Using the interactive whiteboard to scaffold pupils' learning of science in collaborative group activity

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Abstract

Interactive whiteboards (IWBs) are usually used by teachers for whole-class teaching. This paper is based upon an ESRC-funded project[1] in which pupils used the IWB in a semi-autonomous manner when working together on science-related activities designed by the teacher. Using an analysis of video and other data from lessons in UK Year 4 and Year 5 primary classrooms (pupils aged 8-10 years), it focuses in particular on how the 'vicarious presence' of the teacher may scaffold the children's learning at the IWB and influence the nature of their co-regulation of activity (by which we mean shared regulation of both cognitive and metacognitive experiences). We address the following questions: How does the teacher use the IWB to organise and support children's semi-autonomous collaborative learning activity? In what other ways does the teacher structure children's learning environment to support their joint activity? In so doing we address the appropriateness of the concepts of 'scaffolding' and 'regulation' for understanding the vicarious influence of the teacher and its effects on children's activity in contexts where learning is supported by an IWB.

Introduction

The interactive whiteboard (IWB) is a digital hub that comprises a computer linked to a data projector and a large touch-sensitive electronic board, which can display projected images that can be manipulated directly by hand or with a stylus. They are now a common feature of classrooms in the UK and, increasingly, the rest of the world. Their widespread introduction has been largely based on their assumed value as a presentational tool for teachers, but as they become a standard feature of classrooms, their potential value for other educational purposes seems worthy of consideration. Given the increasing recognition of the value of children's talk and

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collaborative activity for their learning (Alexander, 2008; Barnes, 2008; Cazden, 2001; Mercer & Hodgkinson, 2008; Mercer & Littleton, 2007), investigating the potential of the IWB as a resource for children's collective activity seemed both relevant and timely.

Our study focused on the distinctive role of the IWB when small groups were able to use it as a resource for accessing information and thinking collectively during collaborative science activities. We also investigated the teacher's role in organising such semi-autonomous activity, working with a group of twelve primary teachers to do so. We have written elsewhere about the nature and functions of the children's talk while using the IWB (Mercer, Warwick, Kershner, & Kleine Staarman, 2010). Here we will focus on the teacher's vicarious role as the planner, organiser and supporter of the children's collective work, and on the children's responses to activity organised for them at the IWB. In doing so, we are interested in the way the IWB could be used by the teacher in 'scaffolding' the children's activity, creating an intermental development zone (IDZ) through which learning across the Zone of Proximal Development (ZPD) could be developed for each child (Vygotsky, 1978).

We will discuss the concept of 'scaffolding' and our use of it in the context of pupil collaborative activity at the IWB later in the paper. In the following section, we first consider the IWB itself, outlining features that would suggest its potential as a tool for collaborative group activity and learning.

Interactive whiteboards as educational tools

It seems that learning in classrooms takes place as children progress '… towards a goal (usually a product or task specified by the teacher) [which is] afforded and constrained by the combination of the features of the setting and the students' knowledge, skill and dispositions… The features include the teacher (if present), other students, tools and resources, subject culture and classroom ethos' (Kennewell & Beauchamp, 2007, pp. 228-9). In this conceptualisation the IWB is a 'mediating artefact' in learning (Wertsch, 1991), with features that can act as affordances for learning, provided that they are perceived as such by teachers and learners. Typical features or - perhaps more correctly in this context - functionalities of IWBs include:

- Large, touch sensitive, full colour displays on which teacher and pupils can write their own text, call up images, objects, sounds and video from a hard disk, internet or intranet and run a range of software, including simulation software;

- The option to select, display, move and manipulate images (including video) and texts;

- The possibility to save and recall current and previous lesson activities, which may be revisited, reviewed and amended as and when required;

- The use of the IWB to access other ICT equipment, including laptops operated by children in the class, digital cameras, video-players and microscopes.

Several studies have illustrated how the functionalities of IWB might be perceived as affordances for learning in whole class teacher-pupil interactions (Bennett & Lockyer, 2008; Gillen, Littleton, Twiner, Kleine Staarman, & Mercer, 2008; Higgins, Beauchamp, & Miller, 2007; Kennewell & Beauchamp, 2007; Littleton, 2010; Moss et al., 2007). Twiner, Coffin, Littleton, & Whitelock (2010) argue that the multimodality of the IWB – whereby teachers and learners have access to text, images, objects, sound and video – increases almost exponentially the potential affordances for learning that this mediating tool can provide. In such a context, Haldane (2007) urges caution over the nature of the interactivity of the IWB, since interactivity should refer to what users do with the tool rather than to a property of the tool itself; indeed, how teachers see and make use of the potential affordances of the tool can vary significantly. However, we were interested in this technology since it affords the creation of an almost limitless variety of teacher constructed environments that can 'serve in a face-to-face event as a referential anchor, coordinate joint attention and interaction, be an object for manipulation, and thus, support collaboration' (Arvaja, Häkkinen, & Kankaanranta, 2008, p. 270). Our discussions with teachers, about how their lesson plans would integrate this facility to construct task environments for their pupils, suggested that the created screens encountered by the children would reflect the teaching intentions of each teacher, tailored to the needs of specific groups in their classes.

Due to the comparatively malleable nature of the technology, the situation with respect to the use of the IWB to mediate learning is highly complex when the teacher

has almost exclusive use of the tool to assist in direct teaching. It becomes very much more complicated when children's direct use of the IWB to think and learn collectively is considered, with the organisational and pedagogical guidance of the teacher providing vicarious support.

Scaffolding

'Scaffolding' is a term which is now commonly used in research on teaching and learning in schools, and is often used loosely to describe all kinds of support that teachers may offer (Pea, 2004). But it implies much more than this; rather than the provision of generalized support, scaffolding learning suggests actively and temporarily providing learners with just the right amount of cognitive support to bring them closer to a state of independent competence. Its meaning can be traced directly back to the seminal paper by Wood, Bruner & Ross (1976), though the research described in that paper was concerned with interactions between parents and children of pre-school age. Essentially, the term was used to describe how an adult could make available their greater understanding of the world for the benefit of the child's learning, in a way which was not directly instructional but rather facilitatory. The adult can 'reduce the degrees of freedom' of a complex task to make it just manageable for the child, in a contingent manner over time, so that the child could gradually achieve independent competence. The concept can thus be seen to relate to the Vygotskian concept of the ZPD (Vygotsky, 1962) which represents the limits of what a child can achieve intellectually when given appropriate support.

Established conceptualisations of scaffolding therefore see it primarily as an interpersonal process, in which learners are literally 'guided by others' (Stone, 1998, p. 351) to develop understandings that they would be problematic for them to achieve unaided. The face-to-face communicative exchanges that lie at the heart of this conception of scaffolding indicate an interactive process which has some common characteristics. The first of these is *contingency*, suggesting that the teacher's scaffolding approaches are tailored to the specific needs and current levels of performance of the learners. The second characteristic is *fading*, whereby the scaffolding is gradually withdrawn, depending on the learner's developing understanding and competence. The third characteristic is *transfer of responsibility*,

sometimes presented as having three phases – teacher responsibility, joint responsibility and student responsibility (Pearson & Gallagher, 1983). In specific tasks the intention of supporting activity by reducing the learner's cognitive load is the primary intention; and this idea of responsibility transfer intimates a broader underlying intention of scaffolding – the development of learners who have the ability both to co-regulate and self-regulate.

The concepts of the ZPD and scaffolding have been taken up extensively by educational researchers and practitioners over the years (van de Pol, Volman, & Beishuizen, 2010), probably because they offer elegant metaphors for the responsive and dynamic involvement of a teacher in a student's learning process. Scaffolding is designed to support either the learner's conceptual development or the acquisition of specific skills. But more generally it seems to us that it has a function in promoting self-regulatory behaviour in the learner, enabling 'fading' and 'handover' (Bruner, 1983).

Scaffolding and the move towards self-regulation

Self- regulation is essentially the ability to control thoughts and actions to achieve personal goals and respond to environmental demands. Self-regulated learning (SRL) can be 'viewed as pro-active processes that students use to acquire academic skills, such as setting goals, selecting and deploying strategies and monitoring one's effectiveness…' (Zimmerman, 2008, p. 166). The self-regulated learner is one who attends to key features of their environment; resists distractions; persists when tasks are difficult; and responds appropriately, adaptively and flexibly to task demands. SRL involves both metacognition, in that the learner must consider the person, task and strategy variables in a learning situation; and motivation, in that the learner must have a willingness to try challenging tasks and a constructive view of failure. Researchers of the development of children's metacognitive skills have concluded that the ability to self-regulate whilst problem-solving contributes significantly to their effectiveness as learners (Veenman & Spaans, 2005; Whitebread & Pino Pasternak, 2010). Some meta-analyses of such research have even claimed that the emergence of self-regulation is the main determinant of effective learning (Swanson, Hoskyn, & Lee, 1999; Wang, Haertel, & Walberg, 1990). The development of the

psychological capacity for self-regulation has, through the application of Vygotskian theory, been linked to children's regulation by others: for example, parental guidance in joint social activities is eventually 'internalised' as this self-regulatory capacity (Mercer, 2008; Wertsch, 1979). Group-based peer activity might similarly enable such development, whereby children are involved in the regulation of others and shared or co-regulation (Whitebread & Pino Pasternak, 2010); such behaviour was certainly apparent in our study. Within a group that is co-regulating there will inevitably be an ebb and flow between the genuine sharing of regulatory frameworks – and below we cite talk rules as one of these – and other regulation by different members of the group at different times. This seems to us to be a necessary 'staging post' to self-regulation in particular learning contexts (Schunk & Zimmerman, 1997).

Research into both scaffolding and self-regulation thus draws directly on Vygotsky's sociocultural conception of the relationship between social activity and individual cognitive development. Research in relation to both conceptual frameworks, and its operationalization in classroom contexts, has achieved some impressive results which have been shown to have practical educational value; but they have largely been carried out by different groups of researchers and have not been integrated. With several colleagues at Cambridge, we are working to bring these perspectives together. We have already suggested that 'handover' - transferring responsibility from teacher to learner across a series of tasks and situations through the use of appropriate scaffolding approaches – can be thought of both in terms of supporting the cognitive demand of particular tasks *and* in terms of the longer term intention of the development of self-regulated learners. Such a conceptualisation essentially involves an elaboration of Vygotsky's proposed link between the *intra*mental and the *inter*mental, and here the role of language in interpersonal interactions, whilst not the only element to be considered, is central.

The development of talk for learning

Children learn and develop through taking on and using the functional forms of language they hear around them. If learning a subject like science involves learning to 'speak' it, then learning to think like a scientist must involve some internal representation of the subject discourse and its genres as tools for reasoning about the

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relevant phenomena. Thus the genres of various discourse communities provide resources for organizing the process of thinking alone. A student's induction by a teacher into the specialized language genres of subject is a very important aspect of education. Indeed, much of the literature focusing on scaffolding illustrates the importance of the cultural tool of language and the place of talk in 'traditional' scaffolding scenarios (Bruner, 1983; Mercer & Fisher, 1997; van de Pol et al., 2010; Rojas-Drummond & Mercer, 2003; Warwick & Maloch, 2003). By contrast, research into self-regulation has not usually been concerned with the role of language, though some links have been made. One involves a consideration of how social language use can provide a template for the production of 'inner speech', which acts as a self-regulating mechanism:

> When the child, confronted by a tricky challenge, is 'talked through' the problem by a more experienced agent, the child can often succeed at tasks which would otherwise prove impossible (think of learning to tie your shoelaces). Later on, when the adult is absent, the child can conduct a similar dialogue, but this time with herself. (Clark, 1998, p. 66)

A consideration of the role of talk in collaborative groups is essential in considering any account of the relationships between the affordances of IWBs, the pedagogical practices of teachers and the communicative repertoires of pupil groups within the primary classroom.

Research on the educational value of getting children to work collaboratively together reveals an interesting paradox. On the one hand, the evidence is clear that collaborative group work is extremely useful for developing students' communication skills and their understanding, particularly in the areas of science, maths and literature (Baines, Blatchford, & Kutnick, 2003; Bennett, 2007; Blatchford, Kutnick, Baines, & Galton, 2003; Dawes, 2008a; Gillies, 2004; Kutnick, Sebba, Blatchford, Galton, & Thorpe, 2005; Mercer & Dawes, 2011; Mercer & Wegerif, 1999; Mortimer & Scott, 2003; Rojas-Drummond, Mazon, Fernandez, & Wegerif, 2006). There are some particularly intriguing research results – for example, students who are asked to try to agree in their discussions learn more from them, even if they don't reach agreement (Howe & Tolmie, 2003). Paradoxically, though, researchers have also frequently

reported that most group work, in most classrooms, isn't very productive – probably even a waste of time, from an educational point of view. They report that children don't share their knowledge effectively, they argue without reasoning, and they do not all participate (see Littleton & Howe, 2010 and Mercer & Littleton, 2007 for discussions of such research). The likely solution to this paradox is, fortunately, quite obvious: many children, perhaps most, have not learned how to collaborate effectively. Just giving children enough time to collaborate isn't good enough. They need guidance on how to talk and work together, and suitable activities in which they can practice doing so. Whether these activities are related to their study of science or any other subject, collaborative learning seems to have the potential to help them study those subjects in ways that they are unlikely to do through teacher-led discussions. Whether this potential is fulfilled seems to depend on children being helped to understand the process of using talk as a problem-solving and learning tool, and given guidance in developing skills in using it, the quality of their talk improves and so do the learning outcomes. Our own research (as reported in Mercer & Littleton, 2007) and that of others (Baines, Blatchford, & Chowne, 2007; Howe et al., 2007; Reznitskaya et al., 2009; Rojas-Drummod, Pérez, Vélez, Gómez, & Mendoza, 2003; Webb & Mastergeorge, 2003) has shown that if teachers 'model' the kinds of discussion they hope children will engage in and get the children to agree a set of suitable 'ground rules' for enabling a good discussion, the quality of talk can be transformed. The fact that 'talk rules' are agreed, re-inforced and shared as a metacognitive scaffold for learning is vital to group interaction, since '…coregulation in learning presupposes awareness of one's own as well as the partner's metacognitive experience regarding the task in hand' (Salonen, Vauras, & Efklides, 2005, p. 199). In the research reported here, we drew on this idea and set up professional development sessions with the participating teachers in which we offered them strategies for developing children's metacognitive awareness of how they talked in groups and their ability in using this awareness to 'think together' (Dawes, 2010, 2011).

The research setting

Our research investigated the potential of the Interactive Whiteboard (IWB) for assisting children's collective involvement in the study of science. Focusing on

children's collaborative use of the IWB during science curriculum activities, the overarching exploratory research question was 'How do children use the IWB when working together on science-related activities?' We wanted to see if the IWB had distinctive value for (a) enabling teachers to 'scaffold' productive dialogue and interaction amongst students in collaborative science activities in the primary classroom, and (b) for enabling students to share relevant ideas and create new joint understanding through co-regulation of talk in science activities, when working in a small group without the teacher.

Twelve teachers and their classes in Year 4 and Year 5 primary classrooms (pupils aged 8-10 years) in England participated in the research. Teachers received some initial professional development which focused on the organization of collaborative learning, the role of talk in learning and the use of the IWB for designing science-related collaborative activities. The teachers then developed a series of science activities on the IWB which allowed their children to consider options, plan their actions and make joint decisions. These activities were designed to exploit features of IWBs that could be expected to help support pupil's collaborative activity, such as the easy and flexible reference to relevant information, easy annotation of pictures and texts, the facility for moving quickly between different images and writing drafts, and the combined presentation of images, text and sound. For each teacher, data gathered consisted of observational data (digital video-recordings and observational notes of the lessons in each classroom), records of pupils' work, background information about the curricular content and classroom routines, and pupil interview data. The observational data was analysed using sociocultural discourse analysis (Mercer, 2005) combined with an associated consideration of non-verbal interaction such as gaze, gesture and the manipulation of images and text on the IWB. Teachers and university researchers took part in a process of selecting episodes of interest from the lesson videos and reviewing these, gradually building a sense of their meaning (Armstrong et al., 2005; Hennessy & Deaney, 2009). The initial analysis focused on gathering evidence about the apparent relationship between IWB use and processes that are known to be strongly associated with children's learning and knowledge building, such as certain types of talk and collaboration taking place over time (Mercer & Littleton, 2007; Wegerif & Dawes, 2004). Here we re-visit the data in order to consider the relationship between the children's collaborative activity at the IWB and

ideas of scaffolding and the regulation of activity.

Research findings and discussion

Our observations revealed that the teachers remotely mediated the activity of the pupils at the board in two specific and interlinked ways. Firstly, the vicarious presence of the teacher seems to be 'in the minds of pupils', enabling them to appropriate and use introduced rules and procedures, in this case in relation to group talk. Secondly, it is evident in the ways in which the constructed task environment on the IWB guides and mediates the pupils' actions, enabling them to connect with, interpret and act upon the teacher intentions for the task. Here, the teacher's vicarious presence is 'in' the technology (Warwick, Mercer, Kershner, & Kleine Staarman, 2010). In this discussion we use instances of typical occurrences in the data to illustrate how these broad interpretations relate to the concepts of scaffolding and regulation. In doing so we indicate the complexity of classroom interactions in which scaffolding can be seen as relating both to direct and indirect interactions, mediated by established classroom procedures and by technological tools.

a). Indirect scaffolding - internalising and using 'talk rules'
Firstly, let us consider how the children's talk appears to have been scaffolded by the 'talk rules' initiated and sustained by the teachers. As part of the reciprocal professional development programme initiated with the research teachers, the teacher development outcomes of the Nuffield 'Thinking Together' project (Dawes, 2008b) were explored. Using the target of maximising the occurrence of 'exploratory talk' (Mercer, 2000), the teachers developed 'ground rules for talk' with their classes; whilst these varied from class to class, they all reflected the idea that talk is most productive for learning where:

– all relevant information is shared,

– all members of the group are invited to contribute to the discussion,

– opinions and ideas are respected and considered,

– everyone is asked to make their reasons clear,

– challenges and alternatives are made explicit and negotiated,

– the group seeks to reach agreement before taking a decision or acting.

(See Barron, 2003 and Webb, 2009 for analysis of the productive nature of such

strategies).

In agreeing talk rules, modelling their use in their own interactions with children and returning to them for active consideration at the start and end of lessons, the research teachers who fully embraced the idea of 'talk lessons' were scaffolding the rules, intended for use in subsequent group work, through their direct interactions with the children. The start of one teacher's lesson on light sources and reflectors – which took place some weeks after the adoption of talk rules by the class - is a typical example of the regular re-focusing on talk rules that occurred in these classes:

T: Now can anyone think to themselves 'what are the main features of a good group talk?' What sort of things do I want to hear you doing and saying, whilst you're working and talking as a group? I'll give you just a minute there to talk amongst yourselves, and to see what you can come up with.
(The class start to talk in their groups)
Pupil 1: One person talking at once.
Pupil 2: Yeah one, one person talking at once. People giving their ideas.
Pupil 3: And, and listening to each other.
P1: Yeah and looking at them.
P2: And looking at them when they're talking.
P3: Yeah as that would be quite annoying if they were looking at like say Mr (inaudible).

Here the teacher is widening the participation structures in his classroom. These can be defined as '…the rights and obligations of participants with respect to who can say what, when and to whom' (Cazden, 1985, p. 19). Berry & Englert (2005) remark on the importance of the teacher's role in supporting the movement towards new, more productive, participation structures for students; and here we see that Scott is repeatedly sanctioning discussion around the talk rules, legitimising their independent use by the children in their group work.

When working in their groups the children provided many instances of a metacognitive understanding of the talk rules as a cultural tool for collaborative learning. In all classes, despite there being some in which 'talking partners' were

established, the idea of agreed talk rules had been introduced for the first time for this project. In the videoed lessons, for some children the process of handover was complete and they used the talk rules with an unconscious facility, expressing reasoning, asking questions and striving towards agreement without articulating these things as specific intentions within their group activity. To put it another way, the rules had provided a scaffolding for their activity that was initially quite explicit and prescriptive, but which faded over time and with their developing expertise to become a more implicit set of guiding principles for how to talk and work together. Other children, however, had not yet taken responsibility for the unconscious use of the talk rules– the process of transfer was not yet complete (See van de Pol et al., 2010, p. 274) – and it is the discussions in these groups that seems to reveal something about the nature of what might be termed 'indirect scaffolding'. Their group dialogues suggest that the children brought their emerging understanding of the class talk rules to their tasks and worked to achieve co-regulation of their behaviour as a group through the specific articulation of the rules at points in their discussion. The children's responses suggest 'active participation itself as being the process by which they gain facility in an activity' (Rogoff, 1995, p. 151) – in this case, the activity of using exploratory talk in groups. Thus, throughout the lesson transcripts, there are phrases used that illustrate the pupils' concern with the need to discuss, reason and explain. To give one indicative example:

P1: 'So why do we think those first? Why do we think those first?'. . .
P2: 'We need to say why as well.'. . .
P1: 'No don't, don't write anything yet because we haven't really discussed it.'

The phrase 'need to say' is particularly telling here, strongly suggesting an awareness of the teacher's previous direct scaffolding of interactions – their 'vicarious presence' is evident in the terms used by the children. In all cases of this type it is clear that a way of talking in groups has not yet been fully operationalized; rather, understanding is distributed across the group and used to co-regulate group behaviour. It seems that scaffolding involves '…helping pupils to apply frames of reference that they only partially grasp and that they are inexperienced in applying' (Mercer, 1995, p. 75); teachers in the study clearly did in many lessons. But another element of the process of working towards self-regulation of such behaviour in group interactions is the

scaffolding that occurs indirectly as group members articulate the specifics of the rules and how they relate to current group activity. In other words, learners can scaffold one another's learning within productive collaborative situations through co-regulating behaviour (Warwick & Maloch, 2003). Our study reveals that this is not related only to the cognitive content of group dialogue, but to metacognitive elements - the procedural aspects of the group talk itself. In this way the pupils gain, through interaction, an understanding of the thinking strategies that they and their peers are using in particular contexts.

b). Indirect scaffolding – the IWB as a mediating tool

Wood et al. (1976) refer to six scaffolding functions – recruitment, reduction of degrees of freedom, direction maintenance, marking critical features, frustration control and demonstration; and Tharp & Gallimore (1988) refer to means of assisting performance such as feeding back, direct instruction and questioning. A useful table produced by van de Pol et al. (2010, p. 278) illustrates how these scaffolding functions and means relate to three broad intentions: support of student's cognitive activity; support of student's metacognitive activity (as we have seen above); and support of student's affect. They also show how these conceptual frameworks link and support one another in direct interactions between pupils and teachers. Yet pupils working in groups at the IWB are not in direct interaction with the teacher; their learning is mediated by the ways in which the teacher has constructed the task to be accessed on the board and by the children's understanding of the affordances of the board.

In our previous work (Kershner, Mercer, Warwick, & Kleine Staarman, 2010; Mercer et al., 2010; and particularly Warwick et al., 2010) we have briefly considered the links between the use of specific IWB affordances and teacher scaffolding of tasks – some suggested links, related to specific board affordances, are outlined in Table 1 (drawing on van de Pol et al., 2010):

Perceived by teacher as an affordance	Allows pupils…	Example	Scaffolding functions and means	Scaffolding intentions
Object manipulation	Direct contact with the IWB - possibility of external representation of their thinking	Teacher provision of moveable objects and expectation that pupils will engage physically with them	Recruitment	Support of pupils' affective response (positive engagement in response to freedom to manipulate objects)

			Reduction of degrees of freedom (through the provision of limited moveable objects)	Support of cognitive activity
External memory	'Feedback and feed-forward' as part of on-going review of the task	Teacher use of the page sorter and page hyperlinks to guide the pupils	Direction maintenance Feeding back	Support of metacognitive activity Support of cognitive activity
Provisionality, stability and permanence	Guidance on task parameters and possible approaches	Teacher locking and freeing specific board objects	Reduction of degrees of freedom (note possibility of pupil intervention in teacher intentions) Direction maintenance	Support of cognitive activity Support of cognitive activity
Embedded IWB cues	Directions and guidance with respect to task expectations	Questions, instructions, Scenarios on IWB 'Mr. H. says…'	Direction maintenance Marking critical features Instructing and questioning	Support of cognitive activity Support of cognitive activity Support of cognitive and meta-cognitive activity

Table 1: Linking teacher use of IWB affordances and scaffolding strategies (from Warwick, Mercer, et al., 2010)

We use this table here to show how the vicarious presence of the teacher in the constructed task environment on the IWB mediates the pupils' actions, enabling them to interpret and act upon the teacher intentions for the task. In so doing, we extend the argument made above with respect to talk rules to illustrate how the teacher might use the affordances of the IWB to scaffold learning indirectly. We show how groups collaborated in response to this, using the affordances of the board themselves to construct meaning through co-regulation of their activity. To do this we have highlighted particular affordances of the IWB for supporting this co-regulation (see Table 1); there are many others, but those referred to here were used by most teachers in our research group in constructing task environments.[2]

An examination of one representative lesson enables us to consider the ways in which the first three affordances highlighted in Table 1 relate to scaffolding functions, means and intentions. In the second research lesson videoed in Catherine's Year 5 class (9-10 year olds) the central task was to create and justify the positioning of organisms in woodland and pond food chains. Each organism had an initial position

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[2] Ten of the teachers used Smartboards and Notebook software; two used Promethean boards and ActivPrimary3 software.

on the page (see Figure 1a), which can be seen as an 'improvable object' (Wells, 1999), collectively visible and open to interpretation and change.
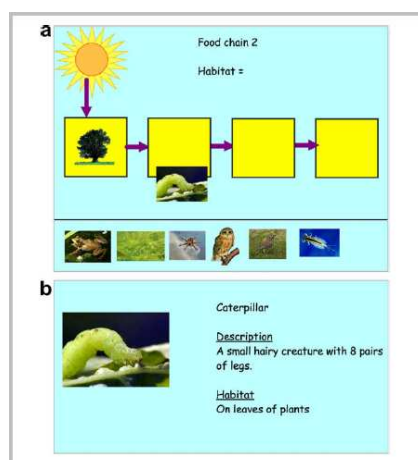

Figure 1, a & b: The food web in used in Catherine's lesson and one of the pages hyperlinked to the organisms on the working page.

The fact that the children were able to manipulate some of the objects on the screen seemed to ensure engagement; certainly the children were on task throughout a one hour lesson and were evidently keen to have 'their turn' at moving the organisms. This acknowledges the importance of the children's affective responses to the task, and the fact that this 'recruitment' is part of scaffolding, helping to motivate the children to adhere to the task requirements. The capacity to set some objects on the screen as moveable is associated with the affordances of *stability, provisionality* and *permanence*. In devising the task, the teacher has determined that some objects, such as the organisms in the food chain, are available and in a set position unless the pupils choose to move them. When they are moved, their new position is provisional and reasons for the choice of position can discussed; they are also stable in their new position until the group decides to move them again or to leave them where they are. Other objects can have permanence, in that they are locked in place. So it seems that the teacher is able to scaffold possible responses at the board by setting the *degrees of freedom* for the children. The children's cognitive activity is thus at least partly constrained within the confines of what is possible when manipulating the board objects. The use of such affordances by the teacher acknowledges a common characteristic of scaffolding - that of contingency - since the way in which the

affordances of the board are used indicates the adaptation of the task to suit the perceived learning needs of the group of children.

In Catherine's class, the fact that some objects could be moved led to some focused and productive exchanges. For example:

P2: What do you think would eat the tree?

P3: Um, maybe the caterpillar might eat the tree?

P2: Not eat the whole tree.

P1: Well eat the plants.

P3: Yeah it'll eat the leaves.

P1: Wait lets just think about this. Let's see, that could go in there, and um then that, but that could be.

P3: Maybe the Mayfly could eat the leaves off the?

P2: I don't think (inaudible).

P1: No, no, no actually. Put this in there.

(One pupil removes the oak tree and replaces it with the algae)

P2: Algae.

P1: Then Mayfly, oh no back. Then maybe that could go on there yeah?

P3: Yeah.

P2: Oh what about the frog?

P3: But the frog could eat the Mayfly.

P1: Yeah eat that, and then the. What could be, what could the frog eat?

P3: No what could eat the frog? Maybe the owl could eat the frog?

P1: No, no.

P2: If a hedgehog was on there, that.

P1: Maybe.

P2: Unless if we could take that off, and put um, and put. Oh I know caterpillar.

P1: Yeah but that, the caterpillar wouldn't really eat that.

P2: Oh yeah no.

P1: That's in the water. Well so, we, why do you think that that could eat that?

P3: Because, and it lives in a habitat near the water.

P1: OK.

P3: For the foods that it's got is that is the best one.

P1: I think that could eat that, the fly because um. Mayfly because um.

P2: Because frogs can eat fly, frogs can eat flies.

P1: Because they both have the same.

P3: Why don't we write our answers on the board?

P1: Well actually; no, no, no, no. What about if we put that there, that could…

(Pupils click and drag the suggested objects into the boxes on the IWB)

P1: That could be eaten like that.

P2: Oh yeah.

P1: Because they, they basically all have the same habitat and so do they. But the water spider can probably eat that, and then.

P3: Maybe we could swap it round.

There are several features of interest in this short exchange; in particular it is clear that the children were expressing their tentative understanding to one another not just through talk (which shows clearly a regard for one another's ideas) but through manipulation of the objects on the screen ('that could go in there'; 'put this in there'; 'then maybe that could go on there yeah?'). This is communication using a multimodal tool (Gillen, Littleton, et al., 2008), where the cognitive load of the task is scaffolded through the task design and the shared expectation of the ways in which the children know they must talk together as a group. Of course 'any scaffold provided by technology such as on an IWB slide, by its nature, cannot be faded unless removed by the teacher, or obscured by a screensaver' (Twiner et al., 2010, p. 217). But the work of this group reflects fading of the teacher's responsibility for scaffolding and transfer of that responsibility to the group. The teacher has given them a start, constructing the task to suit the perceived ability mix within the group (Schetz & Stremmel, 1994), setting the context of the work and providing an engaging task. As the pupils start to co-regulate one another's behaviours and engage in co-regulation by working towards agreement, we see an example of '…scaffolding experiences which are responsive to the spontaneous actions that children use independently when solving the task' (Yelland & Masters, 2007).

A feature of such semi-autonomous work at the IWB thus seems to be the ways in which the children gradually assume responsibility for shared regulation of the task and its outcomes. Given the children's understanding of the affordances of the IWB –

in all our research classes this was obtained primarily from watching the teacher at the board rather than from direct previous engagement with it – this sometimes meant subverting the teacher's planned intentions for the task. In Catherine's lesson, specific objects and pages were hyperlinked for easy cross-referencing, providing a form of external memory for the group. In our example, each organism on the page was linked to a 'fact file' that provided some information upon which decisions about positioning within a food chain might be based (Figure 1b). The vicarious presence of the teacher was thus very clearly embedded in the affordance for learning offered by this hyperlinking. The children, however, chose to use the affordance in a way not envisaged by the teacher; all the pictures of plants and animals were systematically clicked on and the fact files were read before any attempt was made to place the objects in position on a food chain. The 'teacher's constructed environment' (Laurillard, 2003, p. 33) may there suggest different possibilities for the children than those envisaged by the teacher, and the children must engage in co-regulation if these possibilities are to be realised. The task is contingent not just through the tailoring of the task by the teacher but through the actions of the children. And if scaffolding is represented by contingency, fading and transfer of responsibility, then it seems that direct interaction with the teacher may not always be necessary for scaffolding to be enacted in the kinds of contexts that were are outlining here.

Other examples of the use of IWB affordances by our research teachers extend this argument to encompass other functions and means associated with scaffolding (Tharp & Gallimore, 1988; Wood et al., 1976). IWBs enable the embedding of various cues that provide support for cognitive and meta-cognitive learning and which can also provide the re-assurance that children may need in semi-autonomous activity to support the affective dimensions of learning. Specific instructions, problems, questions or suggestions – or a combination of all four – were placed by our teachers within their task structures. Scott, working with a Year 5 class, tended to use a combination of direct instructions and a rather unique 'Mr. H. says' device, in which his picture appeared on screens with suggestions about what needs to be considered in a particular task. This device was used for direct instructions ('Mr. H. says discuss why you think each material is suitable, then as a group choose the best one'), to make suggestions about what the task might incorporate, or to give reminders that were linked to earlier spoken instructions ('Mr. H. says . . . remember to use the key

words.'). Though this was a distinctive approach, other teachers used a range of cues, in different ways, to maintain the direction of the task, mark critical features, instruct and question. The scaffolding intention of such devices seems evident and was supported by the ways in which some teachers chose to present their material on the board. Both Nina and Scott, for example, designed screens where the page sorter was kept open whilst the pupils worked (Figure 2).
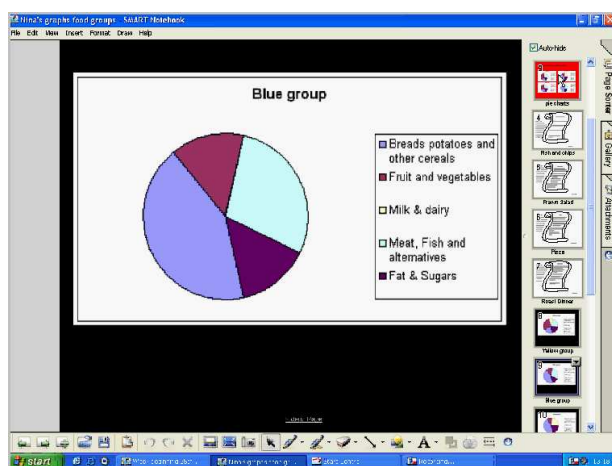

Figure 2: Screen shot from Nina's class showing the page sorter on the right-hand side.

These small versions of the pages that comprise the activities for the lesson might be thought of as acting as an external assistive memory to scaffold the learning of the pupils in both classes – allowing children, as one of them put it, to 'flick back pages in your mind'.

Taking together the ideas presented in this short review, of interactions that have been mediated by procedures and by tools, it seems that there is a compelling case for the idea that conceptualisations of scaffolding do need to be re-assessed in relation to learning contexts where technologies such as the IWB are in use. Yelland & Masters (2007, p. 367) suggest the use of the terms 'cognitive scaffolding', 'technical scaffolding' and 'affective scaffolding' in computer contexts, where problems are being solved. Their framework has considerable merit, but does not seem to quite capture the complexity of the situation where groups are working with endlessly adaptable interactive environments such as those that can be constructed on the IWB.

Rather, this paper suggests that re-examining definitions of scaffolding intentions, functions and means in the context of such environments may be fruitful. In doing so, we suggest that, whilst care must be taken to avoid 'scaffolding' becoming a loose synonym for 'help', it can be a useful concept for the analysis of activity even where interactions between the teacher and pupils are not direct, but instead are mediated by procedures and by technological tools.

Conclusions

We suggest that the concept of 'scaffolding' is useful for understanding how the participating teachers mediated group activity, through prior guidance and the design of IWB-based activities – even though (a) this scaffolding was achieved without the teacher being physically present and (b) we are concerned with the learning activity of a group, not an individual child. Our previously constructed model of teacher mediation of group activity at the IWB provides a depiction of the key components influencing the children's task responses (Kershner, Mercer, et al., 2010; Warwick, Mercer, et al., 2010).
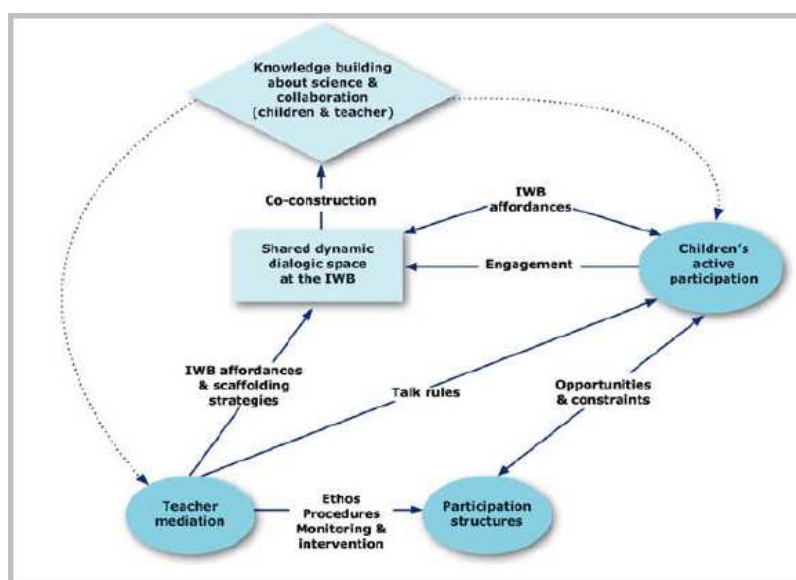

Figure 3: Teacher mediation of group activity at the IWB.

In many ways this model reflects a context for guided participation, one of the three planes of sociocultural activity (Rogoff, 1995), and in which 'the individual child,

social partners, and the cultural milieu are inseparable contributors to the on-going activities in which child development takes place' (Rogoff, 1990). The analysis presented here, however, suggests that mechanisms associated with scaffolding, influencing the children's propensity and willingness to co-regulate their activity at the IWB, might be relevant to such contexts. In the classroom situation, the use of this term needs to take into account a situation in which the teacher commonly has other demands on his/her attention: scaffolding has to be enacted in ways that will enable children's autonomous activity for extended periods and in a technologically-rich classroom environment mediating tools such as the IWB provide a means by which this might be achieved. Also, the scaffolding of collaborative activities needs to be based on judgements about what groups can achieve, not individuals. It seems that scaffolding can occur through a teacher using the IWB (and their pre-activity instructions and guidance) to set up activities which embody some reduction of the 'degrees of freedom', so that children are not frustrated by the task but rather encouraged to stretch their joint intellectual capabilities in its fulfilment.

Some strong words of caution are needed here, however. We are very conscious of the need to maintain a rigorous definition of 'scaffolding', which distinguishes it from the more general ways that a teacher can support or help learners working on complex and demanding tasks. We have thus continually referred back to the principles which underpin that definition, whereby scaffolding reduces the degrees of freedom of a task in ways which are contingent to, and orientated to, the developing expertise of the learners. We also have tried to emphasise the extended temporal nature of this kind of educational support. The scaffolding framework we have described was not provided through, or within, any single IWB-based activity. Each activity did have specific support features, designed by the teachers; but the children's co-regulation of their activity was also predicated on the more long-term establishment of the 'talk rules' that guided their behaviour through a whole series of activities. Our model rests upon the establishment of participation structures and consequent classroom relationships and expectations, whereby the children not only feel free to voice their ideas but have a means by which this can be done in a way that is evidentially productive for learning. As we have previously stated that 'where there (is) little or no sustained emphasis in a classroom on how to talk productively in groups … inadequate, inappropriate or partial interaction by pupils working at the IWB, with a

consequent effect on learning, (is likely)' (Warwick, Mercer, et al., 2010). This in itself enables the children to co-regulate the process of their learning, so that they are able to participate in the activity they are offered in a way which will require less continual supervision and guidance by the teacher than would otherwise be the case.

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