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## STEM policy and science education: scientific curriculum and sociopolitical silences

Annette Gough

**Abstract** This essay responds to the contribution of Volny Fages and Virginia Albe, in this volume, to the field of research in science education, and places it in the context of the plethora of government and industry policy documents calling for more STEM (Science, Technology, Engineering and Mathematics) education in schools and universities and the tension between these and students' declining interest in studying STEM subjects. It also draws attention to the parallels between the silences around sociopolitical issues in government policies and curriculum related to STEM, including nanoscience, and those found with respect to environmental education two decades ago, and relates these to the resurgence of a scientific rationalist approach to curriculum.

**Key words** STEM policies . science education . sociopolitical issues . environmental education . scientific curriculum

Future developments and applications of science and technology, including nanoscience, continue to be seen as the salvation for problems facing society and governments; as Simon Marginson and colleagues (2013 p.13) argue, "STEM is a central preoccupation of policy makers across the world", see for example, from Europe (Rocard et al 2007); from Australia (Office of the Chief Scientist 2012, 2013); from Canada (Science, Technology and Innovation Council 2013); from USA (Committee on STEM Education, National Science and Technology Council 2013); from UNESCO (Fensham 2008); and from other countries (see Marginson et al 2013). The development of the Masters programs in nanoscience and nanotechnology in France and the United States discussed by Volny Fages and Virginia Albe (in this issue) can be thus linked to the STEM policies emanating from Europe (for example, Rocard et al 2007) and the United States (for example, Committee on STEM Education, National Science and Technology Council 2013) respectively.

The various governments' STEM (Science, Technology, Engineering and Mathematics) agenda have several aspects:

- enacting an economic policy agenda with a focus on lifting the general quality of the supply of human capital as STEM qualifications prepare graduate for a wide range of occupations both professionally and vocationally;
- enlarging the high-end STEM skilled workforce to engage in research and development, industry innovation and effective responses to technological change

This review essay addresses issues raised in Volny Fages and Virginia Albe's paper entitled: *Social issues in nanoscience and nanotechnology Master's degrees: the socio-political stakes of curricular choices*.

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- lifting the overall scientific literacy of the population (when the trend is tending to decline)
- attracting more students to study STEM at senior secondary and university levels.

This is particularly the case in Australia at present, where a recent avalanche of documents from a range of authoritative sources are calling for more STEM education to create smarter futures, economic competitiveness and growth as well as a more scientifically literate society. These sources include industry the Australian Industry Group (AIG) (2013); documents prepared for the Office of the Chief Scientist such as strategies (Office of the Chief Scientist 2012, 2013), reports (Goodrum et al 2012) and occasional papers (West 2012); studies commissioned by Australian Council of Deans of Science (Harris 2012); the Australian Council of Learned Academies (Marginson et al 2013) and the Australian Academy of Science (Wyatt and Stolper 2013). However, as these documents generally acknowledge, this is at a time when there is a declining interest in studying such areas from prospective school and university students. There are many aspects of this discussion that remind me of the movie *Field of Dreams* (1989) – if the universities build the programs then the students will come and study them – but will they, and who will teach them and what will they be taught?

This essay responds to the contribution by Fages and Albe (in this issue) from an Australian perspective, within a global context of the tensions between increasing calls for more STEM education, the declining interest of students in studying STEM and the difficulties science educators have in teaching the sociopolitical aspects of STEM and environmental issues. It relates these developments to parallel critiques from the late twentieth century with respect to environmental education and a rational scientific approach to curriculum that was dominant in the government discourses of the period.

This essay also builds on my previous essay in this journal (Gough 2011) where I discussed how the achievement of “Science for All” presented many challenges for science educators, including that science education does not occur in a social and political vacuum (Fensham 1988), and that science education is in a state of crisis. Aspects of this crisis include a diminishing proportion of students studying sciences, particularly physical sciences, both at school and in universities, to the point where there are shortages of skilled science professionals and qualified science teachers, and continuing, if not growing, student disenchantment and disengagement with school science in the middle years. In particular, with respect to the silences around teaching about the sociopolitical aspects of nanoscience and nanotechnology discussed by Fages and Albe, in this

previous essay I drew attention to Sandra Harding's (1993 p.1) argument that seems particularly pertinent in this context:

There are few aspects of the "best" science educations that enable anyone to grasp how nature-as-an-object-of-knowledge is always cultural: "In science, just as in art and life, only that which is true to culture is true to nature". These elite science educations rarely expose students to systematic analyses of the social origins, traditions, meanings, practices, institutions, technologies, uses, and consequences of the natural sciences that ensure the fully historical character of the results of scientific research.

In this essay I further develop this line of argument and apply a sociopolitical lens to STEM policies and related developments. I also discuss the difficulties that science educators have with exposing their students to the consequences of human actions, particularly the impact of scientific and technological developments on other human societies and the natural environment, as has been discussed in the context of the teaching of environmental education.

### **STEM policies**

In the past two years in Australia there has been a focused effort from a number of sources to promote a strategic approach to STEM "in the national interest" (Office of the Chief Scientist 2012, 2013) for government and industry action, but with a strong emphasis on the teaching of STEM subjects in schools and the preparation of STEM teachers for schools to address the five most significant challenges facing society (Office of the Chief Scientist 2013, p.5):

- Living in a changing environment;
- Promoting population health and wellbeing;
- Managing our food and water assets;
- Securing Australia's place in a changing world;
- Lifting productivity and economic growth.

The position paper goes on to argue that, "addressing these challenges requires the development of a high-quality STEM enterprise and its strategic deployment" (p.5).

Australia is not alone in pursuing this direction in STEM policy, as Ian Chubb, Australia's Chief Scientist, made clear when he launched his position paper on *STEM in the national interest: A strategic approach* (Office of the Chief Scientist, 2013). In this speech (Chubb 2013) and the position paper, as well as in the *STEM: Country Comparisons* (Marginson et al 2013) (the consultants' reports for this provided useful comparative data for the Chief Scientists' documents), much is made of comparing the current status of STEM policies and practices in other countries to create a deficit position for Australia, if not now then in the near future. For example, both the Office of the Chief Scientist's (2013 p.8) position paper and his speech (Chubb 2013) quote the Rocard et al (2007) report (in italics below) to support their argument for Australia to have a national STEM strategy:

Around the world there is a sense of urgency – a need to improve a nation’s capacity and a commitment not to take the future for granted or to presume that past practice will be good enough: *because Europe’s future is at stake decision-makers must demand action on improving science education from the bodies responsible for implementing change.*

The Chief Scientist documents also refer in a positive way to the European Union’s plans and strategies that attend to “their STEM enterprise – all of it, education, research and innovation” (Chubb 2013), as well as Canada’s 2007 strategy and the follow-up report (Science, Technology and Innovation Council 2013) and the US strategic plan (Committee on STEM Education, National Science and Technology Council 2013). The US five year plan has five priority areas (p.8):

- (1) improve P-12 STEM instruction;
- (2) increase and sustain youth and public engagement in STEM;
- (3) improve undergraduate STEM education;
- (4) better serve groups historically underrepresented in STEM fields; and
- (5) design graduate education for today’s STEM workforce.

The last of these priority areas complements Fages and Albe’s findings around the growth of nanoscience and nanotechnology programs in the US, and provides a useful point of difference to Australia – the Australian emphasis is on undergraduate education whereas the American and French emphasis is on graduate (or postgraduate) education, a difference which is discussed below. The other four priority areas are generally reflected in the Australian strategy (Office of the Chief Scientist 2013) with its action areas around school and post-compulsory education (pp.13-14), and community education (p.15), but youth is not specifically mentioned, “revision of graduate training to suit tomorrow’s workforce” (p.9) is the only mention of graduate education, and there is only one mention that “Approaches should be developed and implemented to raise the SEM participation of females, and disadvantaged and marginalized students” (p.13). Perhaps one sentence in the strategy sums up some of these deficiencies: “Anxiety about being left behind creates a sense of urgency to address these matter promptly” (p.9), or properly?

The Marginson et al (2013) report was, among other objectives, seeking to identify lessons and ideas from the approaches of other countries – particularly those who were most similar to Australia or who were high performers in STEM – that could be applied in Australia. The authors concluded from the country and regional reports that there is

an almost universal governmental preoccupation with the level of STEM participation in senior secondary school, and the level of achievement in the STEM-related disciplines in both secondary and higher education... There is a widespread interest in building high-end STEM skills, linked to

research and development and industry innovation. It is assumed in most jurisdictions that the quantity and quality of STEM competences affect economic performance. (p.53)

It is therefore perhaps not surprising that the key actions in the strategy being proposed by the Office of the Chief Scientist (2013) focuses on similar themes and target groups. This strategy defines four “pathways to a better Australia”: education, new knowledge, innovation and influence. But before these pathways are explicated there is something a little different that seems to have been inspired by Carl Sagan (1990) and Tony Blair (2002): an engagement with the socio-political aspects of STEM work. In developing his argument for there needing to be a social compact for STEM between scientists and the community Chubb (2013) quotes Sagan – “We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science” – and Blair – “The benefits of science will only be exploited through a renewed compact between science and society, based on a proper understanding of what science is trying to achieve”, and “Science doesn’t replace moral judgement. It just extends the context of knowledge within which moral judgements are made. It allows us to do more, but it doesn’t tell us whether doing more is right or wrong”. This latter quote is important in distancing scientists from the socio-political as well as moral aspects of the impact of their work that is highlighted by Fages and Albe (in this issue) as a concern with the teaching of the nanoscience Masters degrees, and is further discussed below.

According to the Strategy proposal, a ‘Social Compact’ between STEM practitioners and the community will give the community “confidence that the approaches by STEM practitioners and the quality of their work meets the needs, aspirations and ethical expectations of the community” (Office of the Chief Scientist 2013 p.11). In particular:

The substance of the Compact will commit STEM practitioners to:

- continued high ethical standards;
- clearly articulated mechanisms by which standards are maintained;
- provision of a bountiful stream of new knowledge and practical solutions to short and long-term problems of benefit to the community;
- following a best practice, regulatory framework for STEM;
- describing benefits and risks, and the limits of knowledge, when contributing to policy development;
- open access to research outcomes of publicly funded Australian STEM research.

Unfortunately this clear commitment to openness, risk assessment and ethical conduct is undermined by a highlighted box in the text which states: “Since STEM is not the only source of insight and illumination in human affairs, STEM practitioners have no special status in respect of the moral dimensions of the utilisation of STEM; this is the province of society as a whole” (Office of the Chief Scientist 2013 p.11). Neither is there a reflection of the moral dimension of

STEM in the Education section (pp.13-16) where the emphasis is on improving STEM knowledge and skills at all levels of education, with particular mention of schools, post-compulsory education, education and the workforce, and community education.

The proposal for a ‘Social Compact’ is also related to a growing concern about the scientific literacy of the general population. Both of the Office of the Chief Scientist’s reports (2012, 2013) have argued that there is need for widespread and general STEM literacy if Australia is to address the challenges facing society and benefit from the STEM enterprises developed by STEM researchers. Community education in the ‘Education’ pathway of the strategy proposal, for example, is focused on increasing the levels of STEM literacy in the community through “better engagement with science and mathematics in schools and an increased engagement of the community with the STEM enterprise” (Office of the Chief Scientist 2013 p.15). However, as Nick Wyatt and David Stoper (2013) found from their survey sample, although most Australians have a basic grasp of key scientific facts, there is still a large number who hold misconceptions and there was a small but statistically significant decline since the 2010 survey on knowledge of several key scientific facts, especially among 18-24 year olds. This finding complemented the findings of the Denis Goodrum et al (2012) report that Australian high school students have abandoned science studies in recent decades: twenty years ago 94 per cent of Years 11 and 12 students were enrolled in science subjects compared with 51 per cent in 2010 (Lauder 2011). As noted previously, according to Marginson et al (2013) most countries’ STEM documents emphasise the role of secondary and higher education in achieving their STEM policy aims for economic and workforce development. These statements about education are discussed in the next section.

### **Science education in schools and universities**

The vision for science education, and its emphasis on content, that is embodied in the STEM policy documents is very much an instrumentalist (Carr and Kemmis 1986) or a universal scientific postured (Simonneaux and Simonneaux 2012) curriculum: education is seen as an instrument for achieving STEM and economic goals. In regard to this shift to an instrumentalist curriculum, Wilf Carr and Stephen Kemmis (1986 p.14) noted: “the aim of developing the cultivated person was... discarded in favour of developing conformity to an agreed image of the educated person... teaching became instrumental – the means for achieving these given ends”. Paul Davies and John Gribbin (1992 p.7) similarly commented, from a science perspective, that “The behaviourist school treats all human activity in terms of a type of Newtonian dynamical

system, in which the mind plays a passive (or inert) role and responds in an ultimately deterministic way to external forces or stimuli”.

Such an approach is apparent in an Office of the Chief Scientist occasional paper (West 2012, p.4) when it states:

STEM education can deliver value to the Australian economy by preparing STEM students for a range of careers. This includes ensuring the STEM skills that are in demand are effectively taught to students; equipping students with generic skills that will help them function in non-academic settings; and signalling that pathways outside academic research are valid options.

An instrumentalist approach was adopted in the large scale science education projects of the 1960s and 1970s both in the US and Australia, so it is perhaps not surprising to see its resurgence now in a STEM context, particularly given the current broader educational emphases on high stakes testing (such as PISA and TIMSS) and the competitive weight being placed upon international comparisons. Several of the recent Australian reports have referred to Australia’s positioning in these ‘league tables’ – where, despite being significantly above the OECD average and ranked 10th, well above the US and France, for example, the comparison is always with those countries who scored significantly higher than Australia (such as Shanghai-China, Finland, Hong Kong-China, Singapore, Japan and Korea in the 2009 PISA results for science). Goodrum et al (2012 pp.14-15) discuss this in the context of the quality of science education at senior secondary school levels; and both Marginson et al (2013 pp.63-66) and the Office of the Chief Scientist (2012 p.17) discuss Australia’s recent performances negatively compared with the countries. Similarly, the AIG report (2013 p.2) notes that “The 2011 Trends in Mathematics and Science Study (TIMSS) indicates that Australia’s performance in mathematics and science has stagnated over the past 16 years”.

This approach to STEM education is similar to the instrumentalist approach to environmental education adopted in Australian government documents in the 1990s where the accepted role of education was as a tool for achieving environmental goals. For example, In the National Conservation Strategy for Australia (NCSA) one of the ‘strategic principles’ was to “educate the community about the interdependence of sustainable development and conservation” (DHAE 1984 p.16). The first priority national action to achieve the objectives of the NCSA (DHAE 1984 p.17), under the heading of ‘Improving the capacity to manage’, was to

Develop and support informal education and information programs ... which promote throughout the community an awareness of the interrelationships between the elements of the life support systems and which encourage the practice of living resource conservation for sustainable development.



It would be difficult to find a more instrumental statement than this for the task of environmental education, unless that mantle could be assumed by the Commonwealth discussion paper on ecologically sustainable development (DPMC 1990 p.19) which states, in one of its few references to education, that

public education campaigns can help in modifying behaviour to reduce demand for products with adverse environmental consequences and encourage the use of less damaging alternatives. The emergence of green consumerism attests to the ability of public education to modify consumption patterns.

Such an approach is consistent with what Paul Hart (1990 p. 58) includes in the stream of environmentalism he calls 'plan': "a rational scientific approach with major planning, research, management and educational strategies primarily aimed at merging economic development with conservation of natural resources", or, in the current climate, STEM enterprise. My contention that the current directions for STEM education in Australia are instrumentalist and determined by the economic agenda is supported by a recent rhetorical question from Barry Jones (2013 p.10), a former Minister for Science, to the incoming Minister for Education: "Is education essentially instrumental, intended to serve the needs of the economy, with the emphasis on training and predictable outcomes, or is it for the development of personal growth, imagination, creativity, wisdom, values, access to culture for the whole of life?".

The universal scientific posture discussed by Jean Simonneaux & Laurence Simonneaux (2012), which adopts a hypothetical-deductive approach in which expressions of values are excluded and "the disciplinary content, and the way it is divided up, constitutes the basis of all learning of a hierarchical nature" (p.81), is reflected in the findings from a recent study of "what science means for Australian society" (Harris 2012). Harris surveyed science graduates and asked, among other questions, "What do you think should be fundamental to a university science education?" and the traits most frequently associated with a background in science. The responses indicated a strong emphasis on knowledge of specific subject areas, on ways of thinking (analytical, objective, evaluative, questioning, open-minded, logical, systematic, structured) and on other skills and characteristics such as life-long learners, problem-solvers, observant and experimental. Only a small number mentioned that the curriculum should include application of theory to real life situations and that ethics should be included in the knowledge component. Consistent with this position on the traits were the responses given to the question regarding the influence of science on the respondents' approaches to contemporary issues, encapsulated in a respondent's quote (p.38): "My approach to societal issues is a science-based approach – systematic, analytical and rigorous".

Sadly a similar approach is found in the new Australian Curriculum for Science from Foundation to Year 10 (ACARA 2013). Here, the content is divided into three strands:

- Science Understanding, which is divided into the traditional four disciplines (biological sciences, chemical sciences, earth and space sciences and physical sciences – environmental science is a silence)
- Science as a Human Endeavour, which focuses on the *Nature and development of science* and the *Use and influence of science*
- Science Inquiry Skills, which, following ‘the scientific method’ are *Questioning and predicting, Planning and conducting, Processing and analysing data and information, Evaluating and Communicating.*

These three strands are seen as interrelated and their content is intended to be taught in an integrated way. Of most interest, from a socio-political perspective, is the strand on the *Use and influence of science* where the content is specified as follows for the secondary years of schooling, and related to particular achievement standards (ACARA 2012 p.5):

- Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations
- Science understanding influences the development of practices in areas of human activity such as industry, agriculture and marine and terrestrial resource management
- People use understanding and skills from across the disciplines of science in their occupations
- People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions
- Advances in science and technologies can significantly affect people’s lives, including generating new career opportunities
- The values and needs of contemporary society can influence the focus of scientific research

While this content is on the right track, it does not engage with the negative impact of scientific innovations on society – except perhaps for the possible discussion of ethical considerations (if these aspects are actually covered by teachers). It is also significant to note that although nanotechnology is not mentioned in the content descriptions or the achievement standards of the curriculum there are two mentions in the recently added elaborations of the *Use and influence of science* content for Years 9 and 10 (see Australian Curriculum website):

- investigating the use of nanotechnology in medicine, such as the delivery of pharmaceuticals (Year 9)
- predicting future applications of aspects of nanotechnology on people’s lives (Year 10)

The Year 10 suggestion does have potential for examining the negative impact of nanotechnology on individuals, society and the environment, but there is no guarantee that teachers will cover this aspect, and it could well be a socio-political silence, as Fages and Albe (in this issue), because of the difficulty the teacher may have in teaching about such issues.

## **Sociopolitical silences**

Fages and Albe (in this issue) are concerned about the absence of consideration of the sociopolitical contextualisation and environmental impacts of nanoscience in the curriculum of the French and American university programs they reviewed. However, that science educators have difficulties with teaching the sociopolitical aspects of science topics has been recognised for some time, particularly in an environmental context. For example, Lucas (1980) saw science education as a limited vehicle for environmental education, I have written about the potential mutualism between science and environmental education (Gough 2002, 2008), and Tytler (2007) discusses a re-imagined science education that considers the socio-political aspects of scientific issues. As Marion Nemenwirth (1986 p.29) succinctly states, “Scientists firmly believe that as long as they are not *conscious* of any bias or political agenda, they are neutral and objective, when in fact they are only unconscious”.

A number of science education researchers have suggested strategies for re-visioning science education so that it is “oriented towards encouraging and enabling students to become citizen activists, ready and willing to take personal and social actions to reduce risks associated with [socio-scientific] issues” (Bencze et al 2012 p.129). However, this does not take into account that the teachers may not be prepared for or confident in handling such approaches in the classroom. Russell Tytler (2007), for example, has argued for re-imagining science education, but he also recognises the complexities of socio-scientific issues that makes them difficult to engage with in the classroom:

- It deals with data that is difficult to treat statistically and is subject to experimental cost and uncontrolled initial conditions.
- It involves complex models that themselves introduce uncertainties into the interpretation of data.
- The outcome is intended to be an action, rather than the production of generalisable knowledge, and, as such, is subject to a range of dimensions that are value-laden.
- The science is highly contextual and subject to variation over which the scientists had no control.
- It involves measuring trace elements at the limit of detection, with resulting uncertainty.
- It involves the generation and comparison of two numbers (pollution indices), representing two conditions which themselves involved the problematic weighting of data based on previous epidemiological research. (pp.48-49)

Tytler concludes, “If students are to be taught how evidence is developed and used in science in authentic settings, they need to grapple with features of scientific methods such as these. Ways need to be found to represent them in the curriculum” (p.49). However, there is also a need for an ethical dimension (as discussed in regard to the Australian Curriculum, above) – and a

teaching workforce that has the knowledge, skills and confidence to teach such issues – whether they be nanotechnology or environmentally or other focused.

Over thirty years ago environmental education was engaging in similar debates with respect to the role of science teachers in teaching in, about and for the environment. At that time Arthur Lucas (1980 p.1) expressed concern that “too many science educators seem to believe that their discipline is *the* vehicle for environmental education”. He saw an “omnipotent disciplinary chauvinism” (1980 p.6) in assertions that science teachers could teach topics on society (beyond the social issues that arise from the application of science), and questioned, “will their worldviews as empirical experimenters seriously distort the nature of historical understanding and aesthetic judgement?” (1980 p.21). He concluded, “science educators must not ignore the other forces acting to promote environmental wisdom, and must begin to look beyond the confines of their own and other educational literature for inspiration for research and practice” (1980 p.21).

At that time, as now, many environmental educators were concerned with the political character of environmental problems and the implications of this for the type of education they were advocating. Their argument was that science and environmental education were incompatible and that environmental education could more appropriately be implemented in curriculum areas other than science, because the science curriculum of the time was inhospitable to engaging with social issues. This argument has many parallels with those rehearsed by Fages and Albe (in this issue): science teachers, because of the universal scientific posture (Simonneaux and Simonneaux 2012) of their own education, struggle to shift to a different epistemological posture (such as engaged and sceptical) which is better suited to facilitating discussion of socio-political issues in science classrooms. Until such changes occur the silences around discussion of socio-political issues in science classrooms are likely to continue.

### **(Di)vergent directions**

The various STEM policy documents from around the world discussed earlier in this essay are, in many ways, single minded about the purpose of science (or STEM) education – contributing to the economy by preparing students for a variety of careers, and increasing the overall scientific literacy of the population. These documents also recognise that the current school science curricula are not achieving this goal, and that something needs to change if more students are going to be attracted to study science (or STEM). Some documents, such as the Office of the Chief Scientist’s (2012) report on *Mathematics, Engineering and Science in the National Interest*, assert that “Inspired teaching is undoubtedly the key to the quality of our system, and to raising student interest to more acceptable levels” (p.7) and argue for “a re-think on how we prepare our

teachers and how we support them: support to strengthen their content knowledge, to maintain it at contemporary levels and to instil the confidence to deliver the curriculum in interesting and novel ways” (p.7). That the focus here is on content knowledge and the curriculum is significant – students are envisaged as passive recipients of these – yet the evidence from numerous studies, such as the ROSE Project (Sjøberg and Schreiner 2005), Tytler’s (2007) work on re-imagining science education and the recent STEM country comparison (Marginson et al 2013), indicates that an increasing proportion of high school students do not have positive attitudes to science, do not see themselves pursuing a science, engineering or computing career and do not continue their studies of science or mathematics subjects beyond the compulsory years in high school.

There is a growing literature around re-thinking the aim(s) of science education, with some convergences. Peter Fensham (2008 p.8) for example, recommends that

Policy makers should consider replacing the generic use of “scientific literacy”, as a goal of school science education, with more precisely defined scientific knowledge and scientific abilities, that have meaning beyond school for the students at each of the stages of schooling, for example, lower primary, upper primary, lower secondary, the last years of compulsory schooling and the final secondary years.

For students in the later years of schooling consider introducing at least two science courses, one designed for all students as future citizens, and the other designed for students with future studies in the sciences in mind.

Michael Reiss (2007) argues similarly that a diversification of school science courses may be what is needed – one, with the features of “impersonality, objectivity and the absence of value judgements” (p.17) which may make it attractive for students who will become employed as future scientists and another for the great majority of students who will not become scientists. He places this argument within a broader discussion of the aim(s) of school science education which he sees as encompassing producing a supply of future scientists, a reconceptualisation of scientific literacy to ‘science as culture’ (see earlier quote from Sandra Harding), individual benefit, democracy, social justice or socio-political action, and criticality.

Recognition of the challenges facing science and technology education (STE) is evident in the declarations from the two recent ICASE world conferences on science and technology education (ICASE 2007, 2010), and different approaches are recommended. This particularly includes recognition of the relationship between science and technology education and sustainable, responsible, global development (2007) and health and safety (2010). Rather than just focusing on science content the declarations resolve to “promote critical awareness of the contribution of science and technology to personal, social, economic and environmental wellbeing” (2007) – but there is no mention of promoting critical awareness of the impact of science and technology on

these things – and “an inquiry approach is central to STE, where students formulate scientific and technological questions, investigate those questions and build and apply conceptual understandings” with “an emphasis on the development of life competencies such as problem-solving and decision-making skills” (2010). Such an approach to science education is consistent with the findings from Kerri-Lee Harris’ (2012) survey discussed earlier, but it is not in the same direction as that proposed by Reiss (2007) or Harding (1993) who argue for ‘science as culture’ and a much more socio-politically grounded curriculum than that which is embodied in the STEM policies and Australian curriculum directions – or in the nanoscience and nanotechnology programs discussed by Fages and Albe.

### **(Un)Employment opportunities**

My final contribution to this forum is to draw attention to the muddy relationship between STEM qualifications, industry demand and employment. The nanoscience and nanotechnology degrees being established in France and the USA discussed by Fages and Albe have their parallels in Australia, where developments to date have been more at the undergraduate than postgraduate level, but this is more a reflection of the general structuring of university education in Australia compared with the postgraduate specialization focus in France and the USA. In Australia, a more common position is that “postgraduate study is a costly and time-consuming route into a good job. There are good positions available for people with their general interests and aptitudes from bachelor degrees in IT, engineering or health”, although “employers do find use for science graduates with postgraduate qualifications” and “PhD-level professional and managerial employment rates typically exceed 90%” (Norton 2013).

The typical entry requirements for nanoscience and nanotechnology degrees in Australia are the completion of high school or higher-level studies in physics and/or chemistry, mathematics and English. At present 10 universities offer undergraduate degree programs, 4 offer Masters level programs and 6 others offer courses in nanoscience, nanotechnology, nanomechanics, nanochemistry and/or nanoelectronic engineering, with new offerings appearing each year. The undergraduate programs are seen as preparation for a career in manufacturing or research and development, but they are attracting small numbers with only 30 offers of undergraduate places in the 4 year B.Sc (Nanotechnology)/B.Sc (Applied Sciences) programs being made at La Trobe and RMIT universities in 2013 with entry scores of around 78 at both institutions (compared with entry scores in the high 90s to get into medicine or law programs, with the highest possible entry score being 99.95). It seems that the universities are responding to the calls for such programs by governments (Office of the Chief Scientist 2012, 2013) and industry (AIG 2013),

but the students are not applying for these programs in large numbers and there are no clear employment data.

A major issue across many countries, according to Marginson et al (2013) is that there is little data on uptake of STEM graduates in the workforce, and ‘leakages’ in the STEM ‘pipeline’ occur at many points between kindergarten and graduation from university. Indeed, Marginson et al (2013 p.129) quote a United Kingdom consultants’ report which found that “the majority of STEM graduates did not use their STEM specific degree knowledge at work, whether they were or were not in a STEM related job”. The Australian Industry Group (2013 p.1) report argues, “The importance of STEM disciplines for the future economic and social well-being of Australia cannot be underestimated. International research indicates that 75% of the fastest growing occupations require STEM skills and knowledge”. The report goes on to argue that too few students are participating in STEM skills at schools and universities and that industry is experiencing difficulty recruiting employees with STEM skills. However, Andrew Norton (2013) contends that enrolments in university science studies are increasing and so are the numbers of graduates in employment, and this was supported by a report on ‘The STEM labour markets in Australia’ commissioned as part of the Marginson et al project (2013 chapter 11). However, “only 57% of science graduates say their qualification is important or a formal requirement for their job” and “graduates in life sciences, maths, and chemistry had considerably more difficulty finding full-time jobs in 2012 than they had in 2011”(Norton 2013).

While it is not possible to tell from available data if this situation is relevant to graduates in nanoscience and nanotechnology, it does rekindle some concerns regarding the *Field of Dreams* approach that is implicit in many of the STEM policy documents, and perhaps it is time to reflect on the instrumentalist economy driven direction for education and develop well rounded creative, ethical and wise citizens?

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