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Can the interactive whiteboard support young children's collaborative communication and thinking in classroom science activities?

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Abstract Interactive whiteboards (IWBs) have been widely introduced to English primary schools (5–11 years) in the last decade and this has generated much research interest. In the past, research has focused on IWB-use in teacher-led sessions, attending particularly to the nature of teacher-pupil interaction at the IWB and the apparent motivational advantages for children. In contrast, this study focuses on children's communication and thinking during their semi-autonomous use of the IWB during collaborative groupwork in primary school science lessons, aiming in part to see if the IWB is suited to this type of use. Over the course of one school year, twelve primary teachers of Years 4 and 5 (8–10 years) took part in a professional development and research programme which involved them in devising a sequence of three science lessons incorporating small-group activity at the IWB. The functionality of the IWB is analysed here as means for supporting the children's joint communication and thinking, using embedded cues and the availability of certain features in the IWB technology. Our observational analysis of two examples of children's collaborative activity in different classrooms, together with subsequent group interviews, suggests that the IWB can make some identifiable contributions to children's productive communication and thinking. However the IWB is not seen to be an entirely distinctive or pedagogically transformative learning resource in the primary classroom. In our developing conceptual framework, the children's knowledge building is closely related to their active engagement in using IWB affordances and their productive dialogue, essentially supported by the teacher's scaffolding strategies, the establishment and use of "talk rules" in conversation, and the opportunities and constraints applying in classroom participation structures. These conditions help the children to deal with interconnected social, cognitive, and technical problems arising over time. Certain aspects of this form of computer-supported collaborative learning (CSCL) are discussed. These relate to the integration of the

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IWB with other classroom learning systems and resources, and to the nature of progression in children's activity and learning with this new type of highly integrated system of CSCL.

Keywords Collaborative groupwork · Classroom communication · Collective thinking · Interactive whiteboard · Primary/elementary education · Science learning · Teacher development

Introduction

As a result of government policy initiatives and financing in the UK, interactive whiteboards (IWBs) began to gain a visible and distinctive presence in English classrooms during the 2000s (Rudd et al., 2009; Underwood et al., 2010). Young children's direct use of the IWB for collaborative groupwork is a relatively recent phenomenon in English primary schools (5–11 years), although other forms of computer-supported collaborative learning (CSCL) have been employed for many years. Our intention here is to investigate whether the IWB has features which may support children's collaborative communication and thinking in classroom activities designed by their teachers, focusing on 8–10 year olds (Primary Key Stage 2: Years 4 and 5). Science learning in primary school was selected as a potentially fruitful educational focus for this work, given its central place in the English primary curriculum and its wide range of conceptual and procedural learning goals.

The basic IWB system comprises a computer linked to a data projector and a large touch-sensitive wall-mounted electronic board which displays projected images ("objects") that can be manipulated directly by hand or with a stylus. The IWB allows direct interaction with text and images on the screen, as well as access to previously stored material and the Internet. From their early uses by teachers as stand-alone devices for presenting previously prepared material, IWB systems have now become more commonly understood as digital hubs available for different types of classroom use in combination with other electronic resources such as digital cameras, microscopes, and so on. Primary school science commonly employs different forms of technology to assist with practical investigations and to represent scientific knowledge and understanding, so introducing collaborative groupwork with the IWB for research purposes was seen to be a reasonable fit with familiar classroom practice.

Since the large-scale introduction of IWBs to primary and secondary schools there has been an extensive body of research on their educational uses, mostly focusing on teacher-led sessions. Particular attention has been given to the nature of teacher-pupil interaction at the IWB and the apparent motivational effects for children (Gillen et al. 2008; Hennessy et al. 2007; Higgins et al. 2007; Jewitt et al. 2007; Kennewell and Beauchamp 2007; Somekh et al. 2007). In this study, we shift the attention to children's semi-autonomous, collaborative use of the IWB for science learning, drawing on three strands of our previous research on young children's classroom learning: children's collaborative classroom talk and learning (Mercer et al. 2004; Mercer and Littleton 2007); computer-supported, multimedia classroom learning in science and other curriculum areas (Warwick et al. 2006; Gillen et al. 2008); and primary teachers' understanding of the interactive whiteboard as a tool for children's collaborative learning and knowledge building (Warwick and Kershner 2008).

It has been observed by researchers and teachers that the mere introduction of the IWB does not in itself have a transformative effect on classroom teaching and learning and may indeed reinforce familiar patterns of teacher-pupil interaction in whole-class teaching (Smith et al. 2006; Underwood et al., 2010). This could in part reflect the fact that, in most

English primary schools, IWBs were introduced without a radical change to the curriculum, pedagogy, or physical layout of the classroom (often simply involving the replacement of a plain whiteboard in approximately the same location). In such contexts, the children's IWB involvement would commonly be limited to interacting with the teacher as a whole-class group, with some invited, teacher-led opportunities for individual pupils to approach and move images or write on the IWB screen. Yet many primary teachers aim to help children to develop as self-motivated and collaborative learners who skilfully employ a range of classroom resources for different purposes. A recent review of primary education in England suggests that a growing number of primary schools are radically developing the curriculum to support more active, dialogic approaches to primary learning and teaching (Alexander 2010). So there are potentially tensions between the ubiquitous classroom presence of IWBs, current government guidance on pedagogy (emphasising the value of IWBs for whole-class teaching), and primary teachers' own diverse approaches and preferences for engaging children in active learning.

This wider educational context of our current research is important to acknowledge because it influenced the nature of our exploratory research approach with the teachers and children. However the current educational climate was not the only reason for deciding to focus on this form of computer-supported collaborative learning (CSCL). Previous research which points to the importance of certain forms of talk for collective reasoning and learning, in turn draws attention to the many factors and conditions that may support or hinder effective communication in computer-supported and other learning environments (Mercer 2000). Mercer and Littleton (2007) remark on three general conditions for groups of children to think together productively and advance their understanding: sufficient time and opportunity to engage with a suitable task; tools for pursuing the tasks and recording outcomes; and interactive skills to work together effectively (including the active learning of "talk rules" about questioning, listening, and so on). Productive talk depends not only on the children's communicative skills but also on their shared purpose in the activity, which is developed through the processes of communication and supports that communication. Yet communication is known to be multimodal and situated. Pea (1994), in his discussion of CSCL, writes eloquently about the "social and material embeddedness of everyday communication":

> Conversations and interactions in everyday life take place in a rich referential field. The dense texture of human bodily orientation, gesture, and facial expression are known to communicate and continually transform on a moment-to-moment basis affective, cognitive, and social dimensions of relationships. Just as profoundly, there is a material environment to which attention can be directed, by gaze, pointing, and other means, in this conversational space. It, too, is transformed on a moment-to-moment basis. This material environment certainly includes physical objects, but it is also likely to include external representations, or inscriptions, such as writing and sketches, and in more formal settings, whether in school or work, such symbolic artifacts as equations, diagrams, maps, and designs. (p. 286)

Pea's account of the material environment draws attention to what may be the particular potential of the IWB in the classroom context for focusing children's attention and communication on the external representations of their thinking on the large screen, and hence supporting their productive talk and learning. The IWB offers a quite radical change in perspective for young children's computer use in the ordinary classroom. Its screen is very large compared to PCs and laptops, and it is vertically mounted. The children stand in front of it, reach up and move around freely rather than sit at their tables. The large screen

potentially makes their work publicly available to the teacher and other children across the whole classroom. One of our research concerns with the teacher group was, therefore, to acknowledge such factors in the classroom environment and clearly contextualise our investigation of how the IWB's affordances to support learning were employed by the children to *think collectively.*

Theoretical background and conceptual framework

Our analysis of children's IWB use for collaborative science learning in the primary classroom is informed by a Vygotskian, sociocultural understanding of the ways in which thinking and learning may be shared between those involved in any purposeful activity. This perspective on school learning emphasises the importance of the communications, social interactions, and relationships between children and teachers in historical and cultural context (Daniels 2001; Palincsar 1998; Wertsch 1991). With regard to computer technology, we also acknowledge the influence of Hutchins (2005), who discusses the blending of material artefacts and cognition as a fundamental human process, which both stabilises and extends the way people think about the world and achieve their ends.

In examining children's talk at the IWB, we draw on Mercer's (2004) *sociocultural discourse analysis,* which he describes as "…an integrated set of methods and procedures …(designed) to understand how spoken language is used as a tool for thinking collectively" (p. 138). This approach uses qualitative and quantitative data, retaining the talk transcripts as the primary focus of analysis. Depending on the specific research focus, it can combine close interpretive attention to dialogue in individual episodes occurring at different times in the data with comparative textual analysis of key words and phrases across a representative sample of cases.

This analytic approach acknowledges the *historical* and *dynamic* aspects of talk, which mediate joint intellectual activity. Historical aspects of institutional and cultural contexts are recognised as well as the speakers' own past experience and relationships. In addition, collective thinking is seen to be dynamic in that the development of shared understanding is based on a shifting basis of *common knowledge* and meaning. The fundamental need to acknowledge these and other temporal aspects of learners' interaction and dialogue has been a recently converging interest in the CSCL field, with methodological implications for tracing conversation over time and looking closely at sequences of interaction (Mercer 2008; Sarmiento and Stahl 2008; Suthers et al. 2010).

One of the principles of Mercer's sociocultural discourse analysis lies in the use of a frame of reference for understanding children's group talk in the form of a deliberately simple typology: *disputational*, *cumulative,* and *exploratory* (2004, p. 146). Disputational talk is characterised by disagreements, by individualised decision making, and by short, often confrontational, interchanges between speakers. It is often associated with competitive classroom behaviour and poor learning outcomes. Cumulative talk involves speakers in friendly discourse with positive but uncritical exchanges that build toward a common understanding through accumulated repetition, confirmation, and elaboration. This is often useful at certain points of a task, such as the initial sharing of ideas. Exploratory talk, which is seen to be most closely associated with productive learning, represents constructively critical engagement with each other's ideas, based on reasoned justification and explicit consideration of alternative views (see also Barnes 2008). This typology is not presented by Mercer as the basis for an observational coding system because this would extract the talk from the social and temporal context. In addition, episodes of talk are seen to have typical

features rather than falling into clearly defined categories, so judgement and discussion is involved in their interpretation. Mercer suggests that the typology is a useful heuristic device for perceiving the nature and direction of group talk at any one time and, moreover, "…very useful for explaining the principles and outcomes of discourse analysis to 'users' of research, such as teachers" (p. 146). This last point might be understood as finding an appropriate "grain size" for analysing features of children's talk meaningfully in a mixed research group with teachers—a point directly relevant to the current study. In previous work with a small teacher research network, also focusing on use of the interactive whiteboard as a tool for children's collaborative learning and knowledge building, we found that the teachers and Faculty researchers could effectively carry out joint data analysis and reflection with reference to explicit concepts of sociocultural theory, classroom talk, and learning—including the *exploratory*, *cumulative,* and *disputational* talk typology outlined above (Warwick and Kershner 2008).

The development of a conceptual framework

In general, the success of children's collaborative groupwork is known by teachers and researchers to depend to a greater or lesser extent on a number of interacting factors, not all of which are within the teacher's immediate control. When considering IWB use specifically, relevant factors may vary in their specificity to the IWB or classroom practice in general, and in how they refer to the characteristics and relationships of children, the teacher, the IWB, the classroom, school, or beyond (Warwick and Kershner 2008).

Our current conceptual framework and working model, given in Fig. 1, summarises the factors and relationships seen in this research to be most relevant to children's collaborative activity with the IWB. This version of the model was developed during our data analysis. It has evolved over time, serving at each review both to represent the research team's thinking and to guide further discussion and data analysis. It is given here to acknowledge the wider context of the lesson observations given later in this paper.

The model in Fig. 1 shows the centrality of a *shared dynamic dialogic space*, in which the children's communication is the basis for knowledge building. The children's apparent engagement in the set task, including their dialogue and their use of IWB affordances, is understood to be supported by the teacher's guiding role and the wider classroom participation structures, all developing over time. Omitted from this diagram, but also seen as important, are relevant factors in the surrounding historical, cultural, and political context, such as the government support for placing IWBs in primary classrooms outlined earlier.

The central notion of *the shared dynamic dialogic space* is the focal point of the children's collective reasoning and co-construction of knowledge (Mercer et al. 2010). This concept draws on Wegerif's (2007) notion of "dialogic space" as "…a social realm of activity within which people can think and act collectively" (p. 2). Wegerif argues for a significant shift toward dialogic ways of thinking as a fundamental educational aim, with related implications for computer use and CSCL. In the eyes of teachers and children, certain forms of computer technology may afford specific motivations, opportunities, and supports for productive talk and learning. However task design, software, and hardware can also hinder or distract learners in their goals. In the current study, the shared aim in the research group was to create conditions in each classroom to enhance the children's productive communication at the IWB. The children's interactions were then analysed for signs of where the IWB appeared to offer resources for supporting effective collaborative reasoning (linking *dialogic space* with *children's active participation* and *knowledge*

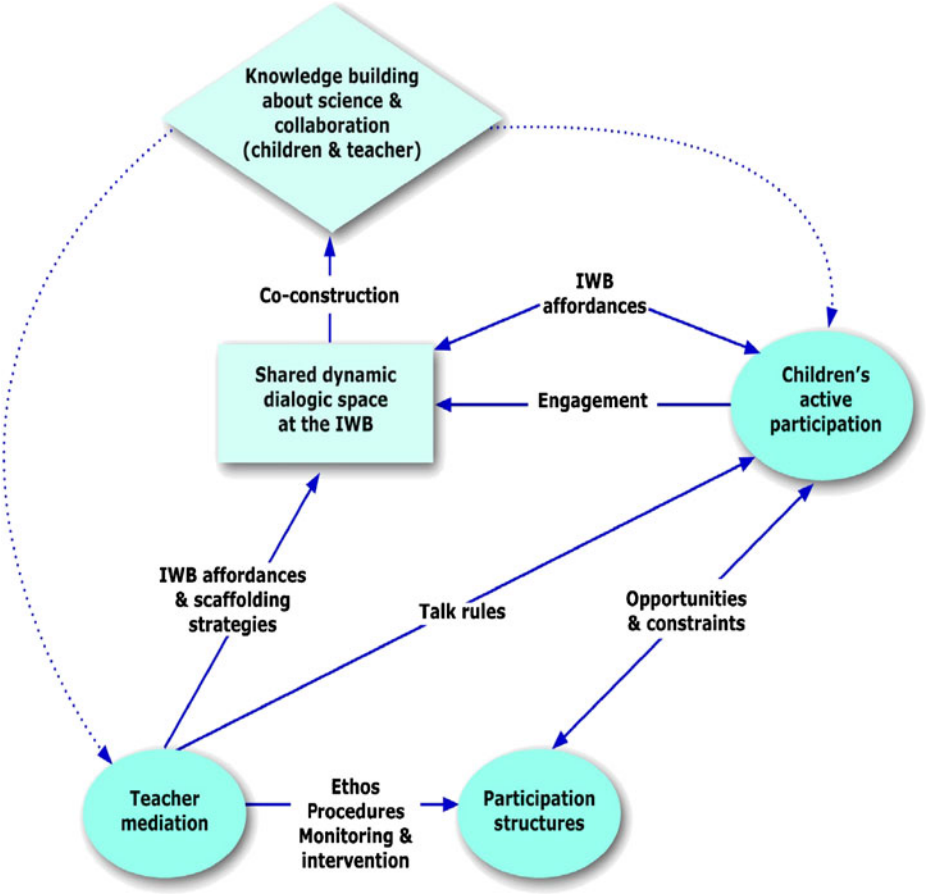

Fig. 1 A model of collaborative activity at the IWB

building in Fig. 1). Over time, the dialogic activity and knowledge building are understood to feed back to influence the thinking and future actions of the teacher and the children (dotted arrows).

The supporting conditions for children's collaborative learning at the IWB are represented partly in Fig. 1 by the connection of *teacher mediation* with *dialogic space*. Three main types of teacher activity include: the use of IWB affordances to set up the task (although note that children also perceive their own IWB affordances, which may not match the teacher's thinking); the use of other dialogic and interpersonal scaffolding strategies for supporting the children's talk and group activity (including the introduction of "talk rules" mentioned above); and the teacher's influence on classroom participation structures. The *participation structures*, defined by Cazden (1986, p. 437) as "…the rights and obligations of participants with respect to who can say what, when, and to whom," appear in the establishment of the classroom ethos and the use of accepted routines as well as moment-to-moment social interactions. Specific participation structures (such as co-operative turn taking) provide opportunities and constraints for children's *active participation* at the IWB, as discussed later in this paper. However, they may in turn be affected (double arrow) by the

introduction of new patterns of group interaction during children's increasingly independent use of the IWB resource and classroom space previously held by the teacher.

The central idea of dialogic space as collective thinking constituted in talk can be related to the concept of *joint problem space* (JPS) applied by some CSCL researchers. Sarmiento and Stahl (2008) trace the development of the JPS concept from its apparent information-processing origins in individualised constructions of *problem space* to the irreducible collective phenomenon by which shared problem-solving activity is constituted in the collaborative coordination of communication and representation (Teasley and Roschelle 1993). In line with previous analyses of small group research, the JPS is seen by Sarmiento and Stahl to be both cognitive and social in that participants attend to their social relations as well as the cognitive problem itself. Further, in their analysis of online Virtual Math Teams, Sarmiento and Stahl (p. 5) point to the evident temporal unfolding of activity, such that the group is variously oriented toward the knowledge artifacts relevant to the problem-at-hand, the management of participation, and the relationships between current, past, and future activity. Looking back to the typology of exploratory, cumulative, and disputational talk used in our own study, it appears that the cognitive orientation to collective reasoning is foregrounded in episodes of talk with exploratory features. Exploratory talk visibly indicates that speakers have internalised ways of talking to each other constructively about the problem-at-hand. In contrast, both cumulative and disputational talk (commonly associated with overtly friendly or more confrontational interactions) tend to highlight social aspects of the management of participation, which has yet to be fully resolved. This may hinder the development of the constructively challenging conversation that is required to move forward certain forms of collective reasoning and learning. Although it should be noted again that cumulative talk can be very appropriate for certain types of group activity and collective thinking.

Research questions and methodology

Our initial exploratory research question was: *How do children use the IWB when working together on science-related activities?* This open question was seen as necessary for a new field of school-based research, to allow for a first phase of discussion within the research group about aspects of the children's group activity that appeared to be socially, cognitively, or otherwise educationally significant in each class context. As the project progressed, we focused on different aspects of cross-case data analysis relating centrally to the following areas and the connections between them: the children's talk and other forms of interaction; the teacher's role; and the IWB functionality. In this paper, we focus mainly on the relationship between the children's collaborative communication and thinking as evidenced in their talk and other forms of interaction, and in their use of IWB functionalities.

Twelve class teachers and their pupils (aged 8–10 years) participated, all based in schools in the East of England. In our recruitment of participants for this project, we sought to involve teachers and schools who were already promoting collaborative learning and who expressed an interest in working further in this way as part of a professional development and research network. The teachers needed to have some familiarity and skills with IWB use, although not necessarily applied to children's collaborative groupwork in science. The pupils were novice IWB users, although they had observed their teacher's use of this technology in class. One group of three children in each class was identified by the teacher as the "target" group for our observations over the course of three lessons. Most

teachers selected target groups that included children of at least average attainment who were felt to be responsive and unlikely to be worried by the classroom filming. Several target groups were already used to working together in class as established "talk partners" across the curriculum.

Research group meetings with teachers

The first Faculty-based meetings with teachers included discussion of academic material on collaborative group work structures, classroom talk and knowledge building, and social and cognitive aspects of collaborative learning. The teachers were introduced to the analytic framework of three types of talk—*exploratory*, *disputational,* and *cumulativ*e—discussed above. They were also given demonstration planning materials regarding classroom "talk rule" activities for children (Dawes et al. 2003; Dawes 2008), and how these could be applied in collaborative science activities with the IWB. The teachers planned and facilitated IWB activities that they saw as appropriate for children in their own class contexts, drawing on the shared understanding of learning principles discussed in the initial research group meetings. As the project continued, the teachers attended further Faculty-based meetings at which they brought samples of their own observational analyses for discussion and reflection on emerging findings.

Data gathering

A series of 3 lessons was videoed in each classroom, providing over 30 h of video recordings, employing one fixed and one roving camera focusing on the group activity. This was combined with the gathering of other related data through field notes, pupil interviews, teacher discussions, teachers' written commentaries, and other documentation including the IWB screen records. All relevant data was transcribed for analysis, using conventions of standard spelling and punctuation to represent interpreted speech, the inclusion of non-word utterances when seen to have communicative function, and additional comments on other features of talk and nonverbal interaction (Mercer 2004). The project followed British Educational Research Association guidelines on ethical research (BERA 2004). All children's names have been changed.

Data analysis

We created analysis tables for each teacher's series of three lessons, identifying themes and strategies that were pursued across episodes and lessons. Case studies were compiled, focusing on the target group activity at the IWB, supported by contextual information on the classroom. Teachers and researchers took part in the iterative process of selecting episodes of interest from the videos, sharing and reviewing these, and gradually building a sense of their significance through within-case and cross-case analysis. Our initial selection of episodes focused on instances of children's exploratory science talk accompanied by direct use of, or reference to the IWB. This was then supplemented with searches across the data set for episodes with specific features of emerging interest (e.g., physical movement) and for counter-examples (e.g., extensive disputes or disengagement in the group). We analysed children's activity and communication in three connected ways: the identification of sections of talk with *exploratory*, *cumulative,* or *disputational* features; the more fine-grained analysis of sequential utterances; and the associated nonverbal references such as gesture and gaze.

The children's observable activity is located within a generic "problem solving" framework of task functions and processes (i.e., representing and acting on the problem; monitoring and evaluation; and completion and presentation of outcomes). This is intended to offer a way of focusing attention on identifiable elements of the children's communication and thinking at a level that can potentially be matched with the task and the IWB functionality. However, it should be noted that this labelling does not necessarily match the children's own representations of their work. With reference to the notion of JPS discussed earlier, the children's emerging "problems" appear to lie variously in the social and cognitive domains of tackling the task set by the teacher, finding ways to work together, scientific thinking, solving technical difficulties, and so on.

Lesson observations and analysis

This section includes a qualitative analysis of group activity in two different classes. The first was selected as an example of a lesson in which the children's conversation and collective thinking became more explicit and coordinated over time. The second is discussed more briefly as a contrasting example of a lesson in which the children engaged in relatively stable patterns of communication as the lesson continued. The lessons are summarised in Table 1, with reference to the general task functions and processes, the apparent focus of the collective thinking, and the relevant IWB functionality and affordance.

The selected lessons both relate to an open-ended IWB group activity which was commonly set up by the teachers, often at the start of a new topic. This generally involved the children in categorising certain items into sets or otherwise sharing ideas about certain phenomena and relationships (e.g., food chains, light sources, and so on). The items or problems were often deliberately ambiguous and challenging, because the teachers each took on the research group's aims of stimulating productive dialogue between the children as an end in itself as well as a basis for collaborative knowledge building.

A. "Dark or light?"

This first example involves Patricia, Katherine, and Lianne as the target group working together at the IWB on a categorisation activity. This is the first lesson in a unit on "lights and shadows" and the two main tasks are to decide together on whether items are "light" or "dark," and then a "light source" or "not a light source." At the start of lesson, the teacher is sitting at the IWB talking to the whole class of children gathered in front of her. She refers

Table 1 Summary of selected lesson episodes illustrating collective thinking in scientific discussions

Title of episode	General task functions and processes	Focus of collective thinking	IWB functionality and affordance
A. 'Dark or light?'	Representing and acting on the perceived task	Offering alternative ideas	Copy and paste; drag and drop; visual feedback from large screen.
B. 'Animals' teeth'	Planning, monitoring, evaluating and presenting results	Sharing knowledge; Developing strategies for visual representation	Drawing and erasing on large screen; visual feedback; physical working space around IWB and surrounding area.

to the IWB, which has a question written on it: "What do you know about light and shadows?" accompanied by two question marks below on right and left. The teacher begins as follows to the whole class:

> ….we're starting a new unit, a new bit of work on light and shadows, and what we're going to do today is just have a little think about what you already know, ok?

She introduces the activity as "word sorting." Most of the children in the class will be using bags which contain words printed on cards for sorting out on their tables. The IWB group has the equivalent on the IWB screen. The teacher asks the children to decide as a group where to put each word. In this context, she reminds them of their "speaking and listening rules" as listed on another IWB screen:

00.02.39	Teacher	…remember: Talking helps you think; Respecting each others' ideas; Make sure everyone is asked what they think; Make sure you've thought of all the choices before you decide; And make sure that everyone agrees. Ok...?	*The teacher has switched to another IWB screen and reads out the rules*

This explicit approach to reminding children of the established "talk rules" and reasons for them, and engaging the whole class in conversation about these at the start of lessons, was discussed in the initial teacher meetings and it proved to be common in many of the lessons observed.

At the start of the lesson, the IWB group is mainly concerned with considering their options and deciding on possible answers. Katherine takes the lead in holding the IWB pen. She is standing nearest the screen on the right with Patricia next to her and then Lianne on the left in a rough semicircle. (Lianne is noticeably shorter than the other two and later has some difficulty reaching to the top of the screen.) As the lesson continues, the children systematically take turns with the pen as they tackle each new item from the virtual pile of cards at the bottom of the IWB screen on the right. The "Earth" card, which is the only one that has a picture as well as the written word, is selected first:

Extract 1:

1	00.05:12	Katherine:	The earth, that's……	*K. moves 'The Earth' card to the middle of the board and remains with her finger pointing close to the word.*
2	00.05:13	Lianne:	That could be light and dark, because … I think it's light and dark because…	
3	00.05:16	Patricia:	Shall we copy and paste it because…?	*P. is now pointing up towards the IWB formatting icons, while K. is still pointing to the Earth card. Lianne keeps her hands down throughout.*
4	00.05:19	Katherine:	No hang on a second	*The children's talk is rapid and overlapping; K. is clicking and dragging the Earth image on the IWB, but she seems to be mainly trying out the movement rather than clearly directing it one way or another.*
5	00.05:22	Lianne:	I think it's better because half, because —um—over the other side of the world	*K. keeps her finger on the Earth card on the board, but she and P. both turn to look at L. while she's speaking.*

6	00.05:24	Katherine:	No because it goes, because it goes around, so like this is the sun…	*K. rolls her arms round each other as she talks about the sun and earth revolving. K. continues this gesturing while L. is also talking, turning first to P. (apparently for confirmation of her ideas) and then to L. A shadow of her gesturing hands appears on the IWB, although the children do not refer to this.*
7	00.05:26	Lianne:	Because half of the world is light	
8	00.05:27	Patricia:	At some point, at some point …	*P. does not finish what she wants to say.*
9	00.05:30	Lianne:	And the other, say when we're dark, the other side of the world is light, and when they're dark we're light	*L. touches P.'s arm and now has the attention of both K and P.*
10	00.05:33	Katherine:	Yeah	*K. and P. both nod, and make eye contact with each other as they speak simultaneously.*
11	00.05:33	Patricia:	Yeah	
12	00.05:34	Lianne:	So that's what I think, yeah	*L. concludes her argument and P. speaks almost simultaneously (Line 13).*
13	00.05:34	Patricia:	So it's the same	*All the children are now looking towards the Earth card on the IWB. L. has her hands on her hips—she has not reached out towards the IWB in all the time she's been talking. Neither has P., except for her initial pointing when she says 'copy/paste' (Line 3); she keeps her hand near her body.*
14	00.05:37	Katherine:	No, no, no the sun makes the light and the sun goes round the earth don't it? No, the earth goes round the sun, so there's, that's….So it's like that isn't it?	*K. is now turned towards the IWB and has her hand on the Earth card; When she says 'the sun goes round the earth, she moves her arm in a circular motion round the Earth card, echoing her previous gestures (Line 6). When she goes on to say the earth goes round the sun she brings her left hand up and moves it round her right hand in a demonstration. She is looking at the card rather than the other children.*
				P. and L. both have their hands down and are looking towards the Earth card. This resembles a 'teacher' stance by K. at the IWB screen, half-turned away from the other two looking upwards.
15	00.05:45	Patricia:	Yeah I think we should copy and paste and then put one in each	
16	00.05:47	Lianne:	Yeah	
17	00.05:49	Patricia:	I'll copy them	*P. reaches to touch the IWB for the first time, up to the icon at the top of the IWB.*

This extract then continues for about half a minute with rapid activity and elliptical talk about cutting and pasting in which the children work out between them how to use the copy and paste function on the IWB to create "two earths" in order to place one in each set. K is the only one touching the IWB throughout, except for one occasion when P. moves the Earth card at the top left, apparently just to check it can still move on the board. K. and P. have a minor argument (I'll do it…. no I'll do it… you're always doing it…) which K. ends at 00.06:14 saying "This is

my one," apparently confirming her rights during her IWB turn. At 00.06:22, Patricia takes over, bringing up the next word: SEE. They cannot decide how to place this one and, therefore, place it at the bottom left of the screen, returning to it later in the lesson (see Extract 3).

The main part of this initial episode, which lasts less than a minute (Lines 1–17), is difficult to understand in terms of the spoken language alone because much of what is said has essential visual, physical, or social referents. The tone is good-humoured throughout, but the group experiences a split in thinking at a very early stage when Patricia quickly suggests the "copy and paste" strategy directly after Lianne speaks about the earth being both "light and dark" (Lines 2 and 3). From that point, Lianne tends to follow her own line of argument, regarding the light and dark sides of the earth (Lines 2, 5, 7, 9, and 12). Katherine responds to her after a few seconds with "No because …." (Line 6) and then continues to develop her own ideas about the orbiting earth. She supports this with her physical demonstrations (Lines 6 and 14) and—in holding the pen—she retains control of the final decision about where to place the earth card. Katherine and Lianne do not succeed in bringing their separate scientific arguments together, and Patricia's persistence with the copy-and-paste idea is eventually accepted by both of them after Patricia restates her view about what they should do and reaches to the screen for the first time (Line 17). The children then engage collectively in the technical challenge of working out the copy-and-paste function. When they finally succeed in producing "two earths" for placement in both columns (00.06:07), Lianne comments, "There you go, now you've got two earths"—notably saying the distancing "you" rather than "we."

At this early stage in the lesson, it is only Katherine and Patricia who engage with the IWB technology. Lianne does not touch the IWB in the entire time and tends to keep her hands at her sides. The interplay of talk, eye contact, and bodily positioning between Katherine and Patricia gives the impression of a more equal social relationship from which Lianne is excluded. Yet Lianne does participate in the conversation through her scientific argument and her affirmations of the other two's actions.

As the lesson proceeds, the group continues to use the copy-and-paste function to allow duplicated responses. In the next extract, it is now Lianne's turn and she selects "SHADOW." We see here that Lianne is relatively silent during her turn with the IWB. Katherine and Patricia begin to reason together from Line 19, but this is quickly ended by Katherine's suggestion that they copy and paste as before (Line 24). The rest of the extract demonstrates Lianne's technical capability (Line 25), Katherine's apparent technical knowledge of the need to touch the screen one at a time (Line 29), and a short period of subsequent collaborative IWB interaction between all three.

Extract 2:

18	00.07:02	Patricia:	Shadow	*L. moves the card from the pile at bottom right of the IWB and stands with her finger on while P. and K. go on to talk about where to put it.*
		Katherine:	Shadow	
19	00.07:03	Patricia:	I think that goes in more dark	
20	00.07:05	Katherine:	That's dark, yeah, shadow in dark …	
21	00.07:05	Patricia:	Because you make shadows with the dark, don't you?	

22	00.07:07	Katherine:	No, no, no, no, you make shadows with the light.	*L. is looking at the other two and moves the card towards the centre line, from the bottom left.*
23	00.07:10	Patricia:	Oh yeah, you…	
24	00.07:11	Katherine:	But the shadow is dark, so shall we copy and paste it?	
25	00.07:14	Lianne:	Yeah	*She moves the card a little to the left, perhaps just to be in easier reach, then uses the mouse right click menu on the touch screen to find the copy function (unlike P.'s previous strategy of reaching up to the icons at the top of the board). Lianne quickly produces two cards—and moves one up toward the top right of the screen.*
26	00.07:21	Katherine:	you can't reach	*(Laughing, not unkindly)*
27	00.07:22	Lianne:	no	*(Laughing)*
28	00.07:24	Patricia:	There you go…	*She reaches behind L and moves the other shadow card towards top left.*
29	00.07:25	Katherine:	No, Patricia—you can't do it at the same time…	*K. and L. then complete by arranging SHADOW on the list below the Earth cards, K. dealing with the right hand column and L. the left hand one. Generally good-humoured interaction.*

The children go on to the next cards and continue to use the copy-and-paste option regularly when they cannot agree. At several points of this lesson, the children's activity focuses entirely on sorting out technical difficulties, often persisting for several minutes. As the lesson continues, there are signs that the extensive, repetitive use of the copy-and-paste function, and the screen evidence available as visual feedback to them, serves a useful purpose in representing their progress through the activity (see Fig. 2 for a sample screenshot).

From a cognitive perspective, it could appear that the children's use of copy and paste is becoming too automatic and easy for them, in effect closing down discussion too quickly (bearing in mind that an extended search for resolution can itself aid cognitive growth, (Howe and Tolmie 2003)). However, the children are not unaware of this. At 00.10:52, Patricia says "I think we've copied and pasted all of them so far," and then a few minutes later:

00.12:10 Patricia: I think I'm getting used to this. (laughs)
00.12:13 Lianne: Yeah, we're getting too used to copy / paste, copy / paste.
(L. says the last words in a staccato repetitive fashion, with apparent good-humour.)

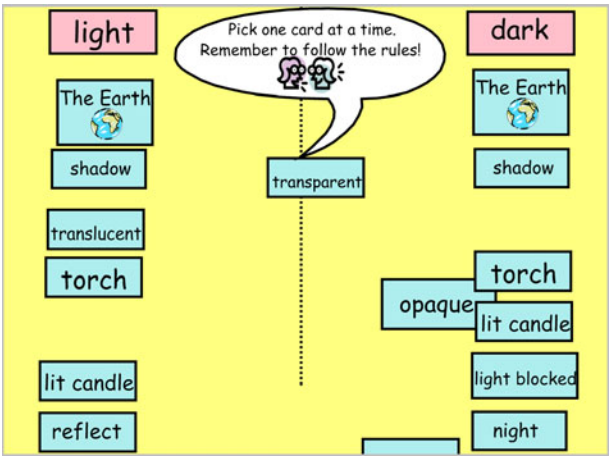

Fig. 2 "Dark or light?"—the final IWB screen with "two earths" and other copied cards

Patricia and Lianne's comments here seem to be acknowledging their shared history so far in the use of copy/paste. The role switching that had its origins in the children's agreement about systematic turn taking does not now just refer to whose turn it is to touch the IWB screen. There is also evidence of switching in the participation in Extract 2 compared to Extract 1: Lianne remains silent, Patricia offers some scientific thinking and Katherine now suggests that they copy and paste.

In the next extract at 18 min into the lesson, the children return to the card "SEE" which they had left aside earlier. It is Katherine's turn:

Extract 3:

30	00.18:10	Patricia:	I think 'see' might be light	*K. moves the SEE card up the screen and enlarges it a little. She begins to move it diagonally downwards to the right (dark) side.*
33	00.18:12	Katherine:	Why?	*This is the first sign of the use of a 'talk rule'—i.e. asking for reasons or elaboration.*
32	00.18:13	Patricia:	Because…	
33	00.18:14	Lianne:	Yeah, good idea Katherine, why?	*This affirmation seems to be referring to K.'s use of the talk rules in saying 'why'.*
34	00.18:18	Patricia:	In dark you can't, I'm not being, I don't know? You just can't see it, can you?	*K. has now brought her arm down and both she and L. are turned towards P. (away from the IWB) as P. gives her explanation. Note the apologetic 'I'm not being…'.*
35	00.18:21	Katherine:	You can't see what?	*Again K. invites more explanation from P.*
36	00.18:22	Patricia:	Dark	
37	00.18:23	Lianne:	You can't see through dark basically.	*L. provides a fuller statement, apparently completing P.'s idea.*
				K. now turns back to the IWB, and lifts her hand to touch the SEE card.
38	00.18:26	Katherine:	You can't see dark, you can see. Oh no, no, no you can both because like, say it's light here, but when I see to, when I'm in the dark I can see it's dark. I know it's dark.	*K. first reduces the size of the SEE card, as though ready to decide and move it to the right place. However when she begins 'say it's light here' she turns towards the other two with her back to the board and gestures her arms up and down firmly as she explains her more idea.*
39	00.18:34	Lianne:	Yeah	*In a tone that sounds as though she's been convinced by K.'s explanation, and K. turns towards her.*
40	00.18:36	Patricia:	I'm not sure. I think we should copy and paste	*This is said quickly while K. is already turned the IWB and beginning to the move the card up towards the dark column on the right.*
41	00.18:38	Lianne:	Yeah, copy and paste it Patricia	
42	00.18:40	Patricia:	Because we've got lots of reasons for both, haven't we?	
42	00.18:44	Lianne:	Yeah, we've got too many reasons for both.	*As they're talking K. uses the menu to copy, without further comment and moves the second SEE down to the bottom left in the 'light' list.*

43	00.18:46	Patricia:	Right, go to the page sorter and do the next one.	*Her 'right' is timed as K. completes the move of SEE down to the bottom left corner. P. is in effect moving them on to the next exercise..*

In this extract (Lines 30–35), there are signs of more productive exploratory talk strategies in the children's use of "I think," "why," "because," and so on. Lianne in particular acts to support and facilitate the discussion by supporting Katherine's question "why?" (Line 33) and by expanding on the meaning of Patricia's idea about see and dark (Line 37). Katherine (Line 38) then offers her own further reasoning: "You can't see dark, you can see…when I'm in the dark I can see it's dark. I know it's dark." She decides for herself that this means that SEE is "both," and she goes on to copy and paste the card without further reference to Patricia and Lianne. They do not object (Lines 40–42), but their talk here is a general further comment on how they have been using copy and paste in the whole activity. This might indicate what they have learned so far in the activity about the existence of multiple views. Functionally it may be acting as a type of temporal *bridging activity* (Sarmiento and Stahl 2008) between the different episodes of activity. After several previous examples of indecision or unresolved placements, Patricia and Lianne are now more explicit in justifying their use of the technical function of copy/paste with having "lots of reasons." However, this is as far as their reasoning goes on this occasion. They do not specifically respond to Katherine's argument about the placement of SEE—a word which in scientific terms presents a genuine dilemma for this or any group.

The activity continues with some further signs of reasoned argument within the group and a mix of opinion brought into the conversation. The next and final brief example is typical of talk with some exploratory features, although it is still not a fully coordinated and extended conversation. The children are now working on the second activity of "light source/not a light source" and it is Lianne's turn at the IWB.

Extract 4:

44	00.25:37	Lianne:	Sun, that gives light	*L. selects 'sun' from the pile of word card images at the bottom right of the IWB and moves it towards her on the left.*
45	00.25:39	Katherine:	That gives light…because it's like warm and it's fire, so fire is light and light is…	*L. keeps her finger on the image and reduces its size, as they've been doing with some of the others. She moves it down a little.*
46	00.25:45	Lianne:	We're talking about the sun Katherine, and the sun's not fire	*L. moves the sun card clearly towards the left list, takes her finger off and turns to listen to P.*
47	00.25:48	Patricia:	When you're outside or something, it's light isn't it?	*L. is continuing to tidy the IWB screen while P. is talking.*
48	00.25:53	Katherine:	The sun is fire … honestly	*K. and P. are standing back a little talking to each other while L. walks across the right of the IWB to extend the screen in order to fit a previous item, 'glow worm', properly on the left hand list. L. is still not taking part in the discussion, having quickly placed the sun as a light source, but disagreeing about whether it's 'fire'.*

In this extract, all the children offer some reasoning, but the most extensive discussion is between Katherine and Patricia. This may be because Lianne decides very quickly that the sun is a light source (Line 44), and she follows this thinking through to her final placement of the card. It is her IWB turn and she does not engage at any length with Katherine and

Patricia's reasoning or indicate that she is persuaded by Katherine's assertion that "the sun is fire, honestly…" (Line 48). Katherine and Patricia both give reasons for placing SUN in the "light" column, although the nature of their reasoning differs: Katherine seems to employ formal science thinking in attempting to connect the sun with light, warmth, and fire (Line 45). In contrast, Patricia offers more direct reference to her life experience of going outside in the light (Line 47).

By this point of the lesson, the pattern of the children's participation and communication has changed in that their talk includes more extended utterances and more coordinated thinking, although the exploratory conversation between the three of them is still not very extended. The subsequent group interview with this group indicated that the children are not unaware of the classroom "talk rules" they have been learning, as also hinted at by Lianne in Extract 3. When asked "what do you think your teacher wanted you to learn in those lessons?" they responded in turn:

> How to talk properly together as a group.
> …Instead of shouting over each other, and agreeing as a group.

When then asked why the talk rules are useful, they also respond with a social emphasis:

> They're easier, instead of arguing all the time.
> …and people speak over each other sometimes.

Later in the interview, one child remarks in the context of further discussion about working together at the IWB: "… it's like one of our talk rules, 'Talking together helps you think,'" but this formal knowledge is not entirely evident in their group activity on this occasion. In practice during this lesson, the children appear to be focusing on the social uses of the talk rules, not their potential role in helping them cognitively to think and learn together. This point is supported in a later interview comment. After being asked whether the IWB had helped them to share ideas, the group agreed that it did for the following reason:

> Because we had one thing and we were taking turns and all that, and that was sharing. And then we were like: "we've got to think about this quicker, I want to move it again." And it's like we want to get it done and we want to do the work more on the whiteboard than we do on paper.

This comment clearly links the turn-taking structure that the group adopted with sharing the IWB, not sharing their ideas. It also highlights the motivation of working with the IWB ("I want to move it again") which leads them to prefer the IWB to paper when doing the work. The next interview comment confirms the novelty value for them: "...because we never get to use it." The children also see a public-spirited classroom role in their IWB work, as a demonstration to others of how to work together fairly and how to tackle the task:

> And it was helpful for the other people who were doing it on paper to show that we can share ideas instead of keeping them all to yourself.
> …if somebody wasn't on the board they wouldn't get what to do…
> So we could probably show them as well as being filmed.

This combination of observation and interview evidence brings out the ways in which this group, at this very early stage in their collaborative IWB use, are prioritising the management of their participation. They are also thinking about sharing with classmates what they seem to see as their good fortune in working with the IWB. It is important to

acknowledge this thinking as progress in using a classroom resource in a new way, rather than focusing on what could otherwise appear to be a relative failure in productive science learning. The children's activity matches the teacher's lesson aims on this occasion in talking about aspects of "light and dark" while using the IWB collaboratively. However, educational action would probably need to be taken to ensure future progress in learning. For instance, one strategy could be to take an extract of the group's embryonic and individual exploratory contributions as a basis for discussion with the children about how the established talk rules could be used to develop conversation further in this case.

B. Animals' teeth

The following briefer example, in a second classroom, illustrates a different type of collaborative IWB activity. It offers a contrast with the "Light and Dark" group's interaction over time in that the "Animals' Teeth" group's collaborative conversation and reasoning is more established from the start and it remains relatively stable throughout. The lesson objective in the teacher's plan is for the children to consider what the teeth of various animals are like and why. The first activity calls on the children to "discuss, sketch, and annotate what the teeth of various animals might look like." So the IWB group is potentially involved in sharing ideas and representing them by drawing on the large screen. The lesson begins with a teacher-led discussion with the whole class in which several animals are considered in terms of their distinctive feeding characteristics, particularly their teeth. This follows on from a lesson the previous week on the topic of animals' adaptation to their environments. As in the Light and Dark lesson, the teacher had planned the lesson for one group to work on the IWB while the other children carried out similar activities on paper at their tables. He had also similarly reminded all the children about the ground rules for discussion and collaboration in their groups.

The children, Natalie, Adam, and Noah, begin their first task by agreeing what they have to do and remembering between them how to use the IWB pen. They initially stand in a close circle about two feet back from the IWB, reading what is on the screen. The children have some previous experience of using the IWB, as evident in Natalie's first comment (at 00.13:09):

> It says "Cows eat grass. Draw a note what you think their teeth look like." Where did, where did… do you know where we clicked on last time to get it so you can draw?

A few seconds later, after working out the drawing function and briefly agreeing that the teeth are "not pointy," they continue to consider an alternative view:

Extract 1:

1	00.13:19	Adam:	They might have the same as our teeth, because we can eat grass	
2	00.13:20	Noah:	They might, they might	
3	00.13:21	Natalie:	I really wouldn't like to eat grass	
4	00.13:23	Noah:	But I don't, I doubt they'll have any canines, I doubt they have canines. I doubt that.	
5	00.13:25	Natalie:	So what, so, so, do we all think that they're not pointy?	*She is seeking confirmation of the early quick agreement about this.*
6	00.13:26	Adam:	Yeah	
7	00.13:26	Noah:	Yeah	
8	00.13:27	Natalie:	Um, so how shall we draw them?	

In this early extract, we see that the group conversation is focused on the task, and each makes a contribution toward the scientific task. Natalie (Line 3) follows Adam's first comment directly in a form of *cumulative* talk. Noah also offers an apparently supportive response to Adam ("they might…," Line 2), although this seems to act at least in part as a means of allowing Noah time to formulate and express his own ideas during which he introduces the word "canines" to the conversation (Line 4). There are individual contributions, which can potentially build toward more collective *exploratory* talk, notably in Adam's early reasoning ("because we can eat grass …," Line 1).

In this extract the children seem to be employing different types of experience, knowledge, and thinking as they move collectively towards their goal of drawing the cow's teeth. At the start Noah is contributing relevant vocabulary—that is, "canines" (Line 4), and the teacher notes that Noah had in fact completed a unit on Teeth and Eating at his previous school. Natalie and Adam connect personal experiences and preferences, relating to their own human teeth (Lines 1 and 3). Natalie takes a lead in directing the group toward the drawing task (Lines 5 and 8).

As the activity proceeds, the children continue to refer to each other in the discussion, interacting in a generally supportive and good-humoured way. There are some significant nonverbal communications, such as when Adam draws two curves in the air, demonstrating how he thinks the teeth should be drawn. He later makes the same gesture more expansively with his whole body before articulating his ideas by asking, "How about sort of like two lumps upside down?"

The children monitor and evaluate their progress and each other's work, as when Natalie receives Adam's drawing efforts as: "That looks like an elephant's foot!" and Adam then comments on Noah's later effort as "I'm not meant to be rude, but they look a bit like a necklace." They regularly erase unwanted work and begin to comment more explicitly on the design aspects, talking about "putting lines on…" and using their own teeth as a model.

The children eventually reach the tiger. They quickly decide that tigers' teeth are "sharp" and "big" and then continue (see Fig. 3 for the outcome):

Extract 2:

9	00.20:15	All:	Tigers eat meat, what do you think their teeth look like?	*Noah has the IWB pen.*
10	00.20:17	Noah:	That's obvious.	
11	00.20:18	Adam:	Sharp…	*Pointing to his own teeth. Noah looks at him.*
12	00.20:19	Noah:	Yeah, they're gonna have big canine, BIG	
13	00.20:21	Adam:	Oh I've got an idea	*He takes the pen from Noah and begins to draw on the IWB a zig-zag pattern.*
14	00.20:23	Noah:	…me seen tiger teeth, they are big	*He is 'dancing' with his hands up and speaking playfully in a rhythmic accent.*
15	00.20:27	Noah:	No, they don't look like that	
16	00.20:28	Adam:	No, they don't, do they?	*Adam starts to scribble over his drawing.*
17	00.20:32	Natalie:	I think tigers' teeth might have like some, a few flat ones and then just like quite spiky	*She is pointing to her own mouth and the two boys turn to look at her.*
18	00.20:38	Adam:	Like these ones are spiky	*Pointing to his own teeth.*
19	00.20:39	Noah:	Yeah, like very short flat ones	*Gesturing similarly to his own teeth, and also pointing back towards a classroom picture.*

20	00.20:44	Natalie:	Those ones are quite spiky	
21	00.20:46	Noah:	Yeah, those. The canines are really big like they're related to dogs	
22	00.20:46	Adam:	Big	
23	00.20:49	Noah:	I've got a dog whose canines are about that big	*All the children are now turned toward each other in conversation, standing slightly away from the IWB.*
24	00.20:50	Adam:	I've got a puppy and his canines are about that big.	
25	00.20:52	Noah:	Yeah, they'll get to that big	

The children are all involved in this conversation, which has features of both *cumulative* and *exploratory* talk. Cumulative talk appears, for instance, when the children are referring to their own dogs' teeth (Lines 23–25). There are signs of exploratory talk features in certain contributions, such as Noah's ideas (Line 21), although this is still not extended in conversation between them. Many of the children's ideas in this lesson only become fully communicated with nonverbal gestures and references to wider personal and classroom experience.

Given that the main "problem" for the children is one of visual representation, it is interesting to see how the drawing itself becomes an object of joint focus which provokes evaluation and adjustment ("No, they don't look like that," Line 15). This apparent feedback role of the drawing in turn appears to be supported by the large size of the screen to which the children can refer together. The teacher reflected this view in his own final written comments on collaborative IWB use: "It is also apparent that the large size of pictures and text on the screen enable all members of the group to be immediately involved in the new task, without competing for a good view, worrying about paper orientation or straining to see a smaller font size." The children made similar points in their later group interview:

> On small paper you don't really have much room, but on that big whiteboard you have loads of room.
> …if you had paper you'd all be crowded around, it would be hard to hearwho's doing what. It was easier to talk to one another.

Fig. 3 "Animals' Teeth"—the final IWB screen with the group's drawing and writing

In contrast with the Light and Dark group, this group focused first on the science topic when asked in the interview what they thought their teacher wanted them to learn:

> …about how to look after your teeth and what kind of different people and different animals' teeth are like.

When the interview turned to what they thought about working together, their explanations were immediately cognitive rather than primarily social:

> …if we can discuss together and bring out our ideas and explain why, then sometimes we can actually get better answers.
> …Three brains are better than one.

They also, as with the Light and Dark group, reflect on how the IWB may help them to communicate ideas to others although in this case their focus is more explicitly on supporting understanding rather than on the general processes of acting on the task and sharing ideas:

> ….you can go back and look at what you've done before and if you say one of your ideas out loud then sometimes people can't understand it and if you write it down and do a diagram to go with it maybe it might help them understand it a bit more.

The implication here is that, in comparison with the Dark and Light group, this group has assimilated productive communicative skills and attitudes to the extent that their prime focus in the lesson is visibly on scientific reasoning and problem solving rather than on dealing with social relations or technical difficulties. They do enjoy the IWB work—Noah says that "The whiteboards are very cool things"—they learn more about its functioning as they work, but they have collectively moved past the novelty factor which appeared significantly to influence the Dark and Light group.

Discussion

The two lessons analysed here highlight certain aspects of this form of CSCL which relate to the integration of the IWB with other classroom learning systems and resources, and the nature of progression in children's activity and learning. Both of these can be referenced back to our working model of collaborative activity at the IWB (see Fig. 1, discussed earlier) and both raise further areas for research.

With regard to integration, the Light and Dark group appear to experience a synergy between the nature of the IWB task embedded by the teacher; the turn-taking routine adopted from previous participation structures; the copy-and-paste function; the historical lack of direct IWB experience; and the placement of the lesson at the start of a new science topic. We might argue that the item-by-item task structure "fits" with the turn-taking routine, as does the IWB function in only allowing one image to be moved at any one time. The novelty of working with the IWB motivates and structures the children's persistence in a task which has clear steps of progress in dealing (somehow) with each card to complete the task—as the children see it.

The actual benefits of this type of integrated experience appear to be mixed in terms of the children's learning. However, this depends on the level and time of analysis. For instance, in any one short extract of interaction the turn taking can be construed as somewhat stifling and exclusionary in that the child with the pen either takes a dominant lead in decision making or withdraws from the conversation (a phenomenon

we have noticed in previous work). Separate task items (e.g., SEE and SUN) also differ markedly in the extent to which they are likely to spark interest and higher-level reasoning rather than the expression of factual knowledge. Yet over time the turn taking and role switching seem to be functional on this occasion in allowing the group to engage in a division of labour to gain IWB experience. They refer to their shared history in terms of the technical copy-and-paste function, which comes to represent their cognitive "many reasons." The way that certain ideas can be traced over time in the children's conversation confirms that what they hear in episodes of silent listening can be taken forward to subsequent conversations.

Overall, the Light and Dark group's conversation and reasoning is not very scientifically productive (with several examples of incorrect scientific reasoning in the lesson as whole). However, the teacher's stated aim for this lesson was to start the children's talking to "activate" their knowledge at the beginning of a new topic. In other classroom examples of similar types of categorisation tasks, we found similar responses in the use of the copy-and-paste function, but this had different results according to where the lesson was placed in a series of lessons together with the teacher's differing aims of either "activating" or "assessing" learning.

The question of the IWB's integration with classroom learning systems and resources can be related to the nature of progression in children's activity and learning. The two groups in this paper are clearly different in their orientation to the social or cognitive aspects of communication, and the apparent learning outcomes also vary. For instance, the thinking of the Dark and Light group moved toward the acknowledgment of multiple lines of scientific argument, resolved by the children's use in this lesson of the copy-and-paste function as a sort of holding strategy. The Animals' Teeth group more evidently shared their knowledge and represented it collectively in their IWB drawing, but further observation would be necessary to see how this feeds into their future science learning.

It is not clear from these two lessons whether the observed differences are primarily developmental, contextual, or personal to each group, and our research design in this study does not allow us to establish this. The Light and Dark group have formal knowledge of the classroom "talk rules," but their overt emphasis in practice is on the social management and sharing of the IWB activity. In contrast, the Animals' Teeth group are more explicitly aware of the cognitive benefits of talking together and the IWB is not the same novel experience for them. This group spends a considerable amount of the lesson in joint conversation away from the IWB, focusing on what proves to be their main "problem" of representing their ideas in their drawings. They do not attend to the management of their social participation in the same way as the Light and Dark group, (although more detailed analysis of the Animals' Teeth lesson not included here suggests the operation of some unquestioned social differentials in taking the IWB lead).

Integration and progression are both areas for further research, bringing in interrelated questions about the type of task (at different points of learning), use of "talk rules," social participation, scientific knowledge building, and so on. In planning such research, a useful starting point may come from our preliminary identification of certain types of IWB functionality and classroom activity that are likely to provide educationally meaningful starting points for such work (Mercer et al. 2010; Warwick et al. 2010). For instance, discussion, refocusing, and referring to previous knowledge can be supported by the self-pacing of screen transitions and the possibility of switching easily between screens to recall previous IWB activity. Editing may use the features of copy and paste, object cloning, and drag and drop, supported by easy slide transitions, hyperlinked pages, and video/audio capability. Each of these activities may involve different uses of the large screen, the surrounding physical working space, and other classroom resources. None of these

functions belongs entirely to IWB use, and some may be better achieved in different ways during different tasks, but they appear to offer examples of using the IWB tool effectively in the primary classroom context.

In general, the IWB may be seen to offer support for easily feeding backwards and forwards in the task structure, considering alternative possibilities as a group, externalising thinking on the screen, referring to existing knowledge stored in the available screens, and providing "online" contingent guidance and support in real time (without the teacher's physical presence). Our overall research also helped us to identify certain types of science activities that may be particularly suitable for such uses, including the open-ended tasks discussed in this paper; a series of cumulative tasks set up by the teacher and paced by the children; tasks requiring the integration of web-based materials and peripheral technologies; and investigative work requiring discussion, visual representation, and note-taking (e.g., science data analysis; planning experiments).

Limitations of research

It was accepted from the start of this research that it would not be easy in a relatively small-scale study to isolate the effects of particular experiences of collaborative IWB-use on primary children's attainment in science. We aimed, rather, to focus on the processes and nature of the children's communication and collaborative activity at the IWB, maintaining close links to the complex systems and structures of ordinary classroom practice. We assume that for some time to come English primary teachers will be in the position of employing already embedded IWBs for different purposes alongside other devices in the primary classroom environment. The specific IWB focus in this study accepts its interrelationship with other classroom resources and activities over time, and does not attempt to compare the IWB directly with alternative ways of supporting children's learning. In practice, the use of the IWB is inevitably located within wider classroom activity. This research is designed to capitalise on this as far as possible by actively including the teachers in the research process to incorporate their perspectives on learning and teaching in each classroom context. However the open-ended case-based approach appropriate for this first exploratory study could benefit in future research from a more systematic agreement within the research group about types of activity to implement and compare between classrooms.

With regard to the analysis itself, in looking across episodes and cases it seemed to be possible to relate certain types of cognitive activity to IWB functionality. For instance, in many cases the IWB "page sorter" function (providing visible icons of pages available in the given activity) served as an "external memory" for the children, and several teachers explicitly exploited this in their planning. This is not to suggest a limited one-to-one relationship between such IWB functions and certain types of thinking. Specific IWB functions may have different uses, and children's thinking can clearly be supported in many different ways in the classroom (including more traditional reading, writing, and drawing on paper). The attempt to link certain functions to particular task demands and thought processes is intended to offer an initial way of pinpointing where and how the IWB could be used in the complex classroom activity system.

Conclusion

Our focus in this paper is to ask whether the IWBs now present in primary classrooms can be adapted from their familiar role in teacher-led activities and used to support young

children's collaborative communication and thinking in classroom science activities. The two lessons discussed highlight similarities and differences in a number of areas including: the children's use of classroom "talk rules" for collaborative communication and thinking; the use of IWB functionality and working space; and the social routines and management of participation. In the course of this research with primary teachers we developed a working model of collaborative activity at the IWB (see Fig. 1, discussed earlier). This represents an interacting system with social, cognitive, technical, and temporal dimensions. The research suggests that the IWB can be used collaboratively in a variety of science activities closely related to familiar classroom practice and the children can engage effectively in the collective learning experience that we have called the "shared dynamic dialogic space." However, this is by no means certain on every occasion. As we found in certain classroom examples not included in this paper, productive collaboration can be particularly disrupted by technical difficulties and by children's sometimes limited skills in communicating and working together productively.

There are undoubtedly potential disadvantages of IWBs in primary classrooms, including regular technical glitches, placement problems on crowded walls, health and safety issues relating to the light sources and screen quality, and so on. When technical issues became frustrating, groups in our study responded differently, either developing a collective self-efficacy through discussion which helped to bond the group practically, or abandoning the task quickly and seeking the teacher's help. We may be seeing an amplifying effect on social relations and inclusion due to the combination of technological challenge, collaborative activity, and learning focus: when the technology is very visible and possibly frustrating a group of children may become either more collaborative or more differentiated in their complementary role taking.

A fundamental principle is that the IWB use cannot be productive in itself if there are significant disruptions to the children's collaborative communication and activity. Basic conditions for success, which need to be established in the classroom, include the children's joint understanding of the task, their positive motivation and responsibility for learning, and their active support for each other. In practice, for any group of children, this type of CSCL therefore depends in part on certain wider factors relating to the teacher's scaffolding strategies, the influence of classroom social routines and structures, and the productive use of "talk rules" for conversation and collaborative reasoning (Mercer et al. 2010; Warwick et al. 2010). This is not a simple "all-or-nothing" finding about IWB use for collaborative purposes. The groups discussed in this paper are captured at a certain stage in their collaborative learning with the IWB and neither demonstrates extended exploratory talk (unlike some others we observed, Mercer et al. 2010). The teachers are similarly in the process of adapting their professional knowledge about IWB use. Our evidence about children's uses of the IWB in their collaborative groupwork demonstrates a highly integrated system of physical activity, spoken dialogue, and nonverbal communication, taking place in an identifiable classroom space with the IWB and other classroom resources. The knowledge building of children and teachers is best judged in context and over time.

The research approach highlights the need to look at the complex interrelated systems of social interaction, communication, and cognition in classroom learning, as orchestrated by the teacher. These are identifiable at different levels of analysis, ranging from the "micro-level" operations of talk, gaze, and gesture between the children, to the lesson episodes discussed in this paper, to the longer term interplay over time between teachers' decisions and actions, general curriculum demands, children's development and learning. As Lemke and Sabelli (2008) discuss, the analysis of education as a complex system is important for setting research agendas and supporting educational development.

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