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Science: Inspiring the next generation

Is it time to start reconceptualising maths and science teacher education?

The place of science in early years

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Editor
Paola Ghirelli
paola.ghirelli@austcolled.com.au

Editorial assistance
Dr Elaine Blake (FACE)
& Ms Kira Clarke (MACE)
Publications working group

Advertising
P: 03 9035 5473
F: 03 9341 6021
ace@austcolled.com.au

ACE membership
P: 03 9035 5473
F: 03 9341 6021
ace@austcolled.com.au
www.austcolled.com.au

Australian College of Educators
PO Box 73, Carlton VIC 3053
P: 03 9035 5473
F: 03 9341 6021

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Are we serious about science?

This edition of *Professional Educator* comes soon after a very successful National Conference, 'What counts as quality in education?' held in Adelaide. Papers and presenters were drawn from across the Australian educational landscape ranging from early years to higher education. A highlight was the National Gala dinner oration delivered by Professor Ian Chubb AC (FACE), Australia's Chief Scientist. His thought provoking address, which was not included amongst the conference papers, is provided in this edition for members.

Other highlights from the conference included the presentation of the ACE Fellowships plus the prestigious 2014 College Medal awarded to Dr Gerald White (FACE), an outstanding Australian educator with a distinguished record of service to the College.

The theme to this edition is given over largely to a matter of international concern in education, that is, of teaching and learning in the Science, Technology, Engineering and Mathematics (STEM) subjects. Professor Chubb's oration provides a 'big picture' view on this area and other contributors also focus in on related matters.

In my paper 'Primary schooling in Australia: Pseudo-science plus extras times growing inequity equals decline' presented at the conference, I highlighted some of the issues facing us in the areas of science and mathematics. These can be summarised as follows:

- There are significant literacy and developmental gaps when young people enter primary education
- the primary curriculum is overloaded with both 'academic' and 'social' aspects, making the role of the generalist primary teacher increasingly untenable
- some primary teachers report lacking confidence and competence in teaching maths/numeracy and science – resorting in some cases to 'cookbook' science, and 'hands-on' maths. It is time that serious thought was given to the introduction of specialist primary maths and science teachers who can work alongside generalist teachers
- Australia's performance on international measures such as TIMSS (Trends in International Mathematics and Science Study), PIRLS (Progress in International Reading Literacy Study) and PISA (Programme for International Student Assessment), although good, is in decline overall, with primary performance relatively poorer than secondary when Australia is compared to a similar 'basket' of nations
- student attitudes, beliefs and achievement in primary maths and science powerfully predict secondary school performance in these subjects
- one third of Australian 15 year old students are being taught maths by an 'out of field' teacher and one quarter by an 'out of field' science teacher. This is worse in government, low socioeconomic status, regional and remote schools (Productivity Commission, 2012) and is nothing short of a national disgrace
- significant numbers of Year 11-12 maths and science students are also being taught by an 'out of field' maths or science teacher and senior students are avoiding the higher level maths and science courses (Chinnapan et al, 2007)
- undergraduate students are avoiding maths and science in favour of other areas such as information technology
- it is difficult to attract suitable candidates to secondary maths and science teacher education courses and primary teacher candidates may lack Year 12 maths/science, or have taken the lowest courses available
- there is a shortage of secondary maths and science teachers
- *and so it goes ...*

This cycle needs to be broken. The articles in this edition explore aspects of these related phenomena and canvass solutions. As such it makes an important contribution to our current thinking in this significant area.

I would also like to remind all members that our *Grass Roots Membership Challenge* is still being actioned, whereby each of us is asked to identify at least one potential member of ACE who will both add value to the College and benefit from the membership. This initiative is proceeding well thanks to all who have already 'sponsored' a new member. However here is no requirement to stop at one new member!

If you would like a list of references for this editorial please email vickit@unimelb.edu.au.

Professor Stephen Dinham
OAM PhD FACE
National President

Challenges and opportunities for Australian Science education

MARK HACKLING

Australia is faced by significant economic, social and environmental challenges that can only be addressed by a well-educated and scientifically literate society. However, science education faces significant challenges of its own. International benchmarking demonstrates that achievement standards in science are static or declining at a time when other nations are improving, fewer Australian than overseas students are reaching advanced benchmarks of achievement, participation in academically demanding senior secondary science courses is declining and most concerning of all, is the huge negative impact of social disadvantage on students' participation and achievement in science. In response to these challenges, we must answer the question of what pedagogical and curriculum formulations can enhance students' engagement with and achievement in science.

The goal of science education is to develop scientifically literate citizens who are:

... interested in and understand the world around them, engage in the discourses of and about science, be sceptical and questioning of claims made by others about scientific matters, be able to identify questions, investigate and draw evidence-based conclusions, and make informed decisions about the environment and their own health and well-being (Hackling, Goodrum and Rennie, 2001, p.7).

Given the importance of scientific literacy for the life chances of the individual and the prosperity and well-being of nations, achievement standards in science are regularly monitored by international and national assessment regimes. Programs such as Trends in Mathematics and Science Study (TIMSS), Program of International Student Assessment (PISA) and National Assessment Program – Scientific Literacy (NAP-SL) have generated important sources of evidence about the health of Australian science education.

Achievement standards

Australian primary science achievement standards, as assessed by the Year 4 TIMSS international tests, have fallen significantly between 2007 and 2011 and our ranking has fallen from 13th to 24th out of 50 countries (Thomson et al., 2012). Australia's mean score fell from 527 in 2007 to 516 in 2011 which is above the international mean of 500 but way below Korea (587) and Singapore (583), the two highest ranked countries. The gap between Australia and top achieving countries increases at higher cognitive domains; the gap increases from the cognitive domain of Knowing to Understanding to Reasoning. Singapore was outstanding in having 33 per cent of its students reach the Advanced Benchmark of achievement (equivalent to 625 score points), whilst only seven per cent of Australian students reached this standard. Only five per cent of Korean students failed to reach the Intermediate Benchmark (475 points) whilst 29 per cent of Australian students were below this standard.

This alarming data shows that the standard of Australian primary science achievement is declining in absolute terms and relative to other countries; and, that far too few students reach the Advanced Benchmark and far too many fail to reach the Intermediate Benchmark. This is most likely related to many teachers' low confidence and self-efficacy for teaching science which results in very little instructional time being devoted to science and consequently limited opportunities for learning (Angus, Olney and Ainley, 2007). There is a strong evidence base to show that the Australian Academy of Science's Primary Connections program has positive impacts on teachers' confidence and self-efficacy for teaching science and that those supported with Primary Connections professional learning and curriculum resources increase the amount of time devoted to science instruction (Hackling, Peers and Prain, 2007).

Australian secondary science achievement standards, as assessed by the PISA scientific literacy assessments of 15-year olds, have shown a small, non-significant decline between 2006 (527 score points) and 2012 (521), whilst

our international ranking has fallen from eighth to 16th out of 65 countries (Thomson and De Bortoli, 2008; Thomson, De Bortoli and Buckley, 2013). Whilst the Australian standard has remained static between 2006 and 2012, 14 countries achieved significant improvement in this time. On the 2012 PISA assessments, the gap between mean scores for the top country China (580 score points) and Australia (521) was large and equivalent to more than one and one-half years of schooling; however, Australia was above the Organisation for Economic Co-operation and Development (OECD) mean score (501). As with the TIMSS primary science data Australia had too few top performing secondary students and too many low performing students compared to top performing countries. Only 14 per cent of Australian students achieved Levels 5 and 6 and were considered top performers compared to 27 per cent for China and 23 per cent for Singapore. Thirteen per cent of Australia students achieved below Level 2 and were considered low performers compared with two per cent for China.

This data demonstrates that Australia is losing its international competitiveness in terms of secondary students' scientific literacy and we face a major challenge to increase the proportion of students who are high achievers and decrease the proportion of low achieving students. The TIMSS and PISA data indicate that our Asian trading competitors in knowledge-based products and services (China, Singapore, Korea, Japan, Taiwan, Hong Kong) outperform Australia in terms of the scientific literacy of its primary and secondary students. As our Chief Scientist, Professor Ian Chubb has argued:

...the world's dependence on knowledge and innovation will grow and not diminish and to be ahead in the race, a community needs the skills to anticipate rather than follow.

No action by Australia would see the gap between our capacity and those of others widen further. In turn that would see us as followers not anticipators and restrict our opportunities to develop a high technology, high productivity economy (Office of the Chief Scientist, 2012, p. 6).

Participation

If Australia is to produce the science graduates needed to drive innovation and economic growth, the number of students continuing in the science education pathway through senior secondary science to post-secondary studies must be increased. The data shows a long-term decline in the number and proportion of students studying Year 12 science subjects that qualify candidates for university admission (Ainley, Kos and Nicholas, 2008; Goodrum, Druhan and Abbs, 2011). Despite the total number of Year 12 examination candidates increasing between 1992 (189,000) to 2012 (220,000) the total number of examination candidates for physics, chemistry, biology and earth science fell from 151,000 to 127,000 during that period. In terms of the percentage of all candidates sitting examinations in Year 12, between 1992 and 2012, participation in physics fell seven per cent (from example, from 21 per cent to 14 per cent), chemistry five per cent, biology 10 per cent and earth science continues with very low enrolments and has been essentially stable (Table 1, based on Kennedy, Lyons and Quinn, 2014).

Table 1: Number and percentage of students who were Year 12 examination candidates in science subjects in 1992 and 2012

Discipline	Number and percentage	Year	
		1992	2012
Physics	#	39,000	31,000
	per cent	21	14
Chemistry	#	43,000	39,000
	per cent	23	18
Biology	#	67,000	54,000
	per cent	35	25
Earth Science	#	2,000	3,000
	per cent	1	2
Total number of year 12 examination candidates	#	189,000	220,000

Note: Rounded numbers based on state and territory curriculum authority data as collated by Kennedy, Lyons and Quinn (2014)

It is recognised that science, technology, engineering and mathematics (STEM) graduates make a disproportionately large contribution to economic growth and that the percentage of Australian graduates from STEM fields is about half of that from Japan, Singapore and China (National Science Board, 2010). Australian data over the period 2001 to 2011 shows that the two STEM fields that have suffered the largest fall in undergraduate plus postgraduate numbers of graduates are agriculture and environmental sciences, and information technology (Table 2).

Table 2: Undergraduates and postgraduate domestic university student completions by discipline and year for all Australian universities

Discipline	Number and percentage	Year	
		2001	2011
Natural and Physical Sciences	#	12,930	15,508
	per cent	8.59	7.83
Information Technology	#	8,301	4,532
	per cent	5.52	2.29
Engineering and Related Technologies	#	7,845	9,391
	per cent	5.21	4.74
Agricultural Environmental and Related Studies	#	3,580	3,279
	per cent	2.38	1.66
Health	#	19,654	33,323
	per cent	13.06	16.83
Other	#	98,193	131,992
	per cent	65.24	66.65
Total	#	150,503	198,025

Source: Department of Industry, Innovation, Science, Research and Tertiary Education (DIISRTE) Higher Education Statistics Data Cube

Social disadvantage

The Australian culture is distinctive in its valuing of equality of opportunity and inclusiveness which is consistent with our democratic ideals; these values are often expressed as 'a fair go'. Equal opportunity in education would be realised as similar learning outcomes and participation rates for males and females, for Indigenous and non-Indigenous Australians, and for those living in metropolitan and remote geolocations. Unfortunately,

our valuing of equality of opportunity has not been realised and the data reveals significant and alarming impacts of social disadvantage.

On the 2011 TIMSS and the 2012 PISA assessments, there was no significant difference between male and female mean science achievement scores despite there being significant differences favouring males in mathematics. The 2012 PISA data show that Indigenous students' mean score was equivalent to two and one half years of schooling lower than non-Indigenous students. The gap between the highest and lowest socioeconomic quartile was equivalent to two and one half years of schooling (Table 3). The gap between metropolitan and provincial schools was equivalent to half a year of schooling and the gap between metropolitan and remote schools was equivalent to two years of schooling. The strong impact of social and economic disadvantage on performance is reflected in the wide spread of scores achieved by Australian students in the 2012 PISA assessments.

Table 3: Performance of Australian students relative to other benchmarking countries on the PISA 2012 science assessments

Country	Rank out of 56 countries	Mean science score
China	1	580
Australian students from the highest socioeconomic quartile		567
Hong Kong	2	554
Liechtenstein	11	525
Australian non-Indigenous students		524
Australia	16	521
OECD average	26	501
Australian students from the lowest socioeconomic quartile		479
Iceland	40	478
Thailand	49	444
Australian Indigenous students		440
Mexico	56	415

lowest socioeconomic quartiles (SEQ), and Indigenous and non-Indigenous students, relative to the performance of a number of benchmark countries. The mean score of Australian students from the highest SEQ would place them between the mean score of all students from the top two countries China and Hong Kong; however, Australian students from the lowest SEQ score at the same level as Iceland, which is ranked 40th. The greatest concern relates to the mean score for Australian Indigenous students who score at a level that is similar to the mean score for all students from Thailand, the 49th ranked country and only a little above the lowest ranked of all countries, Mexico.

Analysis of Western Australian enrolment data reveals that there is also an impact of social disadvantage on students' participation in academically demanding science and mathematics subjects at the upper secondary level. Very few Western Australian students, from below average Index of Community Socio-Educational Advantage (ICSEA) schools, enrolled in physics, chemistry and Stage 3 specialist mathematics in 2012 (Hackling, Murcia, West and Anderson, 2014). It is likely that this pattern of participation also would be evident in other Australian jurisdictions.

Pedagogy and curriculum

Given the imperative to attract and retain more students in the STEM education pathway and to raise achievement standards, considerable attention has been given to pedagogical and curriculum formulations that will engage students in science learning and enhance learning outcomes. There is an international consensus that science should be taught by inquiry-based methods in the early, primary and lower secondary years of schooling (Bybee, 1997; Goodrum, Hackling and Rennie, 2001; Millar and Osborne, 1998). A working group established by the network of academies of science throughout the world identified two key characteristics of inquiry-based science education; these are:

Students are developing concepts that enable them to understand the scientific aspects of the world around them through their own thinking using critical and logical reasoning about evidence that they have gathered. This may involve them in first hand manipulation of objects and materials and observation of events; it may also involve them in using evidence gained from a range of information sources including books, the Internet, teachers and scientists.

Teachers are leading students to develop the skills of inquiry and the understanding of science concepts through the students' own activity and reasoning. This involves facilitating group work, argumentation, dialogue and debate, as well as providing for direct exploration of and experimentation with materials (Inter-Academies Panel, 2010, p.4).

The commitment to inquiry-based science education (IBSE) relates to the focus on students' active engagement in learning through scientific investigations as this approach immerses students in scientific activity thus helping them to understand the nature of science, develop inquiry skills and develop understandings of science concepts based on real experiences of natural phenomena. These three categories of learning outcomes map directly on the three strands of the Australian Curriculum – Science (ACARA, 2014). The active engagement of students in guided scientific inquiry provides rich opportunities for developing higher order thinking, problem solving skills and scientific reasoning which are important components of scientific literacy.

There is a risk that the current focus on explicit and direct forms of instruction, which have proved so successful in developing phonological awareness in young children, may lead to a form of educational faddism where direct instruction is seen as the magic bullet, the simple solution to all educational problems. As in learning to read, learning science requires a mix of pedagogical approaches; however, direct forms of instruction have a limited role to play in science education and the imperative to foster higher order learning outcomes demands that inquiry-based methods must play the predominant role.

Russell Tytler's seminal paper on reimagining the science curriculum (Tytler, 2007) argued strongly for a curriculum which sets science learning in authentic contexts, involves community

partnerships, utilises inquiry-based pedagogies in which students have some agency in their learning, and that the forms of assessment better reflect the higher order learning outcomes that we aspire to. Getting the curricular and pedagogical settings right is essential; however, the effectiveness of curriculum implementation depends very much on the pedagogical content knowledge (PCK) and beliefs of the teacher. The lack of specialist science teachers in primary schools and out-of-field teaching in the early secondary years results in science being taught by teachers with limited specialist science PCK, a limited repertoire of inquiry pedagogies and capability for recognising where students are at in their learning journey and ability to respond to their learning needs. The most effective way of improving teacher effectiveness is through discipline-specific and ongoing teacher professional learning, and as our Chief Scientist has argued, we should:

Provide all pre-service and in-service STEM teachers with training and professional development opportunities to deliver contemporary science using contemporary pedagogy, with a focus on creativity and inquiry-based learning—more like science is practised (Office of the Chief Scientist, 2014, p.23).

What we have learned from our Asian neighbours who outperform Australia in international assessments of students' scientific literacy, is that they are rigorously systematic in their approaches to teacher professional learning. South Australia provides an Australian shining example of such systematic approaches to professional learning with their Primary Mathematics and Science Strategy which provided every teacher in South Australian Government primary schools with three days of science professional learning and Primary Connections curriculum resources, and three days of mathematics professional learning focussing on maths content.

Mark Hackling is Emeritus Professor at the Edith Cowan Institute for Education Research, Edith Cowan University. He has provided leadership to national science education programs such as Primary Connections.

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Is it time to start reconceptualising maths and science teacher education?

JENNY PESINA & GERALDINE CARROLL

Associate Professor Elizabeth Johnson, La Trobe University, August 2014

Overview

There have been growing concerns with the shortage of trained primary and secondary science and mathematics teachers nationally in Australia. At the same time as there have been surpluses of general primary teachers in metropolitan areas, there have been persistent shortages of suitably qualified teachers in secondary school subjects such as mathematics, science and technology (Productivity Commission 2012). This issue is especially evident in rural and hard to staff schools (Hobbs, 2012).

Enrolment of senior school students in science subjects is at present on a long-term declining trend in both absolute numbers and as a proportion of the total cohort. Mathematics participation declined from 76.6 per cent to 72.0 per cent between 2002 and 2010, and there is a continuing shift from intermediate and advanced levels of mathematics to the elementary level. Further decline in enrolments are noted for biology, chemistry and physics (Chubb & Chubb 2012).

There are similar concerns in Victoria. Recent national and international data indicate that Victorian students generally perform well in mathematics and science (PISA 2006; TIMSS 2007; NAPLAN 2008). However, students' interest in science and mathematics is declining. According to the blueprint for energising science and mathematics education in Victoria, while more than 80 per cent of Victorian students are studying science and mathematics at the senior years of secondary school, many do not continue to do so at the tertiary level (Department of Education and Early Childhood Development 2009). The Education and Training Committee for Victorian Parliament noted there are also emerging difficulties in meeting the demand for specialised mathematics and science teachers, particularly in some hard-to-staff locations (Education & Training Committee, 2006).

To address these issues, the Australian Government has committed $54 million in funding over four years towards the 'Investing in Science and Maths for a Smarter Future' initiative. This is in response to the report by Professor Ian Chubb AC (2012), Australia's Chief Scientist: 'Maths, Engineering and Science: in the National Interest'. By establishing collaborations between education, science and mathematics faculties, departments and schools, the program aims to increase the supply of graduates as well as increase the retention rates of existing pre-service teachers.

> *The ReMSTEP project facilitates and supports an improved competence and confidence in the teaching of science and maths, as a pre-service focus, across the Australian Curriculum.*

It is widely accepted that students' choices in pursuing careers in science and mathematics are influenced by their school education. The initiative therefore aims to develop teachers' capabilities in bringing contemporary scientific understanding and practice into schools, including primary and secondary year levels.

The 'Investing in Science and Maths for a Smarter Future' initiative is a basis for inspiration to the Office for Learning and Teaching (OLT) program entitled 'Enhancing the Training of Mathematics and Science Teachers' (ETMST). The goal of the program is to drive a major improvement in the quality of science and mathematics pre-service teacher education. A budget of $12.4 million has been allocated for this sole purpose.

The ETMST Program consists of five major projects across Australia; the 'Reconceptualising Maths and Science Teacher Education Programs' (ReMSTEP) project is centred in Victoria.

Welcome to ReMSTEP

The ReMSTEP project facilitates and supports an improved competence and confidence in the teaching of science and maths, as a pre-service focus, across the Australian Curriculum. Four leading Victorian universities have established a network under the ReMSTEP umbrella, dedicated to developing new teacher education practices that align contemporary approaches in science, technology, engineering, and mathematics (STEM) with innovative and engaging approaches to teaching and learning.

The project directly promotes collaboration between researchers and educators in science, mathematics and education. Active partnerships have been established with specialist science and mathematics centres, the Melbourne Museum, professional organisations, scientists and mathematicians.

These partnerships will drive positive change in the quality of mathematics and science teachers by creating programs where undergraduate STEM students and pre-service teachers work collaboratively with education faculties and researchers to create new materials, units of study and expertise in inquiry-based classroom practices.

The project partners collaborating under the ReMSTEP umbrella include the University of Melbourne (lead institution), Deakin University, La Trobe University and Monash University. At the core of ReMSTEP, seven innovations have been identified to focus project's activities over the three-year period of the initiative:

Innovation 1: Contemporary science and mathematics in integrated science and pre-service units of study.

Innovation 2: Undergraduate science students engaging with schools.

Innovation 3: Science specialisations within primary pre-service programs.

Innovation 4: Specialist Science and Technology Centre collaborations.

Innovation 5: Practicum opportunities in world-class research environments.

Innovation 6: Building on existing student expertise in science and mathematics.

Innovation 7: Building a recruitment pipeline of high potential mathematics and science teachers.

To achieve the goals of seven innovations, ReMSTEP's funding supports teaching relief for academics involved in curriculum development, professional learning, coaching of other staff, materials and development of resources. In addition, there is funding for laboratory equipment for experimental work, collaborative work with specialist science centres, dissemination of materials and training. Two annual conferences are planned for 2015 and 2016. In addition, ReMSTEP has identified a number of leading academics and organisations to take part in its External Reference Committee.

Key developments

A mixed project team from Deakin University, in partnership with the University of Melbourne, has developed a model for collaboration with specialist centres and is currently developing three new topics in consultation with the Gene Technology Access Centre (GTAC). These topics are:

- Stem Cells (Secondary)
- Bionic Eye (Secondary)
- Adaptations (Primary)

The topics will be developed by core teams with representation from GTAC staff, scientists, science and mathematics educators and pre-service teacher candidates from the University of Melbourne and Deakin University. A management team, comprising of ReMSTEP and GTAC representatives will oversee the overall process.

One of the aims of this collaboration is for developed components to be trialled and evaluated at rural government and outer metropolitan disadvanged schools. Core teams will identify appropriate approaches and methodologies for each topic. In addition, concurrent planning is in progress with Melbourne Museum, the Institute for Frontier Materials (IFM) and Quantum Victoria.

As part of the collaboration with Melbourne Museum, a group of pre-service teachers will learn about how areas of the museum's collection relate to areas of the curriculum. The pre-service teachers will be able to work with the museum's science education staff and scientists to gain better understanding of how objects from collections are used to communicate scientific ideas to diverse audiences. The daily research activities of museum scientists will be explored and documented, offering the pre-service teachers rich experience in all aspects of contemporary science practice.

The ReMSTEP project team at Deakin University has established relationships with scientists from the Institute for Frontier Materials at Geelong and Burwood campuses. Planning is underway to develop models of embedded scientific research and practice in pre-service teacher education programs. In addition, an innovative project for pre-service teachers enrolled in chemistry curriculum units at Deakin University's Burwood campus is in progress. Pre-service teacher candidates will engage in discussions with researchers in order to develop teaching resources based on current scientific practices, with a focus on the chemistry strand in the Victorian and the Australian Curriculums. This will form part of the teacher candidates' assessment.

Reconceptualising program and course structures is an essential focus for ReMSTEP. Melbourne Graduate School of Education at the University of Melbourne has introduced a new Science and Mathematics elective in Master of Teaching (Primary) program. Professor Stephen Dinham, ReMSTEP's Project Director, has emphasised that 'the teachers would graduate as fully qualified generalist primary teachers with an extra accreditation in maths or science teaching, giving schools flexibility in how they use them' (Ferrari 2014, n.p.) Previous teaching programs have focused on retraining existing teachers rather than embedding the specialisation in a teaching degree, as is the case at Melbourne University (Ferrari, 2014). Concurrently, a number of activities are being planned with Melbourne University's Master of Teaching (Secondary) mathematics focus.

La Trobe University is partnering pre-service teachers with mid-career scientists (a group currently holding Future Fellowships funded by the Federal Government). Each of the scientists manages a small laboratory. A wide range of science disciplines are covered by the group, ranging from sleep disorders and cancer biology to theoretical mathematics and material science. This initiative, elegantly named 'Scientists as Partners in Education' (SPIEs) focuses on giving teacher candidates a personal experience in contemporary science. This will be a valuable experience for pre-service teachers who will be mentored and guided to develop and trial innovative units of study.


Students during the science experiment at the University of Melbourne

Work is continuing, to identify science researchers to act as partners for pre-service teacher candidates through the Multi-disciplinary Science and Technology Integrated Experience (MSTIE) at La Trobe's Bendigo campus. MISTIE already provides an excellent platform for integrating science and technology into the primary level teacher practicum experience. The work at Bendigo will help strengthen the program, refresh the nature of contemporary science in the program and develop partnerships that will enable the scientists to work directly in schools.

As part of ReMSTEP's collaboration with specialist science centres, La Trobe's project team is working with Quantum Victoria on developing new science materials. The Quantum Centre is one of six specialist science centres, funded by the Victorian Government, with a focus on physical sciences.

The project team at Monash University is currently involved in developing new units of study in its Master of Teaching and Bachelor of Science programs. Alongside these activities, another unit is in planning for a Faculty of Education Research Project subject. Collaboration with the Faculty of Science is underway to gather ideas for the design of Master of Teaching units. An audit has been completed of the existing science outreach at Monash, and this work has identified the potential for developing curriculum based outreach programs for science students.

Conclusion

The need for strong collaborative relationships will underpin the success of ReMSTEP and the ETMST Program as a whole, by building strategic partnerships between scientists, mathematicians, teacher educators, in-service teachers and pre-service teacher candidates to achieve common goals of increasing science and mathematics competence and confidence in pre-service teachers. This will in turn lead to an increase in qualified and passionate mathematics and science teachers in Australian schools and students with appreciation for these areas. It is an important cycle and a necessary step in re-thinking mathematics and science knowledge for life.

Jenny Pesina is the Educational Designer and Geraldine Carroll the Project Manager for ReMSTEP. Email: j.pesina@unimelb.edu.au.

List of terms and acronyms

ETMST - Enhancing the Training of Mathematics and Science Teachers

GTAC - Gene Technology Access Centre

IFM - Institute for Frontier Materials

MSTIE - Multi-disciplinary Science and Technology Integrated Experience

NAPLAN - The National Assessment Program – Literacy and Numeracy

OLT - Office for Learning and Teaching

PISA – Programme for International Student Assessment

ReMSTEP - Reconceptualising Maths and Science Teacher Education Programs

SPIEs - Scientists as Partners in Education

STEM - Science, Technology, Engineering, and Mathematics

TIMSS - Trends in International Mathematics and Science Study

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The place of science in early years

CHRISTINE HOWITT

For young children (from birth to eight years), play and science are naturally interwoven. While there would be little argument, from early year educators on the importance of play in young children's learning, the same cannot be said for the place of science.

Young children have often been called 'natural scientists' as they attempt to understand their immediate world. A natural curiosity is exhibited that translates into wondering, observing, exploring, questioning and discovering as these children develop their own explanations and understandings of how the world works. All their senses are used as they playfully explore their surrounds, and constantly make connections in their learning through each new encounter. Howitt and Blake summarised this connection between young children and science succinctly: 'where there is a child there is curiosity and where there is curiosity there is science' (Howitt and Blake, 2010, p.3). An acknowledgement of children's curiosity provides a vehicle for science teaching and learning.

Science has the potential to improve the conceptual knowledge, practical skills, reasoning and thinking skills, communication skills, social skills of children as well as their attitudes and dispositions (Brunton & Thornton 2010; Eshach & Fried 2005). The provision of appropriate science learning experiences can assist children to better understand their world. These experiences encourage children to investigate and explore their environment that in turn aids their practical skills of observation. Science skills of young children are enhanced when their senses are linked to the use of fine motor control, hand-eye coordination and construction. Emergent science also offers many opportunities for reasoning and thinking skills such as questioning, speculating and inferring, problem solving and reflecting. Collaborative participation in science experiences encourages children to develop communication skills including speaking, listening, discussing, arguing, representing, recording and reporting. Through active engagement with science, young children also develop social skills such as cooperation, negotiation, leadership, following instructions and behaving safely. Early science learning, therefore, allows for the development of curiosity, enthusiasm, motivation, responsibility, sensitivity, originality, independence of thought and perseverance as cognitive, practical and self-regulation skills are interconnected.

So, what does science look like in the early years? When a six-month-old reaches out to grab a toy and pushes it beyond her reach, transfer of energy is involved. An 18-month-old who drops a toy from his high chair and wonders where it went is experiencing gravity. A three-year-old watching a caterpillar crawl along a branch is learning how different animals move; while a five-year-old observing a puddle shrink over time is learning about evaporation. Science is everywhere–in everything we do. For young children, food, clothes, toys, the weather and technology can offer examples of science in their everyday life. A child combining sand, water, leaves and gum nuts is learning about mixtures. Another constructing a fairy house from different outdoor materials is exploring the properties of materials and the beginnings of engineering. An appreciation and understanding of the everyday nature of science in children's play is essential for educators to develop and extend these science concepts.

The Early Years Learning Framework (EYLF) defines curriculum as 'all the interactions, experiences, activities, routines and events, planned and unplanned, that occur in an environment designed to foster children's learning and development' (DEEWR 2009, p.45). Thus, what young children encounter every day through their play and curiosity can be a part of the early years science curriculum. Educators who are responsive to children's interests and observant of their play can identify teachable science moments and emergent science curriculum.

Young children have a range of understandings of scientific concepts as a consequence of their interactions with, and desire to make sense of, the world. While their initial ideas may be far from the scientifically correct concepts, these ideas make perfect sense to children as they are based on their everyday experiences and contexts (Campbell 2012).

It is important to note that it can take 12 years (or more) of formal schooling for students to reach the correct scientific concept. Harlen argued that in the early years educators should distinguish between the 'right' answer and the 'correct' answer. A right answer is based on children's everyday experiences and prior knowledge. While a right answer may be a long way from the scientific truth, it allows young children to make observations and gain confidence in their ability to describe what they think is happening and why it might be happening (Harlen 2001). Science in the early years is about providing children with a range of learning experiences that enable them to start developing concepts that have some relationship to scientifically accepted views (Campbell 2012).

The US National Science Teachers' Association (NSTA) recently produced an Early Childhood Science Education Position statement. Within this they identified six key principles to guide learning of science in young children (NSTA 2014). These are summarised below.

1.

Young children have the capacity to engage in scientific practices and develop understandings at a conceptual level. This acknowledges that all young children have the capacity to construct conceptual understandings; using reasoning and inquiry, observing, exploring and discovering their world. Educators tend to underestimate young children's capacity to learn science core ideas and practices, consequently failing to provide opportunities, experiences and appropriate scientific language for them to develop science skills and build conceptual understanding.

2.

Adults play a central and important role in helping young children learn science. While children are constantly learning through play, adults also have an important role in this learning. This role includes preparing the learning environment; co-constructing knowledge; being a source of expertise, skills and knowledge; actively listening to children's ideas; encouraging children to ask questions; asking productive questions; initiating and stimulating talk; and modelling how to think things through (Blake & Howitt 2012; Brunton & Thornton 2010). It should be noted that materials on their own do not teach scientific concepts. The best science learning opportunities occur through conversations between children and adults while interacting with materials (Fleer 2009).

3.

Young children need multiple and varied opportunities to engage in science exploration and discovery. Science understandings are best developed in young children when they are provided with multiple opportunities to engage in exploration both indoors and in the natural environment. The range of experiences provides opportunities for children to identify patterns, formulate theories, consider alternative explanations, and build on their existing knowledge.

4.

Young children develop science skills and knowledge in both formal and informal settings. Children learn about science everywhere. This includes formal pre-school/school settings along with informal settings such as homes, parks, zoos, museums and science centres. Parents, grandparents, carers and educators can purposefully support children's science learning through everyday activities such as cooking, gardening, cleaning, using playground equipment, fixing and using machines and visiting the park or beach (Robbins 2012).

5.

Young children develop science skills and knowledge over time. Young children require many opportunities for sustained engagement with materials and conversations with adults. They require time to explore resources, discover ideas, construct meaning and learn skills. They also require opportunities to re-visit and re-engage with materials and activities to build on their observations and ideas.

6.

Young children develop science skills and learning by engaging in experiential learning. Young children learn best by doing. The provision of engaging science learning experiences with appropriate and varied materials encourages children to question, explore, investigate, discover and construct meaning.

Young children are highly capable and competent science learners. Through play and curiosity they develop science explanations of their immediate world. Educators who nurture a sense of wonder and enthusiasm for science, and provide opportunities and time for exploration and investigation, can assist young children in developing scientific attitudes, dispositions, skills and knowledge for lifelong learning.

Christine Howitt is an early childhood education lecturer at the Graduate School of Education, The University of Western Australia.

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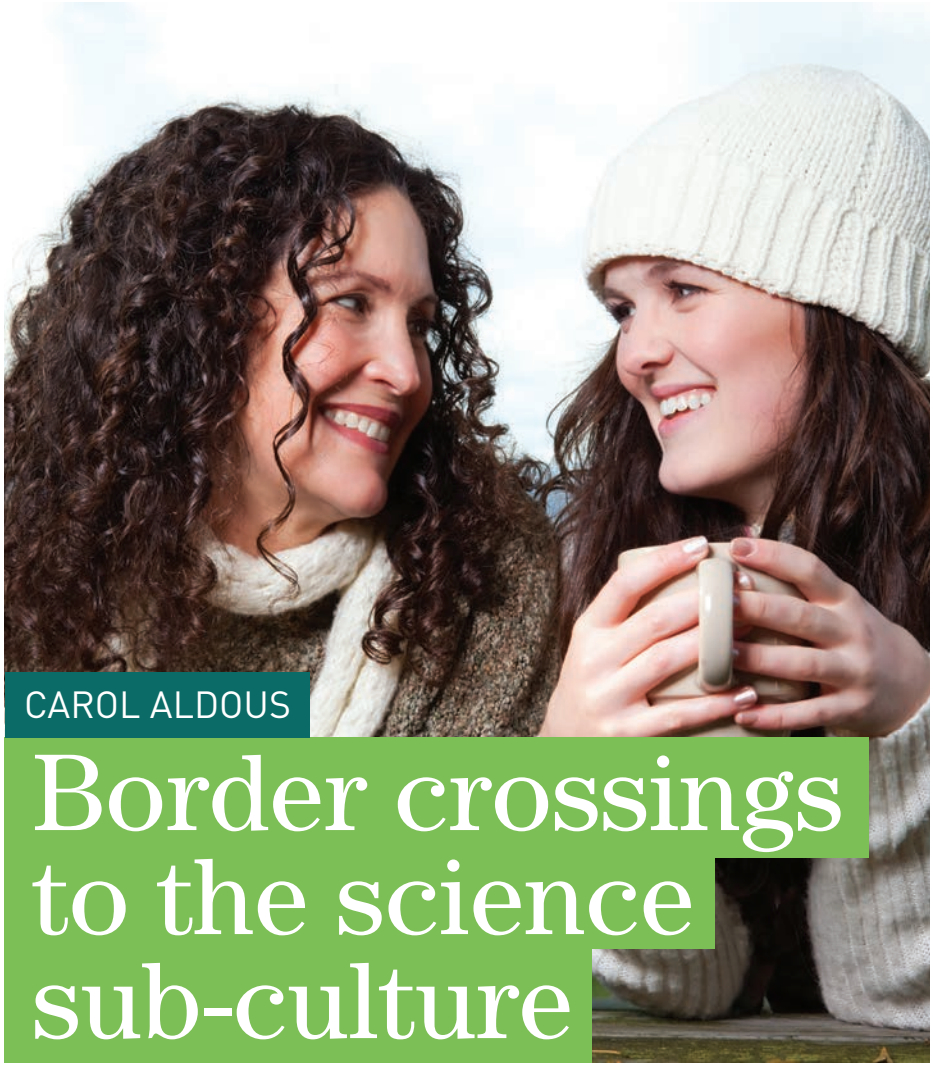

CAROL ALDOUS

Border crossings to the science sub-culture

I began teaching science over thirty years ago. As a graduate with an honours degree in science and a diploma in education, I had completed my university degree on an education scholarship. At that time, while young and enthusiastic, I was also naïve. I remember my mentor teacher guiding me in those formative years. 'Give 'em hell for the first three weeks' he advised. 'Only then can you ease up and have 'em eating out of the palm of your hand'. As an impressionable young teacher, I took the advice seriously and did my best to implement it. My intention however, was to be firm but fair. So it came as something of a shock to hear the words: 'She's pretty... but mean' being uttered from behind me as I walked across the school-yard.

As a young female entering teaching, I could be forgiven for thinking that I should have been pleased to learn that the students thought me pretty. However, to the contrary I was mortified by the contraindication of it. For it had not once been my intention to be mean. According to these students if one were so called 'mean', then one ought not 'to be pretty'. Alternatively, if one were 'pretty', then one ought not, 'to be mean'; but not both simultaneously.

At a deeper level I sensed that these students were personifying the conundrum of what it is to be both female and to teach in the perceived 'difficult' and masculine field of science within a rural secondary school. Over one quarter of a century earlier my mother, while training to be a teacher, had been denied the opportunity to major in mathematics and science despite her gifting in the area. When I asked the reason why, she replied: 'the social moray of the time dictated that ladies didn't'.

Paradoxically, it was from my mother that I first learned that mathematics and science could be awe inspiring, fascinating and great fun. She used words such as elegant, beautiful, wonderful and mysterious to describe them, words that I am sad to say, were never spoken from the lips of my own teachers of science. From her I came to understand mathematics as a type of language, a language with its own grammar and symbols that could be used to express patterns in nature and the world around us with such precision and simplicity that the resultant speech was both elegant and beautiful.

Now to a young female, the idea that mathematics and science could be either elegant or beautiful was revelatory. And it is something that has carried me through into my adult teaching career. But the reason for sharing this personal account is not so much to explain that such is the case (see Arianrhod (2006)), it is to clarify that such passionate and insightful instruction provided me with a way to enter the perceived masculine world of mathematics and science while at the same time, maintain my feminine identity. Some years down the track, Aikenhead (1996), a prominent science educator, would encapsulate just such a transition as a 'border crossing' into the world of science.

To Aikenhead (1996), learning science is akin to learning a new culture. This is because science is a field with its own set of conventions, values, processes and language. Therefore, the ease with which an individual learns science and mathematics is partially related to how well the culture of science aligns with the student's own culture. While the word 'culture', is likely too forceful a term, the word 'sub-culture' can be more aptly applied. Thus, the sub-culture of science can be seen to operate within the much wider but overarching culture in which we live. In the same way, many groups within society can be said to have their own functioning sub-cultures. The ►

sub-cultures comprising the family, the peer group, the classroom, the school and the physical and social environment for example, have been found to strongly influence students' understanding of and engagement with science (OECD 2014).

Enhancing the fluency with which students can move between sub-cultures, switching language conventions and moving backward and forward between the science-world and different life-worlds is important. The creation of 'border crossings' appropriate to different sub-cultures is vital to the process. Needless to say, the nature and extent of the border crossing will vary between individuals and groups and more than one border crossing will likely be required (for an example of the application of a series of border crossings into the culture of science see Aldous, Barnes & Clark, 2008).

Here I should elaborate that, although having majored in history and English, my mother had studied mathematics as a cognate. And when the opportunity arose she had also studied physics for the fun of it, to find out what it was that she was supposedly not allowed to know or do. The irony of course is this, despite having been denied the opportunity to major in mathematics and science, her entire teaching career was spent not in teaching history and English, but in the teaching and learning of mathematics at every grade level, because mathematics and science teachers, particularly good ones, were in short supply.

Programme for International Student Assessment (PISA) studies tell us that Australian students overall 'can do science' but are not necessarily, 'enjoying science' (Thompson & Borteli 2008). As educators it is important to harness the joy and wonder of discovery that is to be found in the study of science and to take hold of the psycho-social and emotional dimensions in learning and teaching to engage students in science. Recent developments in brain science are revealing that the very brain systems that keep us alive (the default mode setting) are the very same as those that help shape our social and emotional identity (Immordio-Yang et al 2012). Deep learning will not happen without engaging

> *"As educators it is important to harness the joy and wonder of discovery that is to be found in the study of science..."*

our emotional selves and this is nowhere more needed than in the learning and teaching of science.

I began my teaching career at a time when there was an oversupply of science teachers at least within the South Australian context. Now we cannot get enough. As Australia struggles to maintain its competitive standing on the global stage, education systems across the nation are in need of well-qualified teachers of science. Yet the numbers of students enrolled in the sciences at the upper secondary and tertiary levels continues to decline (Office of the Chief Scientist 2012). Lasting change requires a sustained, long-term approach. Every aspect of the teaching and learning cycle from early childhood through to tertiary level needs to be addressed and appropriate border crossings and strategies identified. Developments in the new field of complexity science are revealing the interconnectedness of relationships and that a broader all encompassing systems approach to reform is required.

Nobel prize winner Carl Wieman (2007) understood that he knew about the sub-culture of science but that he did not know about the sub-culture of teaching. What we need are individuals who know about and can engage deeply with both sub-cultures.

Carol Aldous is Director: Master of Teaching and Co-ordinator: Science programs within the School of Education Flinders University, Adelaide.

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Toward a carbon neutral school

WARWICK HOFFMAN

Climate change represents an environmental, economic and social threat to our modern society. It is an indicator of our unsustainable practices and is a key challenge our planet will continue to face into the future. The question arises, therefore, as to whether moving towards a carbon neutral school is an appropriate response for a school to demonstrate how to respond to this global issue at the local level. Whilst sustainability is a cross-curriculum priority within the Australian curriculum, many schools are finding it hard to offer more than a tokenistic effort in meeting this priority. An ever-expanding curriculum with a seemingly endless list of priorities can make addressing sustainability, and considering carbon neutrality, seem daunting.

Climate change is a clear indicator of the unsustainable practices present in our lifestyles. The Intergovernmental Panel on Climate Change (IPCC, 2008) predicts, for example, a significant loss of biodiversity, an exacerbation of water security issues and a decline in agricultural productivity in Australia by 2030. In recognition of this, sustainability education has been made a cross-curriculum priority within the Australian curriculum. The ideas under this curriculum give priority to recognising that sustainability is 'obtained through informed individual and community action' (VCAA n.d., n.p.). Action as a school community demonstrates commitment to our students for a sustainable future. A possible pathway towards sustainability of our school is to move 'towards carbon neutrality'.

Let's explore these points:

- what is carbon neutrality?
- why a school should consider becoming carbon neutral?
- a suitable pathway to moving towards carbon neutrality.

What does 'towards carbon neutrality' mean?

The everyday activities of a school generate greenhouse gas emissions, through electricity and natural gas usage, transport (to and from school activities and in general commuting) and the emissions embedded in the production of all the goods purchased for use in the school. It is possible to reduce the greenhouse gas emissions of some of these activities to zero, for example converting to solar hot water heaters. Pragmatically, however, it would be difficult and perhaps impossible, for a school to move to zero emissions through direct actions at the school. Carbon neutrality thus implies the need to purchase carbon offsets.

This requirement for carbon offsets is reflected in formal definitions of carbon neutrality. The Department of Climate Change (n.d., what is carbon neutral?) defines carbon neutrality as 'when the net greenhouse gas emissions of an organisation, event, service or a product are equal to zero'. Carbon neutrality is achieved when an organisation reduces their emissions as far as possible and then purchases offsets for the residual emissions. To be formally accredited as a carbon neutral organisation these offsets need to be purchased 'in accordance with the National Carbon Offset Standard (NCOS) and the NCOS Carbon Neutral Program Guidelines' (Department of Climate Change, n.d., n.p).

Why should a school become carbon neutral?

Sustainability is defined as meeting 'the needs of the present without compromising the ability of future generations to meet their needs' (VCAA, n.d., para. 2). Human- induced climate change is one indicator of our living in an unsustainable manner. On a per capita basis, Australia is one of the highest emitters of greenhouse gases, producing 28.1 tons of carbon dioxide per person, more than four times the world average (Garnaut, 2008). As a country, we have the responsibility to take a leading role in reducing these emissions. At a local level, a school has a responsibility to demonstrate to its community a commitment to act.

The Australian Curriculum recognises the need to equip students with the skills necessary to engage with relevant and contemporary issues, with 'sustainability' selected as one of three cross-curriculum priorities. The curriculum highlights that 'sustainability of ecological, social and economic systems is achieved through informed individual and community action' (VCAA, n.d., Organising Ideas). A school moving towards carbon neutrality models the relevance and importance of community action to their students.

Leadership on climate change demonstrates a commitment by a school to a sustainable future for their students. Moving towards a carbon neutral school is a tangible action to demonstrate this commitment. In 2012, for example, South Freemantle Senior High School became the first certified carbon neutral school in Australia (Simply Carbon, 2012). This accreditation was the culmination of a five-year journey to position the school as a leader in sustainability.

A pathway towards a carbon neutral school

The suggested pathway towards carbon neutrality is based on a procedure used by the Environmental Protection Authority (EPA). EPA Victoria has developed a series of carbon management principles to aid organisations to measure, avoid, reduce, assess and offset their greenhouse gas emissions. A similar approach is adopted in the National Carbon Offset Standard (Department of Climate Change and Energy Efficiency, 2012. A chart can be found in the EPA Victoria's Carbon Management Principles (EPA Victoria, 2007a, p3)

Using these carbon management principles, to move towards carbon neutrality a school may:

- measure their current level of greenhouse gas emissions (i.e. calculate a baseline carbon footprint)
- avoid/reduce emissions from current activities
- offset residual emissions
- set on-going emission reduction targets.

Measuring our carbon footprint

The first stage towards carbon neutrality is to measure what a school is emitting, as 'you can't manage what you can't measure' (EPA Victoria, 2007, p 5). It will also be necessary to set operational boundaries around what is measured. The World Business Council for Sustainable Development's Greenhouse Gas Protocol (WBCSD, 2004) defines three types of emissions:

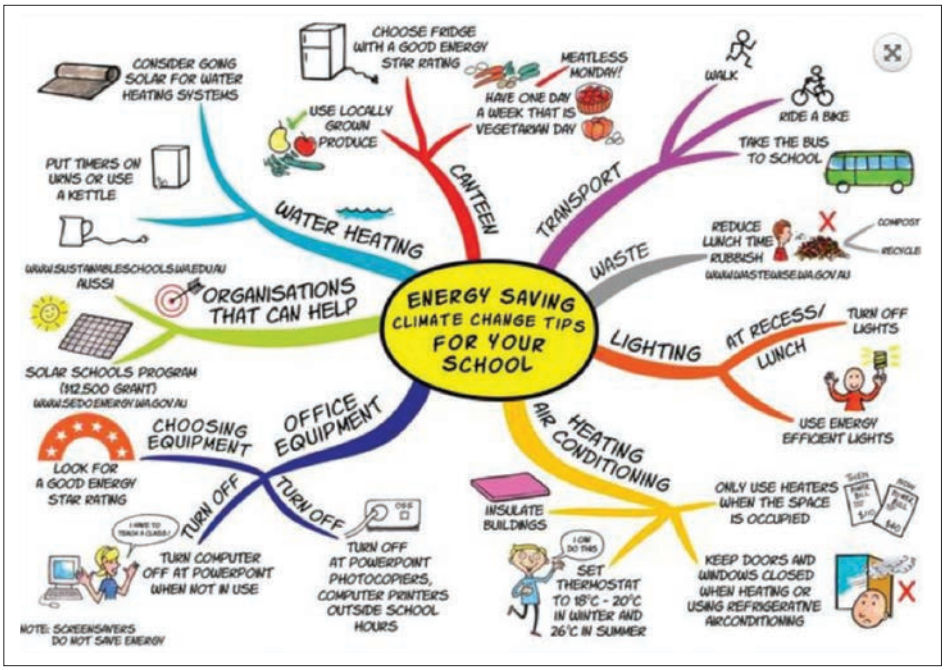
- Direct (Scope 1) – Petrol for vehicles, natural gas, refrigerant leakage in air conditioning and refrigerators
- Indirect (Scope 2) – Purchased electricity
- Indirect (Scope 3) – Staff commuting and carbon embedded in activities such as waste disposal, catering, employee travel, paper usage.

Schools can initially report Scope 1 and Scope 2 emissions, due to ease of information gathering and computational pragmatism. The calculation of Scope 3 emissions is more challenging and could be gradually introduced in future years.

Measuring the school's carbon emissions requires a systematic identification of sources and then using established emission factors to calculate the level of emissions. Online calculators can aid in the calculation of a carbon footprint (for example, Carbon Neutral, n.d.). It is important, from an accountability and credibility basis, that the footprint calculation be based on an accepted reporting protocol, such as the Greenhouse Gas Protocol developed by the World Business Council for Sustainable Development (2004). This protocol sets principles for relevance, completeness, consistency, transparency and accuracy of the information used to calculate an organisation's carbon footprint.

Avoid or reduce emission from our current activities

The primary focus of moving towards carbon neutrality is to identify opportunities to avoid/reduce carbon emissions from a school's activities. Whilst it may not be possible to achieve a school with zero emissions, opportunities will exist to minimise emissions. The aim is to reduce your emissions to the lowest possible level, with offsets only being used for the residual carbon emissions remaining. The Australian Sustainable Schools Initiative (Sustainability Victoria, n.d.) offers guidance on how to identify opportunities for reducing carbon emissions.



Ideas for Reducing a School's Carbon Emission (Learning Fundamentals, n.d.)

> *Offsetting can pose an ethical dilemma as it has been associated with organisations' buying their way out of poor environmental behaviour*

South Freemantle Senior High School formed a Carbon Neutral Committee to manage the process of identifying opportunities for reducing carbon emissions (Simply Carbon, 2012). With broad based representation (teachers, parents, community members, academics and the principal), the committee met fortnightly to discuss opportunities for reducing carbon emissions. A mind map of energy saving ideas from the school's carbon neutral project is reproduced in the figure (page 18).

Offsetting the school's residual footprint

Offsetting is the final stage of becoming carbon neutral. A typical offset is the purchase of green power (power generated from a renewable resource). Kollmuss, Zink and Polycarp (2008) discuss five major types of offset projects (bio- sequestration, industrial gases, methane, energy-efficiency, and renewable energy projects) highlighting the advantages and disadvantages of each method. Offsetting should only occur once efforts to reduce the school's carbon footprint have occurred.

Guidance on choosing an offset provider can be found at the Carbon Offset Guide Australia website (a partnership between Low Carbon Australia and the University of Queensland, 2012). This website lists the type of offset projects available, indicative costs and the accreditation schemes under which their offsets are provided. Note that some offset projects consider social as well as environmental issues (for example, the Gold Standard).

Offsetting can pose an ethical dilemma as it has been associated with organisations' buying their way out of poor environmental behaviour (Dhanda & Hartman, 2011; Murray & Dey, 2009). There have been issues in the development of the offset market, although the introduction of accreditation standards is helping to make the market more transparent. Kollmuss, Zink, and Polycarp discuss how these standards must meet: 'accounting standards' (to ensure the offsets are real and permanent); 'monitoring, verification, and certification standards' (to quantify actual savings when a project is running); and contain 'registration and enforcement systems' (to ensure offsets are only sold once) (Kollmuss, Zink, and Polycarp 2008).

Set reduction targets for the future

Targets (both short and long term) should be set and renewed to drive continuous reductions in a school's greenhouse gas emissions. On-going reductions in emissions will minimise the requirements for offsets. An aspirational aim might be a zero offset school (i.e. to be carbon neutral without the need to purchase offsets) however more practical goals are recommended.

How to sustainably resource the initiative

Successful implementation of a 'carbon neutral' school will require the leadership team to adopt 'achieving carbon neutrality' as a key priority. The school principal must ensure adequate resources/staff time can be committed to achieving carbon neutrality. In addition, sustainability needs to be considered by all staff as an integral part of the way they perform their jobs. Sustainability champions should be identified and supported within the school (both staff and students). The wider school community (parents) also forms a considerable resource to harness.

The initiative is doomed to fail if it is reliant on a single staff member. However, the appointment of a dedicated project officer may be critical in the initial stages to kick- start the project. This project officer can also be given accountability for leading a team to commence the integration of sustainability across the curriculum.

Options for seeking external funding should also be investigated. Grants are available from many organisations to support green initiatives. Novel funding approaches should also be investigated. For example, the South Freemantle Senior High School sought approval from the state government to retain funding from energy savings for use in future sustainability initiatives (Simply Carbon, 2012).

Integrating sustainability across the school curriculum

The adoption of 'towards carbon neutrality' as a school priority, provides the authentic reason for a school to consider sustainability across the curriculum. South Freemantle High Senior School, for instance, has used carbon neutrality as its mechanism to integrate sustainability across the curriculum, indicating how it provided 'innovative and practical learning opportunities' for students across a wide range of disciplines (Simply Carbon, 2012, p4).

Recommendations

For schools and their communities considering a coordinated and disciplined approach to carbon neutrality, the following three initial steps are recommended.

1. Make moving 'towards carbon neutral' a part of the school's vision

To codify the commitment to a sustainable future, it is essential that the school leadership team adopt carbon neutrality as part of a school's vision and mission. A member of the school leadership team should be made accountable for delivery of a carbon neutrality plan and performance against this plan reported to the board of the school. This team should be encouraged to use external resources (for example, Australian Sustainable Schools Initiative) and interact with leaders in the field (for example, South Freemantle High Senior School).

> *By adopting carbon neutrality as part of a school's vision, a tangible interest in sustainability is created.*

2. Use carbon neutrality as a springboard to full integration of sustainability across the school's curriculum

By adopting carbon neutrality as part of a school's vision, a tangible interest in sustainability is created. This authentic link, backed by school leadership team support, provides the real impetus to investigate integration of sustainability across the school's curriculum. A cross-domain team (including student representatives) should then be created to plan and be made accountable for real integration of sustainability across a school's curriculum, using towards carbon neutrality as the central theme to base the integration.

3. Calculate the school's baseline carbon footprint

To create initial interest in a school's carbon neutrality journey, calculation of a baseline carbon footprint should commence immediately (using a simple estimate of Scope 1 and 2 emissions). These calculations can be performed before other systems are operational within the school. The science domain can be made responsible for its calculation and integrate the task as part of the junior school curriculum. This baseline can also be used to estimate what offsetting costs the school may experience.

Warwick is an education student at the Melbourne Graduate School of Education.

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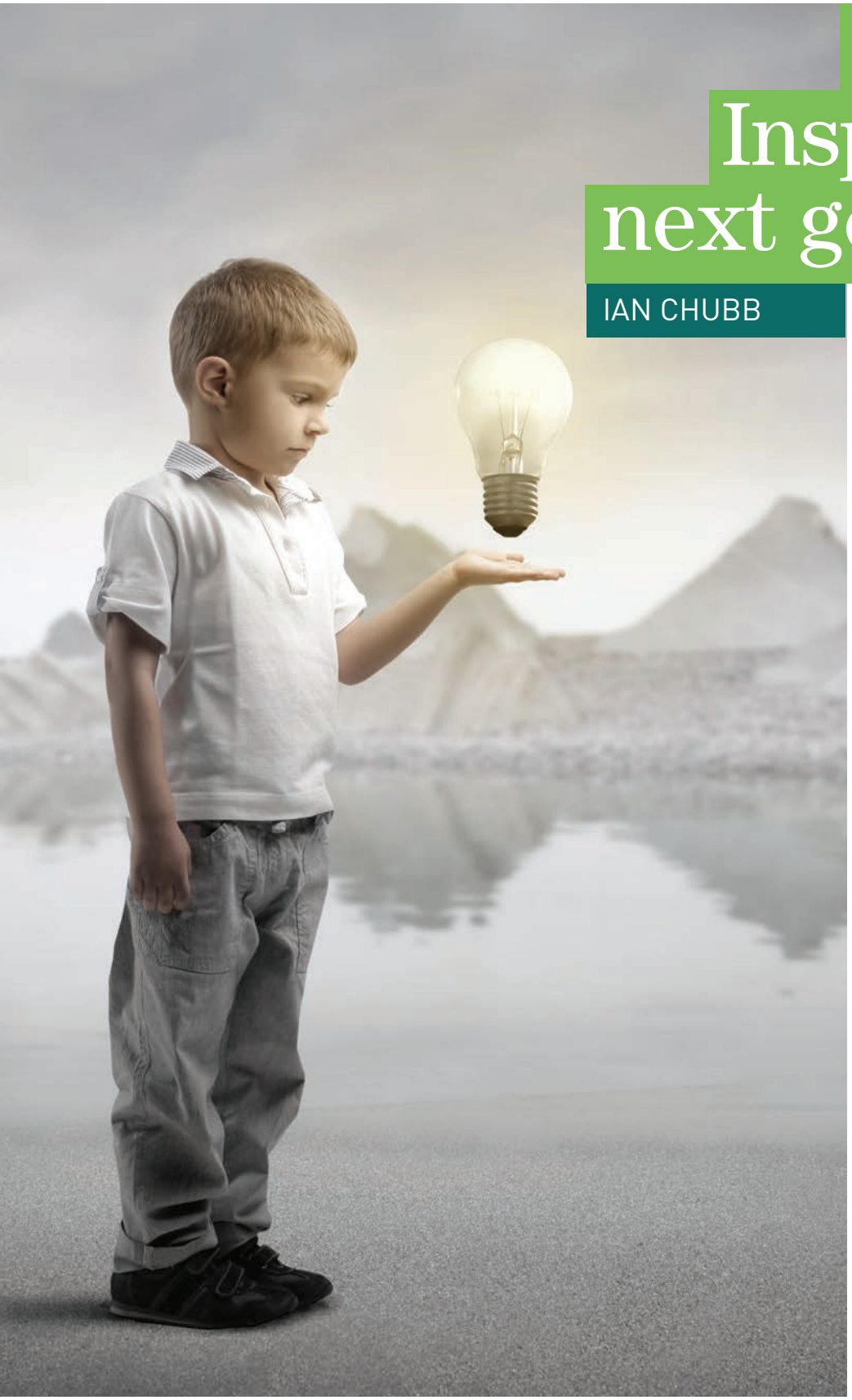


Science: Inspiring the next generation

IAN CHUBB

Australia's Chief Scientist, Professor Ian Chubb addressed the Gala dinner as part of the ACE 2014 National Conference – 'What counts as quality in education?' on the evening of Thursday 11 September, 2014.

These are his notes, however Professor Chubb departed from them as he delivered the speech. Those wanting to quote from this speech should contact the Office of the Chief Scientist for clarification (see details at the bottom of this article).

"I'm acutely aware of the fact that I'm the one coming between you and your dinner so I'll try to keep this as terse as possible.

I'm also aware that many of you in this room are not scientists, but nonetheless I hope I will be able to persuade you that science is interesting and important in education – to inspire the next generation to wonder, whether they go on to pursue a life in science or not.

From as early as they are able, children are natural explorers, naturally curious and have the basic outlook on the world required to be scientists.

They turn up rocks and rummage around looking for bugs; they pick the petals from flowers; they're always trying to find out what things are and how they work. And they are constantly asking questions about the world. 'Why? Why? Why?'

What's the response of adults? 'Don't touch that, it's expensive', 'don't play with that, it's dirty', "because I said so'.

Obviously 'if you touch that, it'll burn you' and 'if you eat that, it'll kill you' are appropriate limitations to put on their adventures, but much of this explorative and inquisitive nature is stifled before they even get to school.

Professor Ian Chubb

Astrophysicist Neil deGrasse Tyson put this fairly succinctly when he said: 'We spend the first year of a child's life teaching them to walk and talk and then the rest of their life to shut up and sit down. There's something wrong there' (http://www.goodreads.com/quotes/562509-we-spend-the-first-year-of-a-child-s-life-teaching).

I say this in the context of a world that is changing fast – in ways we only dimly understand.

But I saw it well expressed in an article in the *New Statesman* by Ian Leslie:

Before the internet and the before the printing press, knowledge was the preserve of the one per cent. Books were the super yachts of 17th century kings.

Today, in a world where vast inequalities in access to information are finally being levelled, a new cognitive divide is emerging: between the curious and the incurious.

Twenty-first century economies are rewarding those who have an unquenchable desire to discover, learn and accumulate knowledge.

It's no longer about who or what you know, but how much you want to know.

So perhaps it's time we stopped stamping on the fire – and got to thinking about how we nurture the flame.

It's been just over a week now since I launched my proposal for a national science strategy.

It's been gaining momentum.

I could not doubt it when I we starting trending above a naked actress on Twitter.

But we've also been inundated with positive comments from the research community, educators, businesses and industry; as well as the political sphere.

Ian MacFarlane, the Minister for Industry and the minister responsible for science was at the launch and spoke warmly about his desire to champion science in the government.

He said: 'The Australian Government looks forward to working with Professor Chubb on our shared goals of strengthening the role of science in the community and using it in ways that make us more competitive.' [emphasis added] (Media Release – 2 Sept, 2014, Minister for Industry).

And if my ideas are finding a reception I hope it is because I am not in the business of tinkering around the margins.

I am advocating something very different - a national cultural change.

A national culture that appreciates the role science plays in every aspect of our lives, from our health to our economy; from our food, to the way in which we communicate with each other.

That is the means to the end we all share: a stronger Australia, for our own sake and the good of the world.

When most Australians value the incredible role science plays in our wellbeing, everything else will begin to fall in to place.

When people in air-conditioned government offices start to think this way the teachers get very nervous.

If you ask any intelligent and successful adult about their schooling, I bet you'll find in most cases that they had at least one inspirational teacher or mentor at some point in their early development.

So we know the value of inspired teaching and we become very good at lecturing teachers about it.

We're not nearly so good at supporting them.

My one professional regret is that I am not sure that I was too good at being a mentor. I took very seriously my responsibilities, but I don't think I was patient enough to be a good mentor.

So when I say teaching isn't an easy job, I'm not being patronising – I'm saying it based on experience, albeit limited. I have enormous respect for those that can nurture the pleasure of finding things out in others.

Someone who can teach young people **how** to think not **what** to think.

And when teachers have the relevant knowledge about (and passion for) the subject that they're teaching, they can have the confidence to share their enthusiasm, expand on the curriculum, teach it in an engaging way and not just rely on textbooks and teaching students to simply pass exams.

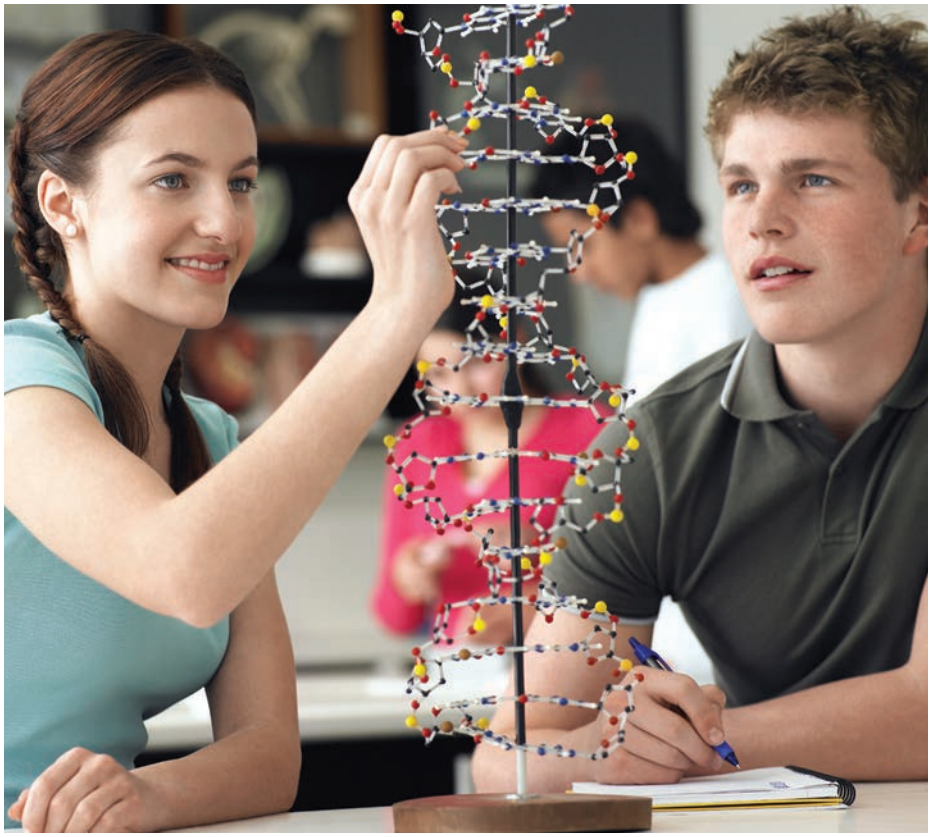
But too few high-performing science and maths graduates aspire to teaching careers – and too many of our graduating teachers bypass science and maths altogether. Teaching 'out of field' is the new norm (http://amsi.org.au/wp-content/uploads/2014/03/discipline-profile-2014.pdf).

The other big issue is that science is not taught as it is practised very often.

They don't do what scientists do: ponder a problem, design an experiment, unpick what they did to find out how they can explain what they observed; the debate, the skepticism, the very basis of the scientific process is rarely taught apparently – no time; crowded curriculum.

It is time to re-think how we prepare our teachers and how we support them:

- to strengthen their content knowledge
- to maintain it at contemporary levels
- to instill the confidence to deliver the curriculum in interesting and novel ways with relevant pedagogical development.



President Obama has said: 'efforts to improve STEM education are going to make more of a difference in determining how well we do as a country than just about anything else that we do here.'

Which I would like to echo for Australia.

Getting science education right at all stages in the pipeline – getting the support for teachers and getting students engaged in science will allow us to achieve everything else.

Time is not on our side.

International research indicates that 75 per cent of the fastest growing occupations now require STEM skills and knowledge.

In Australia, the Australian Industry Group is already reporting that a quarter of employers believe that the biggest barrier to recruitment is a lack of applicants with STEM skills (http://www.aigroup.com.au/portal/binary/com.epicentric.contentmanagement.servlet.ContentDeliveryServle t/LIVE_CONTENT/Publications/Reports/2013/Ai_Group_Skills_Survey_2012-STEM_FINAL_PRINTED.pdf).

That is no temporary blip on the market signals radar. It is because economies all around the world are evolving.

Countries at all levels of development are recognising that new technologies are pushing smart companies to the lead; companies that rely on the skills that come from a science education: analytical, logical, systematic, sceptical and problem-solving skills.

It is because they recognise this shift that they are prioritising science in their economic plans.

And the global economy isn't going to wait for us to catch up. Science education isn't just important for those who will go on to study science at university and/or go in to a job that requires science skills and knowledge. A basic understanding and appreciation of science in everyone would benefit society as a whole.

It would help the public to see through idiotic statements such as 'half of our schools are performing below average'.

It would certainly change the way in which the public conducts scientific debate on topics such as climate change, vaccinations, stems cells and others.

I find it incredible that certain scientific issues such as climate change have become a political debate. Yet I've never heard a politician or an economist want to give their opinion on, say, $E=mc^2$.

It's important to understand that science isn't a collection of facts; it's a method and a way of thinking.

If we can give every child a solid foundation of science and maths – if we can train them to think critically and sceptically, imagine how much the quality of public and political debate would improve in this country.

It is a grand ambition. But it is also an achievable agenda.

If it is worth doing, we have to be capable of that focus, alignment and scale.

And it is worth doing well - for Australia's future.

Thank you."

Professor Chubb has been Australia's Chief Scientist since May 2011. His previous roles have included:

2001-2011 Vice-Chancellor, The Australian National University

1995-2000 Vice-Chancellor, Flinders University of South Australia

1993-1995 Senior Deputy Vice-Chancellor, Monash University

1990-1995 Chair of the Commonwealth's Higher Education Council

1986-1990 Deputy Vice-Chancellor, University of Wollongong.

He was appointed a Companion of the Order of Australia for his 'service to higher education including research and development policy in the pursuit of advancing the national interest socially, economically, culturally and environmentally and to the facilitation of a knowledge-based global economy'.

References and other information please contact: Head of Communications Office of the Chief Scientist, Mick Bunworth at: mick.bunworth@chiefscientist.gov.au

WHAT COUNTS AS QUALITY IN EDUCATION?

A quality National Conference

Last month's ACE 2014 National Conference (11 & 12 September): 'What counts as quality in education?' held in Adelaide, was an overwhelming success attended by more than 140 educators from all sectors of education including: schools, early childhood, higher education and VET.

Nationwide media attention was given to papers by Professor Stephen Dinham and Ms Virginia Simmons with Professor Lingard's and Mr Whitby's presentations also among the well-received (please see full papers at www.austcolled.com.au).

The Gala dinner held on the Thursday evening, featuring the presentation of the ACE Fellowships and the prestigious College Medal, saw members thanked for their significant efforts and contributions to education above and beyond their professional roles.

The collegial atmosphere was assisted by music from Brighton Secondary School and special dinner guest, Australia's Chief Scientist - Professor Ian Chubb's presentation on the quality of science education in Australia. Professor Chubb spoke about 'a national culture change that appreciates the role science plays in every aspect of our lives, from health to economy; from food, to the way in which we communicate with each other' (for the full presentation please see pages 21 to 23).

Dr Gerry White, who was awarded the College medal, said in his acceptance speech: 'This award is a great honour for me from the most eminent education organisation in Australia. For me to receive this award is somewhat overwhelming and I thank you sincerely.'

ACE would like to greatly thank all those who attended, especially all the presenters who stayed on to benefit from the full program, all organisers/volunteers and National Office staff who dedicated many days to bring this successful event to fruition.

Please keep an eye out for future information on the 2015 National Conference which will carry the theme: 'Educators on the edge', to be held in Brisbane on 24 & 25 September, 2015.

ACE Fellows and College medal for 2014

This year the ACE Fellowships and the prestigious College Medal were awarded during the Gala dinner as part of the ACE 2014 National Conference – 'What counts as quality in education.

These awards were granted to educators who have been judged by their peers to have made significant efforts and distinctive contributions to the field of education above and beyond their professional roles.

The 2014 ACE Fellows are:

Dr Michael Bezzina
Ms Anne-Maree Creenaune
Professor Philip Foreman
Mr Simon Gipson
Ms Bronwyn Hession
Mrs Ann Lockwood
Mr Warren Marks
Ms Robyn Monro Miller
Mr Andrew Newman
Mrs Susan Wyatt

HONORARY FELLOW

Mr Philip Malcom Grutzner

The College Medal

The 2014 College Medal was awarded to Dr Gerald White from SA for his outstanding involvement in Australian education for well over 40 years.

Since 2008, Dr White has worked for the Australian Council for Educational Research (ACER) in Adelaide as Principal Research Fellow. He was the inaugural CEO of Education.au Limited, from 1997 to 2006, and also ran the Education Network Australia (EdNA), MyFuture and other national projects. He was a member of the Australian ICT in Education Committee (AICTEC) and its schools, training and higher education sub-committees and related bodies from 1997 to 2006 and was awarded the' ICT Leader of the Year' by VITTA in 2009.

Prior to this Dr White was a leader in Curriculum Management in the South Australian Education Department (now DECD) and was the Deputy/Acting Director of Catholic Education in South Australia, as well as the National Co-ordinator of ICT for the National Catholic Education Commission.

Throughout his career Dr White has made a strong contribution to education outside the school sector on the state, national and international scene as a regular presenter, writer, researcher, keynote speaker, and panellist at numerous national and international conferences.

He also has been the ACE SA State President from 1999 to 2000, a National Board member and a Fellow of the College and is highly respected by educators across Australia for his distinctive contributions to Australian education.

Moreover, Dr White was also a teacher, a principal, a curriculum manager and consultant in the government sector earlier in his career.

Dr Gerald White's acceptance speech given at the Gala dinner:

"Professor Stephen Dinham, Distinguished Guests, College Fellows, My Family (Irena, Caroline and Chris), Ladies and Gentlemen

This award is a great honour for me from the most eminent education organisation in Australia. For me to receive this award is somewhat overwhelming and I thank you sincerely.

I have been extremely lucky in my career to have been mentored by and learn from some of Australia's education greats: my wife Irena, Professor Peter Brinkworth (MACE), Professor Jonathan Anderson (FACE, National President), Garth Boomer, Dr Tony McGuire (FACE), Professor Stephen Dinham (FACE, National President), Dr John Ainley (FACE), Mr Geoff Spring (FACE), Dr Brian Croke (FACE) and a host of remarkable and inspiring colleagues. These education greats were also members the College which is testimony to the prominence of the organisation.

My career within education has taken me on a trajectory of teaching and leadership, including in mathematics education as well as teaching and learning with digital technologies. As a teacher, I saw teaching colleagues skilled in pedagogy make a difference; as principal, I saw teachers and principals skilled in pedagogy make a difference; as

a lecturer, I saw teachers and principals skilled in pedagogy make a difference; as an educational administrator, I saw teachers and principals skilled in pedagogy make a difference; as the national head of the Australian education and training technology agency, I saw teachers and principals skilled in pedagogy make a difference; as a researcher, I saw teachers and principals skilled in pedagogy make a difference. My disposition about what makes a difference in education is fairly plain to see.

I have never seen an economist, an accountant, a business person, a banker, a politician, a lawyer, a journalist, a treasury official or a policeman make a difference in education.

However, I have seen some of these professionals support teachers and principals in ways such that they did have an influence on making a difference.

I am reminded of the statement that Professor Alan Reid wrote when we worked together in the Curriculum Directorate of the then SA Education Department. In a document called Our Schools and Their Purposes: Into the 80s, he wrote, 'The interaction between teacher and learner is at the heart of schooling' (Our school and their purposes: Into the 80s. (1981): Education Department of South Australia).

This fundamental education truism is being muzzled in the rhetoric of the Western world among nonsense such as free schools (UK), Charter schools (USA), Teach for Australia (Australia), independent school governance (Australia, WA), teacher quality instead of education quality (Australia), increased funding does not make a difference to education (Australia) and teaching computer programming to all school students (UK).

I'll leave you with this thought which for me is at the very core of education.

'And what is as important as knowledge?' asked the mind.

'Caring and seeing with the heart,' answered the soul (unknown).

Thank you so very much."

Science, stereotypes and the cinema

MEGAN IVORY

Meg Ivory examines, for *Professional Educator*, how popular culture can play a part in how science and scientists are viewed by society.

Mad scientists and absent-minded professors have dominated Hollywood depictions of scientists for many years. These archetypes tap into our collective fear of science and those who practise it. Stereotypes that indicate we are only not serious about science; we are terrified of it.

Frankenstein, arguably the ultimate 'mad scientist' movie, has been filmed over 130 times making it one of the most popular tales ever brought to life on screen (Haynes, 1998). Dr Frankenstein incorporates all the elements of the archetypal mad scientist, a man more interested in his creation than in human beings, or annoyances such as ethical considerations, he messes with nature to create life with no regard for the consequences. The popularity and timelessness of the story is found in its ability to reflect our deep fears about science, scientists, and the terrifying implications of humans creating life, messing with the divine order, or with nature in a way that threatens us all.

The last fifteen years have seen a move away from these stereotypes and towards a more realistic image of scientists, and their craft in movies. We also have seen Hollywood producers increasingly engaging science consultants to try to bring scientific realism to their sets, to avoid the kinds of errors, or 'bad science' as it is known in scientific circles, that can have scientific communities and internet forums up in arms. The scientific community itself has also been making an effort to strengthen ties with producers; setting up groups to promote science in popular culture, and provide film and television producers with access to scientific experts to ensure accuracy in their productions.

Lab Coats in Hollywood explores the way scientists interact with Hollywood (Kirby 2011). This excellent book tracks the engagement of science writers on Hollywood sets. From Stanley Kubrick's epic 2001: A Space Odyssey to today, David A. Kirby tracks a trend that sees more and more producers engaging science consultants to ensure their movies are factually correct.

As detailed in *Lab Coats in Hollywood*, science consultants, while becoming more prevalent on sets, are not in a position to dictate exactly how science and scientists should be depicted; the story is king. The influence a science consultant or any expert, can have on set is affected by many factors; from the interests and beliefs of the producers and directors, which genre the movie belongs to, the intended audience and more. If the story sacrifices scientific accuracy for the sake of entertainment that is a price most producers and directors are prepared to pay. The presence of a consultant does not guarantee scientific accuracy; advice can be accepted or rejected based on a need for a particular plot line, for artistic integrity or to preserve key sub-plots or many other reasons.

It is encouraging that we are seeing moves by the film industry to be more accurate in the science and technology they depict on the screen. It shows an increasing respect for science and scientists, and a cultural shift away from fearing the mad scientist to a renewed public support of, and interest in science. Does this indicate that we are less afraid of science and scientists? It certainly seems that we are no longer content with just a good story; scientific accuracy can and should be upheld, stereotypes of scientists seem dated, and increasingly unfashionable.

Scientists and institutions have sought to influence the portrayal of science on the screen. The creation of The Science and Entertainment Exchange, a branch of the National Academy of Sciences, was in order to allow producers and directors access to a group of professional scientists who are available to consult and to assist in providing technical expertise for filmmakers. They offer script proofing, expert advice and opinion and many services for producers and others to ensure scientific accuracy is preserved in cinema. They also work to promote the good image of science and its practitioners. By making expert advice and opinion accessible, they are able to positively influence how science is perceived by filmmakers and thus depicted on the screen.

> *“Our relationship with science and with scientists is changing, as we can see in the increasingly close ties between scientists and the film industry and the shift away from damaging stereotypes”*

The National Aeronautics and Space Administration (NASA) has seen the value of being featured on the silver screen, allowing the use of its logo, its facilities and other resources to create Hollywood blockbusters. This increasingly positive relationship can be good for scientists and scientific institutions, highlighting the importance of their work to a huge audience. This publicity can lead to greater recognition of their work, increased funding, higher public regard, and support for their programmes. Hollywood can be a force for good amongst scientific communities when viewed in this light. It is no wonder that scientists are happy to consult, and institutions are eager to work with Hollywood filmmakers, given the rewards can be immense.

A quick glance at the highest grossing Hollywood productions of 2013 reveals a number of films that have scientists or science as key features of their plots or characters; the most obvious of these is the blockbuster *Gravity*. The film had some members of the physics community up in arms, with Neill de Grasse-Tyson taking to Twitter to condemn the scientific inaccuracies in the movie. The science consultant on set, Kevin R. Grazier, was quick to defend the movie's science but to also point out that Gravity was a movie, not a documentary.

The detailed discussions and articles that appeared discussing the physics in *Gravity* is surely a boon for the scientific community. It is difficult to see how else questions of mass, velocity, gravity, and propulsion could have caused such a stir in the mainstream media. A film that sparks an interest in physics can only be a force for good.

Countless movies in the past have gotten away with unrealistic, inaccurate or simply laughable science depictions. It seems this laxity is no longer being tolerated in the broader community; the ability of armchair experts to take to their computers and decry a lack of accuracy has made Hollywood more accountable. Hand in hand with a push from within the scientific community, there is increasing demand for entertainment that takes its facts seriously.

Our relationship with science and with scientists is changing, as we can see in the increasingly close ties between scientists and the film industry and the shift away from damaging stereotypes. The inclusion of experts on set, the changing portrayal of scientists all point to a changing relationship with science. Whether Hollywood is instrumental in driving these changes, or whether filmmakers are merely reflecting our fears without altering them is too complex to be satisfactorily answered here, but it is clear that as far as movie-goers are concerned, there is no longer an excuse for 'bad science' or lazy stereotypes.

Megan Ivory is currently undertaking further studies in these areas at the University of Sydney, in addition to holding a position as a part-time academic.

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Take a risk in Science education

STEPHANIE ADAN

It is my belief that what you say as an educator is no way near as effective as what you do. It is what you do that makes a difference to your students' lives and their learning. This article aims to provide support for educators who have an anxiety towards teaching science. One of our main goals as educators is to take risks professionally in order to be a change agent for science education.

What is the true aim of science education? Is it for teachers to transfer scientific knowledge and skills into students' minds with heavy scaffolding? Science pedagogy should be student-centred and promote deep, authentic and lifelong learning to open doors for students to pursue science, or more importantly, engage students to work scientifically in everyday life. Science education should equip students to be scientifically literate citizens who engage in scientific problems and make informed decisions.

Through my experience as a first-year teacher, I have observed that science is a subject that naturally intrigues students. It harnesses curiosity beyond the classroom walls and provides opportunities for students to observe the world at an atomic level as well as exploring the universe on a grand scale. Scientific knowledge causes powerful discussion and debate as students negotiate their explanations and construct meaning at a personal level. Science naturally makes students wonder and encourages them to question their world as well as develop their imaginations to solve real problems.

By adopting an authentic pedagogical approach, science teaching can be very enjoyable for both the educator and students. Taking risks professionally means going beyond the bare minimum curriculum requirements. Risk taking, to me, is having the courage to teach the way your students learn.

The following are examples of authentic learning I have experienced as a learner and as a teacher:

Antarctica unit

A real life explorer came to visit my class to talk about his expedition in Antarctica. He played a tape with personal voice recordings of his journey enabling us to visualise his surroundings and feel the cold. He showed us the layers of clothes he wore in Antarctica and explained frostbite. We laughed when he pretended to be a penguin and showed us how penguins transported eggs to each other. He also brought in liquid nitrogen (which none of us had seen before) and explained how something cold could burn you.

Plants in action unit

Here I used Twitter to find a plant scientist and found Dr. John Troughton. John happily donated resource books, photos of plants, seeds and a professional thermometer we constantly use in class. Importantly, he provided me with confidence to teach plant science. When John eventually visited our class students he presented personal interest projects based on their knowledge of plants.

What causes day and night unit

Here students carried out their own independent research about planets (although not part of the syllabus outcomes) simply because they were curious. Astronomer, Simon O'Toole, from the Australian Astronomical Observatory, became engaged and commented on our class blog throughout the term. Students then sent Simon their questions about astronomy and he created his presentation based on those questions. Simon willingly shared his knowledge from how he first became interested in science (due to a sombrero-shaped galaxy) to how to become an astronomer and the various types of scientific work required for this field of science.

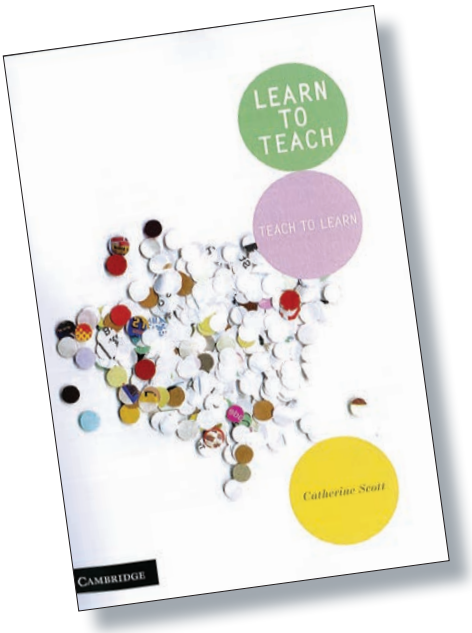
Reflecting on my practice

Our love of science learning experiences does not stop. In our classroom economy we have hired students as garden scientists, astronomers and meteorologists. These students report to class during our weekly news program, sharing their news in science.

I am inspired by educators and scientists who encourage other educators to find a scientist and ask them what intrigues them about their field. Part of our job as professional educators is to take risks and be the change agents for science education.

This article is dedicated to Jackie Slaviero, a risk taker and the most inspiring science educator I know. Thank you for always believing in me.

Stephanie is a first year primary school teacher at John Purchase Public School, Sydney. She holds a Bachelor of Arts/Bachelor of Education, twitter@stephyadan.



Learn to Teach, Teach to Learn by Catherine Scott

Book review by Barry McGaw

There is much excellent research in cognitive science, much of it in the carefully controlled laboratory settings required as complex processes are investigated. There are often grand claims about the implications of that work for real-world situations, even with particular educational practices or products commended on the basis of the science despite the weakness of the evidence on transferability from laboratory to life.

There are also long standing practices in education that are similarly commended on the basis of new scientific evidence of efficacy when that evidence is suspect.

In this very readable book, Catherine Scott applies the criterion of 'evidence-based' in a rigorous way to clarify what the research shows and what current practices the research challenges. She is careful not to over-claim what the science shows and also careful to identify and reject claims of support from science that is the product of 'confirmatory bias', the human tendency 'to more easily notice information that confirms what we already think' (p, 5).

The book begins with an overview of psychological and cultural ideas that have shaped thinking about teaching and learning and why ideas subsequently proved wrong have unhelpfully endured in education. The role of culture is further developed in Chapter 2 with many challenges to current orthodoxies. Its role in human development, particularly as seen in the work of Vygotsky and his followers, is discussed in Chapter 3. This is followed by a review of the work on defining and measuring intelligence and consideration of how the concept is culturally shaped (Chapter 4).

Two chapters on memory (5 and 6) begin with the observation that 'learning is memory' and then discuss the structures of memory used in current research models of memory, memory processes, meta-memory (an individual's knowledge about memory) and ways in which teaching can help students to memorise appropriate things.

Important non-cognitive factors that influence success in school are the focus of Chapter 7. They include attributions, stereotypes, mindsets, effort and the quality of teaching. Chapter 8 deals with important research on the differences between novices and experts and the steps through which expertise is developed and applies it to student learning and the professional development of teachers.

The final two chapters turn to the full complexity of the classroom, Chapter 9 dealing with social aspects of teaching and emphasising the importance of language as the 'teacher's primary tool, no matter what new technologies appear on the market'. The focus is on how language can be used most effectively to facilitate student's learning and cognitive development. Chapter 10 covers assessment and feedback.

The book is aimed at initial teacher education but it would be equally valuable for many practising teachers. It is thorough in its presentation of research but delightful in its inclusion of personal reflections by the author drawn from a rich experience as parent, teacher and teacher educator. The language is very accessible but never patronising. In the spirit of Chapter 8 this whole book is an expert helping others to increase their level of expertise. It invites an internal dialogue in the reader as the case develops and would support a very rich dialogue when used in university courses or professional development programs.

Professor Barry McGaw AO, PhD is a Vice-Chancellor's Fellow at the University of Melbourne and Chair of the Board of the Australian Curriculum, Assessment and Reporting Authority (ACARA) and was a former President of ACE 1995 – 1997.

Australian College of Educators

Professional Educator is the professional journal of the Australian College of Educators (ACE), a professional association representing educators across all sectors and systems of education. We encourage and foster open, collaborative discussion to enable our members to provide the best outcomes for Australian students across all levels of education.

Contact Details

Phone	03 9035 5473
Fax	03 9341 6021
Email	ace@austcolled.com.au
Web	www.austcolled.com.au
Postal address	PO Box 73 Carlton South VIC 3053
Street address	Level 5, 100 Leicester Street Carlton VIC 3053

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As a member of ACE you will be part of a community of educators who have made a commitment to raising the status of their profession, and to their own professional growth and development, by joining Australia's leading education professional association. ACE members engage with enduring educational issues, and the hot topics of the day, through networking, professional reading and a range of events and activities organised through our regional groups across Australia. Member benefits include:

- the opportunity to contribute to an informed advocacy body for the education profession
- the entitlement to use the letters MACE as a recognised, professional post-nominal
- opportunities to network with your colleagues and cutting-edge presenters at ACE conferences and events
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