Multi-modal representations in primary science: What's offered by interactive whiteboard technology

By Karen Murcia

This paper reports on exploratory research that examined how students learn Science with an interactive whiteboard. In this study, the IWB was found to support a range of multi-modal representation types including verbal, graphic, tabular, mathematical, pictorial and kinaesthetic. The affordances offered by the technology are discussed in this paper and examples from primary science classrooms are used to illustrate how students learn Science and demonstrate understanding through the multiple representations afforded by interactive whiteboard technology.

Introduction

Educational technologies such as the interactive whiteboard (IWB) have the potential to expand the dimensions of the primary science classroom and the way students experience learning and teaching (Warwick & Kershner, 2006). It is argued that in the digital age Internet Communication Technology (ICT) is central to advancing science education and improving student outcomes (Hackling & Prain, 2005). This view is also evident in the Australian School Science Education National Action Plan, which stated *students learn science by seeking understanding from multiple sources of information, ranging from hands-on investigation to internet searching* (Goodrum & Rennie, 2007, p. 14). Teachers' pedagogy must evolve to meet the demands of changing learning environments and learning needs of contemporary digital students. These students have only known a technologically connected society and as such confidently use technology and fluently connect with online environments (Shelly, Cashman, Gunter & Gunter, 2008). Engaging these students educationally requires greater consistency between their experiences inside and outside the classroom, particularly in the way information is accessed and manipulated. Integrating digital technologies into the science classroom could assist in bridging these environments. However, greater understanding of the impact of digital tools on learning and teaching is required as they have the potential to change the way knowledge is represented and re-represented. This is particularly important in learning and teaching science as this discipline represents ideas in multi-modal forms such as verbal, experimental, mathematical, figurative and kinaesthetic. In fact, Lemke (1998) argues that the use of multi-modal representations in science education is essential to empowering students in scientific activity.

> *There are also other essential 'languages', in the sense of cultural systems of semiotic resources in science: the languages of visual representation, the languages of mathematical symbolism, and the languages of experimental operations. The goal of science education, I want to argue, ought to be to empower students to use all of these languages in meaningful and appropriate ways, and, above all, to be able to functionally integrate them in the conduct of scientific activity* (online).

Interactive Whiteboard (IWB) technology has been identified in Australia and internationally as a tool that can bring together a range of ICTs in daily classroom practice (Betcher & Lee, 2009) and potentially increase opportunities for students to experience multi-modal representations of Science.

The technology enables students and teachers to interact with all the functions of a desktop computer through the IWB's large touch-sensitive surface fixed at the front of the classroom. Features of the IWB software are reported to enhance interactivity between the teacher, the learning resource and students (SMART Technologies, 2006). The use of IWB software tools can also promote active learning with manipulations such as drag and drop; hide and reveal; layering, colour, shading and highlighting (Higgins, Beachamp, & Miller, 2007). Teachers can use the IWB as a port for incorporating a range of multimedia resources such as written text, pictures, diagrams, photos, video and online websites into classroom teaching and learning activities. The enhanced interactivity and the 'drag-ability' of text and objects on the board's surface has been observed adding another dimension to traditional learning and teaching (Murcia and McKenzie, 2008; Betcher & Lee, 2009).

This paper reports on emerging themes from an exploratory case study that documented how teachers and students used interactive whiteboard technology in the primary science classroom. A socio-constructivist perspective of science education has informed the research and contributed to a multi-modal conceptual framework. Classroom practice and IWB teaching resources were viewed through this multi-modal lens, the aim being to document how teachers and students used the interactive whiteboard for representing key science concepts. Case studies were conducted over six months with six primary school teachers. An IWB education specialist also consulted to the project team and worked collaboratively with the teachers. The research activity occurred in conjunction with the teachers' normal classroom science programs. All teachers participating in the study were using *Primary Connections*, which is a national curriculum resource, produced by the Australian Academy of Science (2007). Data contributing to the case studies included semi-structured interviews, classroom observations and interactive notebooks produced by the teachers. A 'notebook' is the IWB software's design and working space. Teachers built up their own science notebooks by creating a sequence of pages that contained text, images and interactive activities.

Initially, literature on the role of multi-modal representation in science education is reviewed. Consideration is then given to the potential of IWB technology for supporting the integration of multi-modal representations in science learning and teaching. Synthesis of this reviewed literature generated the multi-modal research lens used here for looking at the case study teachers' use of an IWB in their science classrooms. A range of activities have been extracted from the teachers' interactive science notebooks and included in this paper to illustrate the different ways in which the teachers and students used the IWB to support multi-modal representations of science. A descriptive narrative that uses the 'voice' of the teacher is included to explain the context of each notebook page. The narratives are an interpretation of data from classroom observations, conversations and interviews with the teachers.

Multi-modal representations in science

Science as a discipline is multi-modal. That is, it involves the negotiation and production of meanings in different modes of representation. Multi-modal is defined by Prain and Waldrip (2006, p. 1844) as using *different modes to represent scientific reasoning and findings*. These modes are descriptive (verbal, graphic, tabular), experimental, mathematical, figurative (pictorial, analogous and metaphoric), and kinaesthetic or embodied gestural representations of the same concept or process. It is argued that new scientific understandings are generated through multiple representations of ideas, affective responses and evidenced based judgments (Tytler, 2007).

In order to understand the values, language and practices of the discipline, students need to experience multiple representations and explorations in the classroom. This is supported by Lemke (1998) who argued:

> *we need to see scientific learning as the acquisition of cultural tools and practices, as learning to participate in very specific and often specialised forms of human activity* (p.1).

This suggests greater emphasis is required on meta-cognitive practices or more simply how students construct meanings and understandings in order to expand beyond seeing Science as content to be simply practised and remembered (Yore and Treagust, 2006). Tytler, Peterson, and Prain (2006) argue that:

> *constructing and refining representations is a core knowledge construction activity within Science, and should therefore be a major emphasis in the science classroom* (p. 17).

Learning the nature of scientific knowledge requires students to engage with, understand and translate multi-modal representations of concepts.

Multi-modal representations of knowledge have been observed to not only motivate learners but to lead to a deeper understanding of the subject being taught (Ainsworth, 1999). The transformation from one mode of representation to another allows students to make meaning for themselves and develop a *relational* understanding between modes (Hand, Gunel and Ulu, 2009). It is argued that the *slipping and sliding* from one mode of interpretation or representation to another, as described by Yore and Treagust (2006) is a necessary skill in developing scientific literacy. The activity in conversions is the mechanism that leads to the underlying understanding. Jewitt, Moss & Cardini (2007) further argue that:

> *images do not supply a similar version of a concept; they provide a different representation of it; to talk about a concept, to draw it, to animate it, all draw on different aspects of a concept* (p. 310).

IWB integration of multi-modal representations

Unfortunately, technology-led initiatives in education are often not accompanied by an adequate understanding of the technology's impact on pedagogy. Evidence from the initial uptake of IWB technology could support this inference. Warwick and Kershner (2008) report that the tool has been observed complementing traditional teacher-led, whole class learning, where the IWB is simply used as a surface for writing notes or projecting images. Yet, teachers using effective interactive pedagogies do much more as they become *critical agents in mediating the technology to provide a more dynamic, interactive and appropriate learning experience* (Rudd, 2007, p. 6).

When used effectively, IWB tools can assist teachers in producing and engaging students with multi-modal representations in the science classroom. Teachers and students can use an IWB to bring together ICT tools that support students' production of drawings, tables, graphs, written text, verbal and video accounts. Social constructivist teachers using ICT tools can create an environment in which students observe, question and evaluate contemporary knowledge as they connect via the World Wide Web to current science information and practises (Murcia, 2008). Thoughtfully-structured learning activities can enable students to use ICTs to socially construct shared meaning as they work collaboratively on tasks (Krause, Bochner, Duchesne, 2003). Teachers are able to use digital tools on the IWB for modelling inquiry processes and developing evidence-based explanations. In the science classroom teachers are able to access multiple examples in rich multi-media formats, which generate opportunities for students to talk through their ideas and debate, and negotiate ideas and understanding (Hennessy, Deaney, Ruthven & Winterbottom, 2007). Furthermore, Warwick, Wilson and Winterbottom, (2006) reported that student learning is enhanced when individuals are given the opportunity to make their ideas public, as in rich dialogic discourse in which concepts are shared and vocabulary is developed and practised. Such opportunities for social interaction contributing to construction of knowledge are broadened by the central location and highly visible nature of the IWB.

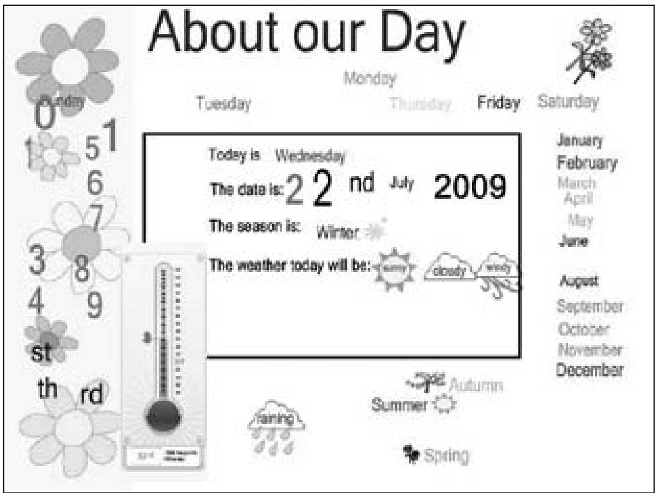
The pedagogy that has evolved with the embedding of interactive whiteboard technology into classrooms is reported by Lee & Boyle (2003, p. 13) as similar in some ways to the *multi-media, multi-sensory and multi-faceted* style of learning that children experience with their computer games and TV. The efficiency of transitions and use of colour, movement and animation all mirror their everyday experiences with technology. Higgins et al. (2007) reports that teachers are using the IWB to capture or link with a diverse range of multi-modal materials in order to create visually stimulating interactive lessons that are contextually relevant (Higgins et al., 2007). These observations suggest that the IWB could support or extend the modes in which students could develop and represent their science learning and understanding.

Looking at multi-modal representations in the IWB science classroom

It is difficult to capture the true nature of interactive learning activities in a static mode of representation. Each image displayed below is a single 'page' from the case study teachers' interactive 'notebooks'. What has to be imagined by the reader is the movement of images and text that occurs as the teachers and students engage with the whole interactive sequence of learning contained in a notebook. The narrative with each notebook page captures the teachers' ideas and actions surrounding their development and classroom use of the IWB representations of science. The title of the *Primary Connections* unit framing each IWB notebook has been used to identify the teacher and classroom. A description of each unit from the Australian Academy of Science (AAS) *Primary Connections* website accompanies each case study teacher's notebook pages.

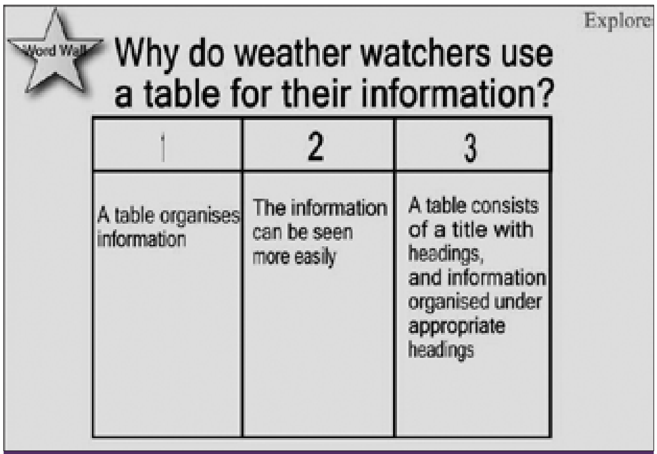
Weather in My World (Early Stage One): A Year One and Two split age-group classroom

Each day the weather affects our work and leisure activities. The weather influences our decisions about what to wear and the things we do. Severe weather phenomena such as droughts, floods and cyclones have serious impacts on communities. Horticulture, farming, fishing and tourism are highly dependent on weather. The accurate prediction of weather patterns and interpretation of weather forecasts are very important to our economy and lifestyle.



Our science topic for this term is weather so I start each day by asking the children to talk to me about the day's conditions. We record the days forecast on the IWB into our weather book (interactive notebook). The children have learned that we show weather with symbols. They take turns to drag the weather symbol into the day's record. I have even started to extend them by introducing the interactive thermometer and showing the day's temperature as a number.

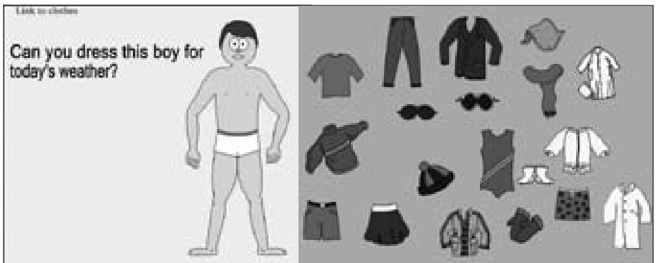
In this example the children are re-representing their verbal accounts of the day's weather as a figurative or symbolic representation. The teacher carefully scaffolded the activity with a range of questions that encouraged children to talk about what they observed and how they could record their information. The daily recordings were saved and built up to form their digital Weather Watch Book. Importantly, this experience encouraged whole class discussion of weather reports on the television and why it was important to weather watch. The colourful visual display was clearly interesting but being able to interact with the symbols and try out ideas by dragging images and text into the table motivated the children and encouraged substantive science talk.



I used the IWB to introduce the structure of a table and the information the children would collect each day and record in their own tables. I wrote words that they used to describe the weather symbols on to our IWB word wall. I kept the link to the word wall on each page of the notebook so we could keep building on the science vocabulary as new words came up.

Explicit science literacy teaching occurred in this lesson as the structure of a table was presented and explained. Working into the table again required the children to move between modes of representation. They were translating the science concept of weather from a pictorial symbol to a word. This encouraged the development and use of scientific language. Key words arising out of discussion were written onto the digital word wall, which was linked to each notebook page.

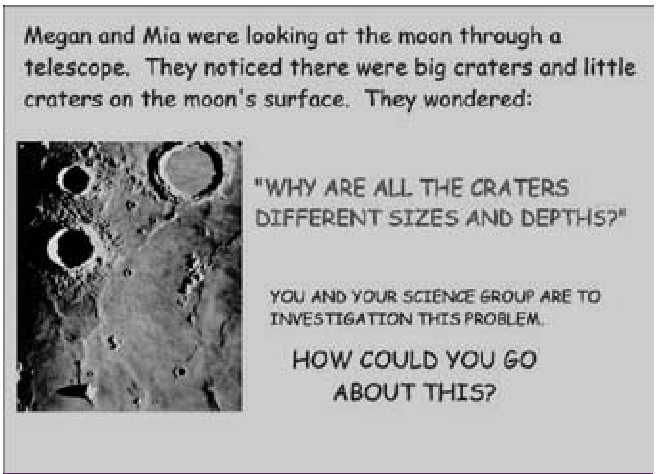
The next activity had children exploring the impact of weather on daily life. Touching items of clothing and dragging them across to dress the boy generated a kinaesthetic learning experience and provided another mode of representation in which the children could demonstrate their understanding.



This was a fun activity that the children really enjoyed. It was a different way for them to show that they understood the different weather types and the effect they have on what we wear. They took turns at the board and dragged the clothes across to dress the boy. It was really interesting to listen to them talk to each other about why they chose each item.

Spinning in Space (Stage Two): A Year Six and Seven split-age-group classroom

What causes day and night? The rising of the Sun and the Moon are daily reminders of the awe and wonder, beauty and power of the universe. Studying the relationships between the Sun, Earth and Moon helps us understand how we experience day and night on Earth. It also helps us understand directions in terms of North, South, East and West, how time is based on the apparent movement of the Sun across the sky and how time can be determined using a sundial.

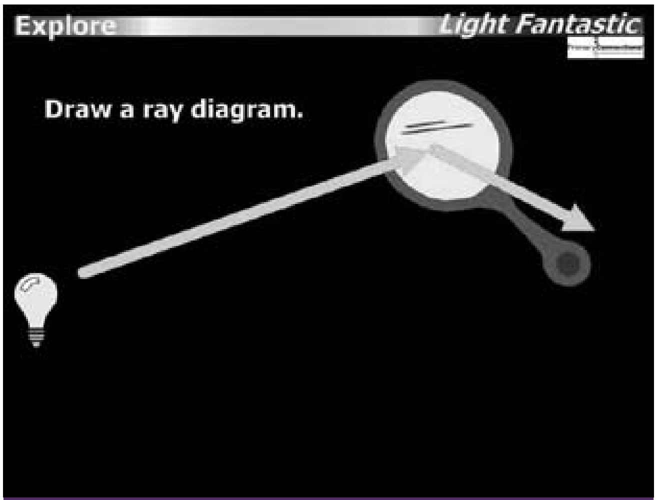


The biggest difference in my IWB lessons would have to be the way I am using video, audio and images. It was fantastic to listen to JFK making a speech and Neil Armstrong talking as he stepped onto the moon. I inserted the media files into the notebook so I could move between each just by touching the board. I could also stop the video and write over the image. This was great for focusing the children's looking and thinking on the moon craters. I think it helped get them excited and motivated for the crater investigation. I also found the children were really keen to use the board themselves. They would go to the 'interesting web sites' I had linked in to my notebook pages. The most popular were the interactive sites like the Earth Sun and Moon explorer. They flew the rocket to the Moon, shooting through meteorites on the way and then choosing the information they wanted to.

Integrating multi-media into the interactive notebook allowed for rapid transitions between activities. In this example the video file was viewed while surrounded by focus questions. The teacher paused the video and annotated the page with arrows and text. The children could hear, watch and translate the information into written text. Whole-class discussion later centred on the appearance of moon craters and questions were generated for investigating their formation. Interesting web sites were identified by the teacher and linked to the notebook pages. Children were able to further explore information online through the selected sites while engaging with a range of representation types such as graphical, pictorial and experimental.

Light Fantastic (Stage Two): Designed for a Year Five classroom

What would our lives be without light? We need it to see everything we do at every moment of the day. We rely on light to read a book, cross the street, admire artwork, watch the sunset, and look into faces. Light plays a role in some of our most sophisticated technology. It enables our CDs to play music or record movies. High-speed optical cable is used in our communications. Lasers are employed in cutting-edge surgery and defence.



My idea here was to connect every day objects with an abstract science concept. I was also introducing the scientific convention of using arrows for ray diagrams.

I used the Primary Connections worksheets as I built my notebook. I put the worksheet PDF onto the notebook page with a picture of what they were going to make. This could help to explain how the 2D shape is folded to make the 3D periscope. You could write over the pictures and draw lines from the pattern to the object.

The notebook Light Fantastic was developed by the project's IWB Education Specialist who worked collaboratively with the project team. He provided expert technical input to the project and was able to advise teachers at their personal points of need. In this notebook he demonstrated the representation of the abstract concept of light rays with familiar images and arrows. He also suggested ways in which student worksheets from curriculum resources such as *Primary Connections* could be efficiently integrated into a notebook, potentially reducing the need to photocopy but more importantly to extend the resource by bringing in mixed representations.

Smooth Moves (Stage Two): A Year Four classroom

Why do balls roll? Why do apples fall from trees? Why do some things slide across ice but not across carpet? What makes our bikes stop when we brake? We use all types of forces including friction, gravity and pushes and pulls when we exercise, ride bicycles and drive cars. Engineers and scientists use their knowledge of forces and motion to design items for our homes, work and school.

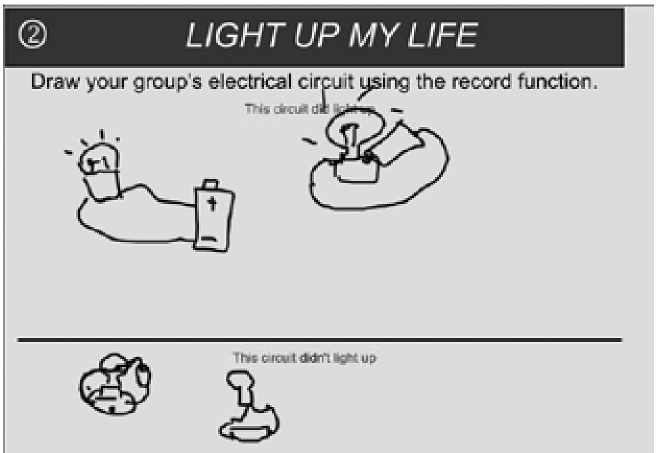
I found this interactive investigation on the BBC schools website. (*http://www.bbc.co.uk/schools/scienceclips/ages/8_9/friction_whatnext.shtml*)

It didn't replace the children's own investigation of friction but helped to reinforce what they had seen. They could try out a range of surface types and see what effect each had on how far the car travelled. The friction sorting activity was useful for reviewing especially as the children could work on the board. There were lots of volunteers to take a turn.

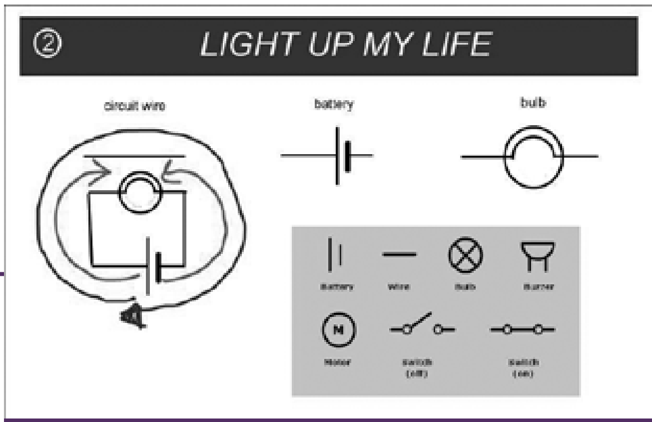
Children could investigate a range of variables quickly through this online simulation. Importantly, the simulation did not replace the hands-on-task, rather extended the representation of friction to include experimental, mathematical, graphical and also verbal modes. The interactive activity expanded the scope of the learning and increased the demands on the children for moving between representational types. Students had to identify similarities between the idea connecting the representations in order to move between them. This 'slipping and sliding' should have supported students meaning making and developing understanding of the science concept.

It's Electrifying (Stage Three): A Year Five and Six split age group classroom

Electrical energy is part of our everyday lives at home, at work and at school. We use it for refrigeration, machines and lighting. Portable devices such as mobile phones, watches and many toys rely on batteries for electrical energy. Electric circuits are needed to allow energy to be transferred from a battery to light bulbs, motors and buzzers, where it is changed into light, movement or sound.



One child from each group drew the electrical circuit built by their group on to the IWB. There was lots of talk from the members of the group as they decided how to draw the circuit; especially from the first group. We used the record function on the IWB to capture each group's action on the board and their voices as they talked about what they were doing.

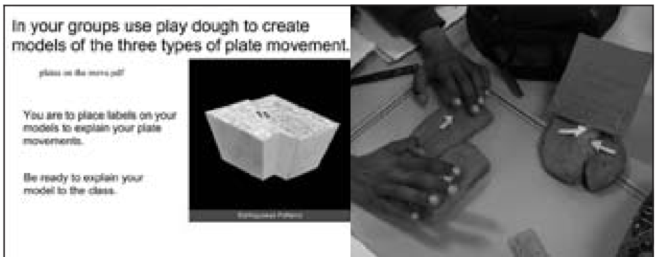


Reviewing the groups' circuit diagrams and the different ways they had drawn the components was a springboard for introducing the scientific symbols for electrical components. We talked about the advantages of having a widely accepted and consistent way of showing electrical circuits. Students then drew over the image to show how they thought electricity flowed in the circuit.

Here students represented their understanding of electrical circuits experimentally and then re-represented the concept through their diagrams. The talk that supported and connected the re-representation was captured by the *record* function on the IWB. Using this function means the students' actions and talk at the IWB are recorded and saved as a digital media file. This option created another way for students to represent their understanding of the science concept. The teacher later asked students a range of questions, which led to her introducing a standard scientific mode of representing circuit components.

Earthquake Explorers (Stage Three): A Year Five and Six split age group classroom

Major earthquakes cause dramatic changes to the Earth's surface. Strong earthquakes can affect millions of lives by causing buildings to collapse, destroying roadways and bridges and damaging basic necessities such as electricity and water supplies. Fortunately, the majority of earthquakes are barely noticed. It is still not possible to accurately predict where and when an earthquake will happen. However, greater understanding of their causes helps scientists estimate the locations and likelihood of future damaging earthquakes.



There were three parts to this lesson on the movement of the Earth's plates. To get the children thinking I showed them a video about the movement of the crust. I had placed the media file into my Earthquake Explorers notebook so I could start it playing from the IWB. The video introduced some of the terms needed for the modelling activity and showed animations of divergent, convergent and transform plate movements. Next I used the IWB to bring up the Primary Connections PDF 'plates on the move', which I also had stored in the notebook attachments. This showed diagrams of the three plate types and gave a written explanation of each. The children then had to use the play dough to model plate movement. The digital photos were useful for showing what the children had done and added to my growing Earthquake notebook.

This example illustrates the complexity and interconnected nature of an IWB lesson. The learning and teaching are not limited to just what happens on the board but also includes what happens at the desk and in the 'Students' Head'. Effective IWB lessons represent and support re-representations of a concept in multiple ways, but clearly what happens on the IWB should be meaningfully connected to all aspects of the lesson. In this example the students experienced rich multi-modal representations ranging from the visual images to modelling. The IWB provided the structure and connection between the representations and enabled efficient lesson transitions.

Scripting multi-modal lessons

Lewin, Somekh and Steadmans (2008) refer to the 'script', that is embedded in IWB lessons. The term script represents a complex idea and is used here with the aim of capturing a sense of the interconnecting content and higher degree of flexibility evident in lessons planned with IWB technology. In the current study the case study teachers were building multi-media resources into a sequence of learning activities. Furthermore, they were creating efficient lesson transitions to online interactive activities and websites by embedding links into the IWB software's notebook. Traditional lesson plans gained a new richness and flexibility as a range of choices about questions and activities were built into the interactive notebooks. The teachers were able to move between interactive resources stored in computer memory which they could access at any time from the IWB.

In addition, the teachers used the interactive whiteboard to bring digital technologies together and to the front of the classroom. This generated a social learning space that encouraged whole class collaborative learning. The teachers were engaging their students with interactive digital learning objects, while modelling processes and facilitating classroom talk; without being hidden by their desktop screen. Interactive activities that provided immediate feedback to students' actions and the links to selected online science sites shifted the role of the teacher from the 'giver of information' to the 'co-constructor of understanding'. Students were encouraged to ask questions and explore possible answers when there were multiple sources and representations of information available through the IWB technology.

Importantly, what happened on the IWB was consistent with the hands-on experiences at the desk and in turn with the questioning used to facilitate students' meta-cognition. Williams and Easingwood (2006) emphasis that:

> *the use of ICT should not replace the practical experience of handling scientific equipment and engaging in genuine scientific investigation and discovery* (p. 36).

Hands-on practical science interests, motivates and engages students with everyday, real world examples and applications of Science. However, the use of IWB technology can potentially extend the learning experience by supporting students' collection and analysis of data and communication of understanding through multi-modal representations.

Conclusion

Teachers with a sound foundation of computer and information literacy are well placed to exploit the potential of IWB technology to transform classroom learning and teaching. Yet, common sense tells us that what a teacher does with IWB technology is far more important than the technology itself. It is critical that the technology doesn't drive the curriculum but rather is used to enhance effective learning and teaching at appropriate times. The teachers participating in this study used their digital technology skills, combined with a variety of teaching strategies, to enhance students' learning. The teachers aimed to match appropriate use of the IWB technology to each lesson's learning objectives. They expanded the nature and range of learning and teaching tools used with the IWB through-out the project and as a result increased the opportunities for students to experience multi-modal representations of Science.

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