Mackinven, K. (2011). Bringing the outside in: Using technology to support teaching of the nature of science strand. *Computers in New Zealand Schools: Learning, teaching, technology*. Vol 23. No 3. pp 227-247.

# Bringing the outside in: Using technology to support teaching of the nature of science strand

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## Introduction

Globally, students are being turned off by school science (Teaching and Learning Research Programme [TLRP], 2006; Osbourne & Henessey, 2003). Declining numbers of students are choosing to study science at higher levels or to pursue science as a career (for example, Osbourne & Collins, 2001; Goodrum, Hackling & Rennie, 2001 and Sjøberg, Steiner & Stefànsson, 2004, both cited in Braund & Reiss, 2006) and students report school science to be lacking in challenge, dominated by repetition (Osbourne & Collins, 2001) and failing to relate science to everyday life (Cerini, Reiss & Murray, 2003). Yet, the very same students are often engaged by out-of-the-classroom science such as that presented by museums, nature, popular press or television (Braund & Reiss, 2006). In these settings, science is seen as exciting, challenging, uplifting (TLRP), 2006) and providing authentic experiences more in line with those of a 'real' scientist (Braund & Reiss, 2006). Encouragingly, these contexts can promote understanding of concepts (TLRP, 2006) and higher scientific reasoning abilities (Gerber, Cavallo & Marek, 2001).

Educators too have expressed concerns that school science is 'boring, irrelevant and out of date' (Braund & Reiss, 2006, p.1373), designed to produce a minority of future scientists rather than a majority of scientifically literate citizens (Millar & Osbourne, 1998). As a result, global science curricula have shifted their emphasis from 'education *for* science' dominated by content, facts and memorisation (Osbourne & Henessey, 2003; Gulikers, Bastiaens, Marten, 2005) towards 'education *about* science', designed to develop students' understanding of the nature of science (Coll, Dahsah & Faikhamta, 2010) and enable them to participate as critical, informed, and responsible citizens in a society where science plays a significant role (Ministry of Education [MOE], 2007a).

The philosophy underpinning the new New Zealand curriculum is a shift towards 'a more inclusive, science-for-all, learner-centred approach' (Coll et al., 2010, p.5) which places learners at the centre of discourse 'as collaborative … co-constructors and critical consumers of scientific knowledge' (Luehmann & Frink, 2009, p. 275). In parallel, the development of technology, particularly Web 2.0 technologies, has been driven by a focus on 'collaboration, distributed expertise and authority, and collective and shared knowledge' (Lankshear & Knobel, 2006a, cited in Luehmann & Frink, 2009, p. 276). The increasing emphasis of both science curricula and technology on the themes of critical thinking, communication and collaboration suggests a role for technology in supporting teaching and learning about the nature of science. Furthermore, inherent in these themes is the connection with 'real science' needed to increase student engagement.

**Scientific literacy: the New Zealand context**

The terms 'scientific literacy' and the 'nature of science' have many diverse interpretations. There is, however, more consensus about what they might mean for education, demonstrated by the overlap between the international aims for science education, curricula and standards documents (Barker, 2004). Central to most descriptions of scientific literacy are higher thinking skills such as using and interpreting scientific explanations (NRC, 2007, cited in Liu, 2009), personal skills such as problem-solving (Holbrook & Rannikmae, 2009) and the use of scientific knowledge in socio-scientific decision making (Coll et al., 2010). Understanding of the nature of science is an essential part of scientific literacy (Akerson & Donnelly, 2010). It refers to an understanding of the epistemology and sociology underlying the activities of science (Hipkins, Barker & Bolstad, 2005) such as how science theory is established, developed and accepted (Wen, Kou, Tsai & Chang, 2010). Scientific literacy is, however, context and culture dependent (Sutherland & Dennick, 2002). Therefore, I will be guided by the New Zealand context for the meanings of scientific literacy and the nature of science.

Teaching of the nature of science was introduced into the New Zealand curriculum in 1993 as part of the integrated 'making sense of the nature of science and its relationship to technology' strand (MOE, 1993. p 24) and its inclusion was seen as an intention to increase students' scientific literacy (Hipkins et al., 2005). However, lack of guidance to implement the strand meant teachers struggled to make sense of it, and for most it represented 'those pages we just turn over' (Loveless & Barker, 2000, cited in Barker, 2010a). Despite this, in the 2006 Programme for International Student Assessment (PISA) on scientific literacy, New Zealand students' mean score was above the OECD mean and, along with Finland, New Zealand had the highest proportion of students performing at the top proficiency levels (Telford, 2010). However, the variation in student performance within New Zealand schools was the largest of all PISA countries, meaning there was also a large proportion of students performing at the lowest proficiency levels compared to other high performing countries (Telford, 2010). If science education is to fulfil its 21$^{st}$ century goals, then it is this which requires attention.

The revised 2007 New Zealand science curriculum, in line with global trends, places new emphasis on the application of knowledge and skills in real-life settings, rather than the foundational knowledge required for the professional training of scientists (Telford, 2010). This philosophical change is embodied by the 'nature of science' strand being given new prominence as the overarching strand which unifies the four context strands (Campbell & Otrell-Cass, 2010; MOE, 2007a; Figure 1b). From its description it is clear that the strand embodies students' development of scientific literacy as well as their understanding of the nature of science:

> '… students learn what science is and how scientists work. They develop the skills, attitudes, and values to build a foundation for understanding the world. They come to appreciate that while scientific knowledge is durable, it is also constantly re-evaluated in the light of new evidence. They learn how scientists carry out investigations, and they come to see science as a socially valuable knowledge system. They learn how science ideas are

> communicated and to make links between scientific knowledge and everyday decisions and actions' (MOE, 2007a, p.28).

However, despite the increased visibility of the nature of science strand, the new curriculum still lacks material to support its teaching (Campbell & Otrel-Cass, 2010). Even internationally there has also been little exploration of appropriate pedagogies (Hipkins et al., 2005) and even less consideration of a role for technology.

## A role for technology?

Using the three identified themes of critical thinking, communication and collaboration as an organising framework, I will discuss the links between the learning affordances of technology, the goals of the nature of science strand of the New Zealand curriculum and technology-enabled 'real' science in the classroom. As much of the research exploring the role of technology in science education does not specifically relate to scientific literacy, I will draw upon broader research around scientific literacy and technology in education, including that from other disciplines and across educational levels, to demonstrate the potential of this approach. For each theme, a number of technologies may be touched upon, but only one will be discussed in any detail.

### *Critical thinking*

Critical thinking is a higher-order thinking skill (Miri, David & Uri, 2007) which involves identifying sources of information, analysing credibility, reflecting on consistency with prior knowledge and drawing conclusions (Linn, 2000, cited in Miri et al., 2007). It is, therefore, at the centre of scientific literacy in separating science from non-science (Norris & Philips, 2003, cited in Holbrook & Rannikmae, 2009), evaluating what counts as evidence, and comparing alternative explanations (Nickels, Nelson & Beard, 1996). In the nature of science strand critical thinking is represented by the requirement for students to 'collect[ing] evidence that will be interpreted through processes of logical argument … evaluate the suitability of the investigative methods chosen' (MOE, 2007b, p.60) and 'appreciate[ing] that while scientific knowledge is durable, it is also constantly re-evaluated in the light of new evidence' (MOE, 2007a, p.28).

Technology can support activities such as concept mapping (Wegerif, 2002), web-quests (Polly & Ausband, 2009), virtual experiments, modelling of theoretical phenomena and virtual collaboration including critical questioning and reasoning (Kubieck, 2005). In these examples, students' understanding of the nature of science is promoted by enabling them to represent what they know whilst engaging in critical thinking about the content they are studying (Jonassen, 2000, cited in Wegerif, 2002, p.21). For example, concept mapping is widely accepted as means to support learning by encouraging students to make conscious connections between concepts and therefore to integrate new knowledge into existing conceptual frameworks (Cheung, 2006). Online concept mapping enhances these processes by facilitating quick and easy revision and maintenance of concept maps (Cheung, 2006) as well as the addition of images, video and audio clips and hyperlinks (Baitz, 2009). Online concept mapping can also be collaborative with students co-constructing concept maps. In editing the map, students must question, challenge, validate and reflect on their own knowledge and representations as well as those of their peers (Cheung, 2006). In doing so, they learn to re-evaluate their scientific theories just as scientists do.

Critical thinking is an essential tool of scientific inquiry (Wegerif, 2002). Inquiry-based learning involves students using the processes of scientists such as asking questions, making hypotheses, managing data, drawing inferences and building theories (Kubasco, Jones, Tretter & Andre, 2008). Scientific inquiry in the classroom often involves collecting limited and predictable data, but online data sources allow students to learn science through investigations of, and contributions to, large authentic datasets (Griffis, Thadani & Wise, 2008) which have real-world connections.

At the simplest level, technology provides access to real-time or near real-time data such as daily solar images, astronomy data, seismic activity or weather patterns (Wood, 2008) which can be incorporated into inquiry-based investigations. However, since thinking is both individual and social, and constantly moving between the two, technology should support discourse between learners and therefore critical thinking through engagement in collaboration (Wegerif, 2002). This is achieved by using technology to enable students to collect 'real' data and partner with scientists in authentic research (Dolan, Lally, Brooks & Tax, 2008; Golick, Schlesselman, Ellis & Brooks, 2003). Using technology in a variety of ways, students have collected data on bumblebee abundance and distribution (Golick et al., 2003), the effects of environmental variables on plants in which scientists have disabled a gene they are studying (Dolan et al., 2008), and on local environmental variables that are then used in scientists' research (Roschelle, Pea, Hoadley, Gordin & Means, 2000). Students can investigate authentic problems such as analysing cases of genetic or infectious disease (Bergland, Klyczek & Lundeberg, 2006) and constructing relationships between environmental variables and leaf traits (Griffis et al., 2008). In an investigation to identify genes causing deafness, students used procedures and tools used by geneticists and demonstrated increased awareness of the role of methods in the scientific process (Gelbart & Yarden, 2006) – a central element of the nature of science strand (MOE, 2007b).

*Communication*

'Communication in science' is a theme of the nature of science strand. Its aim is for students to 'develop knowledge of the vocabulary, numeric and symbol systems, and conventions of science and use this knowledge to communicate about their own and others' ideas' (MOE, 2007b, p.60). At attainment level 6 and above this involves evaluating popular and scientific texts and considering the wider implications of methods of communication and representation (MOE, 2007b). By supporting multiple modes of communication including text, audio, images and video, technology has an obvious role to play in supporting this aspect of the nature of science strand. Producing web pages, online documents, multimedia presentations and podcasts as well as video conferencing with other classrooms and scientists are commonly cited examples of using technology to support communication in science. However, as well as providing a means of communication, technology may also be able to support the learning objectives behind the strand: The potential for podcasts to enhance the development of science vocabulary was demonstrated by a study which found that students who had access to podcasts significantly increased their vocabulary test scores compared to a control group (Putman & Kingsley, 2009).

The nature of science strand emphasises two types of communication: the presentation of individual ideas and the critical engagement with the ideas of others. Blogging is similarly theorised to be the practice of both 'monologue and dialogue' (Werde, 2003, cited in Farmer, Yue & Brooks, 2008, p. 124) where individuals express their own personal ideas through online publication whilst exchanging views with an interactive community (Farmer et al., 2008). This suggests the potential for blogging to support learning about communication in science. A blog is essentially an online journal which allows others to make comments (Ellison & Wu, 2008) and links to other related posts, blogs and web content (Farmer et al., 2008). In a science education context, blogs have been used for posting and analysing laboratory results, discussing the validity of scientific information from different sources and to engage in discussion with scientists about fieldwork (Luehmann & Frink, 2009). In each of these activities, the content of the blog has a role in supporting the development of scientific literacy, but so too does the act of blogging itself through its support of the two modes of communication.

On an individual level, blogging allows students to communicate their ideas and perspectives on a subject (Farmer et al., 2008). In deciding what to write students must read, filter, restructure and organise information (Sawmiller, 2010). Adding multi-media (images, video, audio) and outside content to a blog means students must select resources, verify the validity of their sources and 'situate their work in a larger discussion' (Luehmann & Frink, 2009, p.276). Compared to other writing in science, blogs are more informal and support metacognitive reflection (Farmer et al., 2008). Reflection is also promoted through developing a blogging voice, as students must 'confront their own opinions and contemplate how their views might be interpreted and reflected upon by others' (Mortensen & Walker, 2002, cited in Willams & Jacobs, 2004, p.234). Communication with a wider audience is also facilitated by blogging (Ellison & Wu, 2008). A blog can be limited to the classroom but is best extended beyond these walls to the school community, invited guests such as scientists or made public on the web since awareness of an audience beyond their teacher increases both students' investment and responsibility in their writing (Jacob, 2003, cited in Wheeler, Yeomans and Wheeler, 2008) as well as their motivation to produce quality work (Luehmann & Frink, 2009). Responding to comments on their own blog, commenting on other blogs and therefore considering perspectives divergent from their own (Kajder, 2007), students become more analytical and critical as they 'define their positions in the context of others' writings' (Oravec, 2002, cited in Ellison & Wu, 2008, p.106).

The nature of science strand encourages students to 'develop an understanding of socio-scientific issues by gathering relevant scientific information in order to draw evidence-based conclusions and to take action where appropriate' (MOE, 2007b, p.60). It also suggests critically engaging students with socio-scientific issues presented in the media and in science texts (MOE, 2007b) an activity that the 'Making Science: Making News' project (Alexander, Walsh, Jarman & McClune, 2008) concluded is an effective means of addressing scientific literacy. In doing so students must consider both the science content and epistemology of science (Ryder, 2001, cited in Jarman & McClune, 2010) since they must consider the method of communication and how information is represented to discern the validity of conclusions (LoGuidici & Ende, 2010). Technology, via the internet, provides access to a wide variety of media presented from many different viewpoints. Pace & Jones (2009) suggest that web-based videos which illustrate science concepts and demonstrate how science is interwoven with larger social and cultural issues can assist with developing scientific literacy and blogging has been used to facilitate students' reading of scientific texts (Luehmann & Frink, 2009). Combining technology with science media would exploit the affordances of technology whilst allowing students to respond to current news articles, compare the presentation of socio-scientific issues between different media sources, consider the data being supplied and the conclusions being drawn (LoGuidici & Ende, 2010). Furthermore, use of media reports increases the connection between students and real-world science issues so they can 'make links between scientific knowledge and everyday decisions and actions' (MoE, 2007a, p.28).

*Collaboration*

Scientific literacy recognises science as an endeavour requiring collaboration between scientists (Lee, 2008), peer review (Barker, 2010b) and social negotiation for acceptance of scientific theories (Wen et al., 2010). This is incorporated in the nature of science strand by requiring students to 'identify ways in which scientists work together' (MOE, 2007b, p.65) and to understand 'the processes by which it [scientific knowledge] is developed' (MOE, 2007b, p.60). Social interaction and collaboration are also major drivers for recent technology development (Richardson, 2006). The nature and extent of the collaboration is shaped by each technology: blog and podcast authors have control over content (Wang & Woo, 2009) and collaborate with others through comments, whereas wikis and collaborative mind maps support users to create content by editing a shared document (Kajder, 2007). Social media, such as Facebook, MySpace, Twitter and social bookmarking, offer huge potential for interaction between learners through their ability to support information sharing, feedback, conversation, and networking (McLoughlin & Lee, 2005) but while many studies document attitudes towards and seek to quantify students' use of social media (for example, Jones, Blackey, Fitzgibbon & Chew, 2010; Clark, Logan, Luckin, Mee & Oliver, 2008), research considering the use of social media with regard to science education and science literacy is just emerging. However, examples from other curriculum areas demonstrate social media's potential: Collaboration is at the heart of online literature circles (Stewart, 2009). Using Facebook, each student assumes a role in the circle and engages in critical thinking and reflection as they read, discuss and respond to books with the other members of the circle (Stewart, 2009). The idea of literature circles has already been incorporated into science literacy circles as a means to engage students in collaborative critical thinking. The students use a range of writing including journals, diagrams and sketching to make their own thinking explicit and then collaboratively review all of the ideas within the circle in order to reach their final conclusions (Devick-Fry & LeSage, 2010). This process could be enhanced with the use of Facebook or similar technologies where multimedia would allow students to express their own ideas in multiple formats and easily connect with the alternate views within their circle as they developed. Further research on the use of social media in education is warranted. One technology which has received more attention to date is the use of wikis.

Wikis enable students to ‘collaboratively generate, mix, edit and synthesise specific knowledge’ (Wheeler, Yeomans & Wheeler, 2008, p. 989). In the classroom they can be used for problem-solving, explaining diverse and contradictory ideas, evaluation and synthesis, critical questioning and reflection and analysis of others’ work (Fountain, 2005), research projects, summaries of readings and annotated bibliographies, concept mapping, producing shared resources such as texts (Parker & Chao, 2007) and writing instruction (Lamb, 2004). Demonstrated benefits of wikis include increased student engagement (Cole, 2009), reflective learning (Parker & Chao, 2007), promotion of collaboration in group work (Hazari, North & Moreland, 2009) and increased content knowledge (Bomar, 2009). In science wikis have been used as collaborative online laboratory notebooks (Elliot & Fraiman, 2010; Clougherty & Wells, 2008) and as a platform to allow students to share and discuss information from current biological research (Bomar, 2009).

In these examples the task associated with the wiki relates to how a scientist works and therefore to developing scientific literacy. However, I would argue that the process of producing a wiki could be equally as important in understanding the nature of science as the content of the wiki itself. In this sense, working on a collaborative wiki has an ‘epistemic effect’ with the potential to ‘change the way we think and what we know’ (Wagner & Levin, 2007, p.309). For example, the often contentious issue of negotiating the content of a wiki (Lamb, 2004) exposes students not only to collaboration but also to competition, part of the nature of science which is often overlooked (Wong, Hudson, Kwan & Yung, 2010). This process links to the nature of science strand which requires students to appreciate that scientists ‘work[ing] together to share and examine their own and others’ knowledge’ (MOE, 2007b, p. 64) and that ‘open-mindedness is important because there may be more than one explanation’ (MOE, 2007b, p. 61). Also required is an understanding that scientific findings are presented for peer review and debate (MoE, 2007b). Wikis expose learners to peer review and feedback as their contributions are critiqued and edited by a wider audience (Bomar, 2009). This in turn provides them with the opportunity to appropriate new ideas, and transform their own understanding through reflection (Williams & Jacobs, 2004) providing experience of the negotiation required for group acceptance of ideas and theories such as occurs in scientific communities. Furthermore, non-traditional forms of writing such as stories and debates have been shown to change students' views on the nature of science 'in a direction aligned … with science education today' (Wagner & Levin, 2007, p. 307). Their informal, expressive and non-scientific nature allows students to reflect and develop their epistemological beliefs (Wagner & Levin, 2007). Since wikis also encourage more informal writing styles (Elgort, Smith & Toland, 2008) this provides further evidence for their potential to support students in developing their scientific literacy.

Collaborative notebooks are an innovative use of wikis. Collaborative notebooks involve students sharing data (Badge & Badge, 2009), planning investigations and collaboratively analysing results (Elliot & Fraiman, 2010; Clougherty & Wells, 2008). Using a wiki in this way allows students to demonstrate their knowledge in a non-linear way using hyperlinks, and increases collaboration between students (Elliot & Fraiman, 2010). Online collaborative notebooks using alternative platforms have included interactions with scientists (Dolan et al., 2008) which is equally possible using wiki technology. In addition to the benefits of using a wiki outlined above, this approach increases engagement (Dolan et al., 2008) and gives students the opportunity to participate in an extended learning community which includes external experts and a link to real-world science.

## Technology alone is not enough

Many studies reinforce that technology alone cannot achieve learning outcomes: 'the tool provides the means, the students and teacher construct the meaning' (Luehmann & Frink, 2009, p. 277). The role of the teacher is critical in the successful use of any technology-enhanced learning experience and to realise the potential that technology offers, teachers need to adopt appropriate pedagogies and scaffold students' learning as well as integrate technology into the curriculum (Kubieck, 2005). For example, students can be reluctant to comment on others' work (Ellison & Wu, 2008). They can also struggle with the formality that assessment imposes on the more informal 'non-academic' mode of discourse of blogs and wikis (Farmer et al., 2008; Hemmi, Bayne &

Land, 2009) and mandatory comments can lead to a lack of substantive feedback (Ellison & Wu, 2008). To create a responsive and expressive student audience, appropriate guidance in giving constructive feedback is needed (Kajder, 2007) along with appropriate assessment. In addition, technology allows access to a vast amount of scientific information which is often non-linear, fast-paced, rich and embedded in other contexts. Selecting, organising and integrating this type of information can produce high cognitive load which affects learning. As a result, strategies such as segmenting, looking for patterns in information and understanding different genres may also be required (Pace & Jones, 2009).

Particular to the nature of science, however, is that in addition to enabling learning activities where the content of the activity directly supports students' scientific literacy, technology can also act as an indirect means of support where it is the processes that students are using whilst learning with technology which promote their understanding of the nature of science. In this way technology is conceptualised as a thinking and learning tool (Wagner & Levin, 2007), engaging students with science and the construction of scientific understanding by supporting, for example, 'meaningful epistemic discourse' (Sandoval, 2003, cited in Wagner & Levin, 2007, p. 309). However, the act of simply using technology, such as creating a wiki or writing a blog, is not enough to influence students' understanding of the nature of science. The successful 'explicit- reflective' approach (Abd-El-Khalick & Akerson, 2010) suggests that students need to be explicitly aware of the elements of the nature of science which relate to their use of technology and be given the opportunity to reflect on these activities to promote conceptual change (Wagner & Levin, 2007). Therefore, it cannot be assumed that through engaging learners in technology supported science activities, learning about the nature of science will automatically result. Such learning needs to be intentionally planned and the inclusion of specific nature of science learning outcomes in learning sequences (Abd-El-Khalick & Akerson, 2010) is as essential as content-related learning outcomes.

## Conclusion

Technology presents many new possibilities for education (Kubieck, 2005). The shift in the focus of the New Zealand science curriculum represents a change from a didactic, instructivist approach to a student-centred socio-constructivist approach whose aim is to produce scientifically literate students. With its emphasis on shared knowledge creation and collaboration, the affordances of technology can offer support with these reform-based learning goals (Luehmann & Frink, 2009). The notion behind the nature of science strand is for students to understand how scientists work, how scientific knowledge is developed and accepted and to develop an awareness of the role of science in society (MOE, 2007a). By enabling students to investigate authentic datasets, experiment with remote scientific instruments, experience peer review, communicate and collaborate with wider audiences including scientists, technology is able to directly support activities which are proposed to increase students' understanding of the nature of science.

Although technologies have been included under one of the three themes of critical thinking, communication or collaboration, there is clear overlap. Podcasting, for example, is a platform for allowing students to communicate their ideas. However, in creating a podcast students must locate information, verify sources and think critically about both the content and audience in order to re-present that information. Podcasting can also be collaborative depending upon how the learning activity is designed. Due to this, the integration of technology to support learning through the nature of science strand needs to be specifically defined and planned. Furthermore, since much of the learning about the nature of science in technology-based lessons is not explicit, students should be made aware of how both the content and process of their work relates to learning about the nature of science and be able to reflect on this.

This paper discusses the potential for technology to support teaching and learning of the nature of science, and to increase the connections between 'school science' and 'real science'. However, as much of the research in this area is descriptive or theoretical, empirical research is now needed to discover the extent to which teachers are able capitalise on these affordances and connections to increase scientific literacy.

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