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INTERACTIVE WHITEBOARDS IN MATHEMATICS EDUCATION: POSSIBILITIES AND DANGERS

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Abstract. *Interactive whiteboards are a new technology for 'traditional' teaching in the whole class. Although they have been installed in educational settings, the emphasis of research has been on their use in office settings. Preliminary findings from a pilot study of a mathematics teacher's use of a 'traditional' blackboard suggest that 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 with and among students. In this paper, interactive whiteboards are placed within the wider context of Information and Communication Technology (ICT) as a tool for Computer-Supported Collaborative Learning (CSCL). The potential of interactive whiteboard is explored 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. Drawing on this field, four steps for the design of technology in educational settings are specified and illustrated.*

1. Introduction

The goal of my research is to investigate the possibilities of interactive whiteboards in (secondary school) mathematics education. In a companion paper (Greiffenhagen, 2000) a pilot study is reported in which I observed one secondary school mathematics teacher and his use of a 'traditional' blackboard. As a result of this pilot study, requirements for a software application for use with an interactive whiteboard for the mathematics classroom were formulated (Greiffenhagen, 2000; Greiffenhagen and Stevens, 1999). A prototype is currently being developed and will be tested in the summer term.

The aim of this paper is to place interactive whiteboards in the wider context of Information and Communication Technology (ICT). After a brief summary of the development of interactive whiteboards in office and educational settings (Section 2), a framework for the classification of technology in mathematics education will be given. This framework consists of, on the one hand, three areas of research; on the other hand, four (incommensurable) *paradigms* of instruction that underlie the development of educational technology.

Having placed interactive whiteboards within this framework, four steps for the *design* of new technology will be introduced in Section 4. My current research will be used to illustrate these four steps in Section 5.

2. Interactive whiteboards

Interactive whiteboards¹ provide a comfortable and convenient interface with the computer, functioning like a huge blackboard-sized touch-screen². Any application that is used on a 'normal' computer can be displayed onto the interactive whiteboard and controlled from the display (e.g., Cabri Geometry, or Microsoft NetMeeting). The typical application provided with the interactive whiteboard is a Notebook that provides the facility to write and draw on several pages, and to save and print the displayed information.

¹ Several companies produce interactive whiteboards, e.g., SMART technologies (<http://www.smarttech.com>), Promethean (<http://www.promethean.co.uk>), or MicroTouch (<http://www.microtouch.com>).

² There are various kinds of interactive whiteboards: Front-projected and rear-projected ones (the latter are easier to use, but more expensive). Furthermore, two ways of writing on the board have to be distinguished: Either the board works with a special electronic pen, or the whole surface is touch-sensitive, i.e., either a pen or a finger can be used to write onto the board.

The first interactive whiteboard was the Xerox LiveBoard (Elrod et al., 1992) and was used in small office meetings (Pedersen et al., 1993). The LiveBoard was developed after identifying several disadvantages of traditional blackboards for office meetings: space is limited; rearranging items is difficult; they are unreliable for information storage; it is difficult to share information following a discussion; and material once erased cannot be recovered (Stefik et al., 1987; Mynatt et al., 1999).

Research on interactive whiteboards has grown in the last decade. Typical settings include the use for informal workgroup meetings (Moran et al., 1998; Pedersen et al., 1993), as a tool for remote collaboration (Brace et al., 1998; Ishii et al., 1994), and for use in an individual office (Mynatt, 1999; Mynatt et al., 1999).

Interactive whiteboards have also been installed in educational settings: In the COSOFT project (Hoppe et al., 1993) an interactive whiteboard was connected to individual workstations. The IdeaBoard Project (Nakagawa et al., 1996; Nakagawa et al., 1997) provided a tool for arithmetic education where (primary) pupils wrote arithmetic equations on the board and the system provided answers (using optical character cognition). The Virtual Classroom Project supported by the DfEE (1998) aims to explore possibilities for distance education. Finally, interactive whiteboards have been used in the Classroom 2000 Project (Abowd et al., 1996, 1998) for the capture and support of university lecture courses.

However, apart from a few questionnaires to teachers (e.g., DfEE, 1998; Bell, 1998) there has been no research on the use of interactive whiteboards in educational settings. In my research, I hope to make a first step towards a classroom specific evaluation. As part of this project, it is important to place interactive whiteboards within the wider context of ICT in educational contexts. This will be the topic of the next section.

3. ICT in education

In this section interactive whiteboards are placed within the context of Information and Communication Technology (ICT). It is argued that they should be seen as a tool that could enhance and provide new resources for the ‘traditional’ classroom. To distinguish between different uses of interactive whiteboards, different paradigms of ICT are discussed and interactive whiteboards are then situated within the paradigm of Computer-Supported Collaborative Learning (CSCL).

3.1 Three areas of research in ICT

Recent lines of research in ICT may be subsumed under the areas of (Hoppe et al., 1993):

- (i) *Individualised student-oriented and problem-centred instruction; and*
- (ii) *Remote or distance teaching and learning through educational networks.*

Rarely has there been research into technology for teaching and learning in ‘traditional’, whole-classrooms³. One reason for this might be that computers (usually used synonymously with ‘ICT’) have been considered as too disruptive for ‘normal’ classroom practices. But, with development of new technologies such as interactive whiteboards (see above) or Personal Digital Assistants (PDAs; see Myers et al., 1998), this may change⁴. Weiser (1991) and Buxton (1997)

³ A notable exception is the paper “Classroom Restructuring: What Do Teachers Really Need?” (Fishman and Duffy, 1992).

⁴ Norman (1998) has observed that we use the word ‘technology’ to refer to tools that are not easy to use: “After all, in everyday speech, we use the word *technology* to refer to things that are new, where the technology dominates over usability and usefulness. We call the digital computer ‘technology.’ We call the internet ‘technology.’ But what about a

argue that computer technology needs to become ubiquitous in order to let us focus on the *task* that we would like to perform rather than the *technology*.

Consequently, a third line of research has emerged recently, viewing computers as enrichments of natural communication and interaction. This thinking is encapsulated in the notion of:

(iii) *Enhancing the resources for communication and collaboration in the 'traditional' classroom.*

The focus of (iii) is to integrate computer technology with 'traditional' classroom procedures and provide support for collaborative activities (Tewissen et al., 2000). Examples include:

- The idea of a 'Computer-integrated Classroom' or CiC (Hoppe et al., 1993; Tewissen et al., 2000). An implementation can be found within the NIMIS project at the University of Duisburg⁵;
- The notion of an Interactive Teaching Theatre (Keil-Slawik, 1999; Hampel et al., 1999) as part of the DISCO project at the University of Paderborn⁶;
- The application of ubiquitous computing to a university classroom (Abowd et al., 1996, 1998) to capture and support university lecture courses within the Classroom 2000 Project at the Georgia Institute for Technology⁷.

Although interactive whiteboards are sometimes used in 'computer classrooms', they are often installed in 'traditional' classrooms, providing teachers and students with a convenient interface with the computer. The potential of interactive whiteboards for mathematics teaching therefore lies in providing additional resources for the 'traditional' classroom, i.e., (iii).

However, the above distinction between tools for individualised learning (i), distance teaching (ii), and the 'traditional' classroom does not capture the diverse uses, and potential uses, of interactive whiteboards in schools. In particular, a framework is needed to distinguish between using these boards as a 'presentational' device (e.g., for the teacher who uses PowerPoint) and as an interactive, 'communicative', device that enhances and provides resources for communication within the classroom. In the next section, four different paradigms of instructional technology are introduced, and interactive whiteboards are placed within the Computer-Supported Collaborative Learning (CSCL) paradigm.

3.2 Four paradigm of ICT

Koschmann (1996) undertook a Kuhnian analysis of instructional technology (IT) and came to the conclusion that research in IT has undergone several paradigm shifts Kuhn (1996). Koschmann's central contention was that the paradigms discussed below utilise different research practices and are based on incommensurable views of learning and instruction. Different views of learning then (e.g., behaviourist or social constructivist) entail different goals for technology - and different methods of evaluation.

pencil or a paper? How about a gas stove or a safety pin? In actuality, all are technologies, all follow advanced scientific and engineering practice in their design and manufacture. But pencils, paper, stoves, and pins are so commonplace that we take them for granted. We assume the technological features are reliable and robust, and so, on the whole, we ignore them." (Norman, 1998, p. 27)

⁵ <http://collide.informatik.uni-duisburg.de/Projects/nimis/>

⁶ <http://iug.uni-paderborn.de/iug/projekte/disco>

⁷ <http://www.cc.gatech.edu/fce/c2000/>

Koschmann (1996) outlined three existing paradigms: (a) computer-assisted instruction (CAI); (b) intelligent tutoring systems (ITSs); and (c) Logo-as-Latin Paradigm. He then contended that we are currently witnessing the emergence of a new paradigm in IT research; namely, (d) Computer-Supported Collaborative Learning (CSCL).

Whereas CAI and ITS are based on behaviourist or information processing views of learning, CSCL incorporates perspectives from social constructivism (Ernest, 1992; Cobb and Bauersfeld, 1995; Jaworski, 1994), Soviet sociocultural theories (Vygotsky, 1978), and situated cognition (Kirshner and Whitson, 1997; Lave and Wenger, 1991). Under such theoretical framework, learning is understood

as a distributed, ongoing process, where evidence that learning is occurring or has occurred must be found in understanding the ways in which people collaboratively *do* learning and *do recognising* learning as having occurred. (Jordan and Henderson, 1995, p. 42)

The research interest within CSCL lies in the question of how technology might serve to facilitate collaborative methods of instruction (Koschmann, 1994; Koschmann et al., 1996; Crook, 1994). This is concurrent with similar developments in mathematics education (for example Voigt, 1985; Cobb and Bauersfeld, 1995; Jaworski, 1994; Krummheuer, 1992; Bauersfeld, 1994).

Table 1 summarises the four different paradigms of ICT and specifies the underlying theories of learning and instruction.

	<i>Theory of Learning</i>	<i>Model of Instruction</i>	<i>Research Issue</i>
(a) CAI	Behaviourist	Programmed instruction/ instructional design	Instructional efficiency
(b) ITS	Information Processing Theory	One-to-one tutorial, interactive	Instructional competence
(c) Logo-as-Latin	Cognitive constructivist	Discovery-based learning	Instructional transfer
(d) CSCL	Socially oriented theories of learning	Collaborative learning	Instruction as enacted practice

Table 1: Four Paradigms of Research in ICT (Koschmann, 1996, p.16)

This framework helps us to distinguish between the different goals of the use of interactive whiteboards in schools. So far, the companies that produce these boards are selling them to teachers as a tool to enhance the presentational resources during lessons. Placing the emphasis on the teacher's presentation supports a "transfer of knowledge from teacher to learners" view of learning, i.e., (a) or (b) above. This is largely incompatible with a view of learning, that sees learning as a collaborative enterprise and that focuses more on the process than the product, that emphasises the importance of communication and interaction of students, i.e., (d) above.

In my pilot study (cf. Greiffenhagen (1999, 2000) and Section 5 below) the potential of the interactive whiteboard was seen as a *communicative* tool for teachers and students, i.e., as a tool for CSCL. From this perspective, the view of interactive whiteboards as a presentational device might have a 'negative' effect. Rather than providing teachers and students with new resources, the established patterns and routines (Voigt, 1985) in the classroom may be reinforced, and the "mistakes of existing practices may be multiplied" (Bauersfeld, 1985, my translation).

4. Requirements Engineering

My current research aims to address the potential of interactive whiteboards from the perspective of Requirements Engineering (Luff et al., 2000; Jirotko and Goguen, 1994), a branch of

computer science that aims “to determine what properties a system should have in order to succeed” (Goguen, 1993, p. 194).

The introduction of new technology has often not been as successful as hoped for (for example Selwyn, 1999; Gibbs, 1997; Grudin, 1988). To discover reasons for this failure, researchers in the field of Computer-Supported Cooperative Work (CSCW) in the last decade started to approach the design of technology in a new way: the focus was shifted from the individual person to the whole social setting (Grudin, 1990), and from an idealised picture of work practices to the details and ‘messiness’ of everyday work practices.

These ‘workplace studies’ (Plowman et al., 1995; Luff et al., 2000; Button, 1993) were influenced by methods drawn from anthropology and ethnography, in particular ethnomethodologically informed interaction analysis (cf. Suchman (1987); Dourish and Button (1998); Goodwin (1981); Garfinkel (1996)). The methodology employed makes frequent use of repeated analysis of videotapes to identify the everyday practices of participants that are otherwise easily overlooked (Heath and Luff, 2000; Hindmarsh and Heath, 1998).

Incorporating this new approach, Koschmann et al. (1996, pp. 83-84) propose four steps for the *design of technology in educational settings*:

- (1) Making explicit the instructional requirements that serve as design goals for the project;
- (2) Performing a detailed study of current educational practice with regard to these goals;
- (3) Developing a specification based on the identified requirements and limitations of the instructional setting, and the known capabilities of the technology; and
- (4) Producing an implementation that allows for local adaptation to instructional practice.

For my research, the first step consisted of positioning the research in the framework of ICT outlined above, namely adopting a social constructivist view of learning. The next step was a detailed pilot study of everyday practices of the teacher using the board, followed by focused interviews. The commitments in (3) were called the *capacities* and *needs* respectively (Greiffenhagen, 1999,2000):

- What *capacities* can interactive whiteboards offer?
- What are the *needs* in teaching/learning that interactive whiteboards might support?

These two questions stand in a dialectical relationship to each other. The capacities of interactive whiteboards shape the focus of the educational issues addressed; on the other hand, the needs of the teacher and pupils influence which capacities of interactive whiteboards are explored in greater detail.

This dialectical relationship has also an effect on the relationship between the analyst (system designer) and the practitioner (teacher). In contrast to traditional engineering problems that involve finding a new technical solution for a given function, requirements are constantly changing:

The requirements emerge as a trade-off between various interests and alternatives rather than as a self-contained specification of a technical solution to a well-known problem. (Keil-Slawik, 1992, p. 172)

Furthermore, requirements are not complete well-defined concepts ‘out there’ waiting to be discovered. Goguen (1994, p. 177) argues that requirements are not captured, but emergent:

Requirements are emergent in the sense that they do not already exist in the minds of clients or requirements engineers (or anywhere else); instead, they gradually emerge from interactions between requirements engineers and the client of the organisation.

Therefore Suchman and Trigg (1991) demand that tools should ‘co-evolve’ with practice. This places a special weight on the relationship between the requirements engineer and the

practitioner (here: the teacher). Both have to learn from each other. Consequently, Keil-Slawik (1992, p. 173) argues that the development of new software and new technology must be regarded as a *collaborative learning process*.

The recommendation to view requirements engineering as a collaborative learning process provides a strong link between recent developments in requirements engineering and educational research. Wagner (1997) advocates a view of educational research as a *co-learning agreement*:

How can researchers and practitioners thoughtfully determine the forms of cooperation that will work best for them? (p. 20)

In my research this approach is being pursued by working closely with a mathematics teacher. Experiences and preliminary results are discussed in the next section.

5. Current research

Following the framework outlined by Koschmann et al. (1996) the ongoing research is discussed in this section. After a short summary of the design goals and a description of the pilot study, the identified requirements ('needs') will be considered. Finally, the current state of the research is outlined.

1. Design goals.

The view of learning mathematics advocated here has been discussed above within the framework of CSCL. Mathematical learning

is a process of active construction that occurs when children engage in classroom mathematical practices, frequently while interacting with others. (Cobb, 1994, p. 16)

Consequently, teaching is not simply a transfer of knowledge, and the goal of the teacher should be to help pupils communicate *about* mathematics and help pupils come up with their own ideas, i.e., focusing on the *process* rather than the product of learning (Bauersfeld, 1994, p. 141).

This view of learning stands in contrast to that advocated by the companies that produce interactive whiteboards. These companies still see the teacher as an instructor and interactive whiteboards as a tool for 'better' instruction.

2. Pilot study.

A pilot study was conducted that aimed to elicit the 'needs' in mathematics teaching that could be enhanced and supported by interactive whiteboards. The pilot study was conducted in one secondary school in Oxfordshire and involved observing, interviewing, and video-recording one mathematics teacher. This teacher showed an interest in experimenting with an interactive whiteboard after this pilot study (for a more detailed discussion see Greiffenhagen (1999, 2000)).

Following the recommendation of Keil-Slawik (1992) and Wagner (1997) the pilot aimed to be a collaborative learning process. Short interviews were conducted after each lesson, the shared experience sparking discussions about the difficulties encountered during the lesson ('needs') and the possibilities for interactive whiteboards ('capacities').

3. Identified requirements.

The two main findings or identified 'needs' were (for a longer discussion see Greiffenhagen, 1999, 2000):

- Interactive whiteboards should not only be seen as a *presentational* device for the teacher, but as an *interactive and communicative* device that enhances the resources for (student) communication;

- Interactive whiteboards might provide new resources for *students' writing* in the mathematics classroom, for example, by quickly displaying their written work at the front, or allowing them to write on the board from their desk.

The greatest potential of the interactive whiteboards might be their interactive nature. These boards could be seen as an *interactive and communicative* device that might enhance the resources for communication in the classroom. For the teacher in the pilot study, mathematics “is about communicating numerical mathematical ideas to other people”. However, he complained about the lack of communication skills of his students and the overemphasis of pupils on getting the right answer. It would be of enormous benefit if interactive whiteboards could help teachers break up the ‘exposition and practice’ approach to teaching, thus focusing on the communicative and social aspects of mathematics and mathematics learning. This might be done through:

Electronic pads: to give students direct access to the board,

Hand-held scanners: to provide an audience for students’ written work.

To sum up: The main finding from this pilot study was that the goal should not be to produce a “glorified blackboard” for the teacher, but rather to use the interactive whiteboard to enhance the communication and interaction in the classroom, in particular pupil participation in communication. The possibilities to display more students’ writing on the board (by scanning their written work), or to potentially allow students to write on the board from their desk were seen as particularly valuable.

4. Implementation.

A prototype software for an interactive whiteboards is currently being developed (Greiffenhagen and Stevens, 1999). It is planned to use two input devices as adjuncts to the interactive whiteboards: hand-held scanners at the first stage, and electronic tablets (large format PDAs) at a later stage. The key property of both devices is that they can fit within existing classroom practice. They are compact enough for use on a standard classroom desk and can be easily shared between pupils and classes and physically handed around. As such, an affordable pool of equipment can readily support day-to-day teaching in ordinary classrooms.

6. Final remarks

As mentioned above, technology in mathematics education has been accused of amplifying the ‘mistakes’ of current educational practices (Bauersfeld, 1985). The potential of computer technology is often not being used to improve lessons but only to imitate them (cf. Krummheuer, 1992, p. 214). The teacher that I worked with during the pilot study remarked:

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)

By pursuing an approach guided by the principles above, it is hoped that interactive whiteboards will provide innovative resources for teaching and learning mathematics, a resource for CSCL - and not simply a “glorified blackboard”.

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