From traditional blackboards to interactive whiteboards: a pilot study to inform system design

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Interactive whiteboards are a new technology that has gradually found its way into classrooms. The aim of this study is to explore the potential of interactive whiteboards for the teaching and learning of mathematics. From field observations, videorecordings and interviews with a teacher this research develops a description of the teacher's use of a traditional board, and discusses how the teacher perceives the potential of an interactive whiteboard.

Rationale

The study reported here aims to explore the potential of interactive whiteboards for the teaching and learning of mathematics. Studying the use of a traditional board by a mathematics teacher in a secondary school raises two research questions:

1. In what ways did the teacher use the board?
2. How did the teacher perceive the teaching potential of an interactive whiteboard?

These two questions will be addressed after a brief outline of existing studies of educational technology for classrooms.

Background

Research on Information and Communication Technology (ICT) in educational settings has been conducted mainly in two areas: (i) individual and pair learning software and (ii) distance learning (e.g., Kaput and Thompson, 1994). Rarely has there been research into technology for teaching in the 'traditional' whole-class classroom. Interactive whiteboards are a technology for the whole-class context that potentially offer a new way 'into the computer'. This study is guided by two broader questions:

- What *capacities* can this new technology offer for mathematics teaching?
- What are the *needs* for teaching and learning mathematics, which this technology might support?

These questions are approached from the perspective of *Requirements Engineering*, a branch of computer science that aims to determine what properties a system should have in order to succeed.

Requirements Engineering

The introduction of new (computer) technology has not often been as successful as hoped (e.g., Selwyn, 1999). In search of a rationale for this failure, over the last decade researchers in the field of Computer-Supported Cooperative Work (CSCW) started to approach the design of technology from a new direction. They shifted focus from the individual person to the social setting, and from an idealized picture of work practices to the details and 'messiness' of everyday work practices. These 'workplace

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studies' (Button, 1993) were influenced by methods drawn from ethnography and anthropology, in particular ethnomethodologically informed interaction analysis (Garfinkel, 1967; Goodwin, 1981). Further, they usually make extensive use of repeated analysis of videotapes to address the everyday practices of participants that are easily overlooked (Hindmarsh and Heath, 1998).

This study aims to elicit requirements for a new software application for an interactive whiteboard that could be used in the mathematics classroom (Greiffenhagen, 1999).

Boards in mathematics teaching

Many different types of boards can be found in schools: chalkboards, blackboards, whiteboards, markerboards, rollerboards, etc. However, there is a noticeable absence of research on the use of boards in teaching. They are usually simply regarded as large public displays. The few studies that have explored the advantages and disadvantages of boards come from a technological perspective. These studies (e.g., Stefik et al., 1987; O'Hare, 1993; Mynatt et al., 1999) identified the following common problems for the use of traditional boards in offices: (i) finding usable space among content that users did not want to erase; (ii) difficulty of sharing information following a discussion; and (iii) material once erased could not be recovered.

Interactive whiteboards provide the facility to modify the display electronically, and to save and print the displayed information. They can also be utilized in conjunction with video-conferencing. For mathematics, they offer the possibility of combining written text, symbols and diagrams in an electronic medium – which is hard to achieve using traditional computers with keyboards as the only input method.

Although they have been installed in many educational settings, such as the Classroom 2000 project[1], the NIMIS project[2] and the Collaborative Classroom project[3], key questions are rarely addressed: What could be their *educational* benefit for the teaching and learning of mathematics? What new facilities are offered for the mathematics classroom that could not be achieved with existing tools like textbooks or overhead projectors? This study aims to start addressing these questions.

Methodology

The lessons of a single secondary school mathematics teacher were observed and video-recorded over a period of three months. Being a passive observer I would sit at the back of the classroom trying to interact as little as possible with the students. After each lesson, short semi-structured interviews were conducted, which focused on the observed lesson and opportunities for an interactive whiteboard. The shared experience of the observed lesson initiated the interview (Cooper and McIntyre, 1996) and grounded the discussion of how an interactive whiteboard might be used in events that actually happened in the lesson.

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[1] http://www.cc.gatech.edu/fce/c2000/ (last updated August 1999)

2 http://collide.informatik.uni-duisburg.de/Projects/nimis/ (last updated June 1999)

3 http://dcr.rpi.edu/ (last updated December 1997)

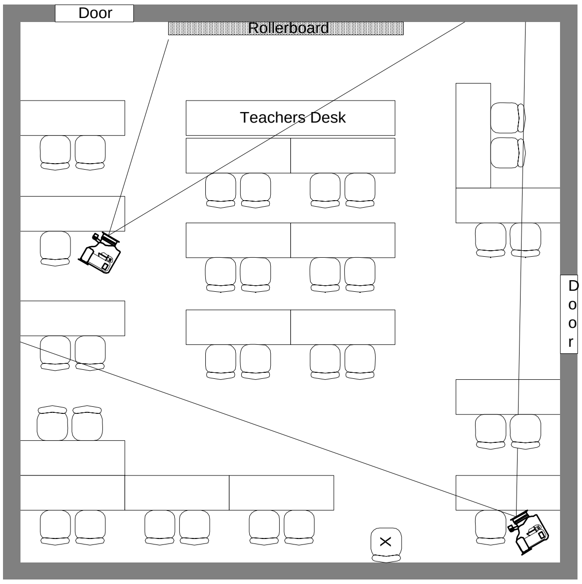

Figure 1: Placement of cameras

To gain insights into the everyday practices of using the board, the lessons were recorded on video to form the basis of an 'interaction analysis' at a later stage. Two cameras were placed in the classroom. The first was aimed directly at the board to capture local interactions. The second camera, in one of the rear corners, aimed to capture as much as possible of the general classroom interaction (see Figure 1). Thus, while still focusing on the teacher, the classroom could be observed as well. With a special machine it was possible to view both tapes simultaneously, focusing on the items written on the board as well as the interaction in the class. One advantage was that once the cameras were set up, no one was needed to 'direct' them, and I could sit away from the cameras creating less disturbance. The main disadvantage was that only the back of the students' heads was recorded. This was due to the initial focus on the teacher rather than the students. Through the repeated analysis of the videotapes, it was possible to focus on the everyday actions performed at the board; actions which are otherwise hard to observe and analyze.

1. In what ways did this teacher use the board?

Usually, each observed lesson was divided into two parts. In the first part, the teacher introduced a new topic, or revised what had been learnt earlier, in a whole-class setting. In the second part, the students would work on their own or in pairs on textbook questions. The board was only used during the first part. This organization seems to be fairly typical in mathematics teaching, as Jaworski (1994, p.8) observes:

> Typically, the teacher introduced the mathematical content of a lesson using exposition and explanation (teacher talk), usually from the front of the classroom (using blackboard and chalk). Pupils were then given exercises through which they practiced the topics introduced by the teacher.

From a constructivist point of view (Jaworski, 1994), in order to learn mathematics, students need to be brought into contact with mathematical concepts in a way that allows sense-making and cognitive structuring. Creating a classroom discourse that raises and questions mathematical ideas would draw students into a mathematical world in which mathematical sense-making is an active part of communication, thus making it possible for individuals to access and process mathematical ideas. Hence, the question arises whether interactive whiteboards could be used to create an environment in which students are more actively involved in the lesson – for example, through the use of electronic tablets or radio-mice, which students could use to 'write' from their local vicinity, the desk.

The analysis of the videotapes identified several actions on the board: contact with the board; pointing by the teacher; and by the student – which will be described below:

Contact with the board

The teacher used various ways to erase items on the board, sometimes a proper eraser, but usually his hand or part of his shirt. These events could occur immediately one after the other. On one occasion, the teacher initially used an eraser, followed only seconds later by his hand. The board was touched to (i) write; (ii) erase; (iii) point; and (iv) balance while writing.

These could occur simultaneously. For example, a student was observed writing on the board with his right hand while leaning on it with his left arm. These different ways of touching the board hold implications for the physical ergonomics of electronic whiteboards. There are two different types of boards: touch-sensitive ones, and ones that are written upon with an electronic pen. They create different sets of problems: Using the touch-sensitive board the student would have created signals both with the pen and his arm. The signals from his arm would be interpreted as undesired 'writing' on the board. Using the second type of board, erasing would only be possible by using an electronic pen or wiper.

Pointing by the teacher

The teacher often pointed at the objects on the board. This was done to refer to what he was talking about, or to confirm what he had just said. For example, in one lesson the teacher started by drawing two axes. Having asked the students which one was the x-axis and which was the y-axis, he labeled them accordingly. He then continued:

> These are things you need to remember: x-axis is the horizontal axis ((hand moves from left to right)) and y-axis is the vertical axis ((hand moves from bottom to top)).

One way to think about this is in terms of *resources*. Generally, two kinds of resources are to be distinguished: transient and persistent ones. In the example above, a transient resource (pointing) was used to reinforce a persistent resource (the drawing on the board). Pointing by the teacher was also used to reinforce a reference made by the student[4]:

> The teacher has drawn two axes on the board; writes "y=x+1" and "y=x+2".
> T: What do their graphs look like?
> P: The last number goes through the origin (.) that number.
> T: This number ((points at "1", leaves hand there))

The student verbally referred to "the last number". The teacher then put his hand there, making it visible for the whole class and reinforcing what the student has just said.

[4] The notation found in the transcripts is derived from the conventions described in Goodwin (1981). '(.)' denotes a silence of a tenth of a second. A colon ':' indicates that the sound preceding is noticeably lengthened. A bracket '[' connecting the talk of different speakers shows that overlapping talk begins at that point. Comments are displayed in double parentheses: '((comment))'. The teacher is referred to as 'T' and pupils as 'P', 'P2', etc.

Transient resources are available only at that particular point of time (in contrast to persistent resources). Therefore, students who do not pay attention when the teacher is talking and writing on the board lose what has been said (the transient resource) while still having access to what has been written (the persistent resource). However, what has been written might have an incomplete or different meaning without the additional verbal information. Hence, the meaning of the persistent resource (the writing on the board) might change over time through the availability of the transient resource (teacher's and student's talk).

The architecture of writing and drawing form an essential part of mathematics. “Mathematics is perceived overwhelmingly written.” (Pimm, 1987, p.1) In fact, “*being thought* in mathematics always comes woven into and inseparable from *being written*” (Rotman, 1993, p.x). One of the problems of conventional computers is the restriction to typed test – in contrast to using pencil and paper, which allow a mixture of text, symbols and various forms of diagrams. There are few other subjects in which the writing on the board is so much the focus of attention during the lesson. This is one of the reasons why interactive whiteboards with their ability to record, highlight and save the content of the board might be beneficial for mathematics teaching. In addition, they might provide resources for students to point at the board:

Pointing by the student

How can students point to objects on the board while staying in their seats? What difficulties do they have to overcome? An example will be used to illustrate this:

> The teacher has drawn two axes on the board and has just explained that there are four “quadrants”. Students are James (J) and Rachel (R).

T: Which is the first quadrant? James? ((James sits in the first row))
J: ((points at second quadrant))
T: This one? ((Figure 2))
((points at second quadrant))
No, it's not this one.
[…]
Which one is it? Rachel?
((Rachel sits in the last row))
R: It's
[
T: ((points at first quadrant)
R: (.) It’s ah:::
[
T: ((hesitates, pulls hand back))
R: It's ah (.) where they are all positive.
T: Where they are all positive. ((puts hand in first quadrant))

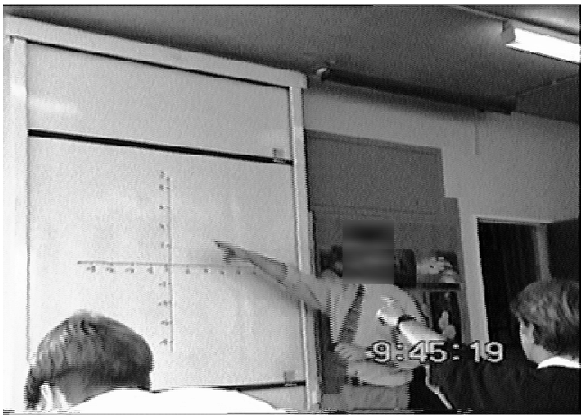

Figure 2: Student and teacher pointing

This example demonstrates the different resources available to students: The first student, James, was able to point at the board because he was sitting at the front, whereas the second student, Rachel, had to use words to describe the location – which is a very indexical way of transmitting information. As mentioned above,

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mathematicians find it very difficult to only talk about concepts without having a piece of paper or board to illustrate; they usually talk *and* write simultaneously. Interactive whiteboards with the support of electronic tablets for students would provide students with the opportunity to say *and* point to their suggested quadrant.

In fact, having electronic tablets available for every student would provide the means for asking new types of questions. Rather than asking James where the quadrant was, the teacher could have asked *every* student to point at their tablet where they thought the first quadrant was. These answers could then be used as a basis for discussion among the whole class. During an interview, the teacher came up with a similar idea:

> When all the students could have some tablet or something. […] I mean, that would be good. […] you could kind of, almost “what do you think the answer to this question is?”, couldn't you? ((laughs)) You could have some software saying, “Well, ten of you think the answer is this, and six of you think the answer is that.” And you could discuss the diff (.) You know why some people think that this is the answer and why others think that that is the answer. And you could get people who perhaps haven't got the correct answer to explain what they are doing. (Interview, 18.6.99, p.9)

Through such discussion, the mathematical concepts become part of the communicative discourse of the classroom through which individuals can start to build their own sense of them.

2. How did the teacher perceive the teaching potential of an interactive whiteboard?

One of the most obvious features of the interactive whiteboard is that it can be used to save the notes on the board, which can be printed at a later stage. Other features could be pre-prepared grids (e.g., 1mm, 3D, or isometric) or the possibility of annotating existing notes or other software applications. Because all the notes on the board are digital, the board could be used like a piece of paper, i.e., rotated or flipped (e.g., to demonstrate how to draw a particular graph). These facilities are specific to *mathematics* because they focus on particular aspects of writing. They have therefore not yet been implemented in the software provided with interactive whiteboards.

These features might all be ‘useful’ and facilitate the teaching, but they are only facilities for a better presentation by the teacher. They would not provide new resources for communication in the classroom:

> That's just like facilities which a board could have, isn't it? It's not really improving the quality of the mathematics, which is going on in the classroom, which would be really good, wouldn't it? If you could produce something which would improve kid's ability to communicate mathematics (.) otherwise you would just produce a glorified blackboard, aren't you? A sort of high-tech blackboard. (Interview, 18.6.99, p.11)

Focusing primarily on the teacher, it is easy to think of an interactive whiteboard as “a glorified blackboard”. This has been the approach of most manufacturers and teachers. The main finding from this study however is the importance of focusing on the possibilities of enhancing the communication and interaction of the *students* to potentially achieve a real educational benefit.

As mentioned above, mathematics “is perceived overwhelmingly written” (Pimm, 1987). Focusing on students’ writing both aims to teach the children about mathematics as well as written communication. Mehan (1989) investigating the use of computers observed that “having an audience […] gave students a purpose for writing”. Interactive whiteboards might present students with an *audience*, by providing the opportunity to display the work of students quickly on the board. Audiences could be the whole class or students in a different school.

At the moment, the teacher often tells students that they should not only write down the answer and that they should not forget their audience. But this advice is superfluous because the students are always aware of their audience – the teacher (cf. Morgan, 1988, p.45). This mathematics teacher remarked:

> Yeah, it's giving them, it's giving them audience, isn't it, for their work? Perhaps if they are just writing things in their exercise books, it's between you, them and perhaps their parents look at their exercise books occasionally, you know? […] It's a very narrow audience, isn't it? In terms of who they are communicating to. (Interview, 18.6.99, p.10)

With the new technological opportunities, the work of students could be displayed quickly on the board, giving them instant feedback. It would also mean that more text written by students (rather than the teacher) might be displayed on the board:

> I mean, it's (.) when they (.) if they saw it in their own work, you know, in another student's work, it'll perhaps have more significance than when you do on the board. You can talk to them just about how to set things out properly and how to communicate things properly. Ahh, they kind of think “that's the way the teacher does it”. But if they could see a good example of another student doing it. (Interview, 21.5.99, p.5)

In other words, seeing the answer of a fellow student on the board might help students to develop the mathematical concepts involved in their own language.

Conclusion

This study has started to address some of the issues of interactive whiteboards in mathematics teaching. Traditionally, the use of interactive whiteboards has been restricted to presentations made by the teacher. In contrast, our two main findings are:

1. Interactive whiteboards should not only be seen as a *presentational* device for the teacher, but as an *interactive and communicative* device to enhance the communication by the students; and
2. Interactive whiteboards might provide new resources to focus on the *writing by students* in the mathematics classroom. In particular, they could potentially provide students with an audience and allow the teacher to display more work written by students on the board.

By pursuing these two points, it is hoped that interactive whiteboards will provide innovative resources for teaching and learning mathematics – in contrast to Krummheuer’s observation (1992, p.214; my translation):

The potential of computer technology is not being used to improve lessons but only to imitate them.

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