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Shared cognition facilitated by teacher use of interactive whiteboard technologies

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Abstract

Purpose – The purpose of this study is to examine questioning opportunities afforded by interactive whiteboards (IWBs) by highlighting pedagogical decisions enacted by teachers to ensure that they work with the wider affordances of the device.

Design/methodology/approach – Three primary/elementary teachers participated in a study designed to identify the types of questions that teachers could enable, sustain and afford with an IWB. The teachers selected lessons to be videotaped. Pre- and post-lessons interviews were held with each teacher. Pre-lesson interviews sought the intent of the lesson and intended use of the IWB. Post-lesson interviews included teachers reviewing videotapes of the lessons and teachers reflecting on, reviewing and explaining significant and key events. They provided their reasons and justification behind their informed choices.

Findings – Teachers enacted a framework that demonstrated their commitment to developing communities of learners. They sought strategic ways to utilise the IWB in dialogically focussed classrooms. Teachers used IWBs to sustain conversations that raise and resolve their learners' questions, to present challenges to the group.

Research limitations/implications – This study has a small number of participants, but is fine-grained in analysis. The recorded lessons have only occurred in mathematics classes. Lesson sequences are short, and a longer sequence, over eight weeks, would have also been illuminating.

Originality/value – The study is unique in showing the shift in power and ownership between interactions among the teacher, students and the IWB.

Keywords Educational psychology, Communication technologies, Dialogic classroom, Interactive whiteboards, Mathematics education, Technology-enabled learning

Paper type Research paper

1. Introduction

In this paper, the key foci are the pedagogical approaches used in the dialogic framing of the lessons and the pedagogical strategies that supported distributed cognition. The teachers, with the interactive whiteboards (IWB), were enabled in their development of shared cognition. Claims that it is not the technology tool but the affordances (Gibson, 1979) of these tools in the hand of the skilled pedagogue are now commonly accepted (Mercer and Wegerif, 1999; Osborne and Hennessy, 2003; Redman, 2013b). Interest, appropriately, has now turned towards making sense of teachers' pedagogical

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approaches and the accompanying practices utilised when working with technological tools. The phrase "working with" is an important point for consideration, developed and examined throughout this paper.

Together with the teacher, the IWB in the classroom will be examined, considering how it can be used to support meaning-making exchanges between learners when skilfully utilised to support dialogical collaborative spaces. As a unit, the teacher and the IWB or iPad will be shown to enable a community of learners to collaborate, to develop a social shared language and ensure opportunities for close examination of their existing thinking and, perhaps, unexamined reasoning and tacit knowing (Redman and Coyle, 2013).

The philosophical and educational premise underpinning this approach ascends from the understanding that meaning is constructed and reconstructed in the dialogical exchanges arising between people (Wells, 1999; Harré and van Langenhøve, 1999; Redman, 2013a; Linehan and McCarthy, 2000). Education is concerned with learning, making sense of, and confidently exploring and creating new ideas. This learning journey involves identifying and making connections with the ideas and thinking of others. Digitised tools, with the teacher, can ably contribute to sound pedagogical framing for this learning process (Osborne and Hennessy, 2003). There has been a renewed focus and recognised need to understand how teachers strategically adapt, adopt and repurpose technology tools, software or an application to support learners on this journey. The IWB is an example of teachers hijacking a tool from elsewhere and, in the case of the IWB, from the business world as a result of recognising the affordances of IWBs as a learning tool.

In this paper, we see that teachers devise ways to use the attributes of the tools. They sought to support learners' curiosity and subsequent questions, as desirable outcomes that equate to engagement. Engagement is deemed an essential attribute to have instigated and encouraged in learners. This is especially important for learners when they are entering a new and unfamiliar topic area. Successful use of a tool to create high-level engagement will be seen as achieved when learners care with their hearts and with their heads, and often is played out in their hands. This engagement arises in the social collaborative community of learners, in the classroom, when they share their curiosity, interests and have questions. The care factor, motivated and sustained by curiosity and questions, creates an environment driven by meta-cognition, while also providing an important place of belonging (Linehan and McCarthy, 2000; Sullivan and McCarthy, 2004). Shared language and shared curiosity and questions can help to generate a mutual heightened appreciation of achievement and discoveries within a learning community.

The quick responsive stable attributes of IWBs or tablet devices offer the capacity to easily facilitate learners' specific entry points through a range of resources. Everyday people "google" for answers, watch videos to learn new skills, find or share understandings in Wikis, disseminate their thinking in blogs and consider the views and experiences of other bloggers. There is a plethora of other points of knowledge sources, and there is a range of modalities from which to select. It requires a well-supported environment for teachers to have the time to reflect on what can best be leverage for purposeful targeted learning "with" technology (Chandler and Redman, 2012).

1.1 Identifying the place of knowledge, curiosity and questioning

Using the levels of Bloom's Taxonomy, in the traditional or the revised version (Anderson and Krathwohl, 2001), knowledge appears to have been ascribed a lowly place in the categories. This is deceiving if you think of blooms as only a hierarchy. This could be a subtle trap for young teachers, who are determined to aim for higher-order thinking outcomes, deeming these as having more and an impressive impact on learners. Balancing purposeful instructional teaching and identifying and valuing learners' prior knowledge, and their understanding of it, is a critical first step. Be the knowledge historical, scientific, mathematical, digital or artistic, it informs, shapes and adds to the quality of the daily lived life. However, often one cannot successfully proceed without the appropriate and relevant knowledge existing first. At the beginning of a new topic, identifying existing knowledge is a highly vital and necessary activity. Teachers and learners together need to have identified and critiqued their existing knowledge for both its usefulness and veracity. Easy access to bodies of knowledge in digital forms has enabled the useful review of one's "knowns and the unknowns", and this can now be completed in more structured and refined ways.

It is important to consider how, with the technology, teachers may create heightened levels of curiosity, as this can create an actively enabling and empowering experience for learners. Curiosity gives rise to questions that represent what learners need to know and understand, and that learners are genuinely interested in and care about. Curiosity, questioning, thinking and reasoning in this paper are embedded in the word engagement. Teachers need to understand the contributions of a dialogical teaching approach, of genuine questioning, and this approach needs to become part of teachers' identities and values (Beauchamp and Lynn, 2009).

These features of engagement create the impetus for learning and involve the teacher and the learner in conversations. They require planning and preparation to be achieved. Einstein associated curiosity with contemplating mysteries and this experience resulting in awe. Teachers can support learners to be curious about their existing ideas and assumptions, how they are thinking and ways to be reasoning better. Engagement is about learners' actively identifying prior understandings and making these explicit to both the teacher and each other as learners. The key focus question when creating high-level engagement is "what already exists as our known" and what does it mean to us, and in the body of associated knowledge. Notably, the person who most needs to know the answer to the questions and should care the most – is the learner.

It is in the conversations between learners that curiosity will become evident, surfacing as questions. The conversations that emerge and coalesce in the process of exploring prior knowledge may benefit from using different forms of communication: like drawing, modelling, labelling and talking. Each of these forms of communication sustains active exploration and sharing of existing knowledge and understandings, and generates the required discussions and debates that help to develop and refine the shared definitions. The learners all take responsibility here for their "knowns" and what are identified as the "unknowns", within their learning community. Learners in a community, with shared visions and missions, are also learning effective and productive ways to *learn from, for and with* each other. This is achieved when learners are using their shared language and understanding of key learning goals, and establish their explicit need to know and understand.

A new learning topic requires a focus on the topic's key language, as words and phrases carry the key associated knowledge, ideas and concepts. In science education, the shared understanding of associated topic language makes clear what is being examined. Words can be used as labels, in conversations or on diagrams. Words like friction, gravity, push, pull or force make explicit, within the community, which events are currently being explored and considered. Simultaneously, as these definitions are refined, questions will arise, a shared language forms and is further refined when in use. Curiosity supports the creation of meaningful questions, and these then create connections and bonds between learners and their ideas. Now a community of curious and questioning learners is in place.

In mathematics education, the action of explicitly identifying and sharing how the mathematics language is being used for a purpose with learners and concomitantly highlights the specific concepts and tools being utilised in the specific task. Explicit purposeful use of language intentionally signals and develops the learners' understandings. Careful planned use of language becomes an investment that empowers both the novice and expert mathematics user, highlighting what is central to understand and bring to bear to "this" task.

This paper closely examines how one teacher creates this intentional dialogical space to review, in conversation, with her learners what is understood by key words and the associated mathematical concept. With her use of the IWB, she first challenges the learners to define the key terms and the relationships between the words and a graphic, and then seeks broader implications.

Once this clarity and comprehension around key terms and their meanings have been reviewed, explored and explicitly shared, the teacher can move on. The next focus is on the usefulness of this knowledge and being able to understand it well enough to apply it in a designated outcome. The days of teaching facts and labelling and naming has not gone, rather time is given to do this as an important starting place for a learning journey. The communities of learners must have a shared language as their starting point, to share the subsequent stages of the learning. The existing knowledge of a community of learners can be explored together, and the shared language, and understandings, can then be questioned to establish refined or new understandings. Teachers, with the IWB, will be shown to enable the effective sharing of key language and ideas between members of a learning community.

The ideas, facts and knowledge of the past need to be established through language and tied to meaningful actions. In science education, for example, precise language and concepts around forces needs to be experienced and applied, modelled and represented in a multitude of ways. In mathematics, the language and the concepts need to consolidate in authentic, purposeful and meaningful tasks. The need to have new ideas associated with practices and actions, and see an application for their ideas, is uppermost in teachers' minds, planning and pedagogical practices. Knowledge, facts and concepts need to be comprehended and applied for lasting useful understandings. In the classroom, the community of learners can discuss and share their understanding and the application of ideas. Together, this is the combining of their "say" with their "do" (Harré and van Langenhøve, 1999; Redman and Fawns, 2010). The final aim is often to create and produce an outcome, product, event or experience for others. It has become possible to easily produce polished outcomes, creating appropriate levels of accomplishment in the producers/creators, with technology supporting a range of

multimodalities. It is possible to efficiently produce games, apps, movies, pictures, models, blogs, simulations or stories with technology.

The "sayings and doings" combine to become the discursive practices, linked historically to the idea of learning by doing, producing, creating and sharing, the concept behind the growing "maker movement" in education. A distinctive difference in education is the value and emphasis placed on language, especially collective language, and understanding and supporting the learning conversations must be catered for between learners.

1.2 Overview and history of IWB research

When IWBs were first introduced, the early studies in the UK focussed on pedagogies related to interactivity that involved teacher and students, and between students (Smith *et al.*, 2006; Tanner *et al.*, 2005; Moss *et al.*, 2007). Teachers tried to realise the affordances of IWBs. Criticisms focussed on IWBs easily being absorbed into the existing practices of teachers without pedagogical changes and reflected the past pedagogical practices of teachers. A major UK study concluded:

> IWBs are mainly being used: as a data projector which can navigate to multiple screens; as a surface which can generate a dynamic rather than static form of display; to enhance presentation from the front of the class (Moss *et al.*, 2007, p. 5).

IWBs may have led to less thinking time when the teacher retains control. This study sought to see if more thinking time could occur.

Studies have tried to evaluate the IWBs impact on pedagogy, on uses to reinforce whole class teaching and teacher engagement with the "surface features" of interactive teaching (Rudd, 2007; Smith *et al.*, 2006; Mercer *et al.*, 2010). Others are equivocal, while claiming some positives. Warwick and Kershner (2008, p. 269) commented: "Research evidence on educational gains from IWB use across both primary and secondary phases of schooling is mixed".

There has been limited understanding about how pedagogy develops with IWBs in the UK, USA and Australia (Hennessy *et al.*, 2007). In Australia, attempts to classify IWB impacts in terms of a hierarchy of pedagogical skills led to questions of whether the affordances of the technologies could stimulate higher order thinking skills through interactivity (Vincent and Jones, 2008; Sweeney, 2008). Similar to other studies quoted here, these sought to examine the impact of the technology in changing pedagogy.

This paper presents one teacher's use of the IWB to support shared cognition. Perhaps, earlier disenchantment with IWBs arose because the wrong question was being asked: what can the technology do *for* teachers/students? A more useful question might be: what can the technology do *with* me/students? This teacher's lesson review indicates that she works *with* the affordances of the technology, to support dialogically meaning-making moments in her classroom. Her pedagogical work aligns with the seven pedagogical practices for using technologies (Osborne and Hennessy, 2003). This teacher's in-class voice, and again her voice in the interviews, indicates she understood that a shared language needed to be created before her students could engage in discussions and before they could question and think together about what was happening (Redman and Fawns, 2010). Her class works with ideas afforded by the teacher using the IWB, because they had the necessary language needed to enter a more collaborative and challenging, thinking and learning space, to work with each other.

Luckin (2008) and Beauchamp (2011) used the same concept of "working in partnership" with machines. This helps to redefine and enhance performances, as noted by Salomon *et al.* (1991). Now this includes IWBs and any other digital interactive technologies. Luckin and Beauchamp also take account of the local setting and culture within which tools are embedded. Luckin (2008, p. 451) describes learning taking place within an ecology, and this includes resources, "a set of inter-related resource elements, including people and objects, the interactions between which provide a particular context". This message, with a few exceptions, became lost in the euphoria of the early adoption of IWBs. It is now being re-examined.

A possible pedagogical contribution that IWBs can make to pedagogy practices is by enabling students to work through their ideas both verbally and graphically. Warwick and Kershner (2008, p. 276) report on a teacher who linked the IWB's multimodality affordances with the IWB, using it as "supportive of the collective memory of the group". The thinking of the user is made visible to all, empowering students to more effectively and knowingly participate in collaborative reasoning and hypothesis testing that may well:

> […] go well beyond those afforded by more established classroom devices […]. [the IWB] provides a dynamic and manipulable object of joint reference which offers new forms of supports for "intersubjectivity" (Hennessy *et al.*, 2007, p. 284).

Hennessy has shown that IWBs assist teachers' development of a culture of shared dialogue leading to "shared cognition" in classrooms (Hennessy *et al.*, 2014). Notably, Hennessy is reporting on a study that was conducted with teachers who already had belief and practices revolving around student dialogue. The project concluded that when teachers purposefully create the right conditions to support risk taking and changing of minds, rich new forms of dialogue and activity emerge, both at the board and away from it. Hennessy states that the pre-existing teachers' views about learning and the classroom cultures they nurture are central to developing the more productive dialogic uses for IWBs. Their willingness to at least partially relinquish control over the IWB and to take the time to consider students' views was identified as critical. This suggests that an understanding of a dialogic culture has to exist first, and then, pedagogical approaches will arise.

Classrooms can support collective intelligence and shared cognition, and this can potentially be fostered with IWBs (Alvarez *et al.*, 2013). Harnessing group intelligence to extend students' productivity and depths of understanding, and of distributed cognition, by sharing thinking and insights appears to be possible only once the teacher creates a shared platform. This requires the establishment of a shared language first. These are affordances offered by the IWB and other devices. These activities were rarely seen, or documented, in the early phases of IWBs use, noted by most of the authors already mentioned.

Alvarez *et al.* (2013) observed Swedish teachers in upper primary schools use a framework that supported collaborative and shared solutions. Using the IWB, teachers provided students opportunities to share and deepen their thinking. These students reported that they "had a better understanding of how to solve a problem as a result of the greater communication they had with their peers and their teacher" (p. 376).

2. Methodology

2.1 Project outline, participants and data collection

This project originated as part of ongoing research within the Melbourne Graduate School of Education on the quality of teacher–student interactions and teacher–teacher with technologies generally (Chandler and Redman, 2012; Delaney *et al.*, 2014). It sought to examine the dialogic processes in three classrooms in a primary school when confident teacher IWB users incorporate technologies. In depth, reporting on a young female classroom teacher and her interpretations of her actions are reported on and examined here. Drawing on the work of Hennessy *et al.* (2014) and Mercer *et al.* (2010), the project focussed on how teachers developed skills mediated by the IWB to support dialogic interactivity. It examined how they utilised a dialogic pedagogy that actively developed and extended learner' contributions to conversations so that they could jointly construct and re-construct knowledge.

The aim of this research was to observe and document pedagogical responses to the affordances of the IWBs, especially in relation to teacher questioning and teacher organisation of the thinking dialogues. Pre- and post-interviews with the teachers indicated their intent for their lessons. The three teachers involved, from one primary school, were observed but not part of any training program. The purpose was to examine the impact, if any, of the IWB's affordances on these teachers' dialogical interactions with their students, and note any evidence of the IWB contributing to shared cognition across groups of students.

IWBs have features that are potentially different from a standard classroom display and knowledge sharing facilities. The "potentially" needs to be there because there are many studies that point out that the IWB can easily be used exactly like the older technologies such as screens and conventional whiteboards (Moss *et al.*, 2007; Smith *et al.*, 2005). The IWB does, however, have the potential affordances of enabling shared thinking across groups, interactive motion, audio feedback and animated feedback among others.

Three teachers participated from Foundation (Year 0), Year 3 and Year 6. They were identified and selected by the school as "accomplished" practitioners. They were recognised for the quality of their interactions with students and as regular and confident users of IWBs. In two cases, the teachers had more than six years experience of teaching, and one teacher was a new graduate with an outstanding reputation from her two-year post-graduate Master of Education course. The researchers observed three lessons with each teacher, filming the lessons and coding all the uses of the IWBs.

Data collection was conducted in as naturalistic manner as possible. Filming took place discretely at the rear of each classroom. Teachers volunteered the lessons they wished to have filmed. Teachers were not trained or tutored in any way, and no alterations to the timetable schedule occurred. The researchers fitted around the needs of the teachers. This is not to ignore the fact that any intrusion, like a camera and researcher, into the complex system that is a classroom is likely to have some impact on the learning environment.

Teachers had freedom to choose the lesson topic, but interestingly, the bulk of the observed lessons were in mathematics. Each teacher was briefly interviewed before each lesson to establish the goals for the lesson. Each video film was then edited to isolate occasions on which interactive dialogue of various sorts occurred. A little later,

but always less than seven days, each teacher undertook a video-stimulated interview using the edited film and was asked to comment on and explain the actions observed.

The interviews were then analysed to focus on all the areas where the teachers were able to articulate that learning was happening due to the sharing of knowledge and where meaningful dialogue and questioning arose from the work with the IWB.

3. Results

The outcomes of this project derive from the observations of, and interviews with, three expert teachers. The data collected was extensive and too complex to fully report here. This report concentrates on points of intersection between teacher questioning and the IWB, and the IWB intersections with the students, and evidence of shared cognition by the students.

The teacher reported on in detail here is a graduate teacher, teaching grade four, and she has selected a mathematics lesson. The lesson focussed on moving from angles as objects to measuring angles of rotation. This teacher was in her first year of teaching, having completed a two-year post-graduate Master's program. In this initial teaching course, she had excelled, and observations in her classroom belied her inexperience. The mathematics lesson being used for the case study was introducing the use of the protractor and the concept of measurement of angles.

The following transcripts provide a sense of the lesson structure. This transcript comes from excerpts from an in-class video recording. The teacher commences the lesson by raising a protractor. She creates an imaginary scenario, a storyline, as she seeks to support her students to explain what a protractor is, in a simplified way. She creates a learner community that is inquiring, by using the pronoun "we". She says, "pretend you" which serves to include every member of the community. Careful use of pronouns can establish a learning community by positioning and re-positioning people's identities (Redman and Fawns, 2010):

Teacher: Today we are going to be using this. What is a protractor used for? Tell me? Pretend you are explaining what the protractor is to someone who has absolutely no idea.

Student C: Angles

Teacher: Angles? What do you mean by angles? I understand what an angle is. So a protractor has something to do with angles. Let's use a full sentence to describe what it might do. (Student N) do want to have a go and build on (Student C's)

Student N: I've got two things. One, you can get it on a computer, and two, it's to show the degrees of the angle.

Teacher: Beautiful, so you're measuring the degrees of that angle okay?

Now the teacher focusses on the IWB where she has an angle drawn:

Teacher: someone please draw for me where the angle actually is on this diagram?

The teacher makes time to establish the specific ideas that she wants the children to consider and share. She has established the key words needed, as she has contextually used the mathematics conceptual language of degrees, measuring,

angle, diagram and protractor. She has used the IWB as a conventional board. The angle could have been on any board, and most of the interaction has been verbal. At this point comes a dramatic turn in the lesson. Next the teacher brings up a very large moveable protractor on the IWB while Student S volunteers to come up to the board. The teacher now moves to one side away from the board and only rarely returns to it for the remainder of the lesson:

Teacher: So that is what we're actually measuring. Now I have this protractor but I have no idea how to use it. Has anyone used a protractor before? Ah, so we have a few experts in here. Let's see if we can share our knowledge. If I was to measure this angle where do I put the protractor? Who knows?

Student M: On the bottom line and next to the point

The teacher has focussed on the IWB now showing a projected large protractor that she can move around the screen. She now inquires from the students and asks them:

Teacher: What do I do? Put the two points together, but there are two sets of numbers here and I'm really struggling to know why two sets of numbers, and which ones are I use.

Gesturing, she now points to some of the children inviting them to have a guess, I do not know.

The teacher has taken up a storyline of "not knowing" and she is questioning the students, prompting their thinking and asking what it is she needs to do. She has used the pronoun "**I**" signalling to the children she is the one who needs help (Redman and Fawns, 2010). She has positioned them as a community when she said, "we have a few experts in here" and explicitly asked for the sharing of cognition, "we can share our knowledge".

After the lesson, the teacher was reviewing the video and she was responding to questions in a conversational style approach. In the video clip that shows the teacher is pretending that she does not know how to use the protractor to measure an angle and asks the children, she is asked:

Interviewer: Just unpack that for me again what you did there to make them […]

Teacher: Just in terms of me playing dumb?

Interviewer: That particular one why do you play dumb there?

Teacher: Just because I feel like that it's something that they can come to themselves. They've seen what protractor looks like. Ideally, in this situation, it would be good if they could have all had their own protractor in their hands, and then they could see the structure of it and make the own conclusions from using it. Because well, it is not obvious, but you could come to the conclusion that that's where you've got to put the point because it's the intersections of the lines, so it's a way for them to come to that understanding themselves, but also the sharing in terms of the collaboration. Those ones that are experienced with the protractor can share their knowledge, and the others can use that time to really build up their knowledge.

After explaining that she seeks for her students to support and assist each, now she reviews the in-class video clip recording. It shows her using the IWB to investigate where to place the protractor on the surface:

Interviewer: So you have now started to make the board support your question. What happens now?

Teacher: They look at the common reference point on the board they have established that it needs to line up with the middle […].

Interviewer: What is the board doing at the moment?

Teacher: It is the common reference point. So, it's acting as a collaborative effort, measuring this particular angle. The kids feel like they can infer that you mention the angles using the numbers and then from here, I think with my questioning I specifically lead them to the point where they realize that they have to line up the zero with the line, so you can measure the angle from zero, and so, they're sort of going through that process themselves.

This graduate teacher was explicitly stating how she was working with the board. She describes it as acting as a collaborator, and yet she is aware that she has the control, she leads with her questioning and she uses the board as central point of reference.

4. Discussion

The teacher, while maintaining a flow of probing questions, withdraws to the side and provokes the children to articulate their ideas by reference to the IWB. She more than once uses the device of pretending to know nothing to place the children at the forefront, allowing them to both refer to and to come up to the IWB to share their insights with the whole class. She claims that the IWB is "the common reference point" which provokes collaborative development of understanding.

As the lesson develops by using the animated protractor to build an understanding of why there are two 180°scales, and finally measuring, the teacher repeats these processes. Sometimes she plays ignorant, sometimes she invites specific children to verbalise what they are seeing on the IWB and to share their insights with the class and occasionally she steps in to assume control herself. This is a mature practice. She moves between a social constructivist approach and then returns to an instructional teaching approach.

In her video clip, the graduate teacher uses the very large protractor and introduces the problem of reading the scale in opposite directions.

Teacher: It's quite difficult trying to teach them the protractor without having that sheer size on the board.

Interviewer: Why is it important that they can see it easily?

Teacher: Because I want them to understand that if they don't line it up with the zero, then it's very difficult to calculate how many degrees in between, but if they lined up with the zero, they can easily see how many degrees it is from there. So, it's reinforcing the fact that they have to have it lined up from zero.

In the video clip, the graduate teacher asks how do we know whether we are going to look at the less than 90° scale or the larger than 90° scale for a specific angle. Student A answers that it depends on whether the angle is acute or not.

Interviewer: So what did you do then with him?

Teacher: The vocabulary. So, it's fantastic when they can use the vocabulary. It's connecting the factors between the words. So, that's a big step for him. In terms of the start of the year, he really couldn't even form a cohesive sentence. To deal with these […] and it's quite a challenging concept, bringing back that vocabulary from previous lessons and then that's the starting off point for this sequence of questioning as it really connects those things.

Interviewer: Do you think with a child, like Student A, there is a sense that the visual is actually helping send to long-term memory?

Teacher: I honestly don't think this lesson would have been possible without the interactive whiteboard. Because it's a very difficult thing to collaboratively focus upon (a real protractor) because it is physically so small and I think this visual of having this angle, and he can see from our previous lessons that that's an acute, a right or an obtuse angle, and he's making that connection with the visual.

Video clip: In this section of the video film, teacher uses the visual large protractor on the screen to illustrate the crucial importance of knowing whether we are working with an acute or obtuse angle or clarifying the language for those who are struggling.

Interviewer: So you are drawing and creating angles and stressing the two scales. Why do you have to do that?

Teacher: I think just to make it explicit for them. Also in terms of like their levels of thinking. It has gone from the sort of basic levels that, if you're looking at Bloom, like the understanding and the making the connections to the applying and then we're going onto the creating and we will be looking at that further. It's just about them understanding visually those connections that they have already made verbally but then reinforcing that.

The video clip shows the teacher supporting Student T, who is struggling, as a model for developing an idea of how to measure the angle on the interactive whiteboard.

Interviewer: Can you unpack that section because that was quite a lot of questioning?

Teacher: He is a bit of a struggler in terms of grasping concepts, so it was good for him to be able to go through that process, but in terms of like looking at which set of numbers to choose, it was about him beginning to realize and making connections to like past lessons and knowledge that he already had, and then making new connections to what he is looking at the moment. So, in terms of him looking at the top numbers, we went back to basics and looking at whether it was bigger or smaller than the right angle, and then going through the process of discovering – okay we have to look at this set of numbers – and I think that process to him would have been a very similar situation for quite a few of the kids in the class, going through the

process […] that step by step, and then essentially thinking that maybe I can ask myself these questions while I am doing it. So, it's giving them ideas almost like a checklist – what they need to go through.

Next the video clip is about Student A being asked to verbalise this thinking every step of the way:

Teacher: So he has that very particular need to verbalize. So, depending on the individual needs of the kids, I will really ask them to do different things.

Interviewer: And he does it very well – why do you think he does it very well?

Teacher: Because there's been a lot of lead up and also the previous questioning could have helped him as well.

In this lesson, the IWB is being used and has become a visual means of inviting the children to share their insights. The teacher is insistent that correct language is a key part of the understanding and of sharing the concepts, she promotes actively the correct mathematical language. She glories in the achievements of the children when their use of the vocabulary indicates their own absorption of the concepts in relating previous understanding of the static views of angles as "acute", "obtuse" and "right" to the new dynamic concept of measuring angles of rotation. She actively encourages students to verbalise these ideas to their peers. In this whole section, the teacher is barely seen on the lesson video because she has handed much of the thinking, actions and verbalising to the students. She enacts her pedagogical beliefs and values that language supports meaning-making for learners.

Near the end, as she uses the interactive features to make and measure rotations, she chooses a student who normally struggles, to unpack the process of measuring step-by-step. This was possible because the child could speak about each action, as he activated the animation on the IWB. The teacher claims that the choice of this student was deliberate so that that process to him would have been a very similar situation for quite a few of the kids in the class, going through the process […] that step-by-step and then essentially thinking "maybe I can ask myself these questions while I am doing it". She claims she can use such students as models because of the support given by the IWB's affordances. The sharing with the class through the IWB then aids the rest of the class to clarify their understandings.

5. Conclusions

There have been numerous studies lamenting that IWBs have failed to produce the educational change and improvements in pedagogy that were expected or hoped for in the first decade of the twenty-first century. The case studies described here are suggesting that important pedagogical change can occur under certain circumstances. In particular, it can occur, and is likely to occur, if the teachers already value and incorporate sharing of ideas, creating time to think and have dialogic interactions, high level questioning and thinking, and there is recognition of the importance of children owning and sharing their own learning.

Analysing the pedagogical changes that were observed, it is clear that many of them fall into the category of dialogic interaction and, thus, re-enforce the work of Hennessy. In this study, all three teachers stood back from the board and invited their student to verbalise while access to the boards has produced regular examples of shared cognition,

where the insight of a student supports the learning of peers. All three teachers constantly ask particular children to model ideas while interacting with the IWB, and all claim they choose each child for two purposes: to help the child who is modelling by verbalising ideas and to share this with the rest of the class in the belief that children can often explain better to peers than the teacher if they have the visual and interactive support of the IWB.

All three teachers used IWBs to provide waiting time for children to think and verbalise. To most teachers, this is a difficult area. Waiting time gives opportunity for other children to move off-task. All three observed teachers here deliberately used the visual and interactive affordances of the boards to focus and engage the class, giving the child doing the modelling the time to think and verbalise.

All these teachers deliberately absented themselves from the IWB. Each teacher ensured that students felt they had command over the board, as the teachers stood to one side. This appears to be allied to these teacher beliefs that children must own and share the learning that is taking place, and there was a reluctance to dominate and a deliberate signalling that the child controlled that learning moment.

It was clear from the observed lessons that all three teachers were skilled questioners. All three used the IWB visuals to support open-ended and thinking-rich questioning. However, while IWBs appear to make the conditions for higher-level questions easier, it is almost certain that these three "expert" teachers would use higher-level questioning under any teaching conditions. Whenever teachers asked a child to describe or explain a set of steps in a process of measuring angles, a quiet "why" could be heard, as teachers gently kept interjecting.

So maybe, we have been asking the wrong questions. Instead of asking "what can the special affordances of IWBs *do* to change teaching?", perhaps the question is "what can teachers do to adapt the IWBs for the enhancement of good teaching practice?". By focussing on the natural practices of expert teachers when they come into contact with a teaching medium that includes powerful multimedia, a screen large enough to be accessible to all students and interactivity through touch or wireless, we have begun to see in this project many examples of enhanced practice. It is clear that in these case studies, dialogic interaction, advanced questioning, student ownership of learning and recognition of thinking time are part of the teachers' common practice.

It is significant that the teachers observed were not necessarily experienced. One was a first-year probationer. The reason why these three teachers successfully integrated the IWB's affordances into their teaching did not appear to be connected with experience or age, but rather their values, beliefs and willingness to develop an environment of shared cognition, deep thinking and high level questioning. It is worth revisiting Salomon *et al.*'s (1991) proposals that working in partnership with machines can redefine and enhances performance. Salomon asks us to consider that perhaps, "it is not technology alone affecting minds, but the whole 'cloud of correlated variables' technology, activity, goal setting, teacher's role, culture – exerting the combined attempt".

The first year graduate teacher, from the Melbourne Graduate School of Education at the University of Melbourne, has been educated in the Master of Teaching clinical teaching model. She sought "to be constantly evaluating a student's learning and progress and intervening in specific, targeted ways that are clearly underpinned by research and theory" (Redman, 2014). In conversational style classroom interactions, this young teacher was constantly diagnosing, responding and intervening, working towards increasing student

understandings. She had developed an understanding of the dialogical learning space (Hennessy *et al.*, 2014). She had combined her research-based understanding of the topics' difficulties, with her knowledge of her students as learners, and utilised IWBs' affordances to construct active empowering moments of shared cognition.

These lessons follow the 5E structure (Bybee, 2006) of engage, explore, explanation, elaboration and evaluation. In the engage stage, they dialogically and collaborative explore key words. Together they work out what they know and where the extent of this knowledge useful extends. Communally active and socially engaged in a sense making exercise, they use the IWB to understand their experiences (Harré, 2002). Time has been provided to engage, explore and build up shared explanations (Redman, 2013a, 2013b). Almost incidentally, teacher and learners work together with the IWB, maintaining a clear learning focus, using the representations, visualisations and interactions that IWBs offer (Redman and Coyle, 2013) as affordances (Gibson, 1979). This paper does not present the learning experiences that come in to the elaboration and evaluation stages of the 5E model. Once a dialogic, curious, questioning learning community has been established, then the elaboration stage should be able to be driven by highly motivated self-directed learners.

What this project has observed is indeed precisely that redefining and enhancement is arising from the cloud of correlated variables. It is not, therefore, sensible to expect IWBs to transform teaching. If teachers have expert pedagogies, IWBs and the successive waves of future educational technologies will be successfully incorporated into practice, as both teacher and student grow in their capacities.

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