [5] A. Grasso, M. Muehlenbrock, F. Roulland, and D. Snowdon, “Supporting communities of practice with large screen displays,” in *Public and Situated Displays: Social and Interactional Aspects of Shared Display Technologies*, vol. II, K. O’Hara, M. Perry, E. Churchill, and D. Russell, Eds. Dordrecht, NL: Kluwer Academic Publisher, 2003, pp. 261-282.
- [6] V. Ha, K. M. Inkpen, R. L. Mandryk, and T. Whalen, “Direct intentions: the effects of input devices on collaboration around a tabletop display,” Proc. of the First IEEE International Workshop on Horizontal Interactive Human-Computer Systems (TABLETOP 06), IEEE, Jan. 2006, pp. 1-8.
- [7] I. Hall and S. Higgins, “Primary school students’ perception of interactive whiteboards,” *Journal of Computer Assisted learning*, vol. 21, Apr. 2005, pp. 102-117.
- [8] A. Harris, J. Rick, V. Bonnett, N. Yuill, R. Fleck, P. Marshall, and Y. Rogers, “Around the table: are multiple-touch surfaces better than single-touch for children’s collaborative interactions?,” Proc. of the 9th international conference on Computer Supported Collaborative Learning (CSCL 09), International Society of the Learning Sciences, Jun. 2009, pp. 335-344.
- [9] R. Johnson and D. Johnson, “Action Research: cooperative learning in the science classroom,” *Science and Children*, vol. 24(2), 1986, pp. 31-32.
- [10] C. Lewin, B. Somekh and S. Steadman, “Embedding interactive whiteboards in teaching and learning: the process of change in pedagogic practice,” *Education and Information Technologies*, vol. 13, Dec. 2008, pp. 291-303.
- [11] P. Peltonen, E. Kurvinen, A. Salovaara, G. Jacucci, T. Ilmonen, J. Evans, A. Oulasvirta and P. Saarikko, “It’s mine, don’t touch!: interactions at a large multi-touch display in a city centre,” Proc. of the 26th annual SIGCHI conference on Human factors in Computing Systems (CHI 08), ACM, Apr. 2008, pp. 1285-1294.
- [12] A. Piper and J. D. Hollan, “Tabletop displays for small group study: affordances of paper and digital materials,” Proc. of the 27th international conference on Human Factors in Computing Systems (CHI 09), ACM, Apr. 2009, pp. 1227-1236.
- [13] M. Prensky, “Digital natives, digital immigrants,” *On the Horizon*, vol. 9, Oct. 2001, pp. 1-6.
- [14] M. Robinson, “Design for unanticipated use,” Proc. of the 3rd European Conference on Computer-Supported Cooperative Work (CSCW 93), Kluwer Academic Publishers, 1993, pp. 187-202.
- [15] E. C. Schmid, “Investigating the use of interactive whiteboard technology in the English language classroom through the lens of a critical theory of technology,” *Computer Assisted Language Learning*, vol. 19(1), 2006, pp. 47-62.
- [16] E. J. Smith, S. Higgins, K. Wall, and J. Miller, “Interactive whiteboards: boon or bandwagon? A critical review of the literature,” *Journal of Computer Assisted Learning*, vol. 21, Apr. 2005, pp. 91–101.
- [17] B. Somekh, M. Haldane, K. Jones, C. Lewin, S. Steadman, P. Scrimshaw, S. Sing, K. Bird J. Cummings, B. Downing, T. H. Stuart, J. Jarvis, D. Mavers, and D. Woodrow, “Evaluation of the primary schools whiteboard expansion project,” Becta-DfES, 2007.
- [18] N. Streitz and P. Nixon (Guest Eds.), “Special Issue: The Disappearing Computer”, *Communication of the ACM*, vol. 48, March 2005, pp. 32-71.
- [19] A. Thomas, “Little touches that spell success,” *Times Educational Supplement*, 23 May 2003.
- [20] R. Wood and J. Ashfield, “The use of interactive whiteboard for creative teaching and learning in literacy and mathematics: a case study,” *British Journal of Educational Technology*, vol. 39, Jan. 2008, pp. 84-96.