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INVESTIGATING THE DISTINCTIVE ROLE OF THE INTERACTIVE WHITEBOARDS FOR MATHEMATICS TEACHING

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ABSTRACT: Interactive Whiteboards (IWBs) are a relatively new tool that provides interesting affordances in the classroom environment, such as construction of visualizations and multimedia. These affordances make IWBs an innovative tool with high potential for mathematics instructional environments. The research involved a small group of Italian mathematics teachers in secondary schools and aimed at exploiting the distinctive role of IWBs in mathematics teaching. Three essential elements were considered: the mathematical tasks on which students work, the discourse activities in the classroom and the support that IWBs give to the previous two elements. Analysing a first series of video recorded lessons, the teachers and the researcher engaged in a discussion about possible improvements relating the IWB use to enhance high-level mathematical tasks and productive discourse interaction. Outcomes of the discussion were used to design and enact a new set of lessons, again video recorded and analysed. Outcomes were compared with those of the previous set. Results show significant improvements in the tasks' quality, in the classroom dynamics and in the exploitation of IWBs affordances. What emerged from the study is that IWBs technology may be used to enrich the lessons' experience and that an attentive orchestration by the teacher leads to the construction of an effective and beneficial learning and teaching environment.

Keywords: Interactive whiteboards, mathematics education, teaching/learning strategies.

INTRODUCTION

Interactive whiteboard (IWB) systems comprise a computer linked to a data projector and a large touch-sensitive electronic board displaying the projected image. IWBs are equipped with dedicated software, but might also be considered as a digital hub which allows the integration of Internet or other hardware resources, as orchestrated by the teacher and the students.

Objects from other technologies, such as geometric dynamic software, can easily be displayed on the IWB, and can be directly manipulated by teachers and students to provide an interactive experience in lessons that is accessible to all. Results from these manipulations can also be stored and retrieved in future lessons to further discussions (Mercer, Hennessy & Warwick. 2010).

Today, the IWB is an increasingly popular educational technology all over the world; in 2013 globally one in eight elementary and secondary classrooms (34 million teaching spaces) had an IWB and by 2015, one in five will have one (Hennessy & London, 2013). It is found in 80% of British classrooms and its prevalence is rapidly increasing in a number of other countries too, notably the Netherlands, Denmark, Australia and the United States. Further rapid growth is expected in the next few years (Hennessy & London, 2013).

Different studies highlighted the IWB potentialities. Many teachers have found the IWB to be an important and highly motivating teaching resource (Warwick & Kershner, 2008). Several studies (e.g. Higgins et al., 2005; Moss et al., 2007, Somekh et al., 2007) state that IWBs aid the teaching of difficult, abstract and complex ideas,

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improve students' motivation to learn, increase lessons' pace, promote classroom interaction and reinforce conceptual learning through the use of animation or visual representation. Different authors (e.g., Beauchamp, Kennewell, Tanner & Jones, 2010; Glover, Miller, Averis & Door, 2007; Jewitt, Moss & Cardini, 2007) presented classroom observations in which teachers working with IWBs developed their own technological fluency, promoted students' group work activities for authentic problems, and for innovative processes of exploration. Other studies (e.g. Jewitt et al., 2007; Kennewell, Tanner, Jones, & Beauchamp, 2008; Miller & Glover, 2007) reported improvements in students' conceptual and cognitive understanding. The IWB is argued to provide collaborative opportunities for reasoning, hypothesis testing and interpretation that go well beyond those afforded by more established classroom devices. Hennessy, Deane, Ruthven and Winterbottom (2007) stated it provides a "dynamic and manipulable object of joint reference which offers new forms of support for interactivity" (Hennessy et al., 2007, p. 284).

Despite these positive observations current evidence from the literature (Glover et al., 2007; Miller & Glover, 2010; Smith, Hardman & Higgins, 2006) points to teachers' limited acquaintance with the educational potential of IWBs; many teachers seem to use the IWB merely as a large-scale visual blackboard or presentation tool. So, often teachers do not succeed in exploiting the above-mentioned more innovative pedagogical advantages of IWBs (Moss et al., 2007, Somekh et al., 2007). In fact, if IWBs are merely used in a presentation mode, they may induce teachers to teach in an expository way, reducing rather than stimulating students' activity and interactivity and exploiting the affordances of a media-rich content only for surface aims. Thus the use of IWBs may have no significant impact on teachers' existing pedagogy and more specifically on enhancing high quality interaction and thinking processes.

The pedagogy associated with IWBs use requires further investigations and in-depth analyses to understand better what underlies teachers' difficulties with exploiting the affordances offered by IWBs and to stimulate the design of new kinds of learning environments (Glover & Miller, 2009; Kennewell et al., 2008, Warwick, Mercer, Kershner & Kleine Staarman 2010). Hennessy and London (2013, p.13) observe that "IWBs are deceptively complex and to fully utilise the interactive aspects of the technology, teachers must invest time to build confidence, design resources, adapt practices and learn to harness their power". Teachers need time to develop the knowledge to exploit technology in ways that effectively enhance student learning.

The research reported here aimed at exploring and exploiting the distinctive role of IWBs in teaching environments, for supporting and contextualising productive dialogue and other forms of interaction in the classroom and developing opportunities for students' learning, in the domain of mathematics education.

THEORETICAL FRAMEWORK

Besides technology, two other basic factors for learning are the tasks in which students are engaged and the nature of classroom activities (Collins, Brown, & Newman, 1989). Therefore, in constructing the theoretical framework for the research, three elements were individuated as essential ingredients of the development of an IWB-supported interactive environment for mathematics teaching and learning:

- the quality of the interaction with the mathematical content, i.e. tasks in which students are engaged;
- the quality of discourse interaction between the teacher and the students and amongst the students, intended as indicator of classroom activities;
- the support that IWB may provide to the two previous elements, i.e. mathematical content and discourse interaction.

The first element refers to the modality and the quality of the mathematical tasks addressed in the classroom. Most mathematics educators have argued that full understanding of mathematics consists of more than knowledge of mathematical concepts, principles, techniques, procedures (e.g. Schoenfeld 1992). It is important to teach students that doing mathematics not only consists in applying standard procedures generally explicated in school textbooks, but in engaging in the processes of mathematical thinking, in reasoning about main mathematical concepts and in solving and managing mathematical problems. Mathematics learning is an essentially constructive activity (Schoenfeld 1992). In effective mathematics instruction a teacher assists students to engage productively with a problem (Hiebert & Grouws, 2007). Teachers have an important role in guiding students' mathematical development by discerning and making explicit the key mathematical ideas in different tasks, deciding which solution strategies displayed by students are worth, and encouraging consideration of those that merit further inquiry (Silver et al., 2005). Hiebert and Grouws (2007) analysed in depth the different approaches to mathematics teaching. They discerned between *teaching for skill efficiency*, that is accurate,

smooth and rapid execution of mathematical procedures, and *teaching for conceptual understanding*, i.e. “the mental connection among mathematical facts, procedures and ideas” (Hiebert & Grouws, 2007, p.380). In the pattern of teaching for developing conceptual understanding they individuated two different key features: *teachers and students attending explicitly to concepts*, i.e. treating mathematical connections in an explicit way, discussing the mathematical meaning underlying procedures, attending to the relationships among mathematical ideas, etc., and *students struggling with important mathematics*, i.e. expending efforts to make sense of mathematics, figuring something out that is not immediately apparent, solving problems “that are within reach and grappling with key mathematical ideas that are comprehensible but not yet well formed” (Hiebert & Grouws, 2007, p.387).

The framework used for classifying the mathematical tasks was elaborated by Stein, Grover and Henningsen (1996). Stein et al. (1996) define a *mathematical task* as a classroom activity the purpose of which is to focus students' attention on a particular mathematical idea; the kind of mathematical tasks with which students become engaged determines not only what substance they learn but also how they come to think about, develop, use, and make sense of mathematics. According to Stein et al. (1996), “the tasks used in mathematics classrooms highly influence the kinds of thinking processes in which students engage” (p.462). So, their concept and operationalization of mathematical task is well-suited for analysing the first element of our theoretical framework as described above. Stein and Smith (1998a) classify tasks at two levels in four categories of cognitive demand:

Low level tasks (corresponding to *teaching for skill efficiency* by Hiebert and Grouws, 2007):

- *Memorization*: committing facts, rules, formulas or definitions to memory;
- *Procedures without connections to concepts or meaning*: the use of formulas, algorithms, or procedures *without connection* to concepts, understanding, or meaning;

High level tasks (corresponding to *teaching for conceptual understanding* by Hiebert and Grouws, 2007):

- *Procedures with connections to concepts and meaning*: the use of formulas, algorithms, or procedures *with connection* to concepts, understanding, or meaning;
- *Doing mathematics*: including complex mathematical thinking and reasoning activities such as making and testing conjectures, framing problems, looking for patterns, and so on.

Furthermore, mathematics learning is conceived as an inherently social (as well as cognitive) activity (Collins, et al., 1989; Schoenfeld, 1992). Therefore, the second aspect of the theoretical framework concerns the discourse interaction within the classroom between the teacher and the students and amongst the students.

Discourse interaction grounds on the concept of ‘dialogic teaching’ (Alexander, 2008; Mercer, 2004) as a means to promote and enhance students’ learning. Basically (Wolfe & Alexander, 2008), a dialogic approach is collective (teachers and students addressing the learning task together), reciprocal (teachers and students listening to each other to share ideas and consider alternative viewpoints), and cumulative (teachers and students building on their own and each others’ ideas to chain them into coherent lines of thinking and enquiry). Often directive forms of teaching consist of closed teacher questions, short student answers which teachers do not build upon, and superficial feedback (Mercer et al., 2010). The dialogic approach to teaching aims to orchestrating classroom talk and activity through open-ended tasks, high level open questioning, high level classroom discussions, topics explorations, sharing ideas and co-constructing interpretations.

A peculiar modality of discourse interaction is enacted in the problem solving work developed by students in small groups, and its presentation in front of the whole classroom for further discussion. According to Collins et al. (1989) and Schoenfeld (1983), small group problem solving sessions favour discussion and argumentation in choosing alternative solution methods, improve students’ collaboration and self-confidence and encourage more critical and elaborated contributions from pupils. Besides solving problems in small groups other forms of dialogic teaching promote an active involvement of the students, such as high quality whole class discussion in which students engage in the same problem and compare the different ways they solved it, or explore different problems with similar solution methods.

Analysis of discourse interaction based on the framework developed by Smith et al. (2006). Grounding on the concept of ‘dialogic teaching’, they conducted a study in which they looked specifically at the different types of discourse moves, and consequently at the different teaching styles in an IWB environment. The scheme of their analysis primarily focused on the three-part IRF structure of a discourse unit (Sinclair & Coulthard, 1975): an

Initiation, usually in the form of teacher’s explain or a question submitted to the students, a *Response* in which students attempt to answer the question and a *Feedback*, in which the teacher provides some form of feedback to the student’s response. Each of the three parts is further divided into more detailed elements. *Initiation* includes *closed questions*, *open questions*, *students’ questions*, and *explain*. *Response* includes *single student answer*, *choral response*, *spontaneous contribution* and *general discussion*. Finally, *Feedback* includes *Repeat question* (questions that shape the course of implementation provide teacher with specific ways of focusing students on the key mathematical ideas leaving less “in the moment” decision-making regarding next instructional moves), *Uptake question* (teacher incorporate students’ answers into subsequent questions), *Probe* (teacher stimulates students for further elaboration), and *Refocus* (get students back on task).

The third central element refers to different kinds of support that IWBs may provide to the previous two aspects, mathematical tasks and discourse moves.

IWBs provide a multimodality environment wherein images, texts, objects from other software can be combined and manipulated directly on the screen by teacher and students. It might also be considered as a digital hub which allows the integration of Internet or other resources, as orchestrated by the teacher and the students. Tools provided as part of the IWB software package include, besides general functions, also some specific mathematical tools, such as a calculator, numbers line, Cartesian axis, etc.

Thus, the IWB affords a flexible powerful environment, where both teachers’ modelling and coaching activities and students’ exploring activities can be easily included. In mathematics lessons, the affordance to use external software, such as dynamic geometrical software (e.g., Geogebra) or spreadsheets in combination with functions as highlighting and annotating, is especially valuable. The potentialities of the dynamic geometry software are emphasized by employing it in an IWB setting rather than being used on individual computers, allowing affordances for whole class discussion and reflection. As the IWB becomes the centre of the classroom activities, it allows a dynamic use of the resources that favours the creation of a learning environment in which the participants actively communicate and engage in the practice of solving problems in a cooperative way. Students can get engaged in the discussion about the topics presented at the IWB and improve their critic abilities monitoring the line of reasoning. Furthermore, IWBs can favour collaborative students’ group activities guided and mediated by the teacher (Warwick et al. 2010). Reflection is enhanced by the IWB affordance to store and retrieve the course of the lesson (including transformed objects); saved lessons may be ‘replayed’ for further discussion.

The tool used for analysing the third element of the theoretical framework, namely the different kinds of support that IWBs may provide to the previous two elements, mathematical tasks and discourse moves, is based on the work of Kennewell and Beauchamp (2007), who investigated how teachers used features of IWBs to enhance learning activities in a set of observed lessons. These activities concerned learner–IWB interaction, teacher–IWB interaction, learner–teacher and learner–learner interaction through the IWB. The authors identified teacher and learner actions supported by IWB features and built a classification framework concerning the impact of these actions on learning. These actions included *Composing* (using IWB as a tool to elaborate or record ideas), *Editing* (easily changing the data stored and displayed), *Selecting* (choosing resources or procedures), *Comparing* (comparing features of same object from different views or comparing different items), *Retrieving* (easily using stored resources), *Apprehending* (students interpreting the display, i.e. text, images, sound, diagrams), *Focusing* (drawing attention to particular aspects of a process or representation), *Transforming* (changing the way data are displayed), *Collating* (bringing together a variety of items from different sources), *Annotating* (adding notes to a process or a representation), *Repeating* (iterating an automated or stored process), *Modelling* (simulating a process by representing relationships between variables), *Revisiting* (returning to an activity with a different focus), *Undoing* (reversing an action). As in mathematics lessons external software is often used, the framework was adapted in this study by dividing the action *Composing* in two categories, *Composing using software* (indicates the elaboration through external software) and *Composing without software* (elaboration without external software).

The three analytic tools are summarized in Table 1.

Tab. 1. Frameworks Used In The Analysis.

<p>Mathematical tasks <i>Low level tasks</i> <ul style="list-style-type: none"> • <i>Memorization</i> </p>
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<ul style="list-style-type: none"> • <i>Procedures without connections to concepts or meaning</i> <i>High level tasks</i> <i>Procedures with connections to concepts and meaning:</i> <i>Doing mathematics</i> 																	
<p>Discourse moves</p> <ul style="list-style-type: none"> <i>Initiation:</i> <i>Teacher's open question</i> <i>Teacher's closed question</i> <i>Student's question</i> <i>Explain</i> <i>Direct</i> <i>Response</i> <i>Single student answer</i> <i>Choral response</i> <i>Spontaneous contribution</i> <i>General discussion</i> <i>Feedback</i> <i>Repeat question</i> <i>Uptake question</i> <i>Probe</i> <i>Refocus</i> 																	
<p>IWB actions</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;"><i>Composing without software</i></td> <td style="width: 50%;"><i>Focusing</i></td> </tr> <tr> <td><i>Composing using software</i></td> <td><i>Transforming</i></td> </tr> <tr> <td><i>Editing</i></td> <td><i>Collating</i></td> </tr> <tr> <td><i>Selecting</i></td> <td><i>Annotating</i></td> </tr> <tr> <td><i>Comparing</i></td> <td><i>Repeating</i></td> </tr> <tr> <td><i>Retrieving</i></td> <td><i>Modelling</i></td> </tr> <tr> <td><i>Apprehending</i></td> <td><i>Revisiting</i></td> </tr> <tr> <td></td> <td><i>Undoing</i></td> </tr> </table>		<i>Composing without software</i>	<i>Focusing</i>	<i>Composing using software</i>	<i>Transforming</i>	<i>Editing</i>	<i>Collating</i>	<i>Selecting</i>	<i>Annotating</i>	<i>Comparing</i>	<i>Repeating</i>	<i>Retrieving</i>	<i>Modelling</i>	<i>Apprehending</i>	<i>Revisiting</i>		<i>Undoing</i>
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<i>Apprehending</i>	<i>Revisiting</i>																
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In line with these three elements of the theoretical framework, this study addressed the following three research questions:

how can the teacher enhance the quality of the interaction with mathematical tasks in an IWB supported mathematics lesson?

how can the teacher improve the discourse interaction within the classroom between the teacher and the students and amongst students in an IWB supported mathematics lesson?

what precise kinds of support IWB may contribute to the quality of mathematical tasks execution and to the discourse interaction?

METHOD

The research involved five Italian mathematics teachers in secondary schools, in the period February-May 2013, who volunteered to participate in discussing the design and in video-recording lessons. The research went through two phases of video-recorded lessons in the classrooms, interlaced by discussion between the researcher and the teachers and design of a new set of lessons, as detailed below. Comparison between the first and the second lessons set helped to understand which kind of configuration would better support mathematical understanding and interactive learning.

The classrooms in which the lessons were video recorded were all provided with a stable IWB, and students were accustomed to use it. The range of the students' age varied from twelve to seventeen years old (High School grades 2 to 7).

The research went through four different phases. In the first phase (February) the five teachers involved in the research developed one or two lessons about a mathematics topic in order to exploit IWB affordances that they considered effective. Lessons were developed by each teacher individually, and the topic was chosen freely and differently by each of them. The lessons were taught in the presence of the researcher and video recorded by him. The researcher analysed the lessons and coded them on the basis of three main variables, i.e., mathematical tasks, discourse interaction and support provided by IWB, following for each element the proposed classification. The three kinds of coding were carried out by registering what was happening in the classroom every 30 seconds, from the beginning to the end of the lesson. An independent observer coded randomly chosen fragments of about ten minutes of each of the taught lessons. The achieved intercoder reliability was calculated

using the criterion that the observer's coded responses were considered equivalent only if they are identical (Lombard, Snyder-Duch, & Bracken, 2002). For the analysis of mathematical tasks reliability was complete, with 100% equivalent responses; for discourse interaction reliability averaged 90% and for IWB support 92%. In the second phase the teachers' group jointly with the researcher discussed some fragments of the lessons and the results of the researcher's classification. The fragments were selected upon indication of the teachers and the researcher, choosing the most significant in the use of IWBs. Three discussion groups were held in March. Teachers and researcher engaged in discourse about students' levels of thinking and achievement of the mathematical tasks, about the role they had in stimulating students' contribution in the lesson context, and about the IWB contribution to the classroom interactivity.

In the third phase, grounding on the analysis of the previous phase, the joint group of teachers, guided by the researcher, designed the main lines of a new set of lessons to teach, again about different topics. General outlines of the lesson design were decided upon collectively, but each teacher refined then her/his own lesson highlighting the important role of the IWB in its design.

In the fourth phase (May) each teacher taught the lesson she/he prepared. These were again video recorded and recordings were analysed using the same analytic tools than in the first phase of the analysis. The researcher compared then the first set (February) with the second set (May) of lessons, checking changes and improvements in mathematical tasks, dialogue interactivity and IWB support. Results from this comparison were briefly discussed with the teachers (the team intends to carry on with the work) and are presented in the following section.

RESULTS

Findings show considerable changes between the two sets of recorded lessons.

Mathematical Tasks

In February lessons topics concerned ellipse's construction, sinus function, derivative calculus, exponential growth and geometry properties of parallels. All the lessons were accurately prepared. The mathematical tasks were classified by the researcher as *procedures with connections to concepts and meaning* in all the lessons except one. In some of them the teacher linked the lesson to previously developed dynamic geometrical files, operating with them in front of the classroom and showing connections between different variables and between different important mathematical concepts; in other lessons the teacher started from a geometrical concept and developed it through the lesson, building geometrical constructions and linking them to real world objects, and guiding students in explorations of the inherent mathematical properties.

In the discussions held in March, February lessons were generally considered rather 'directive' and teacher centred. In this regard one teacher observed: "IWB poses many constraints in the teacher's work and lesson's preparation. I feel freer when I do not use the IWB. When I prepare an IWB lesson I feel obliged to follow the prepared scheme and I give less space to the students' suggestions. This is an aspect that may favour a teacher centred lesson."

Nevertheless, all the participants (teachers and researcher) agreed about the appropriateness to move the centre of the lesson focus from the teacher to the students and improve the collaboration between students and teacher and between students themselves. A possible solution was individuated shifting the mathematical tasks from the level *procedures with connections to concepts and meaning* to the level *doing mathematics*, i.e. problem solving. Interactivity in the lessons might take advantage of this shift providing students more opportunities to develop their potential while struggling with stimulating problems. The discussion engaged in affordances and difficulties to use problem solving in the curriculum, due to lack of time and different lessons' organisation. Problem solving activities require from teachers a considerable effort, in terms of the interactive demands on them during the lesson. During the discussion, one teacher observed that "students are not accustomed to problem solving, and often require teachers to explain". A second teacher remarked how "perhaps students should be given more time to reflect and carry on with their own answers". Finally, the whole group decided to develop lessons through this kind of task. The group also highlighted and approved the utility of working on realistic tasks, situating abstract tasks in more authentic contexts, so that students could understand the relevance of the work.

The May topics concerned exponential law, derivative calculus, geometry properties of the triangle, statistic indexes. All the mathematical tasks were classified as *doing mathematics*. They required students to analyze the task and actively examine alternative solution strategies and solutions, exploring and understanding the nature of mathematical concepts, processes, or relationships. All the tasks required complex and non-algorithmic thinking, where a pathway is not explicitly suggested by the task, task instructions, or a worked-out example. To promote the maintenance of high-level cognitive demands (Schoenfeld, 1992; Schoenfeld, 2006; Stein & Smith, 1998b), teachers encouraged students in engaging in cognitive effort, in making reasoning explicit, in drawing conceptual connections and in struggling with the tasks. In three lessons (over five) the tasks were based on real world problems.

Discourse Interaction

Analysing the discourse interaction through the tool presented in the theoretical framework, the February lessons resulted rather teacher centred, with a prevalence of teacher's explain, closed questions and single student's answer. To increase students' participation and involving them in cooperation and co-constructing knowledge, during the March discussions the team decided to organize students in small groups working in problem solving. These groups had to present their solutions at the IWB, discussing them with the entire classroom, and were encouraged by the teacher to give justifications, explanations and meaning of their solutions. The aim was to involve more directly students in the implementation of the lessons, increasing cooperation and communication among students. Indeed, students were generally given more space in the course of the May lessons. From February to May *initiation* decreased from 42.2% to 20%, *responses* increased from 32.4% to 60.2%, mainly because of *spontaneous contribution*, and *feedback* passed from 24.8% to 20%.

Initiation showed a significant increase of *open questions* (7.8% → 12.6%) and a strong decrease of teacher's *explain* (23% → 5.6%), *closed questions* and *student's questions* practically disappeared. In *Responses*, the prevalent modality was *spontaneous contributions*, intended as students reporting findings of the work groups at the IWB (2.6% → 44.8%), *general discussions* increased (1.2% → 8.8), while *single student answers* drastically decreased (24% → 4.4%). In *Feedback*, the percentage of *uptake questions* (in which teacher stimulates further elaboration starting from students' answers) was the higher (9.2%). The difference between discourse moves in May and February lessons is statistically significant ($\chi^2 = 133.68$; $p < .0001$). Results are shown in Table 2.

Table 2 Changes In Discourse Moves From February To May (% Over Total Lessons)

	February (N=497)	May (N=501)
Discourse moves	Mean percentages	Mean percentages
<i>Initiation</i>		
open questions	7.9	12.5
closed questions	6.6	0
students questions	2	1
explain	23.1	5.6
direct	2.8	0.8

<i>Subtotal</i>	42.4	19.9
Response		
Single student answer	24.1	4.4
Choral response	4.6	2.2
spontaneous contribution	2.6	44.7
general discussion	1.3	8.8
<i>Subtotal</i>	32.6	60.1
Feedback		
repeat questions	6.6	4.2
uptake questions	7.7	9.2
probe	8.1	5.2
refocus	2.6	1.4
<i>Subtotal</i>	25	20

IWB Support

The third element of the theoretical framework, IWB support, was analysed using the tool based on the work of Kennewell and Beauchamp (2007), presented above. Results from analysis showed that in February the IWB mainly supported the teacher's discourse and was directly managed by her/him. Even when students were involved they were always directed by the teacher, acting rather as teacher's assistants. Teachers mostly used the IWB as a normal blackboard (*composing without software*) or as a mean to show students different texts or images. Nevertheless, they also made large use of external software, i.e. Geogebra, for geometrical constructions and algebraic elaborations.

During the March discussions all participants stressed the IWB relevance in modelling the shape of the lesson as strong centre of attention and reflection, and in enhancing mathematical understanding, especially using external software, and exploiting the multimodality IWB affordances. Different teachers stated that IWB concentrates attention on the salient points, that lessons are prepared more accurately, that IWB favours more cooperation and discussion with respect to a lesson with a normal blackboard or to a computer laboratory. IWB use did not exclude the use of other didactical instruments (textbook, hands work, drawings, cardboards, etc.). Orchestrating IWB lessons requires a considerable effort from the teachers, both in terms of lesson preparation and the interactive demands on them during the lesson.

An important aspect stressed by all is the need of having the IWB available in the daily work in the classroom. Analysing the different IWB actions and their use in the implementation of the lesson, some actions appeared to be more effective in developing mathematical tasks and supported more than other an interactive, multimodal use of IWB fostering mathematical conceptual understanding:

composing using software typically dynamic geometry software as Geogebra or spreadsheet as Excel; the software Geogebra is managed for exploration and elaboration, looking for connections or theorem demonstrations. As one teacher said, 'it gets students used to see mathematical objects move';

comparing, i.e. same object are analysed from different points of view;

transforming, i.e. changing data representations;

modelling, simulation of a process by representing relationships between variables.

During the lessons recorded in May, presenting their works students' groups made large use of these effective actions, displaying multiple representations in a dynamic way often through mathematical software, such as Geogebra or Excel. Their solutions were presented to the whole classroom, inviting other students to participate, to criticize and to suggest better ways to solve the problems. The IWB was used constantly during all the lessons (93% of the total lessons time), except for some short periods in which students worked in small groups to elaborate their answers.

A comparison of the data in February and in May shows a relevant decrease in *composing without software* (27.8% → 17.8%) and in *apprehending* (26% → 14.2%), actions which might connote a more traditional IWB use. On the other hand, actions significant for an interactive and multimodal IWB use increase: *composing using software* 22% → 26.2%; *modelling* 10.6% → 17; *comparing* 2.2% → 5.2%; *transforming* 2% → 7.6%; %. Overall, actions significant for an interactive and multimodal IWB use cover 56% of the lesson time, while in

February it was only 36.6%. The difference between IWB actions in May and February lessons is statistically significant ($\chi^2= 64.90$; $p < .0001$).

Data are shown in Table 3.

Tab. 3 Changes In IWB Actions (% Over Actions Total In All Lessons)

	February (N=503)	May (N=499)
Action	Mean percentages	Mean percentages
<i>Composing without software</i>	27.5	17.9
<i>Composing using software</i>	22	26.2
<i>Editing</i>	0.2	2.6
<i>Selecting</i>	0	0.2
<i>Comparing</i>	2.2	5.2
<i>Retrieving</i>	6	4
<i>Apprehending</i>	25.8	14.3
<i>Focusing</i>	0.6	2.2
<i>Transforming</i>	2	7.6
<i>Collating</i>	0	0.2
<i>Annotating</i>	2.2	1.4
<i>Repeating</i>	0	0
<i>Modelling</i>	10.5	17
<i>Revisiting</i>	0.4	1.2
<i>Undoing</i>	0.6	0

DISCUSSION and CONCLUSIONS

By relating the IWB use to the design of mathematical tasks and ways of discourse interaction, teachers have been stimulated to look for effective ways of exploiting its interactive and multimodal features to support the enhancing of two main elements of the classroom practice.

In the first set of lessons, the IWB mainly supported the teachers' discourse. IWB offered teachers a powerful instrument for the kind of high-level mathematical tasks defined as *procedures with connection to concepts and meaning*. The limit was that lessons were mainly teacher centred: though students were often involved in co-operating with the teacher, directly manipulating objects and annotating texts, the thread of the discourse was mainly directed by the teacher.

To increase students' participation the challenge was to design and implement a teaching and learning environment in which students would be more involved in handling the lesson and in building knowledge. As a first step, based on the teachers' critical reflections on the February lessons supported by the theoretical/analytic framework provided by the researcher, the team decided to try to change the kind of mathematical tasks from *procedures with connection to concepts and meaning to doing mathematics*, i.e. activities of problem solving. This change in mathematical tasks helped also in modifying the discourse interaction. Students were more actively involved in managing the lesson. Direct intervention of the teacher, in form of explanations, and questioning in form of closed questions played a minor role, while open questioning and, overall, students' spontaneous contributions, in the form of exposition and elaboration of the group works, had a preminent part in the development of the classroom discourse; the teacher assisted students in engaging productively with a problem, increasing interaction amongst students and with the teacher.

In addition, when looking for ways to make the quality of the interaction better, the teachers came up with the idea of working with group work, directly involving students in the development and implementation of the lessons. So doing, the teachers promoted an environment in which students were expected to serve as resources to each other in working on mathematical problems, collaborating to develop solutions and sharing their strategies with each other. Therefore, students worked on the tasks in small groups and jointly presented the group solutions at the IWB, discussing them with the entire classroom and in this way improving also a high-quality discussion in the whole classroom.

In February the IWB mostly supported the teacher discourse. In May students were much more involved in using the IWB by their own. They used the IWB exploring geometrical properties of an object, researching the best mathematical model of physical and demographic phenomena, investigating different strategies of solving

difficult calculus problems. In these activities students compared different data representations, symbols, tables, charts, graphs, transforming from one representation to the other and looking for the best one. This use was at least partially sustained by teachers' scaffolding whenever students needed guide in discerning and choosing different mathematical strategies or lacked technological experience. The difference between February and May is reflected by the change in IWB actions employed in the lessons. In elaborating their group works students made large use of multimodal IWB actions, such as simulation of processes, comparison between different ways to represent a phenomenon, use of dynamic external software. Actions that might characterize a more traditional use of the IWB, such as displaying texts or images and composing like in a traditional board, decreased significantly. The IWB was exploited like a 'laboratory' for a better understanding of mathematical tasks and connections. Collective reasoning was actualised within a range of evolving multimodal representations that could beneficially be managed, organised, interpreted, saved and revisited so that connections and elaborations were created cumulatively over time. Of course the IWB offers students a large range of affordances, but also involves the necessary competencies, both in manipulating objects from other technologies, e.g. software as Geogebra or Excel, and in managing the tools included in the same IWB.

What emerges from this study is that IWBs technology may be used to enrich the lessons and the students' experience of challenging mathematical situations. Teachers may enhance the quality of interaction with mathematical tasks through an accurate balancing between theoretical attention to mathematical concepts and problem solving activities that involve students more directly. The discourse interaction may be improved basing less on direct explain and closed questions and leaving more space to students' discussions and autonomous works. The IWB sustains the two previous elements affording flexible and powerful tools and actions that allow students to visualize multiple representations, analysing, comparing and modelling relationships between variables. Mathematical tasks, discourse interaction and IWB support play each an important role but it is their attentive orchestration and combination by the teacher that leads to the construction of an effective and beneficial learning and teaching environment,

As stated by Hennessy and London (2013), the key difference between the IWB and a set of desktop computers is that the IWB allows technology to be used flexibly, and it brings technology firmly into the classroom and away from confinement to centrally located computer labs.

Resources and findings described in this paper may be useful in stimulating discussion about pedagogical practices in classrooms where the IWB is currently used and in improving a wider professional development for in-service teachers and pre-service teachers.

Surely, further research is needed to understand what important aspects of applications and modelling are touched (or not touched) upon by the technological environment and how the culture of the classroom is influenced by the presence of this technological device.

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REFERENCES

- Alexander, R.J. (2008). *Towards Dialogic Teaching. Rethinking classroom talk.* (4th ed.). York, GB: Dialogos
- Bantchev, B. B. (2010). *A Brief Tour to Dynamic Geometry Software.*
Retrieved from: <http://www.math.bas.bg/omi/DidMod/Articles/BB-dgs.pdf>
- Beauchamp, G., Kennewell, S., Tanner H., & Jones S. (2010). Interactive whiteboards and all that jazz: the contribution of musical metaphors to the analysis of classroom activity with interactive technologies. *Technology, Pedagogy and Education*, 19 (2), 142 -157.
- Beauchamp, G., & Kennewell, S., (2010). Interactivity in the classroom and its impact on learning. *Computers & Education* 54 (3), 759-766.
- Collins, A., Brown J. S., & Newman, S. E. (1989). Cognitive Apprenticeship: Teaching the Crafts of Reading, Writing and Mathematics. In L.B. Resnick (ed) *Knowledge, Learning and Instruction, Essays in honour of Robert Glaser* (pp. 453-494). Hillsdale, N.J: Lawrence Erlbaum Associates.

- Glover, D., Miller, D., Averis, D., & Door, V. (2007). The evolution of an effective pedagogy for teachers using the interactive whiteboard in mathematics and modern languages: an empirical analysis from the secondary sector. *Learning, Media and Technology*, 32 (1), 5-20.
- Glover, D., & Miller, D. (2009). Optimising the use of interactive whiteboards: an application of developmental work research (DWR) in UK , *Professional Development in Education* 35(3), 469-483.
- Hennessy, S., Deaney, R., Ruthven, K., & Winterbottom, M. (2007). Pedagogical strategies for using the interactive whiteboard to foster learner participation in school science. *Learning, Media and Technology*, 32(3), 283–301.
- Hennessy, S., & London, L. (2013). *Learning from international experiences with interactive whiteboards: The role of professional development in integrating the technology*. OECD Education Working Paper 89.
- Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In F. K. Lester (Ed.), *Second Handbook of Research on Mathematics Teaching and Learning* (pp. 371–404). Charlotte, NC: Information Age Publishing.
- Higgins, S., Falzon, C., Hall, I., Moseley, D., Smith, F., Smith, H. & Wall, K. (2005) *Embedding ICT In The Literacy And Numeracy Strategies: Final Report*. Newcastle, Newcastle University.
- Jewitt, C., Moss, G., & Cardini, A. (2007). Pace, interactivity and multimodality in teachers' design of texts for interactive whiteboards in the secondary school classroom. , *Learning, Media and Technology*, 32 (3), 302-318.
- Kennewell, S., Tanner, H., Jones, S., & Beauchamp, G. (2008). Analysing the use of interactive technology to implement interactive teaching. *Journal of Computer Assisted Learning*, 24(1), 61-73.
- Kennewell, S., & Beauchamp, G.(2007). The features of interactive whiteboards and their influence on learning, *Learning, Media and Technology*, 32(3), 227-241.
- Lombard, M., Snyder-Duch, J., and Bracken, C. C. (2002). Content Analysis in Mass Communication: Assessment and reporting of intercoder reliability. *Human Communication Research*, 28, 587 – 604.
- Mercer, N. (2004) Sociocultural discourse analysis: analysing classroom talk as a social mode of thinking. *Journal of Applied Linguistics*, 1(2), 137-168.
- Mercer, N., Hennessy, S., & Warwick, P. (2010). Using interactive whiteboards to orchestrate classroom dialogue. *Technology, Pedagogy and Education*, 19 (2), 195–209.
- Miller, D.J., & Glover, D. (2007). Into the unknown: the professional development induction experience of secondary mathematics teachers using interactive whiteboard technology. *Learning, Media and Technology*, 32(3), 319-331.
- Miller, D.J., & Glover, D. (2010). Presentation or mediation: is there a need for 'interactive whiteboard technology-proficient' teachers in secondary mathematics?. *Technology, Pedagogy and Education*, 19 (2), 253- 259.
- Moss,G., Jewitt, C., Levañiç,R., Armstrong,V., Cardini,A., & Castle, F., (2007) *The Interactive Whiteboards, Pedagogy and Pupil Performance Evaluation: An Evaluation of the Schools Whiteboard Expansion (SWE) Project: London Challenge* , School of Educational Foundations and Policy Studies, Institute of Education, University of London.
- Schoenfeld, A. H. (1983). Problem solving in the mathematics curriculum: A report, recommendations and an annotated bibliography. *The Mathematical Association of America, MAA Notes*, 1.
- Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense-making in mathematics. In D. Grouws (Ed.), *Handbook for Research on Mathematics Teaching and Learning* (pp. 334-370). New York, NY: MacMillan.
- Schoenfeld, A. H. (2006). Mathematics teaching and learning. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of Educational Psychology* (2nd ed.) (pp. 479-510). Mahwah, NJ: Erlbaum.
- Silver, E., Goussein, H., Gosen, D., Charambolous, C. & Font Strawhun, B. (2005). Moving from rhetoric to praxis: Issues faced by teachers in having students consider multiple solutions for problems in the mathematics classroom. *The Journal of Mathematical Behavior*, 24 (3-4), 287–301.
- Sinclair, J. & Coulthard, M. (1975). *Towards an Analysis of Discourse*. Oxford,GB: Oxford University Press
- Smith, F., Hardman, F. & Higgins, S. (2006) The impact of interactive whiteboards on teacher-pupil interaction in the national literacy and numeracy strategies. *British Educational Research Journal*, 32(3), 443–457.
- Somekh, B., M. Haldane, Jones, K., Lewin, C., Steadman, S., Scrimshaw, P., Sing, S., & Woodrow , D.(2007). *Evaluation of the Primary Schools Whiteboard Expansion Project*. London, Report to the Department for Education and Skills.
- Stein, M.K., Grover, B., & Henningsen, M. (1996). Building student capacity for mathematical thinking and reasoning: an analysis of mathematical tasks used in reform classrooms. *American Educational Research Journal*, 33, 455-488.

- Stein, M.K., & Smith, M. (1998 a). Mathematical tasks as a framework for reflection: from research to practice. *Mathematics Teaching in the Middle School*, 3 (4), 268-275.
- Stein, M.K., & Smith, M. (1998 b). Reflections on practice: selecting and creating mathematical tasks: from research to practice. *Mathematics Teaching in the Middle School*, 3 (5), 344-350.
- Straesser, R . (2001). Cabri-géomètre: Does Dynamic Geometry Software (DGS) Change Geometry and its Teaching and Learning? *International Journal of Computers for Mathematical Learning*, 6 (3), 319-333.
- Warwick, P., & Kershner, R. (2008). Primary teachers' understanding of the interactive whiteboard as a tool for children's collaborative learning and knowledge-building. *Learning, Media and Technology*, 33(4), 269–287.
- Warwick, P., N. Mercer, R. Kershner & Kleine Staarman, J. (2010), In the Mind and in the Technology: The Vicarious Presence of the Teacher in Pupils' Learning of Science in Collaborative Group Activity at the Interactive Whiteboard, *Computers and Education*, 55(1), 350-362.
- Wolfe & Alexander, (2008). Argumentation and dialogic teaching: alternative pedagogies for a changing world. *Beyond current horizons*.
- Retrieved from: http://www.beyondcurrenthorizons.org.uk/wp-content/uploads/ch3_final_wolfealexander_argumentationalternativepedagogies_20081218.pdf