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THE ROLE OF RESEARCH IN RECONCEPTUALISING SCIENCE EDUCATION FOR THE 21ST CENTURY

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> *We are moving from a science of manipulation to one of participation in natural processes which are too complex to be controlled, but we can influence, for better or for worse.*
>
> (Schumacher College, 1998)

Introduction

The special space afforded by the advent of the next millennium provides the science education community with a unique opportunity to engage in critical reflection on the "big picture" state of our global community and the role of science and science education within it. One such endeavour is Science 2000 AD, a project of the British Association for Science Education. This wide-ranging project asks science educators to reflect on questions such as "What is science? Why do science? What science should be taught?" In this paper we add our voice to the discussion.

This paper represents our attempts to reconceptualise science education in the light our own journeys. Like Hildebrand (1998) we believe that our personal journeys should be foregrounded in an open way as we grapple with the incredibly complex and paradoxical tensions that this project presents. As science graduates and practitioners, we have been well-drilled in what we have now come to see as a hegemonic and privileged endeavour, the Western science canon, and actually enjoyed the process. However, our many years' experience as science teachers, particularly of female students and Others (such as Black students in South Africa), presented sometimes agonising paradoxes about whose science it was that we were teaching, who benefited from it and its frightening power as a sorting tool. Moreover our increasing concern over the degradation of the earth's ecological systems has forced us to call into question the power of science as a means of controlling not just women and Others, but nature herself. As academics, our discovery over time of the rich literatures from the sociology of science, critical ecology and futures studies began to resonate and weld together our concerns and experiences. Finally as mothers we have a particularly strong interest in the notion of a just and sustainable future.

In order to reframe science education in the above terms we have drawn from two research strands. In part A we document the literature which provides a theoretical framework for this project. In part B we examine the views of our students as they comment on science, science curriculum and their own future. We intend to use this research as a basis for the development of science curriculum appropriate for the 21st century.

PART A

The Western Scientific Worldview

We have realised that to begin to conceptualise ways forward to a socially just and ecologically sustainable future, we need first to have some understanding of the deep structures, that is the worldview that underpins science and technology. This worldview has given rise to the taken-for-granted system of values and beliefs which have shaped Western thought for the last 400 years. Indeed according to Beare and Slaughter (1993), this is the essential point educators tend to overlook, and in their view it is not even possible to confront the great global issues of our time without also considering the deep frameworks of meaning and value which brought them into being in the first place.

The scientific worldview of the West can be directly traced to ideas arising during the period known as the Enlightenment and the rise of rationalism in the 16th and 17th centuries. Here arose the thought tradition, embodied in modern science with its direct lineage to ancient Greece, which so dominates the world in which we now live. Postman (1992) describes the impact of Western science as a psychic shift of immense proportions which still reverberates around the world today. Its roots lie in the collapse of what he terms "the moral centre of gravity" that allowed humans to believe that the earth was the stable centre of the universe and therefore of special interest to God (see also Suzuki, 1997). The Enlightenment discoveries of Copernicus, Kepler and Galileo recast humanity as insignificant inhabitants of a small planet revolving round a rather average star. If this put in place the dynamite that would blow up the theology and metaphysics of the medieval world, then Newton lit the fuse (Postman, 1992). The scene was set for the reductionist scientific method of Francis Bacon, and the view of Descartes that mind and body were mutually exclusive, mind being associated with the rational, and hence the very essence of being ("cogito ergo sum"). Together they provided the instrumental rationality that underpins the philosophical foundations of Western science. (Swimme and Berry, 1992).

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Here we have the emergence of an immensely powerful knowledge tradition, one that sees the world as an entity that can be interrogated in order to discover empirical truths. Here is a radical distancing of subject and object, where manipulation becomes the very essence of truth (Slaughter, 1996). The science of the Enlightenment is not only conceived of but taught as a value-free, unambiguous, unproblematic set of repeatable truths about knowledge of the cosmos, revealed by adherence to a rule-bound scientific method which rests on observations and is confirmed by experiments (Collins and Shapin, 1989). It is of course obvious that this science has freed us from the tyranny of the claustrophobic confines of religious authority and superstition. More importantly it has provided us a with a reliable knowledge system through its conceptual understandings and rigorous testing tools that have enabled the flourishing of human ingenuity.

Now, recent literature from diverse fields, known collectively as the sociology of scientific knowledge (SSK) (Rose, 1997), and elsewhere as science studies (Harding, 1998; Sirdar, 1996; Cunningham and Helms, 1998; Hamilton Grant 1998), has begun to scrutinise science from a number of perspectives. In Harding's (1998) words "The natural sciences alone, of all human products, are assumed in principle to be capable of bearing no fingerprints of their production process" (p. 40). The result of such scrutiny is fierce battles which rage about the nature and position of Western science at the turn of the millennium with its proponents such as Dawkins, (1995) Wolpert, (1997) and Sokal and Bricmont, (1998), lined up against those who take a critical perspective. With Slaughter (1996), we believe that a scientifically powerful culture that does not scrutinise itself in order to aspire to wisdom and one which lacks foresight, is indeed signing its own death warrant - and that of uncountable others.

Critiques of Western Science

Harding (1998) argues that two distinct schools of science studies have arisen since World War 2 which undermine the claims of Western science to be value free and objective. She terms these schools post-Kuhnian and postcolonial. Post-Kuhnian studies detail how scientific knowledge is constructed by charting and illuminating patterns of scientific institutions, their cultures and practices, and how social and personal beliefs permeate scientific decision making. Similarly, Cunningham and Helms (1998) describe Latour and Woolgar's (1986) microsociological laboratory studies which endeavoured to investigate the interrelationship between scientific method and scientific knowledge in order to understand how statements emerge from practice. They found that individual values, tacit knowledge, social negotiation and reputation influence what can count as scientific truth (also Collins and Pinch, 1993; Knorr-Cetina, 1995; Rose, 1997). Scientists become involved in long, messy processes aimed at distilling meaningful data from the background wash, persuading themselves and others that their interpretations are valid. As the emergent scientific statement passes through a series of modifications, initial uncertainties and references to social, historical and personal contexts are progressively shed, accompanying the rise in status of the claim. "Once the scientific truth is known it is forgotten that non-experimental and non-scientific negotiating tactics were necessary if closure was to be attained" (Collins, 1985, p.152). Cunningham and Helms (1998) argue that these descriptions of science behind the scenes reveal that it partakes of the same diverse and conflicting social and cultural influences in its construction as any other knowledge field. Harding (1998) notes that these notions have been difficult for some to accept even when the science study researchers are scientists themselves which simply attests to the extraordinary status the natural sciences have permitted themselves.

Post Kuhnian science studies also incorporate an important feminist perspective. The writings of scholars such as Fox Keller (1983), Haraway (1989), Harding (1991) and Merchant (1980) argue that the questions science asks are not questions which arise from women's lives nor answer them in ways which serve women's interests but rather serve the interests of dominant social institutions such as corporations and the military from which women have been systematically excluded.

For Harding (1998) and Sirdar (1996), postcolonial science studies can be understood as attempts to reveal the integrity of Other cultures' different scientific traditions. Such studies can be traced to three origins. Firstly, the contentious view (Dawkins, 1995; Wolpert, 1997) that Western science and knowledge traditions of Other cultures should be treated on an epistemological par as each developed in response to a culture's needs to understand, predict and influence its environment. Secondly, postcolonial science studies reveal the link between European expansion and the new kinds of Western scientific knowledge such as oceanography, cartography and botany that it required. Harding (1998) argues that these voyages turned the world into a laboratory for European scientists to test their hypotheses and forage and combine information gained from different cultures. For example, Sirdar cites the co-option of the Chinese view of self-organising nature that is now part of complexity theory. In the process, they destroyed, unintentionally or otherwise, the Other knowledge traditions that would have offered greatest competition to the European science account. In Sirdar's (1996) view, Western science has defined itself as "the *only* (his italics) way of knowing, the sole path to universal knowledge, the exclusive arbiter of what is true and what is false" (p.226). Western science has become one of a privileged truth whose might resides in its power to define. For Sirdar (1996), Western science has been defined as *the* science (his italics) with an instrumental rationality that marginalises and suppresses Other science.

The third source of postcolonial science studies can be found in criticisms of third world development which conceptualise it only in terms of economic growth and the transfer of industrialisation through science and technology. Here we see the impact of Hamilton Grant's (1998) technoscience as it attempts to force its worldview and processes on Other cultures.

Consistent with the critiques discussed above is the ecological critique of science. This perspective finds its voice in the critical ecological literature, and in particular, the writings of ecofeminists. Shiva (1994) is one such eloquent voice, writing both from an ecofeminist and an Other position. Shiva (1994) views reductionist science as an inherently violent epistemology, as a "masculine and patriarchal project which necessarily entailed the subjugation of both nature and women" (p.15). She is particularly critical of Bacon's scientific

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method, grounded as it is in "the severe testing of hypotheses through controlled manipulations of nature" (p.16). She quotes Bacon as referring to scientific inquiry as something that does not "merely exert a gentle guidance over nature's course; (but has) the power to conquer and subdue her, shake her to her foundations" (p.16). Other ecologists, such as Suzuki (1997), see Descartes' dictum as a new myth about our relationship to the world, where humans are the thinkers and the rest of nature is that which is thought about. In the Cartesian mind-body split, body became associated with the seeming irrationality of nature, and the view that nature was a resource rather than an essential part of humanity, logically followed. Nature became disenchanted or desacralised. The participatory consciousness, viewed as the sense of being involved with and part of nature which described the relationship of nature and pre-rational communities, was as good as killed. Those who held on to different views about the workings of the world were marginalised and held in low esteem (Broomfield, 1998; Shiva, 1994). Nature's fate was sealed. Her exploitation for economic ends became legitimised in the very philosophy of the West, and reductionist science became the tool of the corporation (Hamilton Grant, 1998). As Bertrand Russell pointed out in 1952, science, once a means of getting to know the world, had become the means of changing it.

As we reach the end of the 20th century, the dominance of the instrumental rationality and reductionism of Western science, coupled to the de-sacralisation of nature and the loss of the transcendent, have become, according to Slaughter, (1996) the pillars of the "metaproblem" or our time. Indeed many scientists themselves are concerned with the scale of destruction of the planet's living systems and the unsustainable nature of human activity. Key members of the science community including the Union of Concerned Scientists (UCS) in 1992 produced a declaration starkly titled "World Scientists' Warning to Humanity". The declaration, signed by 1600 scientists including 101 Nobel Laureates, concludes that:

> If not checked, many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms, and may so alter the living world that it will be unable to sustain life in the manner that we know. Fundamental changes are urgent if we wish to avoid the collision our present course will bring about. (Suzuki, 1997 p.4)

The UCS considers that no less than a "great change in our stewardship of the earth and the life on it is required, if vast human misery is to be avoided and our global home on this planet is not to be irretrievably mutilated." (Suzuki 1997, p.4). For Slaughter, (1996, p.12) the split between facts (what is) and values (what ought to be) has plagued Western culture since the Enlightenment.

Finally, to the above critiques we would add that an understanding of science is not complete without a futures perspective. This perspective, argued elsewhere (Sirdar, 1996), emerges from the academic discipline of futures studies, which Slaughter (1996) believes offers a whole new world of insight, understanding and empowerment. Futures tools and concepts such as foresight, enable us to view the consequences of the products of Western

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science, such as global warming and biotechnology, as having significant and unpredictable effects into the future.

The Nature and Purposes of Science Curriculum.

Let us turn now to the consideration of the nature and development of school science curriculum. Hardly surprisingly, science curriculum largely recapitulates the Western science worldview, thus lending itself to a similar critique. Current science curriculum has its origins in the late 1950s and 1960s when countries like Australia adopted the Western superpowers' response to the launching of Sputnik. This curriculum, explicitly aimed at training vocational scientists and engineers at an elite level, was developed during a period of great scientism with its unbridled confidence in the social benefits and utility of science. It was highly conceptual, containing an objectified and fragmented body of knowledge and a sanitised scientific method. Over the intervening years, there has been much criticism of the failure of the post-Sputnik curriculum and its many revisions to deal with the conflicting goals of the demand for a specialist elite and the need for a more scientifically-literate citizenry (see discussions in Fensham, 1988; Fensham, 1997; Greenall Gough, 1993). There have also been some admirable if short-lived attempts to come to grips with this distortion including the Australian Science Education Project (ASEP), school-based curriculum development initiatives in the 1970s and Cliff Malcolm's excellent Science Curriculum Frameworks in the late 1980s organised around five socially democratic principles.

Nearly half a century after Sputnik we find ourselves in a world dominated by the forces of globalisation, neo-liberalism and corporate managerialism. Political intervention has lead to the adoption of standards/outcomes-based national and state curricula implemented in Victoria as the Curriculum and Standards Framework (CSF). The "new basics" of literacy, numeracy and science have been singled out to provide the essential prerequisites of a future productive, flexible and efficient workforce (Galbraith, Carass, Grice, Endean and Warry, 1997). But despite the outcomes-based rhetoric and catch-cries of "science for all" and changed economic and social conditions which could have been expected to have spawned authentically new science curricula, Millar and J. Osborne (1998) consider that there has been little real substantive change (see also Mascaskill and Ogborn, 1996; Osborne, Driver and Simon, 1998). For them, science curriculum remains a highly selective and conceptual body of knowledge which presents itself as value-free, objective and detached, requiring the rote learning of facts without any overarching coherence and contextual understanding. Eisenhart, Finkel and Marion (1996) reach a similar conclusion having reviewed the latest round of science reforms in the United States, arguing that the "leading goal" that serves to organise and direct the standards-based science curriculum remains virtually unchanged since the 1950s. This, suggests Ralston Saul (1996), is only to be expected as the real purpose behind a neo-liberalist society is to use the corporatist approach to feed the "best" up through the system to the elite structures. In short, an old conceptual curriculum recapitulating the Western science worldview has been found to well-serve new masters!

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Critiques of Science Education

The legacy of a conceptually-based science curriculum can be judged in part from the perspectives of the mainstream research literature. One major area of concern is the decreasing numbers of young people opting to study science beyond the compulsory years. Osborne, Driver and Simon, (1998) and Dekkers and De Laeters, (1997) report studies in Britain and Australia respectively showing that despite an increase in the total numbers of students remaining at school since the mid 1970s, the numbers in discipline-based sciences of physics, chemistry and biology have remained at best static or declined. Indeed the only increase in numbers consistent with rising post-compulsory retention levels have been in alternative science (e.g. psychology) courses. In Victoria these falling enrolments are seen to be so counterproductive to the state's economic future that they have prompted a high level collaboration between the professional association of science teachers and the appropriate government ministers.

Millar (1996) suggests that the conceptual curriculum is also responsible for the accumulating evidence from assessment and performance unit (APU) studies that show that despite years of formal science education, few students had assimilated appropriate scientific understanding and persistent misconceptions were common. Take, for example, this quote from a 15 year old schoolgirl:

> I know all about elements and compounds and mixtures and that atoms have little circles and dots and how to use a Bunsen burner but I don't know what that has to do with anything.
>
> (Levinson and Thomas, 1997 p. 1).

Such quotes remain only too familiar to science teachers. Only about 35% of 15 year olds appear able to apply scientific knowledge to simple problem solving situations (see also Eisenhart, Finkel and Marion, 1996; Harlen, 1997; Millar and Osborne, 1998). According to Coglan (1992), it would seem that even students who persist with science for instrumental or other reasons can find it a difficult, theoretical subject divorced from the realities of everyday existence.

Of more interest to us however, is the growing number of critiques of science education and the conceptually-based science curriculum drawn from those areas collectively known as science studies or the sociology of science discussed above. In much the same way as these intellectual notions have opened out the construction of scientific knowledge and the power relations within the discipline and its transactions in social-cultural milieus, they also scrutinise the foundations of science education practice (Barton, 1998; Hildebrand, 1998; Meyer, 1998; M. Osborne, 1998). Studies such as these attempt to situate science in discourses of domination, control and power. They combine an understanding of how the intersections of race, gender and class frame access to knowledge and power with current debates concerning schooling and the need for an emancipatory education (Barton and M. Osborne, 1998). From this perspective conceptually-based science curriculum has been traditionally used as a "weeder", privileging the brightest and marginalising many including girls and students from Other cultures (Cunningham and Helms, 1998). In order to meet the needs of all the historically marginalised and diverse learners, Barton (1998) calls for school science to be reframed in a way that promotes a vision of science as socially constructed. She argues that teachers need to actively and continually deconstruct the master narratives of science, and of teaching, learning and curriculum so as to convey democratic depictions of science that are more authentic and more inclusive.

Certainly we would agree with these perspectives. It would seem that despite a couple of decades of literature revealing hegemonic practices regarding gender, class and Other cultures, the promotion of constructivist approaches to the teaching and learning of science and the attention given to the need to embed science in social and ecological contexts, quality teaching in science remains an elusive goal (Shymansky and Kyle, 1992). We still see all too often classrooms where the primary strategy is "talk and chalk" and the aim is to get through as much theory as possible in as short a time as it takes. Textbooks used convey nothing of the flavour of the "non-scientific" human struggles needed to arrive at consensual scientific knowledge, of the confusion, uncertainties, frustration and seredipity of the scientific method (Boulton and Panizzon, 1998; Cunningham and Helms, 1998). They largely present scientific truth and its production as revealed and indisputable, bearing little of the cultural fingerprints used in its generation. It is hardly surprising that too many young people "declare that they find school science boring and complete their period of compulsory science education without the sort of understanding of fundamental science ideas which they can use in out-of-school contexts" (Millar and Osborne, 1998, p.3). It seems to us that an approach to the science curriculum which is based upon insights from science studies, critical ecology and feminist arenas and firmly embedded in futures perspectives can offer hope of a science education that is highly relevant to young people's lives.

Science Education for the 21st Century.

Discussion of new ways of conceptualising school science curriculum are becoming apparent in the literature, see for example Cunningham and Helms, (1997); Lee (1997); Loving, (1997) and Segal, (1997). One interesting approach is that of Millar and Osborne (1998) who suggest the major contributions of Western science could be conveyed through the telling of explanatory stories as historical case studies. Mayer (1997) argues for a science curriculum that uses the Earth System as the integrating theme for developing an authentic global science literacy and a holistic understanding of planet Earth. For him, of critical importance is the inclusion of Eastern thought traditions in an attempt to engender a new understanding and relationship with nature.

Such views are consistent with an orientation of science education for which the purpose is the preparation of students for life rather than work. They are also concerned with a science curriculum which is less socially reproductive and more transformational (after Kemmis, Cole and Suggett, 1983). In espousing our way forward to a science curriculum for the 21st Century, we locate ourselves with the socially critical orientation of Kemmis, Cole and Suggett (1983) in our desire to promote a curriculum with an overtly critical understanding and informed commitment to the improvement of society. Indeed with Segal (1997) we do not shy away from the explicit value positions espoused in these and other propositions for change. We come then, to add our voices to the search for a vision of a new science curriculum for the 21st century. Such a curriculum would:

(a) Be global in its outlook

With Mayer (1997), we believe that nothing less than a planetary framework is required for students to begin to understand the interconnectedness of life on earth. Earth systems can be used as a source of curriculum and their resacralisation holds the key to their protection (Suzuki, 1997). A planetary science, while acknowledging the contributions of those scientists who helped us see the building blocks of nature, nevertheless focuses on organisation and relationships and systems as ways of understanding our world. Through the promotion of ecological literacy or ecoliteracy (Capra, 1996) to the same status as numeracy and language literacy, the interdependence of all life on earth becomes clear again.

(b) Be socially critical

An understanding of science as socially constructed enables an approach to science curriculum which actively deconstructs the master narratives of science revealing the privileged positions within its production. Only then is it possible to convey democratic depictions of science that are more authentic and more inclusive and so work towards an emancipatory and empowering science education for the future (Barton, 1998).

(c) Include Other perspectives

Reductionist science appears to be a product peculiar to Western thinking, and according to feminist scientists, a product of masculinist science (Shiva, 1994). Other cultures have their own science, and the inclusion of their stories enriches our understanding of our relationship with nature (e.g. Broomfield, 1998; Sirdar, 1996).

(d) Include a strong historical and futures perspective

The history and philosophy of science are vital ingredients in a curriculum which seeks to understand the origins of the Western reductionist scientific worldview and its powerful role in the world of today (Loving, 1997). We concur with Postman (1992) who asserts that a critical perspective is not possible without an historical context. Combined with an historical view, a futures perspective derived from futures studies is essential for considering ways

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forward. This offers a range of powerful concepts and tools for developing foresight and being proactive about creating a future worth having (Slaughter, 1996).

(d) Invoke a sense of wonder and transcendence

While science itself is seen by students as central to life at this period in our history (Carter and Smith, 1997), conversely, school science is frequently seen as a dry body of knowledge and facts, boring and irrelevant to their lives and futures (Millar and Osborne, 1998). A sense of awe and wonder is part of all human experience, and should be an integral part of any science curriculum. Awe is apparent when students can see their place in the vastness of space and time, as part of the cosmogenesis (Berry 1992; Swimme and Berry, 1992). They call for us to begin to see ourselves not as conquerors of nature, but as part of its wonder. Such perspectives start the process of rekindling our reverence for nature and our desire for a just future.

PART B

Students' views of science and science education

As well as turning to research drawn from science studies, critical ecology and futures studies for pointers to reframe science curriculum, we draw also from the concerns and perspectives of our own students. As science educators engaged with pre-service primary and secondary teachers, we consider that students' views about the role and content of science should make a contribution to this project. After all, these are the very people who are charged with teaching school science into the next century.

We sought to canvass students' views using a survey questionnaires administered to three cohorts at the beginning of the academic year. These were:

1. 1st year Bachelor of Arts/Bachelor of Teaching primary teaching students, known here as BA/BT1. 30% of these students studied science as far as Year 10 (Form 4) only, while those who completed post-compulsory science studied biology (30%) and psychology (27%), physics (7%) and chemistry (6%). This group of students was also surveyed at the end of their unit in science.

2. 4th year Bachelor of Arts/Bachelor of Teaching primary teaching students who had chosen a specialisation in science education, known here as BA/BT4. 32% of this group of students had science to Year 10 only, with 42% studying psychology, 15% had studied biology above Year 10, while 11% had studied physics and/or chemistry.

3. Diploma of Secondary Education (science method) students (N=25), known here as GDES. These students all had science degrees, mainly in biology (45%), chemistry (26%) and physics (16%).

The survey covered four interrelated areas:

1. Information on the students' attitudes to school science. Here we were seeking to uncover our students' personal experience of school science.

2. Students' views of themselves as prospective teachers of science. We were interested in the importance or otherwise they attached to a public understanding of science, and their opinion of what should be included in science curriculum;

3. Students' views of what science is about. Did they, for example, hold narrow reductionist views as generally exemplified in the current curriculum? Or were their views broader and less bound? They were asked to assess an extract from Chief Seattle's speech (Knudtsen and Suzuki, 1992) as a piece of science writing.
4. Students' general perspectives of the future and the significance science played in those views.

In addition, students in the 1st year cohort only, were asked to reflect on their views and concerns of science at the end of the unit to determine whether they had internalised some of the ways science had been presented.

Survey Results and Pointers.

Views of the Future

When asked what came to mind when they considered the future, by far the largest response from all groups was "technology, computers and space travel". The second most common response from all groups related to environmental concerns. When asked to give their views of the importance of science in the future, most students in all groups suggested that science was important because it aided an understanding of the world and of technology in particular. A minority of students (mainly GDES) saw science a giving us the tools to be proactive in our decision making. In terms of what aspects of science is relevant for a better future, a majority in all groups asked for science of the environment (BA/BT1 32%, BA/BT4 56%, GDES 38%) No other category gave such a strong response.

Experiences of School Science

When asked to comment of their experience of school science, most BA/BT1 and BA/BT4 students found it "OK" and only fairly interesting, while the GDES students, not surprisingly, mostly found it enjoyable and intellectually nourishing. Far more BA/BT1 and 4 students considered that their school science experience was not enjoyable and boring than did GDES students.

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Relevance of School Science

A majority of BA/BT1 and 4 students commented that their school science experience was only fairly relevant to their lives, and even less so to their teaching careers, unlike the GDES students, a majority of whom found it very relevant to both life in general and their career in particular. When asked how they viewed the prospect of themselves teaching science, the majority of BA/BT 1 and 4 students admitted they were "scared stiff", contrasting with the "confident" to "very confident" of the majority of the GDES students.

What should be taught in school science

A significant number of students (>50% of all groups) wanted school science to focus on what they considered relevance and the interrelationships between areas of science. A smaller number stated specific subject areas, with most relating to biological and/or environmental areas.

Science understanding

When asked to comment on what they thought science was about, three main sets of themes emerged. The most common responses described science in terms of concepts and content (BA/BT 1 41%, BA/BT 4 38%, GDES 50%). The second most common set of responses referred to science being about understanding how the world works, while the third related to the future and how science can help us improve our quality of life.

The Chief Seattle passage drew mixed responses. The vast majority of GDES students (86%) saw the passage as piece of science writing, describing the interrelatedness of the world, and the relationship of science to spirituality. Only 14% of these students decided it was not science, some seeing it only as a spiritual statement, others as an archaic view. For the BA/BT students, the statement was considered to be science by only 46% of Year 1 students and by 68% of Year 4 students.

End of unit survey

The students revealed a range of concerns about science and technology. These ranged from the way science is used and whether it is adequately controlled (40%) to a call for science to be channelled into environmental areas (60%). A number of students thought that although science and technology had made life easier, science was problematic, and scientists may act in God-like ways.

Discussion of results

These students clearly have opinions about science. Some may be concerned about teaching science, and frame up school science in terms of a body of knowledge, not surprising in the light of the curriculum as discussed earlier. Their reactions to school science, while not overwhelmingly negative, call for a change to a more relevant science. Of most interest to us in the light of the theoretical arguments developed above, is that many of these students, whether science graduates or otherwise, appear to be able to accommodate Other voices as science. They recognise the interconnectedness of all living things, and plea for a relevant science for the future which has a strong ecological focus. These findings, though tentative, would seem to support a view of science as more authentic and more inclusive.

Those who had been exposed to the unit we developed see science as being both problematic and having the potential to impact on our future in negative and positive ways.

Conclusion

Our project continues. The next step is to consult widely with science educators and students about the science they need and want, informed by a continued reading of the literature. Then we will be in a position to develop a curriculum for trail and comment.

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