Sun and science: an integrated approach to learning science

Wan Ng

ABSTRACT Disengagement with science learning is an issue with many secondary school students. This article describes one school's attempt to re-engage the girls in the school with science learning by adopting an integrated pedagogy centred around the Sun. The research conducted alongside the implementation of this pedagogy showed increased motivation and interest in the learning. The benefits and limitations are discussed.

In Australia, there are concerns about the decline in the number of school students choosing the sciences, particularly the physical sciences, beyond the compulsory years of science education (O'Keefe, 1997; Dekkers and De Laeter, 2001; Goodrum, Hackling, and Rennie, 2001). The report by the Commonwealth Government of Australia on *Australia's teachers: Australia's future* summarised the longer-term trend in year 12 (from age 16) science enrolments as '*a steady decline in the percentage of year 12 students participating in biology, chemistry and physics that has been partly compensated by the emergence of participation in other science studies during the 1990s*' (Committee for the Review of Teaching & Teacher Education, 2003: 19).

This concern is consistent with evidence from several countries of a decline in students' appreciation of school science in their secondary years of schooling that may begin in primary schools. For example, research by Osborne and Collins (2000) and the Relevance of Science Education (ROSE – available online) project, which began in 2002, looked at students' views of school science in three different countries (Australia, Sweden and the UK). Their findings identified three common features of the loss of interest in science:

- teacher-centeredness and content transmission;
- curriculum content being unengaging and disconnected from students' lives and concerns;
- science being viewed as a difficult subject such that while many students acknowledge the importance of science they regard it as 'not for them'.

Schreiner and Sjøberg (2004: 10) summed up as follows in their comparative study of students' views of science and science education:

Educational research, opinion polls, public surveys as well as educational statistics for choices and recruitment, however, indicate that S&T (science and technology) in many countries are facing serious problems. Lack of interest in S&T, at least as school subjects and tertiary studies, and a meagre understanding of the contents and methods of S&T as well as their role in society and culture are among the problems.

If this loss of interest is to be addressed, it is imperative that the pedagogic emphasis in science education at the school level focuses on motivating the range of students with diverse interests and abilities in a classroom to learn science. Addressing relevancy and connectedness with students' lives is one way of engaging students to learn more science and improve scientific literacy in students.

Teaching and learning in context connects students' science learning to what they experience and know around them. This article describes an integrated approach to learning science in the context of work related to the Sun. The students involved in this government-funded project were year 9 students (13/14 year-olds) from a government girls' school in Victoria, Australia. The school had a student population that was very diverse in terms of ethnicity and socio-

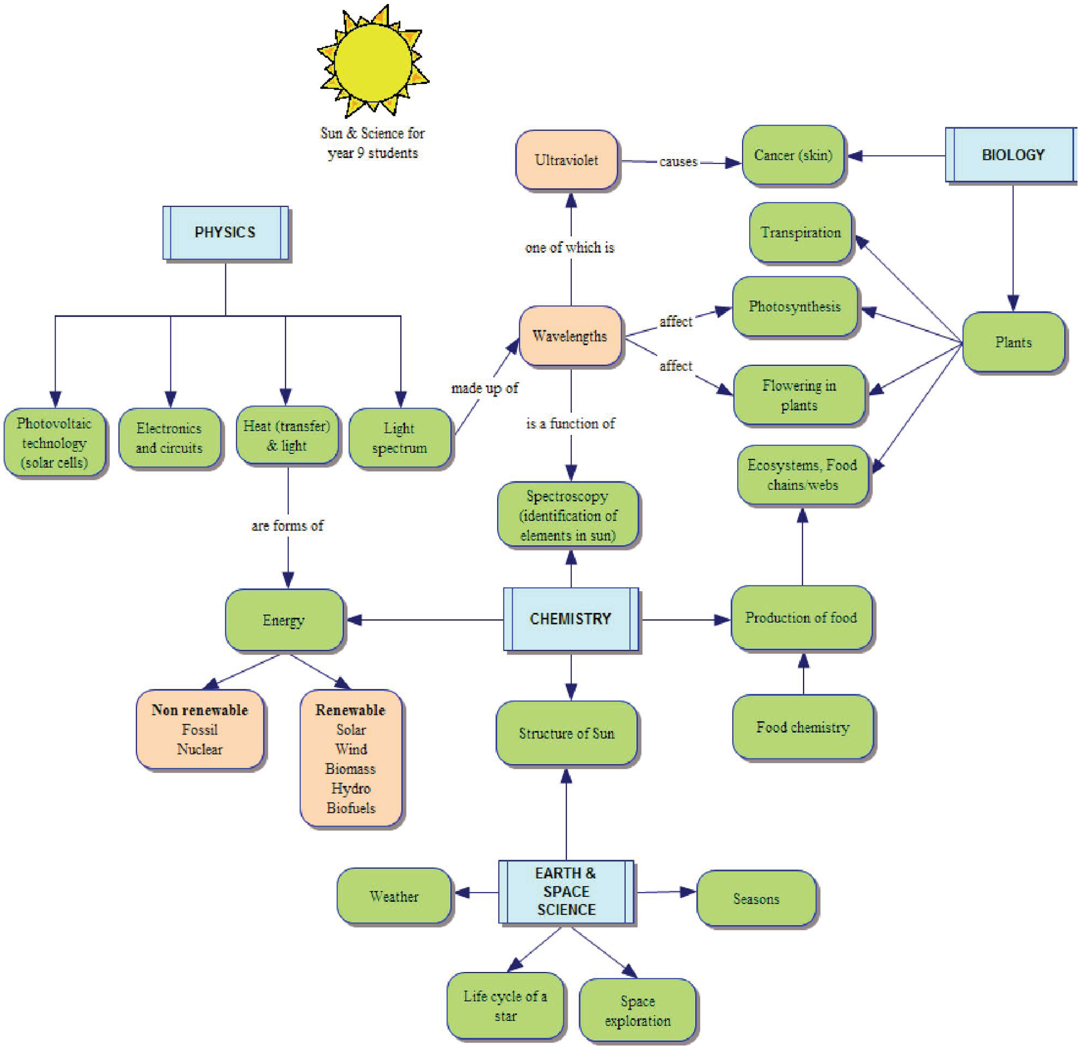


Figure 1 Science concepts related to the Sun.

economic backgrounds. As the girls in the school were generally not enthusiastic about science learning, the funds were sought by the science coordinator for a project to re-engage them in learning science. The 'Sun & Science' project involved students studying science related to the context of the Sun for about 150 minutes per week for 10 weeks. In these lessons, the year 9 students studied concepts of physics, chemistry, biology as well as earth and space science associated with the Sun. They were involved in a variety of hands-on activities to assist with their understanding of the concepts, including a visit to the local centre for environmental studies to learn about energy-efficient homes and alternative forms of energy. Broadly, this approach reflects principles of integrated learning.

Integrated learning

Shoemaker (1989: 5) defines an integrated curriculum as:

education that is organized in such a way that it cuts across subject-matter lines, bringing together various aspects of the curriculum into meaningful association to focus upon broad areas of study. It views learning and teaching in a holistic way and reflects the real world, which is interactive.

Within the context of the Sun & Science project, the integrated nature of the learning in the project was both intra- and interdisciplinary. The intra-disciplinary learning involved concepts under the broad umbrella of 'science' (that is, biology, chemistry and physics as well as earth and space science concepts). Making explicit the connections to the different science disciplines was an important aspect of the project, to enable students to view science as a whole rather than consisting of distinct discipline areas identified by the topics that happened to be taught. It was a means of showing that science is not segregated into compartments known as biology, chemistry, physics or earth and space science, and that understanding objects and/or phenomena around us is the result of an integration of knowledge from the different sciences. The interdisciplinary component of the project draws on knowledge and skills from other learning areas such as mathematics and studies of society and environment. Figure 1 shows examples of the linkages between Sun-related concepts across the science disciplines. Table 1 summarises the concepts that the students in the project could learn according to the requirements of the Victorian Curriculum Standards Framework. However, not all concepts shown in the figure or table were covered within the 10-week programme with the girls (see Table 1, last column).

The curriculum materials produced also integrated mathematics and studies of society and the environment. Apart from the mathematics involved in the data collection during experimental activities, additional, explicit mathematics-based questions were asked. For example:

- How many Earths will it take to span the diameter of the Sun? *(Answer: 109)*
- How many Earths will it take to fill the inside of the Sun? *(Answer: 1 million)*
- Given that the distance of the Sun from the Earth is about 150 000 000 km, if you were travelling in a car at an average speed of 100 km per hour, how many years would it take for you to get to the Sun? *(Answer: 171.2 years)*
- To measure really long distances, the unit 'light year' is used. A light year is the distance that light travels in a year. If light travels at the speed of 300 000 km per second, calculate the distance of a light year. *(Answer: 9 460 800 000 000 km)*
- How long will it take for the light from the Sun to reach the Earth if the distance of the Sun from the Earth is 150 000 000 km and light travels at 300 000 km per second. *(Answer: 8 mins 20 sec)*

Basic mathematical skills and knowledge were applied in these problems. The large dimensions of the measurements proved somewhat of a challenge for the students. Concrete hands-on activities such as the use of large beach balls to represent the Sun, together with Smarties and 'hundreds and thousands' confectionary as representations of Earth, helped students visualise the large number of 'Earths' needed to 'fill' the Sun. Most students commented that they had no concept of how far from Earth and how large the Sun is. Being able to feel the heat and see the Sun had made them think that it is quite near Earth.

Impact of the programme on the year 9 students

Hands-on activities

The year 9 girls appeared to enjoy the hands-on activities, such as the construction of solar cookers using cardboard boxes, aluminium foil, plastic food wrap and masking tape (see Figure 2b). The challenge was to construct a cooker that would melt cheese placed on top of corn chips. However, none of the cookers could successfully trap sufficient heat (80 °C and above) to melt the cheese. Insufficient care was taken to ensure that the aluminium foil was smoothly laid out and that the joints were properly sealed. In constructing the solar-powered battery charger (Figure 2c), the girls had more success and enjoyed the activity while additionally learning some electronics and how to solder.

The girls conducted a variety of experiments including investigating conduction, convection and radiation. They investigated the properties of light and tested for oxygen and carbon dioxide gases when studying photosynthesis and respiration. They investigated different types of materials, for example fabric, aluminium foil, Sunscreen lotion, cosmetic products (foundation) and their own Sunglasses, to determine which were the effective Sunblock materials. They made use of ultraviolet-sensitive beads for this investigation. These beads change colour in the presence of ultraviolet rays and revert back

Table 1 Content that addresses the Victorian Curriculum Standard Framework

Discipline	*Level 6 learning outcomes	Content related to Sun & Science	What the students did in the 10-week programme
Biology	6.1 Explain how ecosystems are maintained in terms of energy and matter	Energy cycle in nature, food chains, food webs, carbon–oxygen cycle, nitrogen cycle, cells and organelles	Photosynthesis and respiration concepts, including extraction of chlorophyll Plant and animal cells: similarities and differences Tests for presence of oxygen and carbon dioxide gases Transpiration Energy cycle in nature, food chains and food webs
	6.3 Describe regulation and coordination in plants and animals	Investigate different factors affecting growth of plants including the effect of sunlight and hormonal influence	
	6.4 Explain cellular processes, including photosynthesis and respiration	Processes of photosynthesis and respiration, including creating concept maps using *Inspiration* software	
Chemistry	6.1 Relate the properties of fundamental groupings of substances to the nature of their constituent particles	Identification of elements present in the Sun from spectroscopy Nuclear reactions in the Sun provide the source of heat and light energy Fossil fuels	Introduction to spectroscopy in relation to elements found in the Sun, i.e. how do scientists identify the presence of these elements. Fossil fuels Introduction to the concept of nuclear reaction – definition and heat released
Physics	6.1 Relate the behaviours of light, such as reflection, refraction, absorption and polarisation, to uses in technology	Electromagnetic spectrum Concepts of light and heat transfer (conduction, convection and radiation) applied to the construction of a variety of solar powered devices such as solar cooker (see Figure 2b), solar heat dryer, solar hat, solar tower (see Figure 2a), solar-powered mini-cars and boats, solar-powered battery charger (see Figure 2c) and solar-powered flashing board.	Properties of light Electromagnetic spectrum Investigate the 3 types of heat transfer Construction of solar cooker and solar-powered battery charger (latter requires soldering and learning about electronics) Investigate UV-sensitive beads and materials that block out UV light
	6.2 Explain the effect of electronic and electrical components in the operation of electronic and electromagnetic devices	Build an electronic device such as a solar-powered battery charger and a flashing unit powered by solar-charged batteries	

Table 1 (continued) Content that addresses the Victorian Curriculum Standard Framework

Discipline	*Level 6 learning outcomes	Content related to Sun & Science	What the students did in the 10-week programme
Earth & Space science	6.2 Describe the extraction, processing and use of geological resources and associated environmental and social issues	Formation of natural resources such as crude oil and coal. Describe the extraction, processing and use of coal in producing electricity. Discuss environmental and social issues related to burning of coal and why the use of solar energy is important	Fossil fuels, alternative forms of energy Environmental and social issues with regard to energy use Structure of the Sun, including how scientists determine the temperature of the Sun via spectroscopy Practical activities and mathematical problems to assist with understanding the size of the Sun and distance from Earth
	6.3 Compare theories about the origin and evolution of the universe	Life cycle of a star	
	6.4 Science Extension: Analyse aspects of space technologies	Investigate the use of solar cells in space technologies	
Others			Day and night, seasons Visit to environmental education centre Project work: construction of a model of an energy efficient home

*based on the Victorian Curriculum Standards Framework for science.

to their colourless state in the absence of these rays. They also tackled the problem 'what is the diameter of the Sun?' using a circle of cardboard with a pinhole in the middle. The vast majority of students were able to apply the appropriate mathematical formula to calculate the diameter of the Sun using the results they obtained from their investigations.

In observing the girls working on investigative activities, it was noticed that they were often too engrossed in following the instructions provided to them to think about why they were doing the experiments. For example, in the convection experiment, potassium permanganate was used to visualise convection in heated water. The girls had problems saying its name and had the impression that they needed a chemical with a complicated name to do this experiment. It did not occur to them that potassium permanganate was only used for the colour. A possible alternative to potassium permanganate would be the use of everyday things that the students are familiar with, such as Smarties or M&M sweets. Similarly, instead of or in addition to using manganese dioxide in hydrogen peroxide as the catalyst for the generation of oxygen, the students could use small pieces of liver and learn about biological catalysts. By using familiar things, students understand that science is all around them and not confined to chemicals with complicated names in the laboratory.

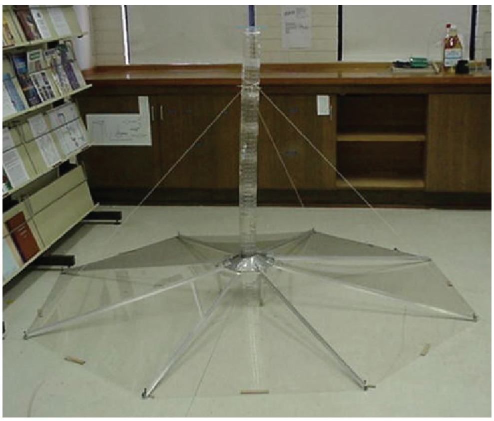
Outcomes of the girls' learning

As part of the impact study of the programme, a short test was administered at the end of the programme. The questions asked were very open, in order to elicit the aspects of the programme to which students related well (or not so well). Questions included:

- What is photosynthesis?
- What do you know about photovoltaic cells (also called solar panels)?
- If you had a bottle of gas:

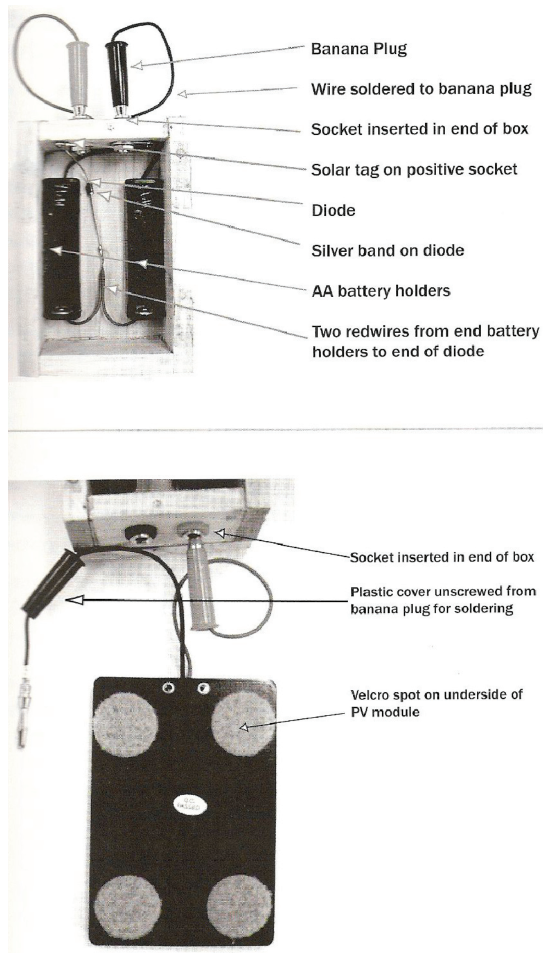
  (a) how could you test to see whether the gas was oxygen?

  (b) how could you test to see whether it was carbon dioxide?
- Most of the energy we use in houses, in factories and for transport comes from oil, coal and natural gas. Write down the names of four alternative sources of energy that can be used instead of oil, coal and gas.
- Reflection and refraction are words used about light. Explain what each word means.



(a) Solar tower. This model was made using plastic sheets as the base and soft-drink bottles for the tower. A paper fan is placed inside the tower to demonstrate convection.

(b) Solar cooker. The girls used data loggers (graphics calculator and temperature probe) to track the temperature rise.



(c) Solar-powered battery charger.

Figure 2 Solar devices. Instructions for these devices can be found at the website: http://www.latrobe.edu.au/educationalstudies/solar/solar.htm.

- What are the three ways by which heat can be transferred? Explain the differences.
- Why are most leaves green in colour? What role do leaves play in the growth of a plant?
- Plant leaves have tiny openings (pores) on their surface, called stomata. What part do stomata play in the working of a leaf?

Analysis of the responses to the questions showed that students were able to grasp quite well the concepts in the areas of biology and alternative energy, including the working of a solar cell. The photosynthesis question was answered well; most were able to describe it as the plant's process of food making, and to explain the role of chlorophyll, sunlight, oxygen, carbon dioxide and water in the process. The physical science questions were not answered so well. A number of students appeared to be confused between reflection and refraction. A similar trend was seen with the tests for oxygen and carbon dioxide, and the three ways by which heat is transferred – all were poorly answered. These results indicate that integrating too many physical science concepts in the 10-week programme meant that there was insufficient time to go into the depth required for the girls to grasp the concepts sufficiently well. Gender could be a factor in this case study as it is not uncommon to find females shying away from studying the physical science subjects, particularly physics, at the year 11 and 12 levels of schooling.

Attitude toward the integrated approach

Pre- and post-project surveys were administered to the group of 35 girls who participated in the programme (Table 2). The attitude survey was divided into three sections:

- attitudes toward science in a social context;
- values held in relation to science;
- attitudes toward science learning.

The Likert-style attitude survey consisted of statements to which students had to select a response from a scale of 1 to 5, with 5 = strongly agree, 4 = agree, 3 = unsure, 2 = disagree and 1 = strongly disagree. The mean and standard deviation (SD) for each statement were calculated using a statistical software package. A higher mean score indicates more agreement with the statement. In addition to the survey, student focus-group interviews were conducted by the researcher. **<TABLE 2>**

As shown in Table 2, the results suggest that there was no dramatic impact of this type of experience on the girls. The mean scores for some of the attitudes toward science in the social context and personal values held in relation to science had decreased slightly in by the end of the project. For example:

- You can get along in life well without science. *(pre 2.86; post 2.59; large SD)*
- I am curious about the world around me. *(pre 4.00; post 3.70)*
- It is important for me to understand the work in science. *(pre 3.74; post 3.49; large SD)*

This slight decrease in attitude mean scores could be an indication that, by the end of the learning experience, the students were more reflective and critical in their thinking with regard to personal opinions toward science and attitudes toward the discipline in a social context. There appear, however, to be some positive improvements in attitudes toward learning science. For example:

- Science is one of my favourite subjects. *(pre 2.66; post 3.03; large SD)*
- I find science boring. *(pre 3.14; post 2.76; large SD)*
- Science makes me think. *(pre 3.66; post 4.08)*

The interviews with students indicated that motivation was increased by the end of the experience in the majority of the students. For example:

We had fun this time, we did more experiments, we learnt a lot. If you do experiments you learn more than writing because it [writing] won't go into your head.

I didn't know that the Sun is so huge. I didn't know anything about the Sun before this.

For those (about 20%) of the students who were not as enthusiastic, a typical response was:

Too complicated, unless you are interested.

Conclusion

This article describes a programme that used an integrated approach to learning science within the familiar context of the Sun. The aim of the programme was to re-engage students from a girls' school in learning science. The research study

Table 2 Students' attitudes towards science pre- and post-project: mean values of responses (*N* = 35)

Statement	Pre-project		Post-project	
Attitudes toward science in a social context	Mean	SD	Mean	SD
Science helps us understand the world around us	4.29	0.519	4.14	0.787
Science is needed for almost all jobs	3.26	1.067	3.54	0.931
Everyone should study some science	3.86	1.033	3.78	1.294
Science is important for everyday problems	3.49	1.011	3.30	1.051
Space travel is important in today's society	3.37	0.910	3.30	1.199
It is important to know something about science to get a good job	3.69	0.867	3.76	1.038
You can get along in life well without science	2.86	1.115	2.59	1.384
Science is important to a country's wealth	3.74	0.741	3.76	0.925
Values held in relation to science				
I enjoy watching science programmes on television	3.00	1.163	2.95	1.177
Science is something I enjoy	2.89	1.471	2.84	1.463
I enjoy listening and talking to people about science	3.00	1.237	2.86	1.206
I like the challenge of science projects and assignments	3.26	1.400	3.16	1.519
I would like to do some more reading in science	2.97	0.891	2.81	1.244
I am curious about the world around me	4.00	1.163	3.70	1.077
It is important for me to understand the work in science	3.74	1.314	3.49	1.426
Science is one of my favourite subjects	2.66	1.589	3.03	1.554
I have used what I learnt in science outside the classroom	3.11	1.183	3.38	1.421
I find science boring	3.14	1.478	2.76	1.480
Attitudes toward science learning				
Science is quite easy to understand	2.91	1.222	3.00	1.155
Doing science experiments is fun	4.00	1.029	4.14	1.134
Science is not too abstract for me	2.66	1.259	2.86	1.316
Science makes me think	3.66	1.211	4.08	1.038
Science is too challenging for me most of the time	3.00	1.111	2.84	1.344
Most of the topics studied in science are useful	2.66	1.211	2.62	1.233
I like finding out why an experiment works	3.89	1.078	3.95	1.053
The things we study in science are relevant	2.74	1.120	3.03	1.236
Science is a lot of memory work	3.77	0.973	3.65	1.379

that was conducted alongside the implementation of the programme indicated that the girls were motivated by learning science in the programme and liked the variety of hands-on activities they engaged with. The class teacher confirmed this motivational aspect by describing the noticeable increase in the participation of some of the students in activities and the desire of some students to work through lunch on the project assignment that was attached to this programme. The pre-and post-attitude surveys indicated that the programme improved the students' motivation and learning outcomes to a moderate degree.

The results indicate that the programme had a limited impact on the girls' learning in terms of test performance. A major drawback of the programme appears to be trying to cover too much in the 10 weeks. There was insufficient time to cover some of the concepts in depth to ensure better understanding by the girls. A slower pace would have allowed for more practical and written activities and time to revisit the concepts that had been studied. There is also a need to provide opportunities for the students to reflect on and make connections between the discipline areas from lesson to lesson. More time spent on the social aspects of science, for example the impact of burning fossil fuel, increase in global warming and the implications on the environment and on future generations, could have had a better impact on the girls.

In concluding, the project described in this article suggests that it is worthwhile teaching science in an integrated manner. However, there are different views about this approach. Wilkinson (1999) has described the benefits of this approach as including: student motivation and engagement as a result of perceived relevant learning drawn from everyday real-life examples and phenomena; and the development of critical thinking and problem-solving skills with questions centred around a familiar context leading to more effective learning. Stinner (1994: 49) has argued the drawbacks to this approach, stating that '*physics teachers often encountered problems when trying to incorporate large contextual settings*' due to students' inability to deal with context-generated problems '*unless they already have content knowledge*'. I would suggest that engaging students in integrated learning should not be a regular pedagogy, but should be incorporated as a strategy that moves away from specific discipline-based learning (e.g. a topic on forces) at least once a year.

Acknowledgement

This project was supported by a small grant from the Victorian Department of Education and Training.

References

Committee for the Review of Teaching & Teacher Education (2003) Australia's teachers: Australia's future. *Advancing innovation, science, technology and mathematics – background data and analysis*. Canberra: Commonwealth Government of Australia.

Dekkers, J. and De Laeter, J. R. (2001) Enrolment trends in school science education in Australia. *International Journal of Science Education*, **23**, 487–500.

Goodrum, D., Hackling, M. and Rennie, L. (2001) *The status and quality of teaching and learning of science in Australian schools*. Canberra: Department of Education, Training and Youth Affairs.

O'Keefe, D. (1997) *Secondary physics population in Victoria: analysis of year 12 physics numbers*. Paper presented at the 1997 Science Teachers Association of Victoria Physics Teachers' Conference, Monash University, Victoria.

Osborne, J. and Collins, S. (2000) *Pupils' and parents' views of the school science curriculum*. London: King's College London.

ROSE. Available at: http://www.ils.uio.no/english/rose/publications/english-pub.html

Schreiner, C. and Sjøberg, S. (2004) *Sowing the seeds of ROSE: background, rationale, questionnaire development and data collection for ROSE (the Relevance of Science Education) – a comparative study of students' views of science and science education.* Oslo: Department of Teacher Education and School Development, University of Oslo.

Shoemaker, B. (1989) Integrative education: a curriculum for the twenty-first century. *Oregon School Study Council Bulletin*, **33**(2).

Stinner, A. (1994) Providing a contextual base and a theoretical structure to guide the teaching of high school physics. *Physics Education*, **29**, 375–381.

Wilkinson, J. W. (1999) The contextual approach to teaching physics. *Australian Science Teachers' Journal*, **45**(4), 43–50.

Wan Ng is a senior lecturer in the Faculty of Education (Bundoora) at La Trobe University, Victoria, Australia. Her research interests include innovative curriculum in science teaching and learning, and the use of ICT in education.
E-mail: w.ng@latrobe.edu.au