Teaching science: Changes to teaching strategies through incorporating on-line resources

Associate Professor Lindsey Conner and Dr Chris Astall

College of Education, University of Canterbury, Christchurch, New Zealand

Paper presented at the ESERA conference, Istanbul, 31st August- 4th Sept, 2009

Abstract

At a time when student interest in science needs boosting and when a new school curriculum mandates a focus on the nature of science, we report on changes in teachers' understanding of the nature of science following intervention workshops and experience of the science learning hub website. The qualitative and quantitative methods for the research included questionnaires, interviews, observations and written evidence of planning junior science units of work to include a range of multimedia resources. We make recommendations for future research projects associated with the use of the SLH and how these influence student learning.

Introduction

Science teaching in New Zealand

The revision and development of the national curriculum for New Zealand has resulted in the *New Zealand Curriculum* (Ministry of Education, 2007). This latest curriculum encourages schools to adapt their teaching and learning programmes to their local needs. It also places emphasis on making links between curriculum areas through learning that utilises multiple sources of knowledge (McGee & Fraser, 2008). In New Zealand schools, teachers have a high degree of professional freedom to design their own teaching materials and pick and choose resources and to incorporate them as they see fit. There are no prescribed teaching programmes but rather the *New Zealand Curriculum* (NZC) is very open-ended with broad objectives. The science learning strand within the curriculum pays specific attention to the 'nature of science' (NOS). The contexts for developing ideas about NOS are derived from the four strands, or 'worlds': *The Living World, The Material World, The Physical World and Planet Earth and Beyond* . This means that teachers are now required to start thinking how they can incorporate aspects of NOS and what that might mean for their teaching and student learning.

Attitudes about science

A number of recent studies have clearly shown a decline in positive attitudes towards science from young children internationally (Lewthwaite & Fisher, 2004; Porter & Parvin, 2008) and in New Zealand (Crooks *et al.* 2008). There is also a growing concern that many school students are not choosing science subjects and are not continuing their science education into tertiary education (RACI, 2005; Rodrigues *et al.* 2007; Trefil, 2008). This has led to international calls for governments to take heed and consider what changes need to be made or what initiatives could be put in place to promote and enthuse students to engage in science education (UNESCO, 2007).

Additionally, the purposes of science education are extending beyond conveying knowledge about science content and training people for careers in science, to include promoting inquiry as a way of thinking and learning about the world and promoting education for responsible citizenry (Holbrook & Rannikmae, 2007). To address these needs and concerns the New Zealand Ministry of Research in Science and Technology funded the development of an interactive website (www.sciencelearn.org.nz) to connect New Zealand science research to teachers and students in schools.

The use of multimedia in instructional design

In a research sense, we are only just beginning to document how instructional design and the use of multimedia can promote learning. Multimedia instruction, as defined by Mayer (2009), is based on the presentation of material which utilises verbal and pictorial representations with the intention of promoting learning i.e. learning from words and pictures. In particular, there is growing evidence that human understanding can be enhanced through the use of multimedia (Mayer, 2009). Instructional technology strategies to enhance learning may include computer simulations, models, video, interactives or digital objects and other multimedia materials (Schroeder *et al*., 2007). The SLH provides multiple examples of a wide range of digital resources and provides some guidelines for teachers as to how they can include them. Studies have shown that when students are supported to learn through using websites and multiple digital media, they can increase their awareness of the relevance of science to daily life, learn enquiry skills and their attitudes towards learning science are more positive (Gaskill, McNulty, & Brooks, 2006; Kay & Knaack, 2007; Williams, Linn, & Hollowell, 2008). Additionally students who have taken part in innovative web interventions have been shown to have a better understanding of the topics covered than students who had not used the web sources. For example, Donovan & Nakhleh (2007) showed how digital representations helped students to visualise chemistry concepts and the links between them.

Wang and Reeves (2006) conducted a study on the use of a Web-LE tool that was used to motivate unmotivated students to learn about the processes of fossilisation. The Web-LE tool included elements designed to stimulate students' curiosity, self-monitoring, challenge and fantasy, as these were considered to enhance intrinsic motivation. Interviews and observations indicated that students felt they had control and a sense of responsibility for their own learning so were motivated to complete the assignment. The curiosity factor was met by the inclusion of tasks that were beyond the scope of the assignment (e.g. a game) and many spent time playing it. Some of the highlighted keywords linked to animations, so once this was discovered, students were more inclined to click on these. With regards to indications of congnitive engagement, it was noted that students watched the movie from beginning to the end, and examined it more than once. Additionally student attention was positive and distractions limited since the teachers did not have to use any discipline strategies. Approximately half the students indicated they preferred visual learning. Motivation was increased, as they could visualise the process of fossilisation, and students reported that it was more fun than learning from a text book.

In a study on the effectiveness of different types of digital media (concept explanations, including applets, animations, photographs, diagrams and teaching and learning activities),

Frailich *et. al.,* (2007) found that the experimental group of students had a better understanding of key chemistry concepts compared with students who had not used these resources. However, this study also involved considerable professional development for the teachers of the experimental group. Therefore it is also likely that students had a more thorough understanding of the concepts compared with the control group, because of the professional development that their teachers participated in. The separation of the effect of the resources themselves from the effects of professional learning by the teachers and their ability to convey the science concepts to students was not identified. However the study by Frailich *et a*l., (2007) does indicate the importance of supporting teachers in their use of multimedia and the benefits of on-going teacher support, to ensure key concepts are understood and activities are implemented in an effective way.

The Science Learning Hub

The Science Learning Hub (SLH) is a collaborative project between science educators at the University of Waikato, the University of Canterbury, the University of Auckland and The Royal Society of New Zealand with scientists throughout New Zealand. The project was initiated at the beginning of 2007. The website that is still being developed, is structured around applied contexts, chosen to demonstrate science concepts and related New Zealand research, in an engaging and relevant way. The pedagogical philosophy driving the material development was inquiry-based but could also be said to be in line with cognitive theories of multimedia learning, as described by Mayer (2009) where visual, audio and text materials are integrated and linked in strategic ways so as not to produce cognitive overload.

At the time this research project was conducted, the SLH website contained eight science-related "contexts" and three "science stories". Each "context" contains science ideas and concepts, teaching and learning ideas, a timeline of important events for the context, an explanation of key terms, a question bank and New Zealand research and people relevant to the context. Contextual aspects related to the nature of science are a key focus, as the nature of science (NOS) has been given much greater prominence and revision in the *New Zealand Curriculum* (Ministry of Education, 2007). "Science stories" also are based on contexts but are smaller in scope in that they do not have as many scientists profiled nor as many other resources.

The professional freedom and autonomy that NZ teachers have as a result of the revised curriculum, means that teachers do not have to follow a prescribed teaching programme. This gives teachers a great deal of flexibility when developing units of work. However, the use of multimedia in teaching is highly dependant on teachers' familiarity and experience in using ICT. In this project, where we explored teachers' use of the Science Learning Hub (SLH) web site, teachers attended meetings which provided opportunities for reflection and deliberation about the pedagogical implications of using the digital resources from the SLH "contexts" and "science stories".

Methods and Analysis

The rationale for this research links very closely and aligns with the New Zealand Ministry of Education's drive to elicit evidence of professional learning through providing support for

teachers to collaboratively develop classroom practice. The intervention was planned to provide professional development for teachers to allow them to become familiar with the SLH website and to incorporate aspects of SLH into their teaching programmes. Specifically our aims were to:

- provide time to enable teachers to have opportunities to explore the SLH web site;
- enable teachers to work collaboratively to develop units of work that incorporated aspects of the SLH;
- explore teachers knowledge about NOS component of the *New Zealand Curriculum*
- explore teachers experience and use of ICT in their teaching and to identify enablers, any barriers and suggestions for the development of the SLH web site.

The mixed-method research approach used could be described as neo-Kantian (Smith, 1998), in that it accommodates both objective truth and subjective values in the same approach. An intervention was designed, where teachers participated in collaborative professional discussions and planning, to incorporate aspects of the SLH into their existing junior units of work in science. They attended three sessions at the university and spent time planning together in-between these sessions. We wanted to record what aspects of the site teachers used as well as their interpretations of the usefulness of various components of the site. Therefore we needed to record specific components that were used as well as teachers' perceptions.

Nineteen teachers from 9 different secondary schools in Christchurch, New Zealand joined the project. They were supported with teacher release funding which not only offered an incentive to participate but also allowed them to participate collaboratively in the half-day workshops.

The first workshop included an introduction to the site (promotion DVD, guided tour on-line through one context with the collections illustrated. This was followed by a discussion of how the collections link. Teachers were asked to complete a questionnaire about their current use of ICT in science teaching and their ideas about NOS. Teachers were asked to collaborate with their colleagues to develop a unit of work that incorporated aspects of the SLH. They were able to choose to use any materials currently available on the site.

The second workshop began with an oral report to the whole group from each school about what contexts/units of work they were developing. The remainder of this session provided time for teachers to work collaboratively on planning and developing units of work. Teachers were asked to continue this work, complete it and prepare a presentation of their units for the whole group at the next session.

The third workshop involved each school presenting their unit of work. All presentations were audio taped. Questionnaires were used in the first and last half-day workshops. These provided background data about the extent of teachers' knowledge and experience. The questionnaires were also triangulated with semi-structured interviews to elaborate on how teachers:

- incorporated aspects of the nature of science into their planning;
- already used websites in their science teaching;
- used the components of www.sciencelearn.org.nz and
- referred to key scientists or scientific studies during teaching.

Data Sources

- Questionnaires – before and after the planning sessions
- Session observations – written notes
- Audio and video recordings of presentations by the teachers of their planning
- Unit plans and supplementary teaching materials from each school
- Semi-structured interviews with a sample of the teachers

All data sources were cross checked so that we could identify patterns emerging. For the teachers' perceptions of their knowledge of NOS, key words were linked to aspects of NOS from the headings of the strands given in *The New Zealand Curriculum* (Ministry of Education, 2007). We were interested in teachers' general knowledge and understanding of NOS and therefore did not prompt them with specific components of NOS as part of the questionnaires. The responses to questionnaires were collated in terms of numbers of teachers identifying each category. Audio tapes were transcribed and used to support data from the questionnaires. Units of work were collected and the aspects of SLH that had been incorporated were highlighted. Videos were analysed and used to develop case studies for each of the nine participating schools.

Results

Nature of science (NOS)

The initial comments from the teachers on their understanding of the NOS component in the *New Zealand Curriculum* (Ministry of Education, 2007) (NZC) had a number of common themes. A large proportion of the group (42%) made comments linked to NOS as described in the NZC without any explanation, or they referred to how they thought NOS should be taught. For example some teachers' comments were:

> *".. a skill set required.."*
>
> *".. the overarching focus of teaching science.."*
>
> *".. C – communicating, U – understanding, P- participation, I –investigating"*

Of the nineteen teachers, 26% indicated some understanding of NOS. Most comments made were that NOS was something to do with a scientific process. This could include devising experiments, enquiry, research or the skills needed to conduct an investigation. Fewer comments identified NOS as a way of knowing or viewing the world and only one reference was made to the impact that science has on society. Comments included:

> *".. the framework that science hangs off. It is the process of establishing science protocol / thinking / history / investigation and those that have preceded us in making science what it is today.."*
>
> *"..the idea that new knowledge is testable and will only be accepted once it is tested by peers.."*

The remainder of the group, however, gave little or no evidence of understanding the NOS component in NZC.

Following the workshops and experience of the SLH, teacher responses to their understanding of the NOS were richer and more diverse. The majority of responses still identified NOS as a scientific process. However the number of responses doubled in reference to NOS as a way of knowing or viewing the world. Greater reference was also made to the societal aspects of NOS that include people involved in science and the impact and the contribution of science on society. For example some comments were:

> *".. way science works – need for suspended judgement until controlled experiments which are peer reviewed leading to the belief in the reliability of results (rational thinking). Gathering data which is reliable and accurate – how we know this. Devising experiments and judging the worth of experiments and ideas -science ideas change as new information is produced."*
>
> *"..People involved in scientific learning and the methods they use."*

Incorporating aspects of NOS into teaching

Initially, only 58% of the teachers surveyed indicated how they incorporated NOS into their teaching. The majority of those teachers who stated that they incorporated NOS in their teaching (70%) had a focus on *Investigating* (fair testing, emphasis on design, experimental projects). Other comments made were about how scientists work, their (scientists) effect on society, how concepts / ideas are applied in society, historical background and relationship between science and the community. When the teachers were asked how often they referred to scientists and their work when teaching junior science, 21% rarely did, 53% of the teachers sometimes did, and 26% often referred to scientists.

The time given to the teachers during the workshops, the collaborative nature of the planning and the structure of the SLH, provided teachers with ideas for adapting their unit of works and to relate them more to an overall theme or context. One teacher commented that they used the SLH to make closer links between the properties of hydrocarbons and their uses/ influence on the environment rather than just teaching hydrocarbons as a family of compounds with formulas and chemical characteristics.

> ***School D:*** *"..have taken a Unit Standard that we want to use on hydrocarbons (alkanes, alkenes and alcohols etc) and tried to link it to NOS by contextualising the unit – based around air pollution / biofuels and sources of hydrocarbons in NZ as opposed to just learning names, formulas and trends."*

After using the SLH, many teachers identified how investigations that have a 'real life context' or 'everyday life' aspect can support the development of NOS. Links on the SLH with the work of scientists provided opportunities to reconsider the reasons why the scientific method is used and why scientific work is presented in a particular way. The teachers thought that access to current scientists and their work would be useful. However, a number of schools are still developing their own understanding of NOS and how it can best fit with their units of work.

> ***School A:*** "*We have recently changed our schemes of work in Year 9 and Year 10 to show which aspects of the NOS are going to be taught. Still a work in progress as to how to use this learning area as a unifying strand"*

Teachers' use of the SLH

The SLH has nine key collections within a context. Following the intervention, teachers were asked to rate their use of the variety of collections within the SLH site. The collation of the results is presented in Figure 1. The teachers' use of the different collections reflects those aspects that were incorporated into their units of work. Clearly the science media collections, including videos, animations and still images, were most widely accessed and it is these collections that have numerous links to other collections within the contexts on the SLH. Teachers liked the idea of using video footage of scientists explaining a concept or sharing their research, as it made it more relevant for the pupils. As one teacher commented:

> **Teacher A** *'Personally I liked 'real scientist NZers' being videoed. It is important for students to get a NZ context for their science. Loved the hub particularly how it was laid out in terms of teaching and learning contexts and you could search for videos and images etc"*

The extent of use of the New Zealand Research, Key Terms, Timelines and Question Bank collections (Fig. 1) suggests that teachers may need more guidance as to how to incorporate these into their planning. Teachers' use of the components is likely to be dependent on the context of the unit of work developed. For example, School E developed a unit called '*Working in the laboratory'* that focused on female scientists. They only used the People collections within their unit of work. Figure 1 does not, however, indicate the collections that were accessed but not used in the planning for individual schools.

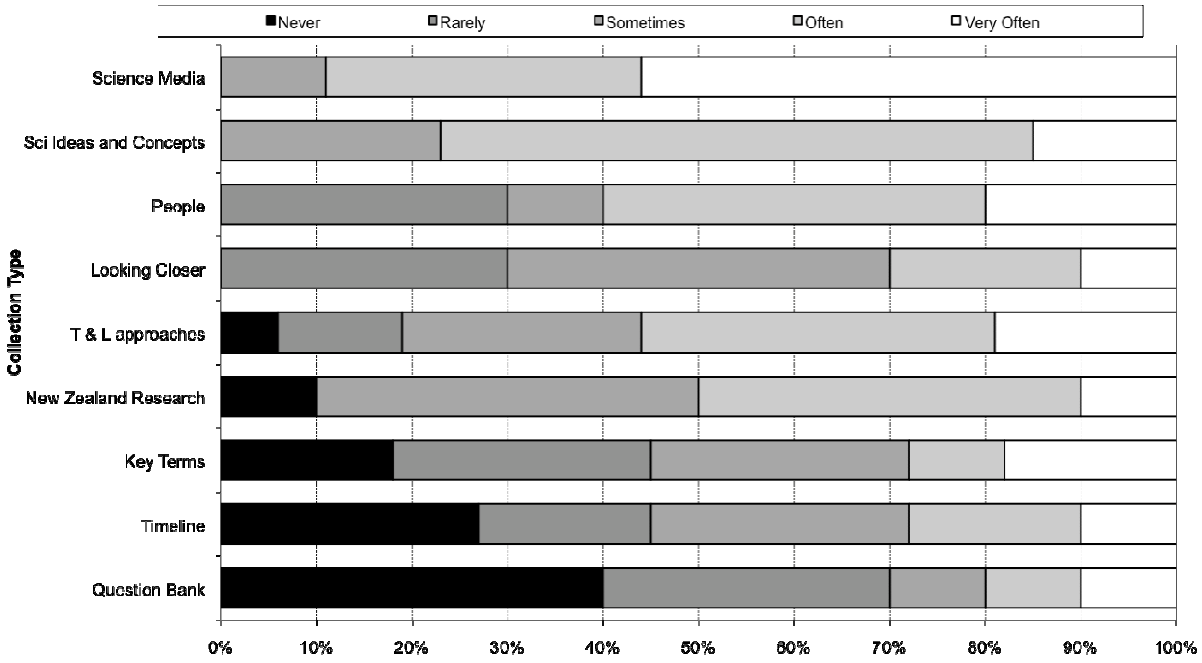

Figure 1. Teachers' use of SLH collections within contexts while planning junior science units (N = 13)

Integrating the SLH into units of work
Teachers were asked to develop their current unit plans for junior science or to look at new topics. Given the short time span of the project, it was unlikely that any school was going to be able to write a new unit, however it was very exciting to see how teachers used a number of contexts in a cross disciplinary manner and were able to support their teaching by combining aspects from a range of collections from the SLH.

The SLH materials tended to be used to support current learning experiences in existing unit plans. Often activities from the *Teaching and Learning* collections, or videos and still images from the *Media* collections were incorporated into unit plans. Of the nine schools that originally participated, units of work were developed by seven of these schools. An overview of the collections used within each context in the SLH is given in Table 1.

Table 1 indicates the range of collections used to support the teaching within the units of work. Most units had a high degree of video material. The appeal of videos is that they show concepts in several modes (visual and audio). It is likely that the media collections were accessed for their novelty factor. Although the media collections were the most accessed (Fig. 1), they were not necessarily the collections that were used in the units of work (Table 1). It is interesting to note the relatively small uptake and use of videos that profile scientists and their work. These may need to be emphasised more as a feature of the site.

Discussion
There were several aspects related to professional learning that this project focussed on;

- Teachers' understanding of NOS
- How teachers incorporated the concepts relating to NOS into their units of work
- Use of multimedia in teaching
- Use of New Zealand research and the work of scientists in teaching

The nature of science (NOS) is emphasised more in the science learning area in *the New Zealand Curriculum* and is a main focus of learning. The intention is that teachers will incorporate aspects of NOS as an integrating component when students learn about the four worlds of the science learning area. In their report *Seeing Yourself in Science,* Bolstad and Hipkins (2008) recommend that resources and professional learning opportunities are needed to support teachers to implement elements of NOS. Our data clearly support this view. In this study it was clear that teachers' understandings about NOS are still emerging. The summary of findings indicates that teachers identified NOS through investigation skills but they need further ideas and support to incorporate other aspects of NOS into their programmes.

Table 1. Summary of units of work developed by schools and collections used from the SLH.

School	Year	Unit Title	SLH Context	Collections used
A	10	**Earth Science**	*Earthquakes*	**T&L** How safe is my house? **Sci Media** Video – Variety of clips about base isolation **Science ideas and concepts** Inside the Earth Plate tectonics Seismic waves
B	9	**Living World**	*See-through Body*	**T&L** Microscope parts
			Icy Ecosystems	**T&L** Animal adaptations
			Enviro-imprints	**T&L** Air pollution activities
C	10	**Communities**	*Icy Ecosystems*	**T&L** A day in the life of a scientist Benthos powerpoint **Sci Media** Video – A guided tour of Tangaroa Video – Biodiversity on seamounts Video – Barnacles and sponges from the seafloor
D	10	**Fuels**	*Future Fuels*	**T&L** Misconceptions about fossil fuels **Sci ideas and concepts** Non renewable energy sources 1 **Sci Media** Video – How oil and gas are made Video – mapping rocks onshore Video – A career in the oil industry Video – Natural gas in Taranaki Video – Anaerobic digestion Animation – Oil formation **NZ research** In search of oil **Looking Closer** New Zealand's biomass resources **Timeline**
			Enviro-imprints	**T&L** Sources and effects of air pollution Air pollution activities **Sci ideas and concepts** Air quality 1 **Sci Media** Video – Particulates Video – Air pollution study **Looking Closer** Air pollution in Christchurch

E	9	**Environmental Issues** **Working in the Lab** **Environmental Issues Essay**	*Future Fuels* *See-through Body* *Earthquakes* *You, Me and UV* *Enviro-imprints* *Science Story* *Future Fuels*	**T&L** Greenhouse simulation **People** Maggie Lee Huckabee **People** Dr Laura Wallace **People** Hayley Reynolds **Sci Media** Video – How can water spread disease **Resource management** Video – Didymo Research in biosecurity **Looking Closer** Nuclear energy
F	9	**Circulatory System** **Heat Energy**	*Icy Ecosystems* *You, Me and UV* *See-through Body* *Icy Ecosystems* *Enviro-imprints* *You, Me and UV* *Future Fuels*	**Sci Media** Video – Antarctic icefish **Sci Media** Image– UV blue toilet lighting **Sci Media** Animation – Label the heart **Sci Media** Video – Getting dressed for the Antarctic **Sci ideas and concepts** Insulation **Sci Media** Video – Temperature inversion Image – Temperature inversion **Sci Media** Video – Sunbed research **T&L** Making a solar oven
G	9	**Recycling**	*Enviro-imprints*	**Sci ideas and concepts** Bio-indicators Biodegradability **Sci Media** Video – Why use earthworms? **People** Dr Ravi Gooneratne **T&L** Biodegradability experiment **Looking Closer** Measuring biodegradability

We found a huge range of competence, confidence and willingness to use the SLH. Teachers commented that in general, the use of ICT has not necessarily improved teaching:

> ***Teacher****: We need to get on top of it and onto it [ICT].*
>
> ***Teacher****: Although most of our kids have their own lap tops, we still see it as a tool [for learning].*

Several teachers commented that there is so much on the site already and that they still are not aware of what they can use, even after participating in the dedicated teacher release sessions. This is supported by the data in Figure 1 that shows that some collections were not accessed at all. Teachers require more resources, professional development and examples of ways in which the SLH could be used than we offered. However, there was excitement about this website because of its uniqueness and wide range of quality digital resources all in one place.
Teachers also used the SLH to develop their thinking about teaching and learning in relation to contexts. There was consensus that specific content and research linked to New Zealand science was very valuable and relevant to students.

> ***Teacher:*** *[Previously through the way we taught this unit] students knew about organic chemicals but not about fuels. So the use of the Hub allows students to learn about fuels in the context on NZ. The learning Hub has lots of possibilities for doing that [making it relevant].*

One of the primary motivations for developing the site was to increase students' interest in science. Teachers considered that the site would allow them to link to scientists and their work and thereby provide role models for future careers. In their meta-analysis of national research in the United States, Schroeder, *et al*., (2007) identified the largest effect size on student achievement in science was using Enhanced Context teaching strategies, where teachers relate learning to students previous experiences or knowledge or engage students' interest through using real-world examples and problems. The teachers in this current study identify with the importance utilising scientists work and applications in their unit plans.
The use of New Zealand research and the work of scientists in teaching was important for the teachers in this study as illustrated by the following comments.

> ***Teacher****: Students need to see link between science and 'normal' jobs. Using current research is a way of showing science as a real-life activity.*
>
> ***Teacher****: Quite important to use NZ scientists so students can see they're ordinary people that are discovering great things. My students have been fascinated by Rutherford and his work with the atom. Newton for physics, Darwin, Wallace, and Crick for biology.*
>
> ***Teacher****: If doing genetic engineering, kids are kind of interested in where the research is at. The research is interesting rather than scientists themselves.*
>
> ***Teacher****: There is a place for scientists [in school science]. They need to be accessible.*

> ***Teacher**: A focus at school is to show scientists are human and that they work in human contexts to generally improve the world. Adam Vonk in discussing how to find oil. Simon Kingham in air quality.*

Clearly, teachers indicated that the provision of release time to participate was essential. The sessions provided opportunity for teachers to reflect, think and plan, and allowed time for them to explore the SLH website. Without this time, out of usual classroom teaching, teachers agreed they would not have been aware of what was on the site or how they could use it.

The media collections are novel and therefore intrinsically interesting but they have not been incorporated into the units of work as much as we would have expected based on the use of the collections (Fig. 1). We are not certain whether this is because teachers are not sure how to use them or that there are constraints on using them in classrooms or a combination of both.

Teachers have found that the site offers new ways of considering contexts that are cross disciplinary in nature (for example that connect biology and physics or chemistry and earth sciences). This is novel and new. The presentation of science contexts broke down the traditional ways of thinking about science as being divided into discrete domains. The visual connections on the site between science concepts, scientists and their research and teaching and learning activities were very useful. It promoted thinking about the interconnections and dependency of science ideas. Comments from the teachers exemplify the changes they made to their teaching. Some of the comments indicate that students have increased their enthusiasm for science:

> ***Teacher**: The feedback we've received is brilliant. We want to give the message that science is cool and is a career worthy of being involved in.*

and that what they are doing is innovative and creative teaching:

> ***Teacher**: My colleagues tell me that this is really cutting-edge pedagogy.*

Limitations and future developments

The website only had eight "contexts" and three "science stories" on-line at the time of this study. Teachers have made recommendations about future contexts and how the site could be extended to include resources for Year 5 and 6 students. The website provided a multimedia resource that allowed teachers to develop units of work that were richer in terms of types of activities. Additionally, teachers appreciated having New Zealand examples of contemporary scientific studies and real scientists who were talking about their work in the videos. Teachers also thought that the use of visual materials was very important and was a strength of the site.

Our findings indicate that teachers varied considerably in their knowledge of NOS but extended their ideas as a result of participating in this intervention. Teachers indicated that they need time to explore the site, plan effectively and that they need continued support to incorporate aspects of NOS into their teaching. The time needed to plan units of work and incorporate new materials or ideas, even extend, adapt and create new activities based on ideas gleaned from a

resource such as the SLH, should not be underestimated. This type of intervention model could be used to research how teachers develop their use of the SLH.

The intention is to conduct future investigations about how the SLH influences students' learning would build on the scant knowledge about the influence of multi-media resources on learning and contribute to current theories about the cognitive theories of multi-media learning that are emerging in recent literature (Mayer, 2009).

References

Bolstad, R., & Hipkins, R. (2008). *Seeing Yourself in Science* (Report). Wellington: New Zealand Council For Educational Research.

Conner, L. & Mayo, E. (2009). Researching understandings of learning and teaching - RULT Summary Report for Teaching and Learning Research Initiative. Wellington: NZCER.

Crooks, T., Smith, J. & Flockton, L. (2008). Science Assessment Results 2007. *National Educational Monitoring Unit Report 44*. Dunedin: Ministry of Education.

Donovan, W., & Nakhleh, M. (2007). Student Use of Web-Based Tutorial Materials and Understanding of Chemistry Concepts. *Journal of Computers in Mathematics and Science Teaching, 26*(4), 291-327.

Frailich, M., Kesner, M., & Hofstein, A. (2007). The influence of web-based chemistry learning on students' perceptions, attitudes, and achievements. *Research in Science and Technological Education*, *25*(2), 179-197. Retrieved April 28, 2009, doi:10.1080/02635140701250659

Gaskill, M., McNulty, A., & Brooks, D. W. (2006). Learning from WebQuests. *Journal of Science Education and Technology, 15*(2), 133-136.

Holbrook, J., & Rannikmae, M. (2007). The Nature of Science Education for Enhancing Scientific Literacy. *International Journal of Science Education, 29*(11), 1347-1362.

Kay, R., & Knaack, L. (2007). Evaluating the use of learning objects for secondary school science. *Journal of Computers in Mathematics and Science Teaching*, *26*(4), 261-289. (ERIC Document Reproduction Service No. EJ775898) Retrieved May 6, 2009, from ERIC database.

Lewthwaite, B. & Fisher, D. (2004). The application of a primary science delivery evaluation questionnaire. *Research in Science Education.* 34, 55-70.

McGee, C., & Fraser, D. (2008). *The professional practice of teaching* (3rd ed.). South Melbourne, Vic.: Thomson Learning Australia.

Mayer, R. (2009). *Multi-media learning*. 2nd Edn. Cambridge: Cambridge University Press.

Ministry of Education (2007). *The New Zealand Curriculum.* Wellington: Ministry of Education.

Porter, C. & Parvin, J. (2008). Learning to love science: Harnessing children's scientific imagination. *Shell Education Service.* http://www.shell.com/home/content/gbr/responsible_energy/shell_in_the_society/social_investment/shell_education_service/learning_to_love_science/ Accessed 21/10/08.

Rodrigues, S., Tytler, R. Darby,L. Hubber, P. Symington, D. and Edwards, J. (2007). The usefulness of a science degree: the "lost voices" of science trained professionals. *International Journal of Science Education,* 29(11), 1411-1433.

Royal Australian Chemical Institute. (2005). *Future of chemistry study: Supply and demand for chemists.* Parkville, Australia: Royal Australian Chemical Institute.

Schroeder, C., M. , Scott, T. P., Tolson, H., Huang, T.-Y., & Lee, Y.-H. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching, 44*(10), 1436-1460.

Smith, M. (1998). *Social science in question.* London: The Open University/Sage.

Trefil, J. (2008). *Why science?* New York: Teachers College Press.

UNESCO (2007). UNESCO International Science Education Policy Forum Report, Perth, Western Australia, 13th July 2007: UNESCO.

Wang, S., & Reeves, T. (2006). The effects of a web-based learning environment on student motivation in a high school earth science course. *Educational Technology Research and Development*, *54*(6), 597-621. (ERIC Document Reproduction Service No. EJ785339) Retrieved May 4, 2009, from ERIC database.

Williams, M., Linn, M. C., & Hollowell, G. P. (2008). Making Mitosis Visible. *Science Scope, 31*(7), 42-49.