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Networked inquiry learning in secondary science classrooms

John Williams, Bronwen Cowie, Elaine Khoo, Kathy Saunders, Simon Taylor, Kathrin Otrel-Cass

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Introduction

This research project aimed to understand and explore the ways electronically networked (e-networked) tools can support authentic science inquiry in junior secondary classrooms in order to address concerns about student engagement in science. Internationally claims are made about the potential for inquiry-based learning to address the challenges of relevance for the 21st century school science learner (Aikenhead, 2005; Bolstad & Hipkins, 2008). Deliberate inclusion of activities such as collaboration, co-construction and confirmation of ideas is appropriate and valued in science inquiry but they tend to contrast with many of the practices found in conventional classrooms. These activities require more student freedom and the capacity to pose and meaningfully pursue questions of their own design. They may also require students to go beyond the confines of the physical classroom, and venture into virtual communication environments. Our findings highlight that e-networked tools can support collaboration and the co-construction of knowledge within and across an inquiry cycle. Tools such as online platforms, Skype, and mobile technology afford new and different ways of communication and the sharing of information and ideas through synchronous and asynchronous, direct and indirect means. The findings also point to the conditions that are needed to leverage the potential of these e-networked tools in junior secondary science classrooms.

Key findings

- E-networked tools are valuable in supporting an inquiry approach to teaching and learning science.
- E-networked tool use enables greater student control, ownership and responsibility for their learning, by affording them access to a wider range of sources of knowledge and resources and media for communicating what they know and can do.
- Meaningful integration of e-networked tools in the inquiry process requires that teachers have sufficient support from their school/school management, flexibility in curriculum design, and active planning to integrate and implement e-networking tools, including scaffolding students' developing understanding of the inquiry process and outcomes and the affordances of the different ICT tools.

Major implications

- Teachers' explicit planning for e-networked-based science inquiry learning is needed to initiate and activate the inquiry process. Classroom implementation of any plans is most effective when it is informed by teacher reflection and takes account of student responses and feedback to refine practices.
- By taking small forays into parts of, or implementing a focused inquiry cycle and progressively building on from these experiences, teachers and their students can develop a better understanding, the confidence and capacity to conduct inquiries using e-networked tools.
- There is value in teachers and students drawing from a range of e-networked tools to undertake different aspects of science inquiry learning. Tools that allow students to simulate/undertake scientific processes such as observing, reviewing and the multimodal expression of emerging ideas are particularly advantageous for abstract or hard to master science content.
- Students and teachers need to recognise that teachers are not the only source of knowledge but that peers and communities accessed through e-networked tools can be valuable for resources to inform and empower their science inquiry investigations, and that,
- School management can better support teachers (and students) in e-networked inquiry practices by investing in robust networking platforms, adopting policies that encourage productive e-networked tool use, recognising teacher efforts in e-networked inquiry learning practices, and allowing some flexibility and responsiveness in curriculum and assessment.

The research

Background

The research project aimed to explore and theorise how inquiry teaching and learning in science can be supported through e-networked environments such as blogs or email and how online resources accessed through the Internet can afford individual and group exploration of content, skills and resources. Such research is important because school science has been criticised for lacking authenticity and having very little to do with issues that are publicly debated (Roth, Eijck, Reis, & Hsu, 2008). This lack of relevance has been associated with students' lack of interest in science and motivation to continue with science beyond the compulsory years at school (Bolstad & Hipkins, 2008). Fensham (2006) argues that science education ought to provide opportunities for students to connect with real-world science and technology issues that they will be interested in and find personally engaging if the problem of declining student interest in science is to be addressed. Student participation in inquiry has been shown to achieve this.

The notion of "inquiry" proposed by the National Research Council (NRC) was adopted to guide this research. The NRC describes inquiry as the "abilities students should develop to be able to design and conduct scientific investigations" and the "understandings they should gain about the nature of scientific inquiry", as well as "the teaching and learning strategies that enable scientific concepts to be mastered through investigations" (NRC, 2000, p. xv). Within the research, it was considered essential to investigate how students might be supported to engage in authentic science inquiries in the sense that their investigations were based on questions for which the answers are not known or at least not known to the students (Feldman et al., 2000). Others have found that when students undertake their own investigations, they take more ownership of their learning and develop the skills of how to learn (Hipkins, 2006, citing Bryce & Withers, 2003). This framing was important because, as Osborne (2007) notes, "schools are not the sole sources of knowledge in society anymore" (p. 110).

The study set out to investigate how e-networked approaches could support the goals detailed above. Many schools in New Zealand now provide e-networked environments, for example through Internet-based systems like Moodle, class websites that provide for blogs and/or the use of email. These environments allow teachers and students to share information and communicate in a virtual space. There is evidence that student and teacher use of e-networked tools, including social networking tools, can add a productive dimension to interaction, dialogue and sharing (McLoughlin & Lee, 2007). These tools provide students with increased opportunities to interact with teachers, peers, experts, and students from other schools (Ministry of Education, 2007, p. 36) and hence contribute to a shift in the power relationships between teachers and students. This study is interested in the way their use might offer new and different ways for diverse students to engage with, explore and communicate science ideas within science inquiry. Within the study, it was considered imperative to work collaboratively with teachers to create a shared vision of inquiry-oriented learning, and to identify what knowledge, skills and attitudes students need to develop so that they can conduct investigations, including those of collecting, analysing and communicating about data in a scientific manner (Feldman et al., 2000).

Research questions

The research questions for this study were:

1. What are the existing ideas, experiences and visions that secondary science teachers have about teaching through inquiry learning in science?
2. What particular research skills do students require and acquire when they are involved in inquiry learning in science?
3. How do individual understandings change as students collaboratively engage in inquiry learning projects?
4. How does a networked environment where students and teachers can communicate through the web in addition to the face-to-face teaching impact on collaborative inquiries?

Methodology and analysis

This study drew from the following data sources:

- teacher planning documents
- field notes from classroom observations
- video-recordings and transcripts from the classroom
- student work produced during and as a result of their inquiries, during homework activities and as part of assessment activities
- online records from networked activities (e.g., blogs)
- reflections and insights from both teachers and students collected during formal and informal interviews.

Data were collected:

- before classroom observations by the research team (researchers and teachers), and throughout the research to detail how ideas and theories were collaboratively generated by the teacher-research team and evolved over time
- during classroom observations by the researchers, through videos of individuals and of the whole class, observational notes, photos of teacher/student interactions, and informal interviews with teachers/students to provide evidence of learning and teaching in the classrooms
- in the absence of a researcher, by the teachers, who recorded their inquiry learning teaching and learning examples using fixed position video recordings, viewing and selecting episodes of teaching and learning that were of particular interest to them to share and explore with the research team
- from student work by the research team (researchers and teachers) in order to collect evidence of students' learning journeys
- after the teaching of a unit by the research team (researchers and teachers) to hone in as a team on telling examples for further exploration and to share insights from researchers and teachers.

The study developed case studies, one from each teacher and their class in each year, which provided rich detailed descriptions of how the process of networked inquiry in science evolves and can be stimulated. These cases were subject to cross-case analysis to search for themes. The goal of the analysis of the cases was to understand innovative pedagogical practices using networked technology in science classrooms, how these innovations change what is done in science classrooms, the roles ICT plays in supporting them, associated with various outcomes and contextual conditions.

The following aspects of scientific inquiry, derived from the National Science Education Standards (NRC, 1996, 2000), were targeted in this study and served as an underpinning framework for data analysis:

1. Scientific inquiry involves asking and answering a question and comparing the answer with what scientists already know about the world.
2. Data analyses are directed by questions of interest, involve representation of data in meaningful ways, and involve the development of patterns and explanations that are logically consistent.
3. Investigations have multiple purposes and use multiple methods.
4. Scientists formulate and test their explanations by examining evidence, and they suggest alternative explanations.
5. Scientists often work in teams with different individuals contributing different ideas.
6. Creativity is found in all aspects of scientific work.
7. Scientists make the results of their investigations public.

The first level of data analysis included initial reflections by and with teachers, students and researchers after the classroom observations which were shared by researchers in the online environment of Google Groups to provide a trail of records to maintain the credibility of the project (Guba & Lincoln, 1994). These notes informed the selection of sequences of video from the classroom observations for the second level of analysis using the analytical software program Nvivo. These video analyses became a central information source in the meaning-making process at a micro-level (Erickson, 2007), informing the third level of analysis which integrated the text (transcripts and reports) and audio (interviews) data. The use of Nvivo software package enabled integrated video, audio and text analysis.

Findings

The key findings from this study are:

1. E-networked tools can support different aspects of the science inquiry cycle/process.
2. E-networked tools support students to: (a) exercise agency, (b) access and share their own and others' input, and (c) access a wide range of sources of information and resources for meaning making.
3. Teacher enactment of science inquiry with e-networked tools is both enabled and constrained by technological, institutional and pedagogical factors.

E-networked tools can support different aspects of the science inquiry cycle/process

Teachers considered the use of e-networked tools as advantageous in supporting all aspects of the science inquiry process including posing questions, initiating investigations, collecting and analysing data, and reflecting on and communicating findings. They made use of different tools at various points of the inquiry cycle in support of different goals. Students had access to a range of tools they could employ for developing questions, information seeking, data collection, the sharing and review of ideas, refining their questions in the light of new evidence, and communicating ideas with peers and or the wider (school) community. In doing so, students learn to draw from a wide repertoire of information and communication technologies and skills in support of a particular process in the inquiry cycle.

A representative teacher quotation highlighted this idea:

> The use of technology to facilitate the inquiry process worked really well as they could communicate with someone who could be anywhere and there is huge value in that. They were able to ask questions and get feedback instantly. . . . In the latest learning on the water unit, they weren't just learning about water but they were also learning about "How do I make this into a PowerPoint?, How do I use Glogster?" They picked up skills about using ICT in science as well as the science so that there was that added component. (Teacher)

Examples of e-networked tools that provided opportunities for students to access, investigate, share, co-construct and communicate science ideas were:

- online information searches using search engines, Webquests, YouTube videos and mobile devices—to access ideas and resources, students also created YouTube videos and websites to communicate ideas
- online post-it notes such as the Wallwisher—for students to share ideas and questions
- Moodle forums—to facilitate class discussions and understanding of a topic
- Skype and email—for students to ask questions and discuss developing science ideas with scientists
- online presentation tools such as Google PowerPoint, Prezi and Glogster—to co-construct and communicate inquiry findings.

The aforementioned tools allowed for connection and multimodal forms and modes (be it synchronous or asynchronous) of communication, and afforded opportunities for deeper knowledge exchanges.

E-networked tools support students to: (a) exercise agency, (b) access and share their own and others' input, and (c) access a wide range of sources of information and resources for meaning making

Exercise agency

E-networked tools, in particular mobile devices (e.g., smartphones and iPads), can support inquiry learning by increasing the opportunities for student participation and collaboration in the inquiry learning process. Student ownership of and control over these technologies meant they could use them in their science inquiries as and when they saw a need, reducing their need to rely on teacher- or school-managed systems. In this way, the devices supported students in the exercise of agency.

Student-initiated use of their own mobile devices was often observed when they needed quick access to the Internet to answer questions that emerged during an investigation. Students used the visual recording facilities on mobile devices to record practical group investigations. This process was particularly valuable in helping students understand otherwise hard-to-comprehend science content. The act of recording meant students adopted an active stance during the activity and were provided with multimodal opportunities to expand their critical observational skills and to reflect on and talk about science. Students typically shared the mobile phone recordings with their peers and sometimes, family members. This enriched their developing science understandings by expanding conversations within and beyond the classroom. Representative student quotations of these experiences were:

> It helps a lot if you are watching a [mobile phone] video, you take it in more . . . and you remember it better.
>
> We record what we see and send it to the teacher. To record the process for when we do evaluation, to give other people an idea of what it's like to do this. It's like taking notes in class just a different form. It's better to take it in a picture, as you can't explain what its like in words always, it's easier to explain what it's like using videos.

For teachers, student mobile phone recordings were a new and additional form of evidence of student learning, as well as a record of the science content that was of interest and had been observed by the students. Some teacher comments were:

> A couple of them have already videoed stuff going on throughout the year and thrown them up on YouTube. They are quite tech savvy. I have a couple of flip cameras for back up. Kids definitely looked at it [kitchen chemistry] from a scientist point of view rather than as a food tech unit.
>
> . . . a few will probably go onto Facebook tonight and probably post it [their mobile phone recording] on Facebook. For them they think it's a cool buzz. They take it home and they show their mums and dads, "This is what we've actually done in school".

Learning environments that allow for flexibility in accessing and sourcing hardware and software can empower and engage students, including their sense of ownership and responsibility for their own learning. Through this, students' learning experiences are broadened beyond the confines of the classroom as they share their learning with their families and communities.

Access and share one's own and others' input

E-networking tools such as Moodle supported student sharing and communicating of ideas and obtaining feedback of work in progress. The fact that the Moodle postings persisted over time meant that students could revisit and revise their thinking on a topic. Both teachers and students participated in this process. Teacher quotations revealed the value of using Moodle:

> By having postings on Moodle it allowed students to have a variety of resources at their disposal for revision. By having these resources in Moodle, this gave the students flexibility with what time they could complete revision. Some completed this at night and others in the morning. More students attempted revision as they felt there was something to their liking and piqued their interest. Also many felt that they had enough material to revise with. It also allowed students to communicate and ask other students questions regarding their revision. This unit's assessment was the one that they performed best in out of the whole year.
>
> Many of my students felt that Moodle was a positive experience and helped bridged the gap between what happened in the classroom and home.

Access a wide range of sources of information and resources for meaning making

E-networks such as Skype and email allowed students to interact with scientists and to gain a better understanding of how scientists work. Their communication with scientists enhanced the credibility and added depth to their inquiry design, questions and understanding. As some students reported:

> It was pretty good as we emailed him [the scientist] and within two days he came back to us. He gave us like three website links and pdf files. He gave us heaps of information. You can't really find that sort of stuff online. Emailing someone is a really easy way to get information, expertise and advice. It is a good way to get information that you want instead of going through websites whereas emailing someone you get the depth of learning.

The teachers also saw value in skyping/emailing scientists as indicated in the next comment:

> The magic of having an expert in the classroom [via Skype] whom they [students] can ask about something they are interested in, the use of technology to do something like that is immensely valuable. That would be where I see the technology won through.

In addition to communicating with outside experts, e-networked tools allowed students to communicate with one another both within and outside the classroom. For example, when students were creating presentations to communicate their findings through Google PowerPoint or Glogster, the availability of these tools on the Internet meant students could create group presentations and access them anytime (including outside of class time) to collaborate and prepare for their presentation. The collaboration these e-networked tools afforded was over and above the forms of classroom collaboration the students were used to. The students and teachers both commented on this aspect:

> It was really helpful that we could go online outside of class hours. We could all work on it [Google PowerPoint] at home. We could all do it together; all add stuff without being together whereas if we do it on a Word document, we'd all have to be together. (Student)
>
> Definitely In the good old days, they'd just have a piece of paper and they'd make a poster. You can only work on it in class, only one person at any one time. You can't all sit round the table to write it all at once whereas this [with Google PowerPoint or Glogster] they can do this anytime of the day, whenever they want. Its nice to see that the learning is continuing at home and they are taking this stuff home and sharing it and continuing with it. (Teacher)

Teacher enactment of science inquiry with e-networked tools is both enabled and constrained by technological, institutional and pedagogical factors

The factors are:

- reliable access to technology infrastructure
- flexible curriculum and assessment structures
- understanding of the affordances of different technologies
- planning to incorporate technology meaningfully in their teaching
- progressive introduction of inquiry possibilities to scaffold skill development and transfer responsibility to students.

Reliable access to technology infrastructure

Effective e-networking for science inquiry can only occur if the infrastructure is working. Slow, malfunctioning or unavailable service and technologies were a source of frustration for both students and teachers. There were a number of instances where teachers and students used their own equipment such as iPhones, iPads, and digital cameras to circumvent infrastructure challenges and facilitate their inquiries.

When the infrastructure was supportive, teachers found that productive unanticipated explorations and outcomes occurred:

> For the higher level class where access to electronic media was pretty much the norm, access to online resources from home was easy for this cohort. Their knowledge of online applications was high, hence, the development by one group of their own web site. They also worked through as a class their own Facebook page that they had set up to discuss school things.

Flexible curriculum and assessment structures

On occasions, significant challenges arose from tensions between the practical realities of class time and curriculum pressures, and the need for flexibility in curricula that accommodate student pursuit of their own inquiries, as the following teacher comment exemplifies:

> Inquiry takes some time to do, it's not something that can be done in a lesson, it's something that needs to be built. Also the students need to learn the skills of inquiry, it's not something that's innate. . . . That creates an issue with assessment, our tests are knowledge-based, they don't acknowledge the fact my students had spent two extra weeks doing inquiry.

This quotation represents the consensus view amongst the project teachers that time was needed to consider and plan for e-networked supported science inquiry learning that went beyond the learning of facts. This planning had to deliberately support students learning to value inquiry processes such as exploration, collaboration, co-construction and the communication of science ideas. This quotation also highlights that changes in pedagogy and learning need to be accompanied by changes in assessment.

Effective and responsive use of e-networked tools for inquiry requires flexibility in school academic structures (curriculum and assessment), and ready access to fully functioning technologies. Ultimately, however, it is the local school or institutional policy, structure and practices regarding ICT use that shape the patterns of interaction within a class and within student small groups.

Teachers developing understanding of the affordances of the different technologies

The teachers working in pairs as critical friends were influential in developing confidence to use technologies. The teacher pairs skyped each other fortnightly to share ideas on teaching plans and how these had played out in class. These sessions helped them evaluate their lessons and analyse the effect and efficacy of the different e-networked tools. This sharing provided opportunities to learn new ideas for networking and inquiry in science. The following comment is indicative of the value teachers saw in this peer support process:

> It [the fortnightly Skype sessions] was useful so it wasn't so long before we met together for the next [team] meeting. It was an opportunity to discuss ideas and try out new things and some of those included problem solving. It certainly added to the confidence and competence idea.

The reflective and iterative research process through regular team meetings also ensured that, over time, teachers felt more confident in exploring the different facets of their inquiry teaching and how this could be supported by e-networks. Gradually, they developed contextualised knowledge of what was possible and practical. Teacher understanding of how to use Skype in e-networking developed in this way; it became more integral to their teaching as a result of classroom use and reflection.

Focusing on what e-networked technologies can offer to the inquiry process in science provided a focal point for teachers thinking, planning and reflection. The development process was also empowered through student feedback and reflections on how e-networked tools supported the inquiry learning process. Students were not simply informants but active contributors to identify further opportunities and refine the e-networked supported inquiry process. Examples of student comments included:

> I reckon we developed independent research skills because of the technology; instead of the teacher telling us exactly what to do and what the answers were, we figured it out for ourselves.
>
> Having to find information and present it in our own way was fun and challenging, it was good because we had new ways to teach which weren't boring.

Teachers engaging with student contribution and feedback was not only useful for the teachers but also facilitated student familiarity with using a tool(s) and enhanced their awareness and skills for engaging meaningfully in the inquiry process.

Teacher planning to incorporate technology meaningfully in their teaching

Although e-networked tools can and do have the potential to support the inquiry cycle, in their planning to incorporate the tools in their units, teachers need to be aware of what are productive rules, practices and purposes for using a particular tool. The postings on Moodle discussion forums and the Wallwisher, compared with face-to-face comments, for example, required a different set of rules and expectations for sharing and collaboration to develop a taken-as-shared understanding.

Through teacher modelling in both the classroom and online, students learned to talk critically and ethically in the online environment. With time and clear teacher expectations and guidelines for online interactions (e.g., guidelines on how to talk online, how to establish a safe and welcoming environment for discussions), students developed the confidence to share their thoughts with others, including those they may not always engage with. Students appreciated this as the following comment illustrates:

> You can chat and research about the question in your group and also it is in a safe environment. I didn't know some of the students in my group and I wouldn't feel comfortable about going round to their place, but it was good to chat to them online.

E-networked tools such as video based websites (YouTube) allowed students to communicate their inquiry findings to the public. Students were initially shy about this but the teacher facilitated this process by linking part of their assessment to the number of views (viewer hits) their videos received over a specified period of time. In this way, the students came to understand the affordance of the Internet in communicating content to think quite carefully about the needs of this wider audience such as ensuring ideas were presented in a clear, engaging way but still science-based way.

Teachers' progressive introduction of inquiry possibilities to scaffold skill development and transfer responsibility to students

Initially the project teachers were quite tentative about providing opportunities for students to develop and pursue an inquiry. For example:

> As a teacher, the initial letting go of the control of the student learning was the biggest hurdle. This was overcome by the initial group planning and brainstorming that set the context and direction of the inquiry.

Over the two years of the project, teachers became increasingly comfortable with implementing an inquiry approach in their classroom. Their confidence and competence developed as a result of time spent discussing and reflecting on the nature of inquiry both individually and as a part of the research group, and also from classroom experimentation.

One of the biggest challenges of teaching science with and through inquiry is that the requisite capabilities can appear challenging, overwhelming, and time-consuming to develop. This is especially true if teachers and students have long-established rules and routines that do not support active student participation in the focusing and development of the curriculum and their learning process. The nature of inquiry can seem ill-defined and hard to guide and manage, particularly when it is new for teachers and students. The freedom to make decisions can be daunting as well as a source of confusion or frustration with both teachers and students feeling they are "in the dark". The teacher quotation below exemplifies this:

> When I first started I didn't think I realised quite how a big a step a teacher needs to take to allow inquiry to happen. It's really easy for a teacher to dictate what happens in the classroom. In order for real inquiry to happen, the teacher needs to play much a secondary role. You force students to go down a certain track; it kills the inquiry, as they need to have ownership of it.

If teachers approach inquiry learning in science assuming that it always has to involve the full inquiry cycle of problem formulation, hypothesis, collection of data and testing of variables, communication and arguing outcomes and future directions, this can deter teachers from exploring its potential in their classrooms. When students are expected to adapt quickly to a situation where they have considerable freedom to think and investigate, this can be frightening for them and they can be left unsure about what they have to do and what they have learned. However, these challenges can be mitigated somewhat by teachers focusing on short and focused episodes of inquiry, such as students asking questions while observing.

Across the two years, there were numerous examples where students were able to experience aspects of inquiry in science by harnessing the affordances of e-networked tools. These allowed them to expand on what they could usually do in a way that deepened their appreciation of the different aspects of inquiry. For instance, video recording, sharing and talking about what had been observed provided opportunities for asking meaningful and authentic questions. Examples such as this helped to develop student confidence and skills in inquiry. One teacher, after establishing Wallwisher as the medium for inter-group communication, found:

> The students were quickly taken away from their "teacher pleasing" roles to that of being the expert amongst their peers. During these times the learning was very evident.

However, unless such inquiry episodes are planned for and discussed with students specifically, they are lost opportunities for both teachers and students.

Teachers progressively opening up the inquiry cycle and allowing students to exercise greater agency over time allows a managed shift from traditional teacher-student roles. This was of mutual benefit in the teaching-learning process.

By including inquiry opportunities at specific points, teachers were able to highlight and draw student attention to the structure of an inquiry. The teacher quotation below indicates how teachers were able to set up structures and open but guided parameters from which students could begin their inquiry investigations:

> [The challenge is in] getting the kids to work together on something they are interested in but still meeting your obligations in terms of curriculum and content. . . . Ultimately it is about them finding out information about where they are interested in that fits within certain topic and then wherever it goes is where it goes, there is no correct answer or ultimate end point, it's not finite.

Teachers scaffolding the development of student inquiry skills was an important feature of lessons and units:

> Significant scaffolding was required prior to any inquiry learning elements being introduced. This had its own difficulties as depending on the students' focus/experiences/ attitudes and abilities a differentiated approach was needed.

The teachers noted that many students also required a scaffolding approach in relation to self-management and the use of different technologies:

> The next stage was to allow the students an opportunity to become comfortable with the resources that we had available. This started by the use of simple recordings with their phones of tasks they undertook in class. A learning method that allowed the students to share and replay their learning was a concept I discovered by default but embraced as a unique learning tool. The reluctant students were now recording their activities, commenting on these activities and sharing their newfound knowledge with others.

On the whole, student evaluations indicated they felt comfortable and liked the inquiry based approach to science learning as they could explore and investigate areas and questions they were interested in rather than having their learning dictated by a teacher:

> If you don't have the teacher nagging on you all the time, you also get more time to do more things, and more opportunities to explore, experiment. You're learning in your own way. You actually enjoy our learning.

Major implications

Implication 1: Explicit teacher planning for e-networked based science inquiry learning is needed to initiate and activate the inquiry process. Classroom implementation of any plans is most effective when it is informed by teacher reflection and uses student responses and feedback to refine practice.

Our findings indicate that e-networked technology can be a powerful source to support inquiry teaching. However it needs to be carefully planned for in order to take full advantage of the affordances of the technology and create an environment conducive to fostering inquiry processes and outcomes.

Implication 2: By taking small forays into parts of, or implementing a focused inquiry cycle and progressively building on student experiences, teachers and their students can develop a better understanding of as well as the confidence and capacity to conduct inquiries using e-networked tools.

Teachers can develop their own and their students' capacity and confidence to undertake short and focused inquiry episodes and build on these experiences. This process helps teachers to focus on inquiry-specific outcomes that can include skill, attitude and/or competency development. It is also effective in scaffolding the development of the skills necessary for students to engage in e-networked inquiry learning. Short inquiry episodes are needed at times to develop student technological skills, the skills needed to work collaboratively and even self-management skills. A series of focused episodes can support students in learning to value the different ways e-networked technologies can enhance inquiry learning.

Implication 3: There is value in teachers and students being able to draw from a range of e-networked tools to undertake the different aspects of science inquiry learning. Tools that allow students to simulate or undertake scientific processes such as observing and reviewing, and that enable the multimodal expression of emerging ideas are particularly advantageous for abstract or hard-to-master science content.

Our findings illustrate the value of student access to a range of e-networked tools in enabling students to undertake scientific investigations. These tools can range from student-owned mobile phones to Skype to Moodle to Glogster and even YouTube. Each of these allows students to undertake different aspects of inquiry. Teachers need to explore and share with students and to encourage students to explore and share with the class community the different opportunities for investigation that different tools afford. When teachers know student technological capabilities and the nature of tools that students own and can bring to class, teachers can utilise this information to build the different affordances into class inquiry episodes.

Implication 4: Teachers and students need to recognise that teachers are not necessarily the source of all knowledge. Students can look to their peers and beyond the class or school community with the support of e-networked tools for resources to inform and empower their science inquiry investigations.

Changes in traditional teacher and student roles are required to take advantage of the possibilities e-networking offers for collaboration and the discussion and exploration of the various aspects of science inquiry. The fact that students can be supported to share their developing ideas and questions and receive feedback from their peers in Moodle or communicate with a scientist through Skype or develop Glogs to collaboratively communicate their inquiry findings in a multimodal manner illustrate the potential for e-networking to provide access to a greater range of knowledge sources. It also points to the need for teachers to facilitate students' confidence and capacity to access and discern between a wide range of resources within and beyond the class community. Students need to recognise and be empowered to undertake more ownership and responsibility for their own learning in the inquiry process.

Implication 5: School management can better support teachers and students in e-networked inquiry practices by investing in robust networking platforms, adopting policies that encourage productive e-networked inquiry tool use, and establishing flexible curriculum and assessment structures.

Our findings indicate that teacher inquiry practices can be hindered by a lack of technological access or technical failure. More robust networking platforms (stable access to the Internet) are required to overcome this challenge. School policies that affirm productive e-networked tool use, for example free access to the

Internet, facilitate teachers and students taking up and incorporating these tools in their teaching and learning. Our findings also allude to tensions between current school curriculum and assessment practices that have an effect on inquiry practices. Current curriculum and assessment structures need to be examined and reviewed to ensure they are adequately flexible to allow teachers and students to pursue inquiry approaches in science. Consideration needs to be given in particular to how to adapt assessments to acknowledge the skills and learning developed through inquiry learning.

Teachers need time to internalise an understanding of inquiry including the skills required for inquiry teaching approaches. They need time to think and prepare for e-network supported science learning that goes beyond mere learning facts, just as students need time to develop the knowledge, skills and attitudes that are integral to the inquiry cycle—collaborate, explore, create and share (science) ideas. Teachers benefit from opportunities to reflect individually and with other peers as a means of enhancing their confidence and informing the refinement of their e-networked inquiry practices. School management and policies supportive of these practices can go a long way to establishing a pro-inquiry school culture.

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Author information

Assoc. Prof. P John Williams

John is the Director of the Technology, Environmental, Mathematics and Science Education Research Centre at the University of Waikato in New Zealand, where he teaches and supervises research students. Apart from New Zealand, he has worked and studied in a number of African and Indian Ocean countries and in Australia and the United States. He directed the nationally funded Investigation into the Status of Technology Education in Australian Schools. His current research interests include mentoring beginning teachers, PCK and electronic assessment of performance. He has authored or contributed to more than 200 publications, and in 2011 he was elected to the International Technology and Engineering Education Association's Academy of Fellows for prominence in the profession. He holds an adjunct professorial position at Edith Cowan University in Perth, Western Australia.

Email: pj.williams@waikato.ac.nz

Prof. Bronwen Cowie

Bronwen is Director of the Wilf Malcolm Institute of Educational Research (WMIER) and was previously director of the Centre for Science and Technology Educational Research at the University of Waikato. She has directed and co-directed a number of successful projects including the 'Linking culturally responsive teaching, learning and assessment to enhance the engagement of diverse students in primary science classroom' project (TLRI 2009–2010), the Classroom Interactions in Science and Technology Education (TLRI 2005–2007), the Laptops for teachers evaluation study (2003–2009), the Quality Teaching Research and Development Project (2006–2007), Science Learning Hubs (2007–2008), Digital Horizons: Laptops for Teachers Evaluation (Ministry of Education, 2003 -2009) and the Curriculum Exploratory Studies project (2008–2009). Bronwen has also been a research mentor in the ongoing project 'SCIAnTICT—Science Classroom Investigations of the Affordances iN Teaching with ICT' (TLRI 2009–2010). Bronwen is an experienced classroom researcher who is familiar with a range of research methods including the use of video, teacher and student interviews, surveys and document analysis. She is experienced in working collaboratively with primary teachers to research and enhance their students' science and technology learning.

Dr Elaine Khoo

Elaine is a research fellow at WMIER, University of Waikato. Elaine's research interest lies in exploring ways to enhance technology-based learning environments, in particular online learning contexts. She has recently completed her involvement in two TLRI funded projects—"Science Classroom Investigations of the Affordances in Teaching with ICT" (SCIAnTICT) and "Exploring E-learning Practices across the Disciplines in a University Environment" (2009–2010) and currently heading a new TLRI project—"Copy, Cut and Paste: How Does This Shape What We Know?" (2012–2013).

Dr Kathy Saunders

Kathy is a senior lecturer in science and biology education and teaches in both primary and secondary initial teacher education programmes as well as supervising research students in science education. She is on the editorial board for two international science education journals. Her ScEdD from Curtin University of Technology, Perth, Western Australia was in teaching and learning about socio-scientific issues in science classrooms. She continues to research in this area with additional research interests in bioethics education, understandings of the Nature of Science at primary, secondary and initial teacher education levels and supporting the use of online learning pedagogies in science education

Dr Simon Taylor

Simon is the Central North Island Secondary Science Adviser at the University of Auckland working with the Ministry of Education secondary student achievement contract. Simon's interest lies in learning environment research and has recently completed his PhD at Curtin University. Collaborative and inquiry learning in Years 9 and 10 science classes are his focused areas with particular attention to raising Māori and Pasifika student achievement. He is also currently involved in the writing of the alignment of the Level 2 and 3 achievement standards with the New Zealand curriculum. He continues to visit schools and offer professional support for teachers, middle school leaders and principals.

Assoc. Prof. Kathrin Otrel-Cass

Kathrin is Associate Professor, Science Education ay Aalborg University, Denmark and honorary lecturer at the University of Waikato. Her research is in science education, particularly in primary science classrooms. Her research is informed by sociocultural theories with a particular interest in the use of ICT in science education and inquiry learning. Kathrin has a strong background in video-based research methods and her research practices aim at developing collaborative research partnerships with teachers. Kathrin was the director of the project during its first year.

Participant partners

Name	Role	School	Year
Michelle Ballard	Teacher	Maunganui	2011
Jim Critchley	Teacher	Maunganui	2011–12
Shirley Dudli	Teacher	Cambridge	2011–12
Darron Cutler	Teacher	Cambridge	2011–12
Shannon Andrews	Teacher	Hillcrest	2011–12
Craig Taylor	Teacher	Hillcrest	2011
Alison Basel	Research assistant	University of Waikato	2011
Nhung Nguyen	Research assistant	University of Waikato	2011–12
Suskia van der Merwe	Research assistant	University of Waikato	2011–12
Steve Chrystall	Research assistant	University of Waikato	2012

From left to right: Simon Taylor, Michelle Ballard, Shirley Dudli, Shannon Andrews, Kathy Saunders, Darron Cutler, Bronwen Cowie, Jim Critchley, Kathrin Otrel-Cass, Craig Taylor, John Williams and Elaine Khoo.