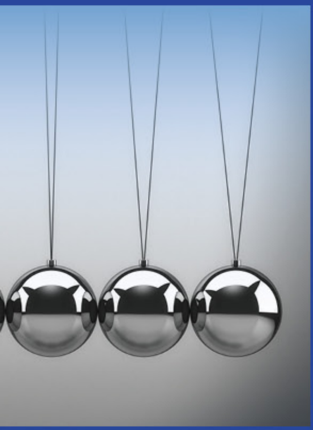
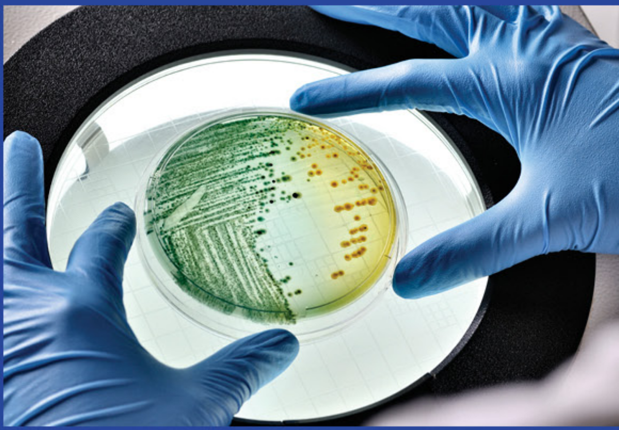
SciCon 2012

Edited Conference Proceedings

Editor: Sally Birdsall





1-4 July 2012
The University of Auckland, New Zealand

THE UNIVERSITY OF AUCKLAND
FACULTY OF SCIENCE

SciCon 2012

The University of Auckland, New Zealand

01 – 04 July 2012

Making Connections

Introduction

This short collection of papers is based around the theme of making connections. The collection opens with this year's Roger Osborne Commemorative Lecture that was given by Associate Professor Bev France. After reminding us of Roger Osborne's seminal work around the need for teachers to connect to learners' ideas about science before teaching, she writes about her research into connecting scientists and technologists with learners. France argues that such connective events are far from simple and require careful, detailed planning in order for successful connections to be made between these two groups of people.

The next two papers deal with strategies that can assist learners to make connections with the nature of science, the overarching strand in New Zealand's revised science curriculum document. In the first paper Gillian Ward and Mavis Haigh write about developing learners' understanding of the nature of science through a dramatic reading based on the history of the atom. In contrast, David Blaker's paper presents a model of NoS in the form of a three-legged stool that he argues can provide learners with a simple, visual and jargon-free image of NoS. He then suggests a strategy for using this model to assist learners' understanding about NoS.

The next four papers present ways of connecting learners with either scientists or ways in which they work. The first in this group is written by scientists who work at the New Zealand Institute for Plant and Food Research Limited at Mt Albert in Auckland. These scientists generously gave of their time during SciCon, providing tours of their facility for interested teachers. Their paper is an overview of these tours as well as giving details of scientists who can be contacted should you wish to organise tours for your learners.

The next paper in this section is written by Phil Jones and it gives the reader an overview of different types of ICT programmes that can be used in the physics classroom. He argues that the use of such technology can connect learners with ways in which physicists work, enhancing the learning experience for learners. David Blaker presents another paper in this section that suggests ways for biology teachers to make connections between evolution and religious beliefs about creation. Teaching evolution can be difficult for teachers when faced with students' strongly-held religious beliefs and David provides strategies and insights into how this type of situation can be sensitively managed. The last paper in this section in written by Carolyn Haslam and details her preliminary research into the use of graphs and teaching of graphing skills in New Zealand secondary schools. She argues that there is a considerable discrepancy between the important role of graphs in scientists' work and the lack of space for graphs in secondary external examinations, textbooks and allocated classroom time. Her proposed doctoral research aims to assist learners make connections between data and graphs, improving their skills of interpretation.

The final paper in this collection is written by Robert Shaw and he argues that in science education, learners will only appreciate science when they can discover its truths.

I hope that you find this collection of papers interesting.

Sally Birdsall
Editor

Contents Page

Connecting isn't the same as communicating. Exploring the issues for science education

The 2012 Roger Osborne Commemorative Lecture

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This address is about making connections with scientists, establishing connections with the science community and reflecting on how successful communication between scientists and learners can be achieved.

My first task in this Roger Osborne Commemorative Lecture is to remind you that Roger Osborne's research on the necessity of making connections between learner and teacher has had a great influence on science education and, as a consequence the need to explore students' prior knowledge, is now is part of the repertoire of all teachers who are committed to teaching within a constructivist learning framework. Nowadays making such connections with the learner are commonplace.

Then I will explore the drivers that encourage teachers to connect the learner with 'authentic' learning experiences where science is practised and applied. I will identify some of the reasons why teachers have taken up the educational challenge of teaching within an authentic context and will identify some examples of teaching strategies that promote such connections. As well as providing this overview, I will discuss the difficulties that may arise when such initiatives occur for I am very aware that teaching science 'authentically' is fiendishly difficult.

In an attempt to explore the complexity of making learning connections between scientists, the science community and learners, Vicki Compton and I have edited a book that provides exemplars of such connections in action and provided some suggestions for educators who are anticipating making such moves. Finally I will consider the components of effective science communication that Belinda Bray, John Gilbert and I have researched and consider if they have any resonance when scientists and learners talk to each other.

As a postscript I will consider whether Roger Osborne's legacy has resonance for science education and suggest that there are lessons to be learned as we embark on our quest to connect science/scientists with learners when teaching 'authentic' science.

Making connections to find out children's science understandings

Why is Roger Osborne so important to New Zealand science education? Dr Roger Osborne developed and led the Science Education Research Unit at the University of Waikato from 1979 until his accidental death in 1985. He was responsible for establishing science education as a research discipline in New Zealand (Bell, 2005). His significant contribution was that he and the research team demonstrated the importance of making connections between learner and teacher when he presented data about children's understandings of science concepts and showed how such understandings could improve learning.

In fact these findings were so valuable that the development of the research tool for this kind of data collection (Interview about Instances) can be claimed as 'a methodology indigenous to science education' (Fensham, 2004, p. 124). This simple but powerful methodology, first developed in the 1980s, has been used by many novice science education researchers and nowadays is part of the repertoire of many science teachers who are committed to teaching within a constructivist learning framework. In fact the idea is so embedded in the pedagogy of science education that it is a basic step in the planning of a science learning experience. I note that many other curriculum areas are using this technique too. I suppose copying is the best form of flattery!

There were other connections being made too. In 1979-80 Roger Osborne had a short sabbatical at the University of Surrey where John Gilbert taught and researched. During this time they developed the Interview About Instances (IAI) technique. As John reflected on Roger Osborne's career and educational influence he noted that from 'an inchoate dissatisfaction with the deterministic interpretations being placed on the work of Piaget' (Gilbert, 2009), Roger Osborne decided to focus directly on children's ideas about science concepts by just asking them what they understood. These days such an activity seems quite logical but in the late 1970s it was a revolutionary idea. When Osborne and Gilbert wrote their paper in 1980 they provided examples of 'Interview about Instances' cards to show how they were able to gain information about the learner's understanding by asking them what these science words meant. For example, "In your meaning of the word force would you say that there is a force on the ...?" And then they were asked, "Why?"

It is fascinating to relook at this seminal methodology that was used to uncover learners' conceptual understandings. Just look at some of the examples they used (Osborne & Gilbert, 1980, p. 377). Have you ever wondered why the illustrations look so sketchy and appear to be primitive representations of the concept being enacted. It is interesting to hear from John Gilbert when describing the development of this technique:

> *... what could we use as a stimulus? We started using photographs, but these were so heavily contextualised that they proved useless. People just got the story from the background. Then we tried full drawings – Roger did the drawings because I'm no good at drawing. Even with these, the contextual clues were heavy. A female figure for example would bring all the gender issues into the responses. So we came to stick figures, on the basis they were less contextualised but also because they were within our mutual limitations in drawing. Then we sat down and though of a variety of situations*

> *in which the concept of interest could or could not have application ... instances and non-instances* ... (Fensham, 2004, p. 124).

What of the connections between Roger Osborne and this gathering today? I decided to study for a Masters of Education at the University of Surrey in 1983 when I realised that my New Zealand BSc was well past its use-by date. During the programme I found that John Gilbert talked about a 'Learning In Science Project' that was happening in New Zealand. I ended up writing a Masters thesis about students' understanding of the concept of evolution and implications for teaching and Professor John Gilbert was my supervisor.

I most vividly remember going for a supervision meeting with John at the University of Surrey on the morning when he heard of Roger's death. No meeting that day – just incomprehension and his grief at the loss of a friend and colleague.

When I returned to New Zealand and was appointed to the Auckland College of Education, I made connections with the Waikato researchers. It was exciting to meet them in person. Valda Kirkwood, Beverly Bell, Alister Jones, Mark Cosgrove and Malcolm Carr who were developing their own research agendas based on his work and have stamped Roger Osborne's legacy in science and technology educational research in New Zealand.

Roger Osborne's educational legacy was still very evident in 1995 when Michael Matthews set out to publicly negate the influence that the Waikato group were exercising on New Zealand science education (Matthews, 1995). Jonathan Osborne's (no relative but a science educator based at Kings College) critique of constructivism in science education (1996) provided another perspective to this assault by noting that there appeared to be a misrepresentation of the views and practice of science and scientists by confusing the manner in which new knowledge is made with the manner in which old knowledge is learned (Osborne, 1996, p. 53). It was fascinating to reflect on the mixed messages and miscommunications when long bows were drawn between learning science and doing science. I hasten to add these bows were not drawn by the researchers at Waikato and Auckland but by others who were attempting to teach within a constructivist pedagogy. No matter how compelling the connection and educational outcome there can be a slippage of ideas. In New Zealand this happened for a while.

No matter the controversy - the message was still strong. Listen to the learner still has resonance in any learning situation.

Why take up this educational challenge?

Nowadays there is a drive to connect the learner with authentic learning experiences where science is practised and applied. For example, Sir Peter Gluckman's report on science education *Looking Ahead: Science Education for the Twenty-First Century* (2011) promotes closer links with the science community and he states:

> *I believe that the use of new technologies and closer partnerships between the science community and the educational community offer a way ahead for both advantaged and disadvantaged schools* ... (Gluckman, 2011, p. 7).

This viewpoint reflects an increasing pressure for teachers to make connective partnerships between their classroom and the world of the science as well as those communities that use science knowledge. This message is reinforced within the organisation of science within *The New Zealand Curriculum* (Ministry of Education [MoE], 2007) where the Nature of Science strand is compulsory and requires all students up to Year 10 to learn about the culture of science and the scientific enterprise. It is anticipated that this strand will provide a frame from which the content of the Living World, Planet Earth and Beyond, Physical World and Material World is explored. Furthermore it is anticipated that when such connections are made students will use this knowledge "... *to make informed decisions about the communication, application, and implications of science as these relate to their own lives and cultures and to the sustainability of the environment."* (MoE, 2007, p. 28). This connective message is also promoted in the section explaining the nature of Key Competencies that teachers are expected to develop, *"... students will be expected to be actively involved in communities."* (p. 13).

This drive to connect learners with scientists is also the subliminal message where constructivist theories of learning have underpinned a pedagogy where students' limited science explanations are actively replaced with concepts that more closely match those held by scientists. Constructivist learning theories link to a pedagogy where an identification of prior knowledge provides opportunity for the learner to interact with activities that will challenge their misconceptions and develop understandings that are more scientific. There are research reports that demonstrate that such an approach works, but these days more is required of learners. Nowadays it is expected that the process of conceptual change will be enhanced by learners' appreciation of how science knowledge is developed in the science community. Consequently sociocultural theories of learning are promoted that recognise that learning is situated and there is a need not just to develop closer conceptual understandings that align with those held by scientists but also to develop an understanding of how the science community 'works' – that is how they provide evidence to explain the world. This is a tall order because this learning theory anticipates that not only will teachers create an environment where learning is contextualised, but also that learning about science will be given 'authenticity' where students are able to model the ways in which scientists think, talk and argue with each other about science ideas (Bull et al., 2011). These skills are promoted within the Nature of Science [NoS] strand in New Zealand's science curriculum document.

To add to the complexity of making learning 'authentic' is the drive to provide students with learning contexts where they are required to critique situations where science is involved or even more radically, to use and critique their science knowledge in order to take action about socio-scientific issues. Interesting classroom based research has been done by Troy Sadler (2011) who is developing a pedagogy for such an approach. It is also worth noting the work of Laurence Simonneaux who is at the forefront of the socio-scientific issue educational push in Europe and provided a wide-ranging and perceptive analysis of this approach at European Science Education Research Association (ESERA) conference in Lyon in 2011. Her review called *Questions socialement vives and socio-scientific issues: New trends of research to meet the training needs of post-modern society* will be published in a book of selected papers from the conference in 2013. If you want to read her recent work, her analysis of students' responses to questions socialement vives (Socially Acute Questions) as they work with scientists on nanotechnology projects gives an interesting explanation of why students may hold negative views about such technologies (Simonneaux, 2011).

Closer to home is Sally Birdsall's recent PhD research on sustainability that provides classroom data about how such complex understandings can be developed with very young children (Birdsall, 2011). Her research feeds directly into pedagogy for teaching sustainability within socio-scientific issues (Birdsall, 2010). Connections with scientists can result in student activism when they use scientific knowledge to justify action about and involvement in issues that the learner considers important. Hodson (2011) in his ground-breaking book provides examples of such an approach from the research literature and suggests a radical curriculum for social activism. I suggest the young are poised to actively engage in science that will support the causes they hold dear, for example the destruction of rain forests; global warming; the death of New Zealand rivers; fracking; and the need for humane animal research.

Strategies for making connections

I hope I have highlighted the drivers and underlying reasons for this push to make connections between scientists and learners. I am not going to traverse the research literature about teachers and students' understandings of the NoS and the development of an associated pedagogy as this is in the hands of international experts that we are privileged to meet and listen to during this conference – namely Drs Norm Lederman and Judith Lederman. Also old friends to New Zealand science education Brenda Keogh and Stuart Naylor, and during this conference Stuart will be providing us with research-informed resources that increase the relevance of science that is taught.

Here I pause to make my case. I argue that making connections between scientists and learners is a very worthy goal but the educational goals are elusive. I assert that there needs to be clarity of purpose when deciding to embark on such an approach. Just like Osborne and Gilbert's realisation that there were too many subliminal messages when they were developing a method to identify students' conceptual understandings, I suggest that making meaningful educational connections between scientists and learners is not simple or straightforward as saying 'with whom' and 'what for'. In fact it requires the organiser to be very aware of the issues that can misdirect and confuse learning.

The next slide could be considered self-indulgence. I include it as a fine historical example of an artistic depiction of scientists connecting with the public. We are looking at a painting by Joseph Wright of Derby “An Experiment on a Bird in an Air Pump” (1768). This painting is an image of scientists doing science and explaining it to the unenlightened. I find this painting fascinating. I include it because I believe it demonstrates how subliminal messages can skew and muddle the message.

What are the messages that this painting tells us? First of all this group of scientists are carrying out an experiment on ‘pneumatics’ and there are bits of equipment on the table that allude to this. For example a pair of Magdeburg Hemispheres, animal lungs in a glass container and a bird inside a sealed jar that looks as though it could be in peril. We could assume this experiment was about gathering empirical data in the course of an experiment as one person seems to be timing the experiment. The person in charge of letting air into the flask has long white hair and provides the magician component.

Another message in the painting is that experiments like these were being discussed within the science community for this was the time of ‘The Enlightenment’ or the ‘Age of Reason’. For those in the know the small boy closing/or opening the shutters on the moon is drawing attention to the Lunar Society (established in 1766) where scientific thinkers and industrial innovators discussed science and technology. Members of the group included Joseph Wright’s doctor – Erasmus Darwin, as well as Josiah Wedgewood and James Watt. It is said that this society helped to power Britain’s industrial revolution (Berry, 1999).

As well as being a marvellous painting about light there appear to be other subliminal messages about these gentlemen doing science. That they were upper class; that men were carrying out the experiments and women were looking on; that animals were used without any regard for animal ethics; that men were scientists, thinkers, teachers, explainers; that men and boys were interested while women and girls were either not interested or too emotional to look.

One could dismiss this painting as a very unsuitable strategy for introducing the culture of science to learners and that there is a case for providing a contemporary example. However I assert that to many of our students contemporary scientists in their lab coats who occupy gleaming pristine laboratories are as far removed as these 18th Century scientists. In fact to our students the world of scientists is the world of CSI where science knowledge appears to be developed once scientists have placed a sample in a machine, twiddled a few knobs and obtained instantaneous results.

Examining the issues of connecting scientist and learner

Once again I state that the contextualisation of science learning is a complex business. If one teaches within a sociocultural view of learning then there is the expectation that students will learn science and learn about science by doing science. During these ‘authentic’ learning episodes it is hoped that in some instances scientists will be involved directly by students ‘learning from scientists’ or ‘learning with scientists’ or indirectly when they are provided with materials ‘to learn about scientists’ (Hodson, 2011).

Vicki Compton and I have just published a book that explored the concept of making educational connections between scientists, technologists and learners (France & Compton, 2012). We decided to embark on this book because we have had the nagging suspicion when reading about the plethora of connection-based initiatives, that there was an assumed ‘simplicity’ or ‘straightforwardness’ surrounding such undertakings. We felt not enough time was spent on clearly identifying and verifying the purpose of and establishing the parameters for development and implementation of such connections. It was almost as if the inclusion of ‘connections’ provided legitimacy to the undertaking. Despite many of these initiatives attracting significant funding, little emphasis appeared to be placed on monitoring and evaluating outcomes.

From our own experience, establishing and maintaining connections between scientists and technologists and our students have been far from simple and straightforward. The book is our attempt to unravel some of the complexity inherent in bringing these communities together. We asked international and national contributors to write about successful connective initiatives that they had been involved in, to provide some educational justification and some evidence about the outcomes. This section of the talk will provide some examples of the connective initiatives between science and education that were included in the book.

A literature review provided key issues that we believed were central to understanding the complex nature of connections. It seems that organisers of connective initiatives needed to:

- Identify the purpose and ontology (way of looking at the world) of the discipline with which the learners were being connected and acknowledge the way in which knowledge was verified (epistemology),

- Organise the connection so that it was coherent with a learning theory that recognised the central role of participation for the learner and if possible, could be reinforced with a critical participatory pedagogy,

- Recognise that there are social and cultural identity-linked decisions that the learner makes when deciding to take part in a connection initiative,

- Identify the component of scientific literacy that will be enhanced by this connection.

There is not enough time to talk about all of the fascinating and informative connective initiatives that are recounted in the book. I have chosen a few to illustrate some but not all of the issues that we believe need attention when setting up any connective initiative between the world of science and the learner.

Ontological issues- the wall-less learning environment
Susan Rodrigues suggests that we need to be thinking about the ontological and epistemological beliefs that our students hold. She argues that social networks are the existent environment for today's learners – i.e. on-line environments are real and this ontological stance is different from the dominant ontology and epistemology of formal learning settings. She proposes that the teaching of science should occur in a wall-less learning environment. It may be controversial but she asserts that, at present, Wikipedia is a community that is harnessing and carrying out the policing of a collective intelligence. She argues for a professional pedagogy to enable all learners to tap into a collective intelligence where the questions that need to be asked are, "Who is communicating?", "What are the means and channels for communication?" and "What is the milieu – physical spaces and virtual spaces for interacting with the subject matter?" (p. 68).

Susan observes that present school ICT use is focussed on tool use: situating tools, informative tools, communicative tools and constructive tools. She contrasts students' use of ICT away from the classroom where they consider ICT as an environment rather than a tool and compares their view of the environment they frequent as:

> *... see[ing] themselves as members of a community with no walls. At present the majority of school aged learners [of science] probably see themselves as window shoppers where the shops are rather elite, and where they are peering in trying to see if they have any need for what is for sale and what they need in their lives.* (Rodrigues, 2012, p. 64)

It is pertinent to note that this shift in epistemic stance may be closer to information management rather than knowledge building (Alexander, 2010) and perhaps Ross Petersen's account of how learners, scientists and technologists are interacting with each other to develop their science and technological outcomes could provide clues to how epistemic competence could be developed (Petersen, pp. 137-146).

Epistemological issues – stories of scientific enquiry
A significant shift for science teachers is the attention given to help students to explore the complex nature of scientific enquiry. *The New Zealand Science Curriculum* (MoE, 2007) reflects this shift. It is gratifying to see teachers responding to this challenge and I look forward to hearing their stories at this conference.

In our book Siu Ling Wong's chapter (pp.147-160) provides a story of her husband Dennis Lo's scientific journey from his memories of being a schoolboy in Hong Kong when he was fascinated by the stories of science and scientists, to his discovery of a prenatal diagnosis technique. He has deciphered the fetal genome by analysing trace amounts of fetal DNA in the mother's blood. This breakthrough made headlines in international news last year and for which he was awarded a Fellowship of the Royal Society (U.K.).

This story as recounted by Professor Dennis Lo reveals many NoS tenets that underpin scientific enquiry. For me what makes his story so compelling is that it provides information about how he was thinking and feeling during this long period of reflection and research and gives an indication of the convoluted way in which science knowledge can develop.

He tells us how he was fascinated by science at secondary school and seeing a photograph of Watson and Crick standing in front of King's College inspired him to initially study at Cambridge. Undoubtedly he was a brilliant student, and his account of coming across a patient with a rare type of rectal cancer when he was a clinical medical student at Oxford showed his scientific potential. He read about the case and discovered that there was little information about the condition with only four reported cases. He wrote up the fifth case that was published in a medical journal and as he comments – *'"... it taught me that even students can make a contribution to science.*" (p. 152).

Later opportunities came his way and he acted on them. When Lo was a medical student receiving training in obstetrics and gynaecology at Oxford he felt concerned about the dangers of amniocentesis and thought that a safer way would be to test the pregnant mother's blood to find out if the baby was carrying any serious genetic disease. Although the current view was that mother and baby's blood was separated, he suggested that this separation could be incomplete and perhaps one could use a small number of fetal cells that had 'leaked' into the mother's circulation to do a prenatal diagnosis.

Lo spent the next six months coming up with an idea for testing the presence of the baby's cells in the mother's blood. He reasoned that if she carried a boy then there was a chance that some DNA from the Y chromosome might be present. He was so excited with these ideas but was frustrated that most of the professors he approached were sceptical of his hypothesis. One suggested that, "... if that phenomenon does exist, why would the discovery be left for you to find out?". However one professor allowed him to carry out the investigation in his lab, and Lo proved his hypothesis and his findings were published in *Lancet* in 1989.

Hoping to find a safer and routine way of doing prenatal diagnosis he studied for a PhD and although he achieved this qualification, he felt that his goal had not been achieved. He was aware that the tiny amount of fetal cells (1 fetal cell per million maternal cells) did not allow him to arrive at a simple method for routine non-invasive prenatal diagnosis.

While on staff he continued to work on this research in the Oxford Medical School. In 1996 he was offered a job at The Chinese University of Hong Kong. As he was preparing for the move back home to Hong Kong, he reflected on the various approaches he had tried in order to improve the detection of fetal cells. He asked himself, “What have I been doing wrong for not solving the problem?”. During this time he came across two papers published in *Nature Medicine* reporting that DNA of tumours could be found in the plasma of cancer patients. He realised the parallel between a tumour and a fetus in the mother’s womb and thought, “A fetus is similar to a tumour living inside a mother’s body”. He asked whether the fetus would release fetal DNA into the plasma of the mother?

The story continued. He attempted to see if he could find the DNA of Y chromosomes in the plasma of pregnant mothers who carried male fetuses. To his surprise he found about 5% of fetal DNA swimming in the mother’s plasma – an amount that would make routine diagnosis possible. This discovery was published in *Lancet* in 1997. Such a finding meant that a number of applications for the diagnosis of different sex-linked and blood-group-linked diseases carried by the baby could be carried out. And in 1998 Lo demonstrated that the accuracy of detection was about 96%. Similar results were reproduced by other laboratories and these tests have become routine for some of these conditions.

Dennis’ next target was to attempt the detection of Down Syndrome. This was a bigger challenge as he needed to detect an extra copy of Chromosome 21 in a baby with Down Syndrome. In 2007 he calculated that according to the ratio 95% maternal DNA versus 5% fetal DNA in the maternal plasma, he would have to develop a DNA test that could identify a 2.5% difference in the amounts of Chromosome 21. At the time such precision was thought to be very difficult. This would require DNA sequencers to count millions of DNA molecules. Finally the technology caught up with his hunch. In late 2008 Lo’s research group in Hong Kong and a group in Stanford University independently demonstrated that they could detect Down Syndrome by using these sequences and provided a non-invasive prenatal technique.

He then went on to detect the entire fetal genome from maternal blood … but I leave you to read this story in her chapter where he explains that after months of pondering on this question, he had an Eureka moment by watching the 3D opening of the movie *Harry Potter and the Half-blood Prince*.

This story provides us with evidence that science investigations often meander along. Dennis commented that doing science is a way of life rather than a job and that the inspiration for research ideas often comes from daily experience in life (p. 152). His story also shows that the posing of a research question is only a beginning and that publishing papers is the core business of scientific research. Other comments that he made about his research add to an appreciation of the diversity and idiosyncrasy of scientific enquiry: such as ‘don’t over-rely on established wisdom’, ‘look in non-obvious places’ and ‘take unconventional approaches’. What is significant for me is that he revealed the subtle reasoning and thinking that occurred during this process of scientific enquiry (p. 156). And the process wasn’t straight-forward and linear!

Provide coherency between learning theory and pedagogy

Cathy Buntting has provided information about an internet resource that has expanded the capacity for connection between modern science (biotechnology) and learners through a virtual portal (www.biotechlearn.org.nz). The content has been developed by a group of experts (scientists, teachers and education researchers) and it is hoped that such connections will enable teachers to make fruitful educational links. The developers are aware of the tension between providing this open access to scientists and the need to focus the teachers'/learners' attention on what they are looking at when scientists are explaining the process of science.

One could consider a virtual link as the complete antithesis of the close connection between scientists and learners when students are mentored and/or work alongside scientists. Hsu, Eijck & Roth (2010) discovered that even during this close relationship students do not see the invisible moments of science. They commented that there was a need to make the invisible aspects of laboratory work visible. We are aware that such an endeavour has been continuing in the NoS educational community for many years where science educators have recognised the need to explicitly facilitate students' views on the nature of science (Abd-El-Khalick, Bell, Lederman, 1998). This focus of making scientific work visible for teachers has been carried out in Auckland with Rena Heap's research (2007).

Consequently even though the Biotechnology Learning Hub and the Science Learning Hub (www.sciencelearn.org.nz) expand the capacity for student and teachers to connect with the science community through this virtual portal, there is a feeling that the scientific enterprise is homogenised and learners are unaware of the messiness of science and those invisible moments of science remain a mystery. It seems that even in the closest of relationships (internships) the problem persists and the writers and developers of these portals have recognised that overt teaching about the NoS needs to occur in order to direct the learner's attention to the science that is happening. Rena Heap (as one of the writers for the Science Learning Hub) has developed a teaching tool that makes these links about the NoS overt for the learner. The following clip provides an example where a critical participatory pedagogy that is founded on sociocultural learning directs students to reflect on an aspect of the NoS that is illustrated by the scientist and is made visible by these students' active critique and reflection.

Dr Mike Williams from NIWA talks about two theories that could explain where the icebergs came from that had been spotted off the Otago coast (http://www.sciencelearn.org.nz/Contexts/Icy-Ecosystems/Sci-Media/Video/Where-did-the-icebergs-come-from). He states that there is evidence that the icebergs came from the Ross Sea, but the sample indicates that they probably originate further north than this. Another theory is that they came from the Weddell Sea on the opposite side of Antarctica. Tracking by satellites does not provide evidence that they come from either area. So there is every likelihood that they came from another area due south of New Zealand.

A teaching and learning activity asks students to assemble puzzle pieces into a tangram square. Then they are given an extra piece and asked to assemble the tangram incorporating this extra piece. In this way they are using this tangram activity as an analogy to explain the tentative nature of scientific knowledge (http://www.sciencelearn.org.nz/Nature-of-Science/Teaching-and-Learning-Approaches/Student-activity-The-extra-piece).

The importance of students' social and cultural identity-linked decisions

Another argument for making connections is that if one accepts that learning is culture acquisition (Wolcott, 1991), then exposing students to the culture of communities that are allied to the proposed learning experience will enhance learning. But it is not that simple.

As Lemke (2001) observes, learning is not just a simple process of understanding because there are social and cultural identity-linked decisions that the learner makes when deciding if it is in their interest to take part. In fact, the learner will decide if they want to interact with a community that holds beliefs, values and ways of working that are different from them (Gee, 2000). If connective initiatives require participation then it is probable that the learner will need to cross borders into a different world (Aikenhead, 2001). However it is even more complicated because, as Gee comments, we have multiple identities when we interact with family, friends, when we play and work. It could be surmised that one of the purposes of making connections with the science community could be to help learners cross boundaries, realise the differences and similarities that occur between them and scientists and develop the capacity to talk across different affinity groups.

For example, when students were engaging with a community of scientists working in an institute laboratory they engaged at a personal level as they explored the life world of these scientists to see if they could see themselves as part of this group (France & Bay, 2010). When Mita was asked, "*What is the most challenging thing about being a scientist?*", she reflected on the answer the scientist provided:

> *And she said it was about balancing her family and being a scientist.*
> *I thought that being a scientist means that it's the one thing you do … like that's what I thought scientists were like … that they were just in the lab by themselves. But after talking to them … she was talking about how it is hard to look after her family … and have a social life at the same time. … scientists do have a social life ... they don't just sit in a lab …* (p. 188).

Futureintech is an organisation that helps students make connections with scientists. It has an ambassador programme where scientists are trained to provide students with an insight into their profession. Scientists can enter a one-off or a longer relationship. It is hoped that such contact might provide some chances for students to develop some affinity with this culture.

Provide a focus for scientific literacy development
Finally there is the issue of scientific literacy. This goal is quoted at the drop of a hat. Although we are supportive of the laudable gaol of developing a critical scientific literacy that empowers people to act in informed ways and engenders a sense of responsibility and stewardship of our natural, built and social world, it tends to be quote that provides a catch-all goal when justifying a connective initiative. We believe that it is important to identify what aspect of scientific literacy will be developed when justifying a connective initiative with scientists.

One connective initiative that was focussed on developing functional literacy, was the co-development of a learning resource that supported students to develop skills to interpret scientific data (Bay, Sloboda, Vickers & Mora, 2012). Although this group at the Liggins Institute espoused a multi-dimensional development of scientific literacy through the programme developed at the Liggins Education Network for Science [LENScience], in this book they described a project that was focussed and measurable. Scientific writing presented by Gluckman et al. (2009) was remodelled in a form that was suitable for Year 10 students (Bay & Mora, 2010). As well as remodelling the information, the figure was supported with a series of questions that allowed students the opportunity to explore the vocabulary, data and scientific story that underpinned this material. Students were provided with an explanatory title and definitions, focus questions to support their developing understanding, and questions posed to help them consider how the data was derived. In order to link this scientific data with societal issues, students were challenged to write a newspaper article reporting on the release of this data and what this might mean for today's teenagers. Another task was to prepare questions for an interview with Professor Sir Peter Gluckman on the topic of the mismatch between the timing of puberty and social maturity in humans.

What did we find out?

We attempted to analyse all of these connections in action and identify how these key issues had been given attention in the connective initiatives that had been reported in this book. It was not our place to make judgements about the wealth of thinking, critique and experience captured in these chapters. However we considered it appropriate to identify a list of principles that have emerged out of the views and experiences provided by this cohort of authors.

These are that:

- *The purpose/s of connective initiatives should be clearly stated and linked to measurable outcomes and realistic implementation plans.*

The most popular purpose was to enhance student understanding of NoS. Next was motivation followed by an opportunity to increase procedural and conceptual knowledge. The science community wanted to increase the alignment between educational programmes and the science community's future needs. There was only one initiative that focussed on student attitudes. Given the identity issues discussed earlier this avenue may require more explicit attention.

- *The worldviews and epistemic beliefs of participants should be an explicit part of discussions around purpose/s, participant roles and outcome identification.*

  We consider that this focus is central to any planning because no matter what the purpose, any connective activity between scientists and learners is about boundary crossing and this process will be enhanced by the increased epistemic competence of everyone who is involved. Questions that could be asked are: What sort of information would you believe to be trustworthy and why? What are the important values of your community? We believe it is important that there is time provided for everyone concerned to identify and value the perspectives of others and come to appreciate that the science community has one particular view of the world and boundary crossing will not be just in one direction.

- *All participants in connective initiatives should be fully aware of the purpose/s and their role in realising intended outcomes.*

  Making connections between the science and educational communities is a complex enterprise. It is essential that everybody is not only aware of why they are taking part but also their role in this enterprise. It is all too easy for a novice placed in the milieu of the everyday interactions of the science community to make little sense of the experience. In fact the novice may only have a few ‘hooks’ to make sense of the experience, let alone see themselves as having a place in this scientific world.

- *Connective initiatives should have a praxial coherence to ensure the effective translation of purpose to realised outcomes.*

  What we mean is that there needs to be a strong link between the learning theory, the intended outcomes and the connection implemented. It is very easy to compromise when time and expertise is limited. Consequently it is important to have an extensive planning phase in order to identify competing pressures and plan an approach that is coherent and achievable. Questions that could be asked include: How does this activity support the purpose of the initiative?

- *Connective initiatives should acknowledge that boundary crossing requires explicit management of identity issues.*

  Finally we believe that it is important to take into account the emotions that participants might experience when transitioning between cultures. It is also important for participants to be open and respectful of each other’s identity and culture. Consequently it is important to think about how to work with participants to make sure the tensions arising from multiple identities are resolved.

At the start of this project both Vicki and I were very aware that making connections between the communities of science and education was difficult. This project has made us realise that there are many worthwhile projects already happening and with a little more planning and planned evaluation, their lights will shine brightly and provide a strongly lit highway for everyone to travel along.

Reflecting on the essential qualities of effective communication

Another area of my research has been to identify from expert science communicators the essential elements of science communication (Bray, France & Gilbert, 2011). We used a Delphi methodology to find out what these essential components were from ten experts based both internationally and in New Zealand. The process is explained in the paper but what is significant for this talk is that there were five statements that everyone agreed were important. This agreement was unanimous and all of the experts listed these five statements as the top most important components that contributed to effective communication. These were that:

- An effective science communicator is respectful of the audience,
- An effective science communicator needs to foster trust between the audience and the speaker,
- An effective science communicator is able to engage the imagination of the audience,
- An effective science communicator is aware of the social, political and cultural environment that surrounds the science that they are communicating,
- Effective science communication frequently uses the tools of storytelling.

How does this message link to what we found out about making connections with scientists and learners? If you substitute learner for audience there is a common thread. Effective communication requires respect for the views of the learner (ontological and epistemic), trust requires everyone involved to know the purpose of the encounter, lets hope these encounters engage these learners' imagination and the takes into account the different cultures and identities that all learners are bringing to this connective initiative.

And my postscript to return us to the significance of Roger Osborne's legacy is that he taught us to ask and listen to the learner. The issues may be more complex when considering sociocultural learning theory but still it comes down to putting the learner at the centre of the experience. He taught us to listen to the learner. He taught us to make the message simple if we wanted to find out what the learner knew.

If there is a message to take from this address about connecting learners with scientists, it is to recognise that it is a difficult enterprise and that it will take time in the planning and implementation in order to provide a focussed and coherent learning experience for all.

References

Abd-El-Khalick, F.,Bell, R. L, & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, 82, 417-436.

Aikenhead, G.S. (2001). Science communication with the public: A cross-cultural event. In J. Gilbert (Ed.), *The RoutledgeFalmer reader in science education* (pp. 149-167). London: RoutledgeFalmer.

Alexander, P.A., & the Disciplined Reading and Learning Research Laboratory (2010). *The challenges of developing competent literacy in the 21st century.* Washington, DC: The National Academy of Sciences. Published at http://www7.nationalacademies.org/dbasse/Research_on_21st_Century_Competencies_Papers_and _Presentations.html.

Bay, J.L., Sloboda, D.M., Vickers, M.H., & Mora, H. (2012). Multi-dimentional connections: The Liggins Educational Network for Science. In B. France & V. Compton (Eds), *Bringing communities together: Connecting learners with scientists or technologists* (pp. 161-173). Rotterdam, The Netherlands: Sense Publishers.

Bay, J. L., & Mora, H.A. (2010). *Me, myself, my environment: Nutrition, New Zealand curriculum. Level 5 . Teacher resource*. Auckland, New Zealand: Liggins Institute, The University of Auckland.

Bell, R., Abd-El-Khalick, F, Lederman, N.G., McComas, W. F. & Mattews, M. (2001). The nature of science and science education: A bibliography. *Science & Education,* 10, 187-2004.

Berry, M. (1999). Chemistry and art. *School Science Review*, 80(293), 31-38.

Birdsall, S. (2011). *The pedagogical realisation of sustainability*. Unpublished PhD thesis, The University of Auckland.

Birdsall, S. (2010). Empowering students to act: Learning about, through and from the nature of action. *Australian Journal of Environmental Education*, 26, 65-84.

Bull, A. Gilbert, J., Barwick, H., Hipkins, R. & Baker, R. (New Zealand Council for Educational Research) (2010). *Inspired by science. A paper commissioned by the Royal Society of New Zealand and the Prime Minister's Chief Science Advisor. Annex A* (pp. A-9-A-54). Auckland, New Zealand: Office of the Prime Minister's Science Advisory Committee. www.pmcsa.org.nz

Buntting, C., & Jones, A. (2012). Expanding the capacity for connection. In B. France & V. Compton (Eds), *Bringing communities together: Connecting* *learners with scientists or technologists* (pp. 101-112). Rotterdam, The Netherlands: Sense Publishers.

Bray, B., France, B. & Gilbert, J.K. (2011). Identifying the essential elements of effective science communication: What do the experts say? *International Journal of Science Education, Part B: Communication and Public Engagement*, 2:1, 23-41. http://dx.doi.org/10.1080/21548455.2011.611627

Christie, A. (2012). Futureintech. In B. France & V. Compton (Eds), *Bringing communities together: Connecting learners with scientists or technologists* (pp. 127-136). Rotterdam, The Netherlands: Sense Publishers.

Fensham, P. J. (2004). *Defining an identity. The evolution of science education as a field of research.* Dordrecht, The Netherlands: Kluwer.

France, B. & Bay, J.L. (2010). Questions students ask: bridging the gap between scientists and students in a research institute classroom*. International Journal of Science Education*, 32(2), 173-194.

France, B. & Compton, V. (Eds). (2012). *Bringing communities together: Connecting learners with scientists or technologists.* Rotterdam, The Netherlands: Sense Publishers.

Gee, J.P. (2000). Identity as an analytic lens for research in education. *Review of Research in Education*, 25, 99-125. http://www.jstor.org/stable/1167322.

Gilbert, J. K. (2009). Roger Osborne (1940-1985), University of Waikato, New Zealand. *Cultural Studies of Science Education*, 4, 315-322.

Gilbert, J. K., Watts, D.M. & Osborne, R. J. (1985). Eliciting student views using an interview-about-instances technique. In C. West & A. Pines (Eds), *Cognitive structure and conceptual change* (pp. 11-27). Orlando, FL: Academic Press.

Gluckman, P.D., Beedle, A., & Hanson, M.A. (2009*). Principles of evolutionary medicine*. New York, NY: Oxford University Press.

Gluckman, P. (2011). *Looking Ahead: Science Education for the Twenty-First Century. A report from the Prime Minister's Chief Science Advisor*. Published at http://www.pmcsa.org.nz/wp-content/up;lpoads/2011/03/Looking -ahead-Science-education-for-the -twenty-first-century.pdf.

Heap, R. (2007). *Myth busting and tenet building: Primary and early childhood teachers' understanding of the nature of science.* Unpublished master's thesis, The University of Auckland.

Hodson, D. (2011). *Looking to the future. Building a curriculum for social activism.* Rotterdam, The Netherlands: Sense Publishers.

Hsu, P-L. Eijck, M. & Roth, W-M. (2010). Students' representations of scientific practice during a science internship: Reflections from an activity-theoretic perspective. *International Journal of Science Education, 32*(9), 1243-1266.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296-316.

Matthews, M.R. (1995). *Challenging New Zealand science education*. Palmerston North, NZ: Dunmore Press.

Ministry of Education, (2007). *The New Zealand Science Curriculum*, Wellington New Zealand: Learning Media.

Osborne, R. J. & Gilbert, J.K. (1980). A technique for exploring students' views of the world. *Physics Education*, 15, 376-379.

Osborne, J.F. (1996). Beyond constructivism. *Science Education*, 80(1), 53-82.

Petersen, R. (2012). Bright Sparks. In B. France & V. Compton (Eds), *Bringing communities together: Connecting learners with scientists or technologists* (pp. 137-146). Rotterdam, The Netherlands: Sense Publishers.

Rodrigues, S. (2012). A classroom without walls: Virtual learning experiences in science. In B. France & V. Compton (Eds), *Bringing communities together: Connecting learners with scientists or technologists* (pp. 61-72). Rotterdam, The Netherlands: Sense Publishers.

Sadler, T. D. (Ed.) (2011). *Socio-scientific issues in the classroom*. Dordrecht, The Netherlands: Springer.

Simonneaux, L., Panissal, N., & Brossais, E. (2011). Students' perception of risk about nanotechnology after an SAQ teaching strategy. *International Journal of Science Education*. http://dx.doi.org/10.1080/09500693.2011.635164

Wong, S. L. (2012). Learning about nature of science through listening to scientsts' stories of scientific enquiry. In B. France & V. Compton (Eds), *Bringing communities together: Connecting learners with scientists or technologists* (pp. 147-160) Rotterdam, The Netherlands: Sense Publishers.

Wolcott, H. F. (1991). Propriospect and the acquisition of culture. *Anthropology and Education Quarterly*, 22(3), 251-273.

A strategy to develop understandings of the nature of science

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Abstract

The Nature of Science [NOS] is the overarching topic that embeds itself within all contextual strands of science in the new curriculum (Ministry of Education, 2007). For teachers to teach NOS they need to have an understanding of NOS themselves. A review of the international science education literature indicates a general consensus in that an 'explicit' and 'reflective' teaching approach best develops a person's understanding of NOS. This study described in this paper investigates teachers understandings of NOS and the usefulness of an explicit and reflective *strategy* designed to enhance an individual's understanding of NOS concepts. The strategy is based around a 'read aloud' drama about the development of scientists' understanding of the nature of the atom (Haigh & Ward, 2005). Both initial teacher education students and experienced teachers were asked to draw a concept map representing their understandings of NOS and they then participated in the dramatical reading. Following this, they drew another concept map to represent their after–the-activity understandings of the NOS. The participants also engaged in a reflective professional discussion of their experiences and how they may in turn use this strategy in their teaching. The teachers' views of the NOS and the success of the strategy are discussed in the paper.

Background

The New Zealand Curriculum [NZC] (Ministry of Education [MoE], 2007) is a relatively new curriculum document for schools to implement. With the advent of this document, changes were made to the learning area of science. In particular the document includes a specific strand entitled 'Nature of Science'. This focuses on science as a way of knowing, emphasising the beliefs and values integral to the way scientific knowledge advances (Akerson, Abd-El-Khalick, & Lederman, 2000). The curriculum document indicates that this strand is the "overarching unifying strand" (MoE, p. 28) for all teaching in science in NZ schools. The document also describes the learning outcomes for the nature of science strand and indicates that these outcomes should be taught through the contextual strands of the document e.g. The Material World. As such, this science curriculum focus on the Nature of Science [NOS] appears more overt and explicit than in the previous curriculum document. Given this, teachers need to have strategies to teach this important area. But what exactly is the NOS?

What is the Nature of Science?

The literature abounds with debates about what the nature of science actually *is*. The scope and nature of this study does not go into these debates. Nor are the researchers critiquing how the NZC (MoE, 2007) frames the nature of science and its alignment with current literature.

For the purpose of this research we have based our study on the consensus view of the characteristics of the nature of science found in McComas (1998). On examining the NZC (MoE, 2007) we believe that the nature of science strand in the NZC aligns with many of these characteristics. This study is associated with the Achievement Aim *Understanding about Science* and it states:

- Learn about science as a knowledge system: the features of scientific knowledge and the processes by which it is developed; and learn about the ways in which the work of scientists interacts with society.

The different levels of Achievement Objectives that link to this aim are detailed in Table 1.

Table 1
Achievement Objectives for: Understanding about Science

Achievement Objectives Level 3/4	Achievement Objective Level 5/6	Achievement Objective Level 7/8
Appreciate that science is a way of explaining the world and that science knowledge changes over time. Identify ways in which scientists work together and provide evidence to support their ideas.	Understand that scientists' investigations are informed by current scientific theories and aim to collect evidence that will be interpreted through processes of logical argument.	Understand that scientists have an obligation to connect their new ideas to current and historical scientific knowledge and to present their findings for peer review and debate.

What does educational literature say about teaching NOS?

In order to teach about NOS, teachers need an understanding of the nature of science. International studies have identified four prominent aspects of NOS that are least understood. The four aspects are:

1. Science involves creativity and imagination
2. There is no set scientific method
3. The importance of empirical evidence and relating this to the tentative nature of science
4. Explaining the difference between laws and theories in such a way that it does not imply a hierarchical relationship.

While there is considerable debate in the literature about the 'best' way to teach NOS there does seem to be an agreement that explicit and reflective strategies are appropriate (Akerson, Abd-El-Khalick, & Lederman, 2000).

This small-scale study describes teachers' understandings of NOS and their perceptions of the usefulness of an explicit and reflective strategy designed to enhance an individual's understanding of NOS concepts.

Method

Participants

Two groups of participants were involved in the study. The first group were ten initial teacher education students who were enrolled in a one year programme to become secondary school chemistry and science teachers. The second group were six experienced teachers from both secondary and primary school backgrounds who were enrolled in a university postgraduate course on scientific literacy. Prior to the study both groups of teachers had some exposure to aspects of NOS professional development through the courses they were enrolled in, particularly those who were enrolled in the postgraduate course.

Data Gathering

Participants were asked to construct a concept map representing their understanding of NOS. After completing the concept map they took part in a dramatic reading about the historical development of the atom (Haigh & Ward, 2005). At the completion the participants were asked to return to their concept maps and to add or alter any of their previous conceptions. This was done in a different coloured pen to enable analysis by the researchers to occur. In addition, the participants were asked to provide a rationale for any changes they made. The last phase of data gathering involved the participants taking part in a focus group activity to discuss whether the participants perceived the task as useful in developing their own understanding of NOS. Both groups were also asked about whether they perceived the task, or one similar, would be useful to help support secondary and primary school students' understandings of NOS.

The focus group interviews were audio-taped, transcribed and a thematic analysis of the transcripts was undertaken by the authors using Miles and Huberman's framework (Miles & Huberman, 1994). The themes were verified with both researchers presenting and defending ideas and supporting or challenging those of the other researcher.

The dramatic reading

Even though the dramatic reading (Haigh & Ward, 2005) was designed prior to the 2007 NZC document being introduced, the researchers believed the dramatic reading could be used as an explicit and reflective teaching tool. When analysing the dramatic reading prior to data gathering, the researchers found that it focused on *Understanding about Science* in the curriculum document. It also highlighted certain characteristics of the nature of science (McComas, 1998). These included some of the issues that have been noted as problematic. These included:

1. Science involves creativity and imagination
2. There is no set scientific method
3. The importance of empirical evidence and relating this to the tentative nature of science

Additionally, the reading highlighted scientific knowledge and its relationship with technological advancement and the way in which scientific knowledge is embedded within social and cultural elements. However, it did not attempt to explain the difference between laws and theories in an non-hierarchical way.

Findings

Teachers understanding of NOS

The activity itself appeared to either generate or trigger thinking that resulted in a broadening of participants' ideas about NOS. The frequency of change between before-intervention concept maps and after-intervention concept maps is outlined in Table 2.

Table 2
Change in frequency of indicators of NOS dimensions on concept maps

	Creativity and imagination	Range of scientific approaches	Nature of evidence	Social and cultural elements	Science's link to technological advances
Frequency in before-intervention concept maps	6	12	11	22	3
Frequency in after-intervention concept maps	6	17	20	41	7
Frequency of additions	0	5	9	19	4

As is shown in Table 2, the dramatic reading had the greatest impact on teachers' understanding that scientific knowledge is embedded within social and cultural elements. There were 22 indications of social and cultural elements in before-intervention concepts maps and after participating in the dramatic reading this increased to 41 indications. Four of the participants included this aspect for the first time and seven of the participants added further notions of social and cultural elements to their post-intervention concept map. However, this knowledge remained absent from three concept maps. In the focus group interviews, some of the participants indicated how the reading impacted on their understanding about NOS:

> *For me it sort of brought in, my initial map was very sort of individual and the reading then brought in the whole social context and the influence of other people. So I did a very pure sort of map and then broadened it. (ITE chemistry student)*

The dramatic reading also had an impact on teachers' understanding the nature of evidence. In the before-intervention concept maps 11 teachers made reference to empirical evidence and/or the tentative nature of science. In the after-intervention concept maps 2 more participants included these aspects and a further 3 teachers showed a broadening of their knowledge by including further information about the nature of evidence. Again, these changes in understanding were noted in the focus group interview:

> *There was the thing that I didn't think of at the time is that there's development ideas, not a single one that comes across but things continually changing. (ITE chemistry student)*

The dramatic reading also had some impact on teachers recognising that there is no set scientific method. In their before-intervention concept maps, twelve of the participants recognised this, indicating that these teachers already had an understanding of this characteristic of NOS. After the reading a further two participants included this aspect of NOS in their concept map and two other participants added additional information about this aspect to their concept map. Two participants made no reference to this aspect.

Finally, the reading had a small impact on teachers' recognition of science's link to technological advances. Three teachers made reference to the association in the before-intervention concept maps. They retained these connections in the after-intervention concept map and another four other participants recognised the association between technological advancement and science.

Analysis of the data indicates that the dramatic reading did not impact on teachers' understanding that science involves creativity and imagination. Of the 16 participants, six indicated aspects of creativity and imagination as a part of NOS in their before-intervention concept map and this number did not change in the after-intervention concept map.

Perceived usefulness of the strategy in the classroom

The focus group interviews opened up discussion about how the dramatic reading could be used as an activity in the classroom.

Although one of the postgraduate participants believed there was no use for the activity and indicated that, "… *in the New Zealand Curriculum there is no room for the nature of science,"* others saw how a focus on NOS, *"... had so much to offer."* Most thought that they could use this or a similar activity with the students they taught. Some thought this particular dramatic reading was mostly suitable for senior science groups:

> *I think for say beginning Year 12 class it would be a very good start [for] understanding scientific knowledge is expanding and evolving and they are starting on a journey to understand the universe and that the whole scientific community is going in that direction. (ITE chemistry student)*

The primary teachers within the postgraduate class also saw benefit in this type of activity and recognised its potential for increasing interest in science:

> *I think this would actually hook in some children [who would usually] go 'oh I don't like science'. … [they might] be like 'oh this sounds really interesting' … (PG student)*

The dramatic reading also provided a springboard for the development of other ideas regarding similar activities that would be suitable for the children they taught. As a consequence, engaging in the reading had a pedagogical professional development focus to it:

> *You could dramatise it more as well. You could actually get the kids to sort of learn parts of it, dress up a bit. (PG student)*

Discussion and Conclusion

These findings show that the dramatic reading, as an explicit and reflective tool, did help to broaden these teachers' understanding of NOS aspects, particularly with regards to the significance of social and cultural elements on science and the nature of evidence. However, even though the reading included aspects of creativity and imagination to the development of scientific knowledge, as well as its link to technological advancement, the teachers did not recognise these NOS characteristics. Therefore, this finding suggests that if such a teaching strategy is to be effective in helping students in the classroom learn about NOS, then teachers need to use the strategy in a very deliberate, focussed, explicit and reflective manner.

Most teachers were able to see how they could use the dramatic reading as a whole or in part, in their own classes in a secondary school or use aspects of it within a primary school setting. The focus group interview provided these teachers with the opportunity to share ideas about how they could use the strategy in the classroom which was an unexpected outcome.

Another unintended consequence of the discussions during the focus group interviews was the opportunity for teachers to further clarify their ideas about NOS. This also led us to realise that conducting a third concept map drawing after the discussion could lead to further analysis of teachers' understandings as the discussion contributed to making NOS characteristics explicit, seemingly enhancing the participants' understandings of NOS.

References

Akerson, V., Abd-El-Khalick, F., & Lederman, N.G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37*(4), 295-317

Haigh, M., & Ward, G. (2005). *From Democritus to Rutherford: Developing our understanding of atomic structure.* Retrieved August 3, 2010, from http://www.tki.org.nz/r/science/science_is/activities/isact_models_atom_e.php

McComas W. (Ed.), (1998). *The nature of science in science education: Rationales and strategies.* The Netherlands: Kluwer Academic Publishers.

Miles, M., & Huberman, M. (1994). *Qualitative data analysis* (2nd ed.). Thousand Oaks, CA: Sage.

Ministry of Education. (2007). *The New Zealand curriculum for English-medium Teaching and Learning in Years 1-13.* Wellington, New Zealand: Learning Media.

The nature of science: A suggested model for students

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A Nature of Science strand [NOS] was added to *The New Zealand Curriculum* (Ministry of Education, 2007) in 2010, and teachers are still working out how best to implement its requirements. This strand requires that science be presented not only as a body of fixed knowledge, but also as a process of investigation, with a growing and changing mixture of both certain and uncertain information, ideas and theories.

The NOS strand presents two kinds of challenges to practising teachers:

(1) By inclination and training, science teachers tend to regard their subject material as fixed and factual, and not all teachers readily embrace notions of scientific uncertainty and change. To some extent this ‘fixed science’ view can be countered by examples such as the ongoing changes in atomic theory. The traditional model of protons and neutrons and electrons was replaced decades ago by a ‘standard model’ that includes 16 different quarks, leptons, bosons etc. And the standard model itself is undergoing change.

(2) The curriculum document describes NOS in academic terms, using language that may baffle students unless re-interpreted and made less abstract. Students are likely to be frightened away from science if introduced too early to the hypothesis-testing deductive approach of observation → hypothesis → experiment → confirm or reject the hypothesis.

This paper proposes a NOS model that is simple, visual and jargon-free. In this simplified view, science is portrayed as being built on three foundations: questions; ideas; and evidence. This arrangement can be presented as a physical tripod, as in the artists’ easel picture below. The word ‘science’ can be replaced with the title of any current classroom topic, from earthquakes to electricity. To the writer’s knowledge, this tripod metaphor is original. Presented as a three-legged shape with questions serving as a starting point for any investigation, the metaphor is self-evident to students. If one leg is weak or missing, then their investigation becomes wobbly.

Experience has shown that it helps students if this tripod image is introduced with an accompanying example, such as plate tectonic theory. The original question was, “Why do the coastlines of Africa and South America match so neatly?” Wegener’s hypothesis (‘idea’) was that the continents were once joined, then broke up and drifted apart. At the start geologists thought the idea was absurd because there was no known mechanism that could move continents. However accumulating evidence eventually proved Wegener’s idea to be broadly correct.

Each of the three 'legs' will now be discussed in turn.

Ideas
The word 'idea' is used in the tripod as a shorthand way of covering any hypothesis or any theoretical model. These terms can be introduced when appropriate – but at earlier stages the word 'idea' may be more student-friendly. The term 'model' also needs to be clarified to students. In popular use it refers to scale models (atoms, cells etc), or to perfect examples (role models, fashion models). In science and economics, 'model', or more correctly 'theoretical model', refers to any big idea that attempts to explain a wide body of information.

Evidence
Teachers should take every opportunity to emphasise that science is evidence-based. In almost any situation where there is opinion and uncertainty, the question can be posed to students, "Now let's see – how good is the evidence for that idea?" If the word 'evidence' is a barrier to understanding, then 'facts' can be used in its place, though the meaning is slightly different.

Questions
Science contains more questions than answers. Curiosity and questions are the natural starting points for any search, whether the investigation is being carried out by a 9-year-old or by a PhD candidate. In classroom investigations it is common for teachers to provide the questions, usually with specific outcomes in mind. The questions tend to be artificial, for example, "Is the blue flame or the yellow flame hotter? Let's find out". Or, "Which ball will bounce higher? Let's find out." Tried-and-true investigations that follow questions such as these can provide good opportunities to introduce principles such as working with variables and using fair-testing, but the problem is that the original questions are not very interesting. Students tend to find them pointless, on the grounds that the teacher already knows the outcome but is pretending not to know.

It is surely preferable and more natural for investigations – whether experimental or reading-research – to arise from students' own questions based on things that they find genuinely interesting or puzzling. Teachers will inevitably find that some students are already highly inquisitive, but may also find that curiosity and a questioning approach need to be actively encouraged in others. Teachers should not assume that that this kind of encouragement has been part of every individual's prior life experience.

Even when student questions seem unscientific, their imagination should be encouraged. Einstein, for example, said he owed more to imagination than to logic. He was not an experimental scientist, and his theory of relativity began with him posing the questions such as, “What would things look like if I could travel at the speed of light?”

Questions from photos

One simple method to encourage a questioning approach is to use a data projector to display intriguing or astonishing photographs of recognisable situations. Students are then asked to come up with their own what/why/where/when/how questions about the situation. Questions can be related to a feature visible in the photo, or to something indirectly related.

Teachers could consider making photo-questions a standard class warm-up activity, and may be surprised by the range of innovative questions that students generate. Students appreciate being able to contribute their own thoughts and suggestions, without the pressure of having to provide scientific explanations of whatever the photo shows. This strategy gives respect to student input as valuable and intelligent, and encourages those who might otherwise consider themselves not competent in science.

Much depends on the nature of the photos used, and teachers may find it is useful to build a photo library beforehand. Some suggestions for photos include rock climbers in action; awe-inspiring landforms; floods; storms, spacecraft; fast cars, bikes and boats; cute or powerful animals; wildlife; machines; surgery; twins; explosions; food; and microscopic close-ups.

Some suggested guidelines for choice of photos to stimulate question-posing include:

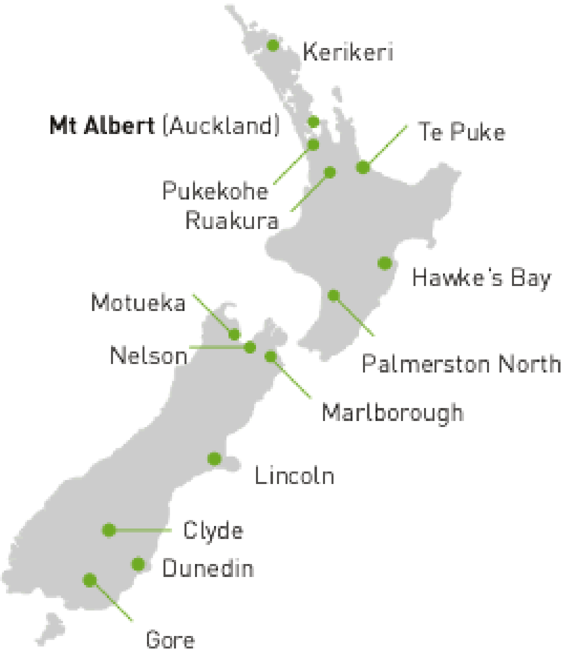
- High-resolution large files are best,
- Visual impact and interest are paramount,
- If a data projector is not available then computer screens will do, or print,
- Reassure students that you would like to hear their questions, not their answers,
- Allowing a few minutes for oral questions may be sufficient,
- Can be individual or group work,
- Teachers should resist the temptation to supply their own ‘official’ answers to every question,
- Accept that many questions may be unanswerable,
- Some student questions may lead to wider discussions, or become the starting points for investigations.

The tripod metaphor does not deal with every aspect of NOS. For example, socio-scientific and environmental issues are perhaps best introduced through case studies. Also, the NOS strand does not diminish the importance of learning the language and factual body of content knowledge that form a large part of science.

However, the tripod model does provide a clear guide to any student embarking on an investigation. A teacher can help by referring back to the tripod, using guiding queries such as, “What question do you have in mind here?” or “What hypothesis/idea are you trying to test?” and “How will you collect your evidence?” In this way, students’ understanding of NOS could be enhanced.

SciCon 2012 Science in Action: Tour of Plant & Food Research at Mount Albert

Robin MacDiarmid, Michelle Beresford, Rob Beresford, William Laing, John Charles, Christina Bava, Cristina Cruz, Sravani Gupta, Ed Walker & John Ingram
The New Zealand Institute for Plant & Food Research Limited



The aim of the tour around the Plant & Food Research (PFR), Mount Albert science facility was for teachers to meet scientists, understand their research aims and methods, and obtain resources to further understand and follow their ongoing research. The Mount Albert facility is the headquarters and the largest of PFR's 14 sites that are spread across New Zealand from Kerikeri to Gore. Teachers, there might be a PFR site near you. Please contact Nadine Andrews (Nadine.Andrews@plantandfood.co.nz) to arrange a visit to a PFR site or contact any one of the scientists directly at PFR (firstname.lastname@plantandfood.co.nz). We will do our best to accommodate your needs around our science demands. We hope that this publication may also assist to further develop contacts with PFR and individual scientists. You may choose to subscribe to Plant & Food Research's e-newsletter, http://bit.ly/PFRnewsletter or follow us online on facebook (www.facebook.com/plantandfood), twitter (www.twitter.com/plantandfood0 or YouTube (www.youtube.com/plantandfood).
Each hour-long tour comprised three science topics such that over the course of the conference five topics were covered. Science topics included:

1) sensory perception of New Zealand foods and wine,
2) understanding the role of genetic engineering in science discovery,
3) reducing pesticides,
4) foods for appetite control,
5) ensuring high safety of chilled food products.

More information on each of the topics can be found on our website (www.plantandfood.co.nz).

1) Tour guides Ms Christina Bava (BA, MA (Hons), Anthropology, and Ms Michelle Beresford (Certificate in Practical Patisserie and currently completing U.C. Davis Sensory & Consumer Testing Postgraduate Certificate), took teachers through the

sensory and consumer science laboratory, one of the largest facilities in the Southern Hemisphere. At the facility human senses are applied using innovative and well-established sensory evaluation tests to define flavour, texture, appearance and taste. We also apply consumer science to understand an individual's consumption behaviour and the ways in which variations in foods and beverages, consumption situation and a person's mood affect decisions. New and existing methods are used to research consumer requirements for foods and beverages to support industry partners with the launch of new products and expansion in new marketplaces, as well as directing elite cultivar breeding programmes and development of new wine styles. Teachers were shown through the facility, which includes a series of individual tasting booths, each with a computer for data collection and green, red and natural-coloured lighting to reduce bias from visual cues. A short discussion was held in a separate room that was later revealed to be a room monitored through a one-way window and equipped with recording devices. This room is used for training panellists, instructing consumers as well as collecting visual and oral data – and, yes, users are informed of the recordings.

2) Three different scientists, each on a different day, shared their research using genetic engineering in science discovery. Tour guide Dr Robin MacDiarmid (PhD) showed teachers through the facilities in which genetically modified (GM) plants are developed and some of those plants were viewed growing in a Physical Containment Level 2 glasshouse facility. GM is used to understand how plants work and what genes are needed for a particular process. For instance, scientists at PFR are currently trying to understand what genes are required to provide tolerance to the bacterial disease that has recently infected our kiwifruit industry in Te Puke region (listen to Associate Professor Matt Templeton (PhD) talk about Kiwifruit Psa Disease Genetics, www.radionz.co.nz/national/programmes/ourchangingworld).

Dr Erika Gasic (PhD) showed teachers through the laboratory that focuses on discovery and function of flowering genes in fruit trees. Erika explained that in woody trees and vines, flowering is often interrupted by winter dormancy when growth is arrested. Flower buds are established in the first season, before winter dormancy, and flower development, pollination and fruiting occur in the second season. Researchers at PFR are interested in genes that regulate initiation of flowering and flower development, as well as establishment and maintenance of winter dormancy. They also want to understand the sophisticated regulatory mechanisms that woody plants use to induce flowering only in a proportion of growing points and maintain a balance of flower and leaf or shoot development. A range of molecular and biochemical techniques are used to isolate genes, analyse their expression and regulation, and test for their function in plants.

William Laing (PhD) studies Vitamin C or ascorbic acid which is an essential vitamin for humans and a few other species. Humans get most of their Vitamin C from plant sources (and also sometimes synthetic supplements), but the quantity of Vitamin C in different fruits and vegetables varies tremendously. The research at PFR focuses on understanding the control of Vitamin C biosynthesis in fruits and vegetables and using that information to select new cultivars with higher levels of Vitamin C. It is expected that this research will lead to new cultivars of fruits and vegetables with higher Vitamin C and thus increase the human intake of this important vitamin from natural sources.

Research at PFR has shown that Vitamin C concentration in many plants is controlled by an enzyme (GGP) at the start of the biosynthetic pathway, and that increasing the level of this enzyme in a range of fruits, vegetables and leaves can significantly increase their Vitamin C concentrations. It has also been shown that the level of Vitamin C in kiwifruit and apples correlates significantly with this GGP enzyme and that GGP can be used as a marker for selecting new cultivars with high Vitamin C.

3) Two scientists described their research into reducing pesticide usage. The Disease Risk Management Team is led by Dr Rob Beresford (PhD). The team is dedicated to reducing the impact of fungal and bacterial plant diseases on New Zealand's crop production systems. The focus is on reducing disease constraints to crop yield, product quality and market access for our export industries. The team's core disciplines are quantitative epidemiology, mathematical modelling, climatology and computer software development. Rob demonstrated some disease models that have been developed to give a quantitative understanding of how weather factors interact with fungal and bacterial pathogen biology. These models are used by industry sector groups in many practical applications; for instance, prediction of regional and seasonal risk of disease outbreaks such as the kiwifruit Psa Risk Model and the Integrated Apple Black Spot Model. When disease risk models are combined with disease control options, like fungicides or biological control agents, they form interactive web-based tools for growers to help with decision-making on efficient disease control. An example is the Botrytis Decision Support System used by the wine industry to manage botrytis bunch rot risk.

A team of PFR's applied entomologists in Auckland is led by Mr John Charles (MSc). This team focuses on the biological control of insect pests of fruit and vegetable crops. 'Classical biological control' programmes are so called because they have been part of bioprotection for more than 100 years. They start with the importation and release of natural enemies from the pest's country of origin. The natural enemies (usually parasitoids) are chosen because they have co-evolved with the pest, and so are particularly effective at controlling them. These days, a significant part of the research programme involves assessing the risks posed by exotic natural enemies to New Zealand's native insect fauna. A better understanding of the biology behind host-parasitoid-plant interactions allows New Zealand researchers to be increasingly sure that the new natural enemies selected are safe in their new environment (i.e. attack only the pests they are supposed to); and the increased confidence will ensure that biocontrol remains a cornerstone of sustainable pest control for the future. Teachers were shown tiny parasitoids (about 1-1.5 mm long) that attack mealybugs and help to control their numbers in fruit crops, thus minimising the need for any insecticides.

4) John Ingram (PhD) and Ed Walker (PhD) shared tour days and discussed their research into foods for appetite control. Chemo-sensory mechanisms of the gut

epithelium, particularly those involved in detecting and relaying to the brain the chemical composition of food during digestion, are the main focus of their research and play an important role in controlling gut function and appetite regulation. The “Foods for Appetite Control” programme aims to develop plant-based foods and food ingredients that can enhance and extend satiety by applying a “combinatorial” approach, targeting specific chemosensory mechanisms that are activated at different times post-meal in the proximal small intestine (duodenum), the distal small intestine (ileum) and the colon. These mechanisms include: 1) duodenal stimulation of the ‘satiety’ peptide cholecystokinin (CCK) release using bitter phytochemicals; 2) activation of the ileal brake mechanism through enhanced delivery of carbohydrate to the ileum; and 3) prebiotic stimulation of colonic microbial metabolite production. PFR scientists use a range of techniques including *in vitro* models of gastric, small intestine and colonic digestion, enzymatic and cell-based screening assays, and consumer and clinical studies in volunteer participants to investigate aspects of this proposed combinatorial approach to enhanced satiety. Teachers were shown through the cell culture facility where human cell lines are used to screen for bioactive plant extracts.

5) Cristina Cruz (PhD) and Sravani Gupta (MSc) gave a double act showing teachers through the Food Safety & Preservation team’s laboratories. This team provides the assurance of post-harvest seafood safety and quality to New Zealand products. This team’s research programmes involve understanding how the bacterial contamination occurs within factories, assessing the risks to the consumer population and developing new safety and quality control strategies. The team also works with bio-preservatives, fish Quality Index Method to assess age and quality of harvested fish catch and modified atmosphere packaging techniques for chilled seafood preservation. Ultra High Pressure (UHP) processing work is also carried out to investigate how these processing regimes, which are designed to assure food safety, influence the quality attributes of seafood raw materials. Investigation is also carried out into how to confer positive eating properties (e.g. texture) or add value to seafood products. Teachers were shown the UHP equipment in the seafood lab and the mechanism and principles of how this equipment is used were explained. The teachers were also given a sneak peak at the functional pathogen microbiology laboratory where researchers deal with the major pathogenic bacteria associated with seafood.

We look forward to increasing our interaction with science teachers. Please feel free to contact us or follow our research through publications, videos and other online productions.

Using computer technology to stimulate your physics students

Phil Jones
Manager, The Logical Interface
(www.logint.com.au)

Abstract

Sophisticated technology, once only the domain of forensic and research laboratories, is now within the reach of every science teacher passionate about nurturing our scientists of the future. Such technologies excite both teachers and students and bring a sense of relevance to learning science. In this paper I examine a number of such technologies for teaching physics, including:

- Video analysis of motion - this technology is an excellent application of the computer to data acquisition and analysis. TLI Motion video analysis software is ideal for analysing motion in one and two dimensions to produce a range of graphs of motion.
- Interactive Physics (IP) - IP is physics modelling software. With TLI Motion we have software for data collection data and analysis. With IP we have a tool to extend this process to do modelling and what if analysis. It is also a superb tool for creating simulations in physics - from Kepler's Laws through to Electromagnetic simulations.
- Simulation software - Krucible is revolutionary software for creating simulations and demonstrating experiments that are impractical in the secondary science lab. With Krucible you can even convert your PC into a fully functional Ripple Tank!
- PC-based signal generator and oscilloscope - TLI WaveGen and TLI CRO exploit the power of the sound card in your PC and convert your PC into a powerful signal generator and oscilloscope.
- Data logging technology - Data loggers are an extremely powerful data acquisition and analysis tool, which support a wide range of experiments from elementary to more advanced experiments such as force on current carrying wire, electromagnetic induction, apparent mass and electronic ticker timer.

Video analysis and TLI Motion video analysis software

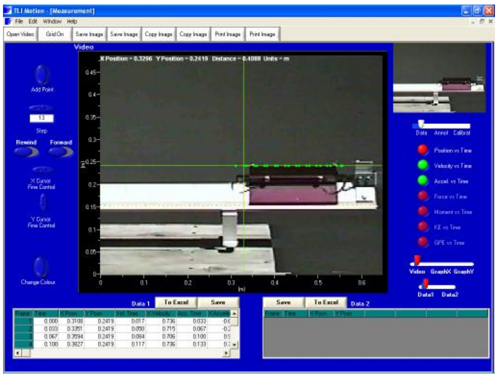
TLI Motion is a program designed to analyse video footage and produce a range of graphs from position versus time to momentum versus time. A large number of videos are included on the CD, which illustrate both one- and two-dimensional motion. They range from objects rolling along horizontal and inclined planes to projectile motion and collisions. In addition you can analyse your own video, if you have a suitable video camera.

Two of the many videos which accompany the software allow us to analyse impulse and projectile motion. These examples are discussed below.

Example 1: Impulse

The figure at the right shows an air track glider colliding with the end of an air track. An air track provides a cushion of air and reduces friction. By stepping through the video and marking the position of the glider a student can produce graphs of position versus time, velocity versus time, force versus time and momentum versus time.

Alternatively students can place a clear overlay on a PC screen and mark the dots for the motion, or project the image on to a screen, take direct measurements and scale their results. Using this data they can plot position versus time, velocity versus time and momentum versus time graphs for the motion before and after the collision. From the graph of velocity versus time they can determine the initial and final velocities and find the change in momentum and impulse.



Frame	Time	X Posn	Y Posn	Vel. Time	X Velocity	Acc. Time	X Accele
1	0.000	0.3108	0.2419	0.017	0.736	0.033	-0.6
2	0.033	0.3351	0.2419	0.050	0.715	0.067	-0.2
3	0.067	0.3594	0.2419	0.084	0.706	0.100	0.
4	0.100	0.3827	0.2419	0.117	0.736	0.133	0.

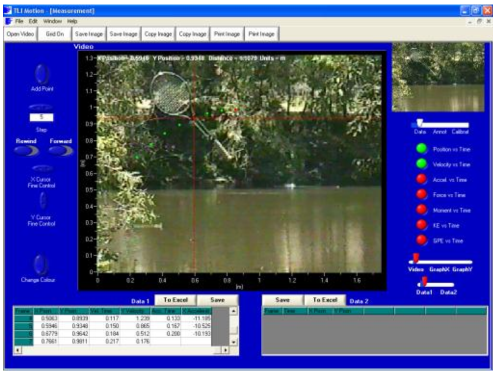
Frame	Time	X Posn	Y Posn

Similar videos are available for one-dimensional and two-dimensional collisions.

Example 2: Two Dimensional Motion: Projectile Motion

The figure at the right shows a picture of a tennis racket traveling across the video. As it travels, it also rotates. In this example students can investigate how the centre of mass of the racket undergoes projectile motion.

By stepping through the video and placing dots on the centre of mass for each frame they produce position versus time graphs and velocity versus time graphs for this motion in the horizontal and vertical directions. They can then compare their graphs with those generated by the computer.



Frame	X Posn	Y Posn	Vel. Time	Y Velocity	Acc. Time	Y Accelera
4	0.5063	0.8939	0.117	1.239	0.133	-11.185
5	0.5946	0.9348	0.150	0.865	0.167	-10.525
6	0.6779	0.9642	0.184	0.512	0.200	-10.193
7	0.7661	0.9811	0.217	0.176		

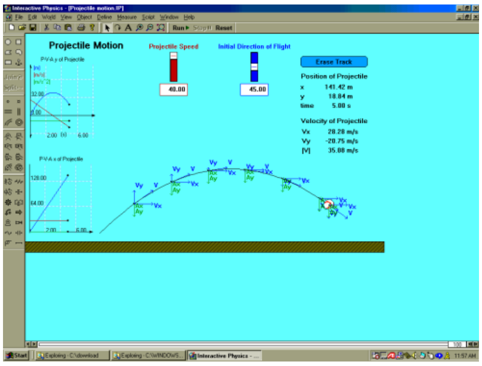
Teacher- and Student-Created Simulations

Simulation software is traditionally directed at demonstrating a particular experiment, or activity. Such software is excellent for performing experiments that are difficult or impossible to do in school laboratories.

However the two products I describe below go far beyond this type of simulation to provide a platform for both teachers and students to create their own simulations. This approach to interactive software exploits students' creativity in a way that has been difficult to achieve in the past. They are ideal for open-ended activities. I have found my students benefit enormously from this approach.

Interactive Physics

Interactive physics makes it easy to integrate modelling and simulation into your physics classes. You can add objects such as springs, dampers, ropes and joints; measure attributes like velocity, acceleration, momentum, and energy. You can also display these measurements as numbers, graphs, or animated vector displays. You can then interact with your model in real time by changing parameters as the simulation runs.

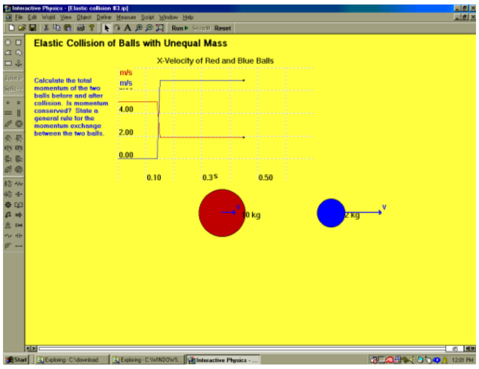


40.00

45.00

Position of Projectile
x 141.42 m
y 18.84 m
time 5.00 s

Velocity of Projectile
Vx 28.28 m/s
Vy -20.75 m/s
|V| 35.08 m/s



Calculate the total momentum of the two balls before and after collision. Is momentum conserved? State a general rule for the momentum exchange between the two balls.

In summary students can:

- open existing simulations covering a wide range of physics topics,
- perform prediction analysis by controlling variables,
- create simulations to enhance understanding of difficult concepts,
- save and share simulations.

Krucible

0.80 Hz

2.80

	Activity	Challenge
1	What are waves?	Working with rays
2	What is frequency?	The quartz watch
3	What is amplitude?	Wave power
4	What is wavelength?	The visible spectrum
5	What's a medium?	Slowing it down
6	Regular and diffuse reflection	Road reflections
7	Law of reflection	Cameras
8	Convex mirrors	Anti-shoplifting mirrors
9	Concave mirrors	Solar cooker
10	Refraction	Find the whale
11	Refractive index	Find the poison
12	Convex lens	Magnifying glass
13	Concave lens	Be an optician
14	Total internal reflection	Endoscopy
15	Doppler effect	Supersonic boom
16	Single slit diffraction	Microwave oven
17	Edge diffraction	Mobile reception
18	Standing waves	Beats
19	Interference – 2 point sources	Good listening

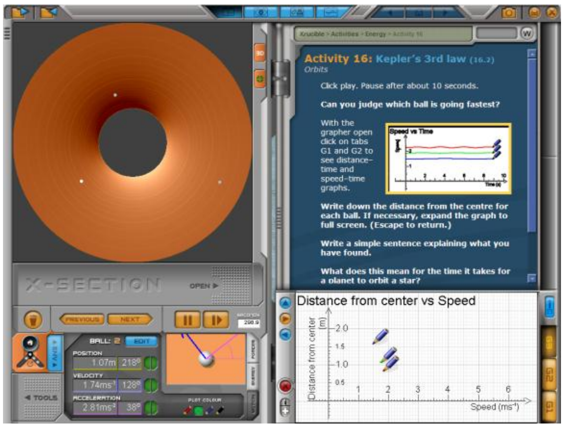
Use the QuickStart Guide for an overview of how to use the simulation's main features.

Krucible provides three experimental platforms to examine:

- Waves – all properties – virtually all aspects of wave motion
- Dynamics and energy
- Forces and momentum

Its approach is different to Interactive Physics in that it has a large number of predefined activities to guide students through the concepts with a more structured approach. You can easily leave your students to work through the activities with a minimal amount of guidance.

Krucible also takes a different approach to simulation construction. It is more limited in its scope than Interactive Physics, however simulations are simpler to construct and therefore students can create simulations in less time and in a more directed manner. These simulations can be saved and reloaded when needed. In this sense it is an open ended program for constructing simulations.



Activity 16: Kepler's 3rd law (16.2)

Orbits

Click play. Pause after about 10 seconds.

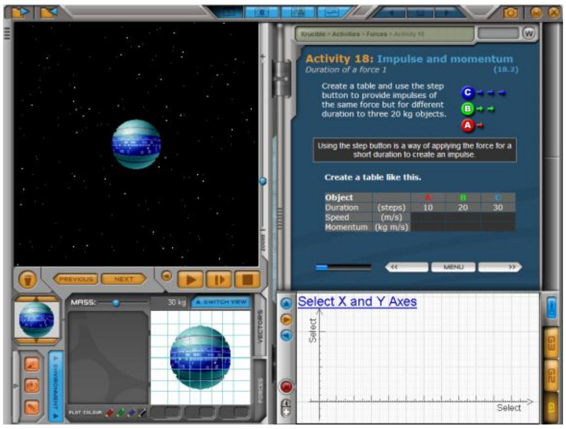
Can you judge which ball is going fastest?

With the grapher open click on tabs G1 and G2 to see distance-time and speed-time graphs.

Write down the distance from the centre for each ball. If necessary, expand the graph to full screen. (Escape to return.)

Write a simple sentence explaining what you have found.

What does this mean for the time it takes for a planet to orbit a star?



Activity 18: Impulse and momentum

Duration of a force 1 (18.2)

Create a table and use the step button to provide impulses of the same force but for different duration to three 20 kg objects.

Using the step button is a way of applying the force for a short duration to create an impulse.

Create a table like this.

Object		A	B	C
Duration	(steps)	10	20	30
Speed	(m/s)			
Momentum	(kg m/s)			

In summary students can:

- plot experiment simulation data with a dynamic graph plotter,
- use a notepad to record observations,
- save and share experimental outcomes,
- complete over 150 activities and apply knowledge to more than 150 real life challenges.

Its features include:

- Clear demonstration of difficult physical concepts,
- Ability to encourage students to question and explore,
- Facility to teach experimental method and observational skills,
- Ideal learning for whole class or individuals,
- Facility to apply theory to real life challenges,
- Ability to enhance your students' creativity.

Using Data Loggers in Physics

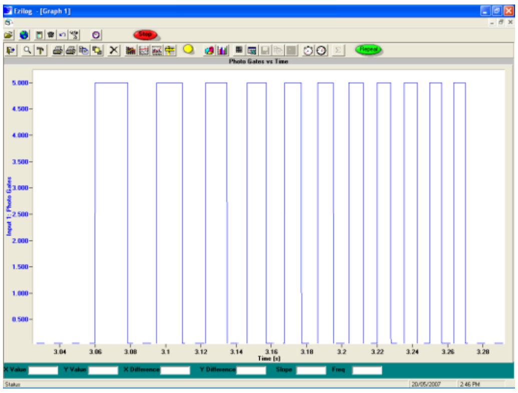
Data loggers have many applications in physics. There are many examples of motion experiments using photo gates and distance sensors (sonic ranges). Below I describe three less common examples of data logger experiments. In these experiments the data logger is used:

- As an electronic ticker timer,
- To record and analyse interference of waves and examine the importance of sampling rate for physics experiments,
- To determine the apparent mass of an object when placed in an accelerating container such as a lift or rocket.

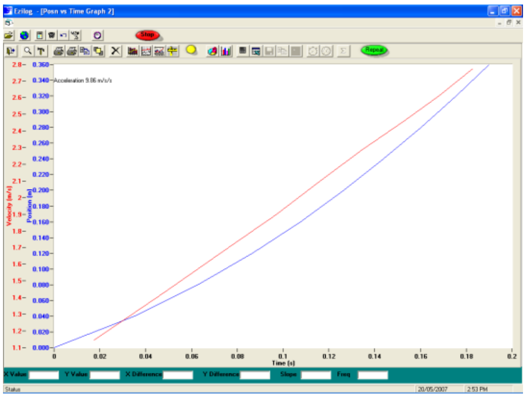
Using your data logger as an electronic ticker timer

In this example a photo gate is used with the Ezilog USB data logger. Some data logger brands allow your photo gate to work as an analogue sensor. However, most simply work as a digital sensor and return time only.

By attaching a picket fence to an air track glider or trolley and placing a photo gate over the track so the picket fence will break the beam, we can achieve the same effect as a ticker timer but with much more ease and accuracy. The graphs below illustrate the type of results achieved. The picket fence produces a series of rectangles, which are then used to measure time intervals in much the same way as we measure distance intervals in a ticker timer pattern. The students can use this data and the picket fence distances to create position versus time and velocity versus time graphs.



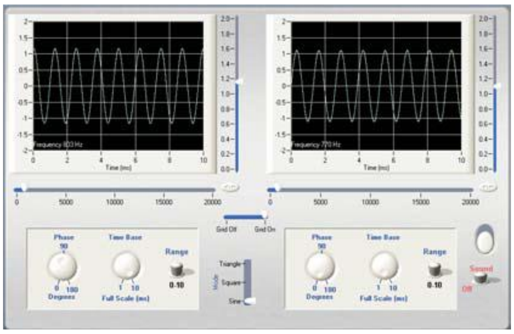
Graph produced fro dropping a picket fence through a photo gate using the Ezilog USB.



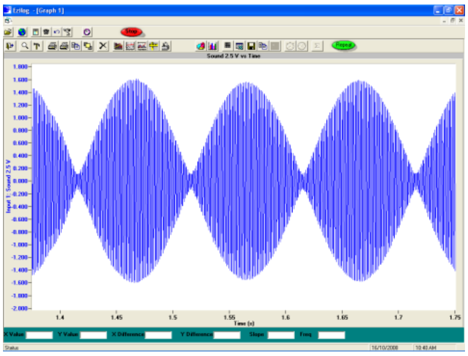
Position vs time and velocity vs time graphs generated from graph a using the Ezilog USB.

The importance of sampling rate for physics experiments: Interference of waves - beats

In this example students used a computer based dual channel signal generator (the TLI WaveGen) to generate beats. A sound sensor (microphone) can be placed close to the computer speakers to record the resultant sound wave produced by the interference of the two waves generated by the signal generator. To extend the experiment various sampling rates are used to record the waveform and the effect of increasing sampling rates to 20,000 samples per second is observed. At this final sample rate the beat frequency and wave frequency are determined. The effect of sampling rate on the quantitative and qualitative results can be examined.



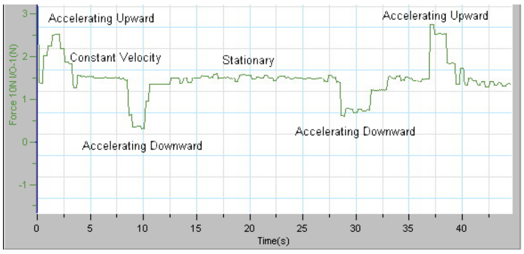
TLI WavGen used to generate beats.



The beat envelope recorded with the Ezilog USB at 20,000 samples per second.

Apparent mass

This example demonstrates how we can use a data logger to examine the apparent change in mass and weight of an object while in an accelerating lift as well as determine the acceleration of a lift when leaving and arriving at a floor.

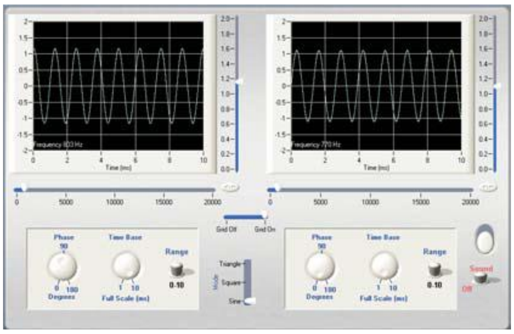


By using a mass balance (TLI mass-balance sensor) attached to a data logger (or computer), students can examine the effect of acceleration on the apparent mass of an object directly. To perform this experiment they need to place their data logger and mass balance in a lift. Place a mass (around 200g) on the balance and record the mass as the lift accelerates upward and downward. This is an example of an experiment that is very difficult to achieve without the use of a data logger/computer.

An extension to this experiment is to examine the impulse when the lift is accelerating and breaking. By converting the mass to force and then determining the area under a force versus time graph students can find the impulse

Simulation versus Direct Data Acquisition with a Computer

Using a computer based signal generator and CRO (TLI WaveLab system) students can examine two ways of looking at interference of waves. The TLI WaveGen has a virtual CRO for examining the output from the generated signals.

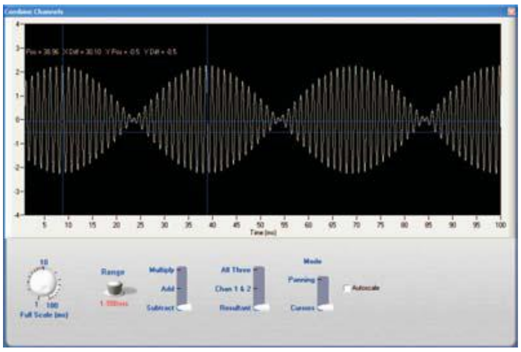


1**.** Interference of waves

In this demonstration we examine beats by creating a wave with frequency of 820 Hz in

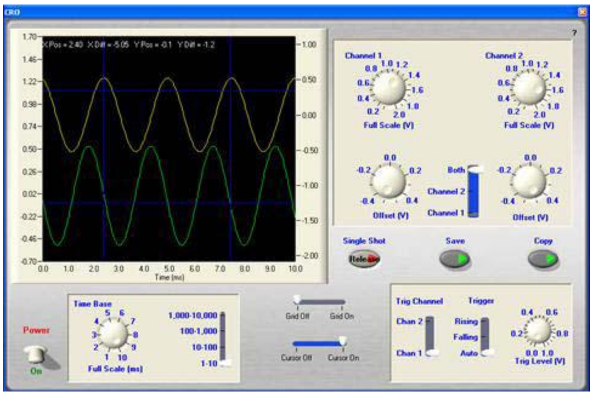
Channel 1 of the TLI WaveGen and 830 Hz in Channel 2.

By opening up the Virtual CRO in the TLI WaveGen we can see clearly the two waves and the resultant wave generated by them. We have not actually acquired the data, but simply created simulated data in this virtual CRO. This technique is great for looking at wave interference and showing our students any variation of interference pattern, but does not teach them about oscilloscopes, or how to acquire real data using an oscilloscope. The students can hear the sound created by outputting the waves to the computers speakers.



2. Using a computer based CRO to collect data
The TLI CRO uses the computer's sound card and the Line In and Microphone Inputs to actually collect, display and record data.

In this example students examine beats by creating a wave with frequency of 820 Hz in Channel 1 of the TLI WaveGen and 830 Hz in Channel 2. They record the generated waves using the TLI CRO software.



Students can view the waves in two ways:

- By taking the generated waves from the computer's speaker output and putting it directly into the computer's Line In input (see figure at right),
- Playing the signal through the computer's speakers and using a microphone to record the generated waves.

Both examples illustrate the actual collection of data and then analysis of data (measurement of frequency, period etc.) by the TLI CRO software and so the students have the experience of using a signal generator and CRO to create, record and analyse data.

By using these technologies, teachers have the opportunity to enhance their pedagogy and encourage students' interest in science.

Anti-evolution views held by students: Suggested approaches

David Blaker
Cengage Learning and Dilworth School

Aim

Teaching evolution has in recent decades become fraught with conflict, with a significant proportion of students opposed to learning anything about evolution. This position paper reviews major origins and types of this form of anti-science, and suggests ways of bridging the cultural divide. Suggestions are based on many years experience teaching secondary school biology.

Background

There is overwhelming scientific evidence for the biological evolutionary idea that humans originated from other primate ancestors. Yet about 40-50% of those polled in the USA regard evolution as a fraudulent and false idea. A similar situation exists in South Korea. In New Zealand the anti-evolution proportion is almost certainly much smaller, but the situation does contribute an ideological resistance to learning science. This resistance is mainly linked to ‘creation science’, a position held by a minority of Christians who regard every statement in the Bible as literal fact. In Britain *New Scientist* magazine indicates that the anti-evolution situation among strict Muslims may be even more acute.

’Creation science’ is strongest in the southern USA. A major reason for people’s strong belief was that in 1963 the US Supreme Court handed down a decision that prohibited prayer in public schools. Many conservative Christians saw this decision as part of an atheist-inspired attack on their culture, and mistakenly identified evolutionary science as one instigator of their problem. In response, a number of ‘creation science’ institutes and foundations have been created. These organisations – some of them very wealthy – lobby for ‘creation science’ to be placed on an equal footing with the teaching of evolution in schools. They also provide free education resources to promote their views. Their resources and websites are influencing students here in New Zealand.

Teachers should not ignore evolution just because it could become contentious in the classroom. It is specified at all levels of the revised New Zealand curriculum document (Ministry of Education, 2007). For example, the objectives at levels 3 and 4 include, “Explore how the groups of living things… have changed over long periods of time...”.

Types of creation science

Not all ‘creation science’ is equal. Young Earth Creationism [YEC] uses the book of Genesis in the Bible as evidence that Earth is only a few thousand years old, and that living things have not changed since the start. This is clearly nonsense, and YEC views are held by increasingly fewer people. Intelligent design theory [IDT] is a diluted version of YEC and is currently in vogue. In IDT, the ‘perfection’ of living things is shaped by divine purpose, not by chance mutations. IDT advocates generally use scientific uncertainty to argue that evolution is ‘just a theory’, and are evasive on the subject of the Earth’s age.

Strategies for Managing Different Ideas

The Dawkins effect

When dealing with students who are opposed to learning about evolution or the origin of humans, the worst thing a teacher can do is to respond with, “I’m right and you’re ignorant. Trust me.” This oppositional approach is central to Richard Dawkins’ 2006 book *The God Delusion*, in which he argues the case for atheism by using sarcasm and emphatic assertion, plus highly selective examples. His approach may have done much to harm science, by conforming closely to the stereotype of scientists as patronising dogmatic know-it-alls.

Dealing with difference

Many teenagers are struggling to find purpose and meaning in life, in what seems to be a chaotic and confusing world. Some of these young people attend churches that are influenced by YEC and IDT mis-information. It is unwise to dismiss such young people as brainwashed. It is surely far better to accept they are searching to find a way in life. If young ‘creation scientists’ are given a sympathetic hearing of their views and reasons, they are more likely to become open to science information they had previously resisted.

When the subject of evolution comes up, some students will very likely ask their teacher, “Which do you think is true: science or religion?” Recommended short response, “Science deals with material reality, religion deals with the human soul. Science and religion contain different kinds of truth. You don’t need to choose between them.”

This pragmatic approach was suggested by Stephen Jay Gould, a Harvard Professor of Palaeontology, and an agnostic. He describes science and religion as ‘non-overlapping magisteria’ that occupy quite different domains. In Gould’s view there are limits to what science can realistically attempt. For its brilliance, science has little or no competence to evaluate or examine beauty, music, love, or the human soul. Similarly, the author C. S. Lewis held the view that humans are part animal and part spirit.

Science excels at dealing with mechanisms and material reality, but is discovering that a mechanistic approach has limits. Advances in nuclear physics show that the universe is not only stranger than we imagine, but may be stranger than we can possibly imagine. In the words of science philosopher Karl Popper, ‘materialism has transcended itself’ in modern physics.

It is helpful – essential even – for teachers to distinguish between the ‘existence’ and the ‘mechanism’ of evolution. The reasons for distinguishing between these two aspects are that disputes about evolution mostly relate to ‘mechanism’. So it may be best start with evidence for the existence of evolution such as an ancient Earth and ongoing biological change, as the factual basis for ‘existence’ is solid. Next, deal separately with the mechanisms of evolution, in other words ‘how it works’ in terms of mutation, natural selection, genetic drift, the founder effect, and so on. Much of this is factually solid, but some aspects are less certain. For example, it may difficult or impossible to prove that mutations are truly random events. ‘Creation scientists’ seize upon uncertainties such as these, but they should be kept separate from the existence of evolution as fact.

Also, it is difficult to be dogmatic that natural selection provides a complete explanation of all of human nature. How certain are we that neo-Darwinism and evolutionary psychology provide full explanations of human complexity, imagination, creativity, art, or a Mozart piano concerto? It may be reasonable to concede such qualities are beyond science, while holding to realities such as the primate origins of humankind. In accepting that science has limits, a teacher need not weaken the teaching of evolution.

The best answer to those who say that evolution is ‘just a theory’ is to point out the word has two meanings:

- An opinion, not a fact,
- A big idea or model that explains many facts and makes good predictions such as atomic theory, evolution theory, economic theory.

This distinction can help clear up confusion.

Dealing with theology

A science classroom is not the ideal place for theological discussion, but in the context of evolution and also cosmology, it may be impossible to avoid such discussion. Not many science teachers have training or background in theology, so the following points may assist.

Firstly, many well-regarded academics experience no personal conflict between evolutionary science and their own personal faith. One good example is Francis Collins, who led the Human Genome Project and was in 2008 was appointed to head the National Science Foundation. Collins was an atheist until about the age of about 30 when he accepted the tenets of Christianity. His 2006 book *The Language of God* contains chapters on DNA, human origins and bioethics. Chapters 10 and 11 outline how he reconciles science and faith – a situation he describes as ‘biologos’, also known as theistic evolution.

Secondly, the Vatican has no quarrel with evolution. Their position seems to be that God slowly creates and adapts new species by using the mechanisms of natural selection. Their answer to YEC and IDT proponents is that, ‘If you don’t like the theory of evolution, then suggest a better scientific theory to explain the facts”.

Furthermore, some Christians insist that every statement in the Bible should be taken literally. There are several kinds of answers to this viewpoint. One is that it is wildly unlikely that the writers of the Bible ever intended to produce a science book, or even an exact history. The creation stories, like many others in the Bible, were written as metaphors intended as guides to the human condition. In addition, many parts of the Bible are totally at odds with modern thinking and Deuteronomy 20-20 is a good example. Chapters 1 and 2 of the book of Genesis give different sequences for the creation process. They can’t both be correct. While the above points are good debating points, it is important not to use them to belittle a person’s faith. Millions of people have strong religious faith that does not depend on biblical literalism.

One can counter YEC arguments with plenty of factual evidence on comparative anatomy and on the age of Earth. Emphasise that science is primarily evidence-based, not argument-based. Counter IDT arguments with factual examples on ‘bad design’ such as the retina having nerve axons in front of the light-sensitive layer, not behind or mammal lungs being much less efficient than relatively smaller bird lungs. Also, the natural world is not all beautiful and benign. As well as hummingbirds and gazelles we have nasty creatures such as parasitic worms that burrow into human eyes.

In addition, there is often a non-rational emotive reaction against being reminded that we are related to apes and monkeys. One possible response is, “Masses of evidence shows that in a bodily sense humans are descended from other mammals, but somewhere along the way we also have acquired ‘factor X’, an essential part of being human. By ‘factor X’ we mean spirit, soul, creativity, the higher mental processes.”

Also, in the view of this writer, the main issue is not scientific evidence or even the mechanisms of evolution. The main underlying problem of science-religion conflicts is concern that an atheist or nihilist agenda is being pushed. Assure students you are not trying to impose non-belief, and that most Christians have no problem with evolution.

Finally, biological evolution and natural selection are not about the origins of life – about which there is very little scientific evidence – so it may be best to avoid being drawn into arguments on how the first cells originated. Evolution is also not about big bang theory, although the BBT is fully compatible with theology.

Suggestion summary

- Be gentle with student beliefs and evolution doubts. Be sympathetic to their ‘meaning-of-life’ search, while not diluting your teaching of evolution.
- Don’t insist that students choose between faith and science; it’s a false choice and can set up needless confrontation.

- Accept that science and theology deal with different aspects of reality.
- Avoid the ‘scientists know it all’ dogmatism.

Graphs are used extensively in science or are they?

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Abstract

Graphs are tools that scientists use extensively to communicate to other scientists and the public. Graphing is an important skill that students studying science need to know but one that they find difficult. This paper will review existing relevant research and summarise the results of three studies on graphing: a) an analysis of the prevalence of graphing content in NZ textbooks; b) an analysis of the prevalence of graphing questions on NCEA Level 1 exams, and; c) teacher classroom coverage of graphing in science in Years 9-11 in New Zealand. I will also present suggestions and the direction of my future research in teaching this skill.

Background

Graphs are spatial aids (Moore, 1993) or graphic representations (Schnotz, 1993) that are used extensively by scientists to present scientific data in a concise manner, to show patterns and relationships in data collected and to aid in the analysis of scientific data (Roth, Bowen & McGinn, 1999; Shah & Hoeffner, 2002). Graphs summarise data while still showing detail (Beichner, 1994). Graphs are used extensively in scientific articles, particularly in biology but are found less frequently in science textbooks (Roth et al.). Learning graphing skills is an important aspect of scientific literacy (Shah & Hoeffner; Ates & Stevens, 2003). Graphing skills include both construction and interpretation (Leinhardt, Zaslavsky, & Stein, 1990). Of these two sub-skills, students find interpretation the most difficult (Leinhardt, et al.). in terms of construction, they find scales on the axes the most difficult (Forster, 2004).

Research in classrooms has highlighted a number of difficulties that students experience when both constructing and interpreting graphs in science (Biechner, 1994; Berg & Phillips, 1994; Shah & Carpenter, 1995; Roth et al., 1999; Shah & Hoeffner, 2002). These difficulties can affect achievement in science as students perform lower than expected on graphing questions (Roth & McGinn, 1998; Woolnough, 1998; Forster, 2004). Interpretation and construction of graphs is an important skill in physics which has been found to significantly influence performance in physics (Forster).

A suggested reason for students' lower levels of achievement in graphing related tasks and disciplines is the lack of time spent on teaching and practice of graphing skills in science classrooms (Shah & Hoeffner, 2002; Reeder & Moseley, 2006). Effective teaching and practice of graphing skills can have a positive effect on improving graphing skills in science students (Phillips, 1997; Shah & Hoeffner; Ates & Stevens, 2003; Reeder & Moseley, 2006). When considering total time spent on teaching graphing skills it is important to note that students do not often transfer skills from mathematics teaching on graphing to graphing in science (Roth et al., 1999).

Based on the reported difficulties students have and the importance of graphing in science, particularly in physics, a preliminary study of graphing skills was conducted to determine firstly, the amount of space given to graphs in textbooks; secondly, the number of graphs in NCEA level one science exams and; thirdly, the amount of time teachers spend on graphing.

The results of these preliminary studies of graphing skills will be used as justification for an intervention study that includes teaching the skill of graph interpretation when introducing the topic of speed-time and distance-time graphs in the Science Achievement Standard 1.1 at Year 11. It is hoped that explicit teaching on graphing, the use of visuals and reducing cognitive load will enhance the learning of complex ideas in the topic of motion in physics.

Method – Preliminary studies

Study One: Textbook analysis

Sixteen textbooks were analysed in detail and all graphs were recorded in terms of size, topic and type of graph (part of teaching about graphing or practise of graphing skills). These were Years 9-11 textbooks from the main publishers and most were written for *The New Zealand Curriculum* (Ministry of Education, 2007).

Study Two: NCEA Level 1 Science Exam Analysis

Twenty-four NCEA Level 1 papers were analysed in terms of the number of graphs, size and type of question (Achieved, Merit or Excellence questions) from 8 years, 2004 – 2011. Only the 3 main topics of biology, chemistry and physics were included. For the years 2004 - 2010 these were Achievement Standards 90191, 90188 and 90190, and for 2011 90940, 90944 and 90948 (AS 1.1, 1.5 and 1.9 respectively).

Study Three: Time spent on graphing skills in Years 9-11

A questionnaire was distributed to teachers at 51 secondary schools in Northland and Auckland. The questionnaire included questions aimed at determining the time spent on graphing in Years 9, 10 and 11 per topic. The skill of graphing was divided into teaching and practice, construction and interpretation. The targetted schools included a range of decile rankings from 1 to 10 and also included Catholic integrated schools, single sex schools, private schools and co-educational schools.
The questionnaire contained six questions which included completing three charts (Questions 1-3), answering multi-choice questions with two short responses for why (Question 4), adding ticks to a charts for Achievement Standards taught in a core science class at the school (Question 5) and selecting from a list of possible strategies used for teaching graphing (Question 6). Question 7 was for optional comments.

Findings

Study One: Textbook analysis (n=16)

Only a small percentage of pages within the textbooks contained graphs (8%). None of the graphs took up a whole page. Consequently, when the average amount of space over the 16 textbooks was calculated, the total percentage space allocated to graphs per textbook was 1.23%. Ninety percent of the graphs were less than 1/8th of a page. Fifty-nine percent of the graphs were devoted to practice of graphing skills and formed part of questions that required students to use their knowledge of graphing in answering the questions. Consequently, they were not in text that focused on the teaching of graphing skills. It was also found that most of the graphs were in physics and biology topics (26% and 27% respectively). When searching through the textbooks for graphs, it was found that on average there were 17.36 pages between one page containing a graph and the next page containing a graph. The total range was from 5.78 to 45 pages between graphs. Finally, only two of the textbooks had dedicated sections concerning the teaching of graphing skills.

Study Two: NCEA Level 1 Science Exam Analysis (n=24)
When all 24 papers were analysed, that is eight for each topic of biology, chemistry and physics, it was found that no biology papers contained a graph, only one chemistry paper contained a graph but all physics papers contained at least one graph. In these physics papers, all mechanics questions contained a graph and most graphs were merit or excellence questions.

Study Three: Time spent on graphing skills in Years 9-11 (n=51)
The analysis of the questionnaire is not yet complete. The preliminary findings indicate that lower decile schools report that their students find graphing more difficult than higher decile schools and that physics appears to be the most popular topic for teaching graphing skills.

The amount of time spent on graphing seems to increase at Year 11, especially for studying Achievement Standard 90940 (Science 1.1 – Demonstrate understanding of aspects of mechanics). While there is a large range of time spent on teaching graphing reported by different schools, compared to the total time available for teaching science over the whole year, only a small percentage is allocated to the development of these skills. Most respondents indicated that time spent on graph construction and interpretation was not adequate for teaching these skills. When asked, “Do you think that students would benefit from more time spent on graphing”? and, “Do you think that students would benefit from more time spent on graph interpretation?”, 80% responded with a yes. The open-ended written responses to “Why?” elicited responses such as, “... *science needs more time to teach numeracy skills.*” or, *“... they are vital skills that are needed for science particularly investigations.*” and, *“... for something so important we don’t seem to spend a lot of time on it*.” Teachers also indicated that they do not use textbooks extensively for teaching graphing skills.

Discussion

In terms of the textbook analysis, there is considerable variation between the use of graphs in different books. The lack of content devoted to graphs may be a reason that teachers reported that they do not often use textbooks for teaching graphing skills. In addition, the high incidence of graphs in biology topics in textbooks does not match the frequency of graphing questions in the external NCEA exams for biology.

The lack of graph construction or interpretation questions in NCEA Level 1 biology and chemistry does not match the frequency of graphs used by scientists when communicating their work. As part of the Nature of Science strand “Understanding science” and “Communicating in science” in *The New Zealand Curriculum* (Ministry of Education, 2007) graphing is an important skill that scientists use and so the lack of graphs in external exams seems to be a lack of alignment with the curriculum document. It is also interesting to note that the word graph does not appear in any of the Achievement Objectives or Aims in the science sections of New Zealand’s national curriculum document.

Overall, there seems to be a discrepancy between the importance scientists and researchers place on graphing and the space allocated to graphs in textbooks, in external exams and the reported time science teachers spend on the teaching and practice of graphing skills in Years 9-11 science. As graphing is an important part of scientific literacy which is the goal of science teaching, especially for those students that do not choose to continue to study science after Year 10, it seems that graphing and the complexity of teaching graphing has been somewhat overlooked. It may be that the lack of graphs in the Year 11 NCEA external exams has reduced the perceived importance of teaching graphing skills.

This preliminary analysis of the teacher questionnaire as well as as the analysis of science textbooks suggest that investigating the efficacy of instructional graphing interventions is worthwhile within the current NZ science classroom. Given that graphing is a complex skill, that time spent on graphing skills is limited both in terms of textbook and teaching coverage, and it is an important skill for learning and communicating about science especially physics, it is critical that the effects of targetted instructional interventions on development of graphing skills be assessed. Current cognitive instructional theory and research, that is cognitive load theory, which has focused on the teaching of complex information will be employed as a vehicle for the development of a targetted graphing intervention.

Using the findings

Using these preliminary findings, an intervention study will be designed. The intervention study aims to investigate the use of pre-training as a strategy to help students in science to learn complex information. Information that is complex has many interacting elements that need to be held simultaneously in our cognitive processing system in order to understand it. These elements have the potential to overload the system and hinder further processing which can affect understanding and learning. The main theories underpinning this strategy are cognitive load theory (Sweller, 2005; Sweller, Paas & van Merrienboer, 1998) and the cognitive theory of multimedia learning (Mayer 2001; 2005).

Cognitive load theory is primarily concerned with the impact of performing a particular task on the human cognitive processing system (cognitive load) and the design of instructional materials to facilitate understanding and learning. Instructional methods are suggested which reduce the cognitive load of processing information which could potentially overload the cognitive processing system.

The cognitive theory of multimedia learning (Mayer 2001; 2005) is concerned with the use of words and pictures to promote meaningful learning. This theory promotes the integrated use of words and pictures to reduce the cognitive load of learning complex information by utilising two different channels of our cognitive processing system to make sense of incoming information.

Pre-training is a strategy where complex information is presented in two stages to reduce the number of elements which need to be processed at any one time (Mayer & Moreno, 2003). This strategy is also referred to as the isolated element strategy (Pollock, Chandler & Sweller, 2002). By introducing the intellectually demanding information in a two stage process the load on the cognitive processing system is reduced. In stage one preliminary ideas are introduced without full understanding of all the information which has the effect of artificially reducing the complexity (Pollock, Chandler & Sweller, 2002) and providing learners with prior knowledge which they can use to make sense of the complex information when it is introduced as a whole in stage two (Mayer & Moreno 2003). Mayer & Moreno (2003) also refer to this stratgey as building a component model of a system in stage one, and then a causal model of the system in stage two.

Therefore, the following research question has potential to guide my doctoral research:
Can pre-training reduce the potential cognitive overload for high school students when learning complex science information like graphing skills?

References

Ates, S. & Stevens, J. T. (2003). Teaching line graphs to tenth grade students having different cognitive development levels by using two different instructional modules. *Research in Science and Technological Education*, 21(1), 55-66.

Beichner, R.J. (1994). Testing student interpretation of kinematics graphs. *American Journal of Physics,* 62(8), 750-762.

Berg, C.A. & Phillips, D.G. (1994). An investigation of the relationship between logical thinking stuctures and the ability to construct and interpret line graphs. *Journal of Research in Science Teaching*, 31(4), 323-344.

Forster, P.A. (2004). Graphing in physics: Processes and sources of Error in tertiary entrance examinations in Western Australia. *Research in Science Education* 34, 239-265.

Leinhardt, G., Zaslavsky, O. & Stein, M.K. (1990). Functions, graphs, and graphing: Tasks, learning, and teaching. *Review of Educational Research*, 60(1), 1-64.

Mayer, R. E. (2001). *Multimedia learning*. New York, NY: Cambridge University Press.

Mayer, R. E. (2005). Cognitive theory of multimedia learning. In R.E. Mayer (Ed.), *Cambridge handbook of multimedia learning* (pp. 31-48). New York, NY: Cambridge University Press.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, *38*, 43-52.

Ministry of Education, (2007). *The New Zealand curriculum*. Wellington, New Zealand: Learning Media.

Moore, P.J. (1993). Metacognitive processing of diagrams, maps and graphs. *Learning and Instruction*, 3, 215-226.

Schnotz, W. (1993). Introduction. *Learning and Instruction*, 3, 151-155.

Phillips, R.J. (1997). Can juniors read graphs? A review and anlaysis of some computer-based activities. *Journal of Information Technology for Teacher Education,* 6(1), 49-58.

Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning and Instruction, 12, 61-86.*

Reeder, S. & Moseley, C. (2006). Predator and prey relationships: Students make natural connections through the integration of mathematics and science. *Science Activities*, 43(3), 9-14.

Roth, W.-M. & McGinn, M.K. (1998). Inscriptions: toward a theory of presenting social practice. *Review of Educational Research*, 68, 35-59.

Roth, W.-M., Bowen, G.M., & McGinn, M.K. (1999). Differences in graph-related practices between high school biology textbooks and scientific ecology journals. *Journal on Research in Science Teaching*, 36(9), 977-1019.

Shah, P., & Carpenter, P.A. (1995). Conceptual limitations in comprehending line graphs. *Journal of Experimental Psychology General*, 124, 43-61.

Shah, P. & Hoeffner, J. (2002). Review of graph comprehension research: Implications for instruction. *Educational Psychology Review*, 14(1), 47-69.

Sweller, J. (2005). Cognitive theory of multimedia learning. In R.E. Mayer (Ed.), *Cambridge handbook of multimedia learning* (pp.19-30). New York, NY: Cambridge University Press.

Sweller, J., Van Merrienboer, J., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10,* 251-296.

Woolnough, J. (1998). How do students learn to apply their mathematical knowledge to interpret graphs in physics? *Research in Science Education*, 30(3), 259-267.

Truth and science education

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Abstract

Sceptics, relativists and other deniers of truth do science a great injustice. Timid science teachers – who fear the consequences if they lay claim to truth – do the discipline of science a great wrong. The root of the difficulty is a lack of understanding about the nature of science. Constructivist theories of science, which are hegemonic in Western education, inevitably undervalue science. Science disappears as another culture. To penetrate the nature of science you must grapple with truth. This paper uses Newton's engagement with optics as an example to show what modern science is in and of itself. It distinguishes modern science from other forms of enquiry and suggests how the science curriculum might be reformed to restore modern science to its rightful place in Western education.

Introduction

Given the alleged importance of science as a driver of economic growth, student apathy in Western nations appears unpatriotic. Science blossomed sometime after the Second World War and has been wilting ever more noticeably for at least the last thirty years. It is not just the students who are blamed for the statistics. In New Zealand, secondary school science teachers traditionally take the criticism. Over the last five years, science learning at primary school level has also become a concern and it is primary school teachers who are currently found wanting. In 2012 it became the school principals' turn to appear as the culprits. A Government official's report states that:

> *Few principals and teachers demonstrated an understanding of how they could integrate the National Standards in reading, writing and mathematics into their science programmes. In the less effective schools principals saw science learning as a low priority. They struggled to maintain a balance between effective literacy and numeracy teaching, and providing sufficient time for teaching other curriculum areas.* (Chief Review Officer, 2012)

Science education is unlikely to advance when teachers are asked to relate one thing about which they are unclear (national standards) to another thing about which they are confused (science). There is no shame in being unclear or confused for the concepts at issue are essentially contested and attempts at stipulative definitions as the foundation of policy are bound to fail. Philosophers of education struggle to define and justify curricula and philosophers of science find the nature of science a challenge. The belief that we can advance science education through the imposition of stipulative definitions is a remnant of the managerialism (an expression of neo-liberalism) which entered New Zealand schooling twenty or so years ago (Devine, 2003; Fitzsimons, 2002).

It is not only governments that have distracted us from the abiding nature of science. The philosophy of science for much of its short history has focussed our attention on that which is of lesser importance. It is not necessary to linger here on the contributions of positivists and constructivists. Few of the important theorists in these traditions dwelt on the implications of their theorising for science education. The contrast between the leading traditions in the philosophy of science was explicated in a pivotal conference that was held in the late 1960s (Suppe, 1974). That conference marks the transition from theories which render science as predominantly about disembodied, abstract scientific theory and theories that hold that human beings are essential to any account of science. From the 1970s onward the latter accounts gained favour, particularly those which asserted that science is a human construct akin to our constructs of culture. This still appeals to some school teachers because of the affinity that is established between science and some theories of learning.

Progress may be made on the many issues extant in the context of science in Western nations – research and education – if we attend to the essential nature of science. In this enterprise we align ourselves with those who produce modern science for us, people such as Descartes, Galileo, Newton, and Einstein. All these scientist/philosophers struggled with notions of truth and reality. Modern science today is still about notions of truth and reality, but you would not know it by reading science textbooks and websites.

The purpose of this paper is to introduce the concept of truth and show how that is essential to an understanding of modern science. The concept of truth enables us to distinguish between the three schools of thought regarding the nature of science. They are the schools of thought in the philosophy of science and two of these are well known in schools – positivism and constructivism. The third school of thought – the hermeneutic philosophy of science – is (in my experience at least) less well known to science teachers but it is the most convincing account of modern science. The paper introduces two concepts of truth and shows how they are involved in the practice of science. Isaac Newton provided us with examples of the practice of science and deliberations about truth. Newton’s work on optics – nothing less than the foundation of modern optics – explicates truth. There is earlier work on this topic in relation to the practice of teaching (Shaw, 2010, 2012).

Truth

Researchers and teachers alike forget that *modern science* began in a struggle to discern truth. Galileo and Newton, as well as Heisenberg and Einstein, were consumed in the struggle about truth. Einstein in his famous 1935 essay, *The World As I See It*, nominates ‘truth’ as an ideal that “lit” his way (Einstein, 1954, p. 9). What is truth? There are libraries of responses to this question, but for the purposes of pedagogy we need to distinguish only two schools of thought. The first holds that truth is essentially located in propositions (sentences, statements, laws, or algorithms). There are many elaborations of such theories but here they are grouped under the heading “correspondence theories”. The second are those theories of truth that locate truth in human experience or the “events”. The event of truth is the moment some insight stuns you.

The positivists’ account: truth as correspondence

Positivist accounts of science emphasise sets of highly general universal statements (laws) whose truth or falsity is assessed by means of systematic observation and experiment. Laws achieve a double function: they are the explanation of things past and the predictors of things to come. Greatly associated with this broad approach to science are Peter Hempel and Carl Popper.

Scientific systematization is ultimately aimed at establishing explanatory and predictive order among the bewilderingly complex ‘data’ of our experience, the phenomena that can be ‘directly observed’ by us. It is a remarkable fact, therefore, that the greatest advances in scientific systematization have not been accomplished by means of laws referring explicitly to *observables*, i.e. to things and events which are ascertainable by direct observation, but rather by means of laws that speak of various *hypothetical*, or *theoretical entities*, i.e. presumptive objects, events, and attributes which cannot be perceived or otherwise directly observed by us. (Original reprinted in Hempel, 1965, p. 177). Hempel problematizes theoretical entities, but even more importantly for our present purpose, he captures the intrinsic nature of truth in science. Truth is established in the relationship between *observables* and laws. Theoretical entities are remarkable because they do not display this relationship. Elsewhere in the same collection, Hempel develops his idea that theoretical terms are “*essentially quantified variables*” and thus meet the fundamental requirement of science, namely that a theory is able to “*predicate truth or falsity*” (Hempel, 1965, p. 217).

Scientific theories or laws adhere to nature and the more closely they reflect nature the more we approve of them. It is difficult to improve on the expression which the American philosopher Richard Rorty made popular through its use in the title of his book. Science is the *mirror of nature* (Rorty, 1979). Representational theories of perception and correspondence theories of truth upset Rorty. We do not need a notion of truth at all! Rorty knew well that there are various ways to characterise the relationship between scientific laws and human observation. They are catalogued by Aquinas. In all such accounts the proposition, statement, sentence, or equation is the foundation of science. It is in laws that the relationship between science and reality is defined.

In these accounts of truth, truth is located in an agreement, or correspondence, between reality and mental or linguistic representations. The agreement we access through propositions, sentences, algorithms, or assertions. For example, correspondence is apparent in “the sky is blue” (a relationship between “the sky” and “blue”), “blue is a colour” (a relationship between “blue” and a concept, namely “colour”), and “2+2=4” (relationships between abstract concepts). The German philosopher Martin Heidegger dubs correspondence theories of truth the “traditional” and “usual” concepts of truth and he considers their exposition in ancient and scholastic philosophy (Heidegger, 1927/1962, p. 257; 2002, p. 6; 2007, p. 280). Heidegger finds such accounts of truth undoubtedly meaningful and observes that there are many renditions of the correspondence theory of truth. The generic word Heidegger prefers to refer to this form of truth is the Latin *adaequatio*, because it indicates “similarity” which implies a human judgement that involves an equation whilst remaining silent on the content of the equations or judgement. This is the leading account of truth which appears in Hempel’s philosophy of science.

The constructivists’ account: elaborated truth

If truth is the focus of our attention, it is a relatively small step from positivism to constructivism. However, truth is but one aspect of discussions about constructivism and the epistemological foundations of constructivist accounts of both learning and science have been found wanting (Gould, 2003; Matthews, 1997, 1998; Nola, 1997, 2004; Small, 2003). One way to begin a comparison of positivism and constructivism is to reflect that the positivists have a strong belief in the reality of nature whilst the constructivists dispute all formulations of ‘ideal states’. Thus, that between which there will be correspondence is different for positivists and constructivists. For the constructivists the conceptual and cultural context of science is highly relevant. Experience is constructed and the experience that we call ‘science’ is just one experience amongst many. Context is a construction and science is a human construct from a particular context. This being the situation, constructionists often assert that all science (sciences) stand equal in a fundamental way. Egyptian science, Greek science, Māori Science and modern science are all meritorious as expressions or outcomes from their socio-linguistic foundations and they deserve respect.

In constructivism the pre-eminence of assertions, which has already been alluded to in relation to positivism, holds, but now there is also some emphasis on the relevance of she who asserts. Kant’s preoccupations concerning the nature of modern science (Kuehn, 2001; Lefèvre, 2001; Lefèvre & Wunderlich, 2001) come to the fore: what is there about human beings that they can gain such profound access to the truths of nature? How can Newton – the human mind – have such unimagined insights into nature? For many people these had previously been insights only available to God. What is the nature of human beings’ new penetration and what might be its limits?

The hermeneutic account: truth as the event/disclosure of nature

The term “hermeneutics” (roughly it means “interpretation”) need not concern us here except to notice that the word appears in the expression ‘the hermeneutic philosophy of science’. It is this philosophy of science which privileges truth. The formation of truth which it privileges is truth as disclosure or truth in an event. A word of caution is appropriate here: the hermeneutic philosophy of science appears as two traditions, one that derives from Heidegger’s work on truth and another which derives from Gadamer. The present paper is concerned with the former. The latter is most developed in science education by Martin Eger (Eger, 1989, 1992, 1997).

Truth, as an *event* of *modern science* – as an involvement of a human being, technology and nature – was a preoccupation for Isaac Newton, as it was for others at the birth of modern science. Newton, however, did not produce a philosophy of science that privileged the event of science. Nevertheless, his practical work in optics and what he wrote indicate that he was reaching for what we would today call a hermeneutic philosophy of science. The breakthrough in understanding science as an accumulation of the forced disclosures of nature occurred hundreds of years later in the work of the German philosopher Martin Heidegger (Babich, 1995; Kockelmans, 1985).

Twenty-two-year-old Isaac Newton – in 1664 – at Trinity College, Cambridge, headed his notebook "*Questiones quædam Philosophiæ*" (Certain philosophical questions). Above the title he wrote "*Amicus Plato amicus Aristoteles magis amica veritas*" (Plato and Aristotle are my friends, but truth is a better friend). He borrowed the expression from the English natural philosopher Walter Charleton (Cambridge University Library, 2002; Newton, 1664-65, folio 1; Tarán, 2001, p. 4 & p.12). The slogan means that truth stands superior to the teachings of any human teacher. Thus, truth is independent of human assertion – truth is not to be found in correspondence arrangements that involve other people. The role of truth in Newton's philosophy of science is apparent in his *Opticks*, of which the historian of science Cohen says it is the "… *most comprehensive public statement he ever made of his philosophy of science or his conception of the experimental scientific method.*" (Cohen & Westfall, 1995, p. 127; Newton, 1999). The period of relevant work is that subsequent to his 1672 paper on colours (sent to Oldenburg), and it is a time that "tells us less about optics than about Newton" who for "… *eight years ... had locked himself in a remorseless struggle with Truth,*", eight years of *"… uneaten meals and sleepless nights ... of continued ecstasy as he faced Truth directly on grounds hitherto unknown to the human spirit …"* (Westfall, 1980, p. 238 & p.239). Newton's practical engagement with truth did not achieve for him a hermeneutic philosophy of science – nevertheless, it set others on that pathway.

What occurred that established truth in Newton's work on optics? Where do we locate disclosed truth, truth as the event, in Newton's demonstration with a light beam, a prism, and a screen? Newton begins his account of the demonstration, "*I procured me a Triangular glass-Prisme, to try therewith the celebrated Phænomena of Colours.*" (Newton, 1671/2, pp. 3075-3076). Consider the situation as it is for Newton and for our students today. Newton and the students must darken the chamber/laboratory and have a "small hole" in the window/screen. The light from the sun/lamp passes through the hole, and falls on a wall/screen. Newton and the students force reality/nature to reveal itself.

It is germane that Newton's account of what occurs is personal. He does not record dry 'findings' or 'results' until later in his letter to the Royal Society – initially he writes of his excitement and perplexity. Of the refracted image on the wall he says in his first paragraph, "*I became surprised to see them in an oblong form; which, according to the received laws of Refraction, I expected should have been circular.*" This is the report of his experience of truth. What was to be round was a rectangle. Nature knows right angles! Students may achieve exactly the same abidance with nature that Newton achieved, and indeed they do in many school laboratories. Elation is a good indicator of disclosed truth. So is certainty. When you observe something that is stunning, distinctly personal, emphatic and incontrovertible, you abide with truth.

Once Newton, or the student, develops work habits and skills with light, prisms, and observation, he achieves a situation where the instrument, the procedure (including prediction and measurement), *and the disclosure* constitute a single embodiment. In experimentation the context of disclosed truth is always apparent:

> *… experimentation in the fullest sense involves the possibility of a human subject embodying himself in instrumentation not only for the purposes of observation, but also to create that context, physical and noetic, which is the condition of possibility for the scientific object to manifest itself in observation.* (Heelan, 1977, p. 34).

The scientific objects (disclosed truths) that Heelan refers to are achieved in science education though demonstrations. Demonstrations perpetuate modern science. Students do not enter into scientific truths when they develop and test their own hypotheses. Because demonstrations – and not student-inspired experiments – are essential to the continuation of the disciplines of science, it is impossible to overestimate the importance of the science teacher in the perpetuation of scientific truth. It is through their own involvement with phenomena that students abide with the essence of science. To reiterate: in science education the event of truth occurs within a demonstration.

The implications for science teachers

We should not blame governments or teachers for the current preoccupation with the utility of science. Galileo and Newton began that line of thought. Galileo did not go south to introduce government and church officials to the wonders of truth or even the truth within optics. He announced that he had the means to provide advanced warning when ships were to attack from the sea. Likewise, Newton's great work on optics begins by saying in detail what the problems are that confront instrument makers and how he can assist them. He does not feature the engagement with truth that he achieved decades earlier at Woolsthorpe Manor. From the outset, modern scientists have emphasised to officials and the public the utility of science. Unfortunately, this ready pitch has the effect of hiding from us what is essential to science itself. We focus attention on the wrong things.

This misdirection makes science teaching difficult. The personal nature of science is hidden; the individualised, private experience of truth has but a minor place in science education. The drudgery sets in when the correspondence theory of truth gets a grip on science teaching. Teaching towards examinations, as such actually undermines science. Without the personal experience of truth as disclosure, without the experience of forcing nature to reveal more of itself, the student cannot grasp what science actually is in itself. To the student the whole discipline seems a bit pointless apart from the possibility of employment in industry and national prosperity.

External motivations flag, somehow employment and prosperity are uncertain and well into the future.

The implications for curriculum are clear. Teachers must not render ‘the nature of science’ as the sociality of science, the psychology of science, the economics of science, science and society, the utility of science, the joy of science or scientific entrepreneurship. These things have their place in the curriculum but there is a prior call upon the science teachers’ time – science itself. The challenge is to have each student experience modern science: this means each student must use technology to force nature to reveal more of itself and to contemplate what it means that they can achieve the truths of modern science. Students can experience truth as Galileo and as Newton experienced truth.

References

Babich, Babette E. (1995). Heidegger's Philosophy of Science: Calculation, Thought, and Gelassenheit. In Babette E. Babich (Ed.), *From Phenomenology to Thought, Errancy, and Desire* (pp. 589-599). Dordrecht: Kluwer.

Cambridge University Library. (2002). Footprints of the Lion: Isaac Newton at work Retrieved 5 May, 2009, 2009, from http://www.lib.cam.ac.uk/Exhibitions/Footprints_of_the_Lion/learning.html

Chief Review Officer. (2012). *Science in The New Zealand Curriculum: Years 5 to 8*. Wellington: Education Review Office, New Zealand Government.

Cohen, I. Bernard, & Westfall, Richard S (Eds.). (1995). *Newton: texts, backgrounds, commentaries*. New York: Norton.

Devine, Nesta. (2003). Politicising technology and technologising politics. *Access : Critical Perspectives on Communication, Cultural and Policy Studies, 22*(1/2), 67-72.

Eger, Martin. (1989). The ‘Interests’ of science and the problems of education. *Synthese, 80*(1), 81-106.

Eger, Martin. (1992). Hermeneutics and science education: An introduction. *Science & Education, 1*(4), 337-348.

Eger, Martin. (1997). Achievements of the hermeneutic-phenomenological approach to natural science A comparison with constructivist sociology. *Man and World, 30*(3), 343-367.

Einstein, Albert. (1954). *Ideas and opinions. Based on Mein Weltbild* (Sonja Bargmann, Trans.). New York: Crown Publishers.

Fitzsimons, Patrick. (2002). Neoliberalism and education: the autonomous chooser. *Radical Pedagogy* Retrieved 8 November 2002, from http://radicalpedagogy.icaap.org/content/issue4_2/04_fitzsimons.html

Gould, Carol C. (2003). *Constructivism and practice : toward a historical epistemology*. Lanham, Md.: Rowman & Littlefield Publishers.

Heelan, Patrick A. (1977). Hermeneutics of experimental science. In Don Ihde & Richard M Zaner (Eds.), *Interdisciplinary phenomenology* (pp. 7-50). The Hague: M. Nijhoff.

Heidegger, Martin. (1927/1962). *Being and time* (John Macquarrie & Edward Robinson, Trans.). Oxford: Blackwell.

Heidegger, Martin. (2002). *The essence of truth: on Plato's cave allegory and Theaetetus* (Ted Sadler, Trans.). New York: Continuum.

Heidegger, Martin. (2007). On the essence of truth (Pentecost Monday, 1926) (Theodore J. Kisiel, Trans.). In Theodore J. Kisiel & Thomas Sheehan (Eds.), *Becoming Heidegger: on the trail of his early occasional writings, 1910-1927* (pp. 275-288). Evanston, Ill.: Northwestern University Press.

Hempel, Carl G. (1965). *Aspects of scientific explanation, and other essays in the philosophy of science*. New York: Free Press.

Kockelmans, Joseph J. (1985). *Heidegger and science*. Washington, D.C.: University Press of America.

Kuehn, Manfred. (2001). *Kant: a biography*. New York: Cambridge University Press.

Lefèvre, Wolfgang. (2001). *Between Leibniz, Newton, and Kant: philosophy and science in the eighteenth century*. Dordrecht-Boston: Kluwer Academic Publishers.

Lefèvre, Wolfgang, & Wunderlich, Falk. (2001). The concepts of Immanuel Kant's natural philosophy (1747-1780). In Wolfgang Lefèvre (Ed.), *Between Leibniz, Newton, and Kant: philosophy and science in the eighteenth century* (pp. 267-281). Dordrecht-Boston: Kluwer Academic Publishers.

Matthews, Michael R. (1997). A Bibliography for Philosophy and Constructivism in Science Education. *Science & Education,* 6(1), 197-201.

Matthews, Michael R. (Ed.). (1998). *Constructivism in science education: a philosophical examination*. Dordrecht: Kluwer.

Newton, Isaac. (1664-65). Questiones quædam philosophiæ (Certain Philosophical Questions) (Additional Ms. 3996 Cambridge: Cambridge University Library). *The Newton Project*. Retrieved from http://www.newtonproject.sussex.ac.uk

Newton, Isaac. (1671/2). A Letter of Mr. Isaac Newton, Professor of the Mathematicks in the University of Cambridge; containing his New Theory about Light and Colors. *Philosophical Transactions of the Royal Society 80*, 3075-3087. Retrieved from http://www.newtonproject.sussex.ac.uk

Newton, Isaac. (1999). *The Principia: mathematical principles of natural philosophy*. Berkeley: University of California Press.

Nola, Robert. (1997). Constructivism in science and science education: A philosophical critique. *Science & Education, 6*(1), 55-83.

Nola, Robert. (2004). Pendula, Models, Constructivism and Reality. *Science & Education, 13*(4), 349-377.

Rorty, Richard. (1979). *Philosophy and the mirror of nature*. Princeton: Princeton University Press.

Shaw, Robert Keith. (2010). *Truth and physics education: a Heideggerian analysis.* The University of Auckland, Auckland. Retrieved from http://hdl.handle.net/2292/6051

Shaw, Robert Keith. (2012). The Implications for Science Education of Heidegger's Philosophy of Science. *Educational Philosophy & Theory*, 1-12. Retrieved from doi:10.1111/j.1469-5812.2011.00836.x

Small, Robin. (2003). A Fallacy in Constructivist Epistemology. *Journal of the Philosophy of Education, 37*(3), 483-502.

Suppe, Frederick. (1974). *The structure of scientific theories*. Urbana: University of Illinois Press.

Tarán, Leonardo. (2001). *Collected papers, 1962-1999*. Leiden: Brill.

Westfall, Richard S. (1980). *Never at rest: a biography of Isaac Newton*. Cambridge: Cambridge University Press.