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Seeing a World in a Grain of Sand: Science Teaching in Multicultural Context

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ABSTRACT. This paper briefly describes two unusual curriculum plans: the Imagining Nature Project at Deakin University in Geelong, Victoria, Australia[1] and the Native Eyes Project at the Institute of American Indian Art in Santa Fe, New Mexico[2] Among other things, both projects entail the teaching of science and technology studies to non-science majors of highly diverse cultural origin. Both projects also incorporate innovative strategies designed to make science and technology more credible and relevant to indigenous people.

To see a world in a grain of sand
And a heaven in a wildflower
Hold infinity in the palm of your hand
And eternity in an hour.

William Blake, 'Auguries of Innocence'

If the feeling behind Blake's words is applied to science teaching, then the best place to teach may be on a beach or in the countryside. This story, about the role of science in the arts curriculum, starts twenty years ago with the founding of a new university in an Australian sheep paddock not far from the country's best known surfing beach. We soon learned that teaching, wherever it may take place, is more effective when its aims and methods take account of the needs, interests, and social background of the students.

From its establishment in 1977, Deakin University's student body was culturally diverse, reflecting Australia's high post-war immigration policies. It also included a contingent of Aboriginal Australians from the university's Koori teacher education program. Furthermore, more than half the Arts students were 'off-campus' and 'mature-age', generating special teaching imperatives. Both this heterogeneity and the particular requirements of the interdisciplinary curriculum were to prove important in how we structured the teaching program.

From the beginning, all Arts subjects were taught by interdisciplinary course teams. One of these, called Knowledge and Power, was charged with examining scientific and technological knowledge with an eye to its cultural and historical dimensions. Three staff members were trained historians of science, but because the Course Team also included academics from many disciplines in both the arts and the sciences,[3] we decided that the program should follow the broader approaches of Science and Technology Studies. Furthermore, we agreed that the program would be integrated around a focus on the production, legitimation, transmission and use of knowledge. From the outset we assumed that the ideas, theories, methodologies and impact of science and technology would be studied alongside other ways of knowing, including traditional knowledge systems of indigenous people around the world.

While some of the educational techniques, described below, do not fit easily into the traditional science curriculum, many of the ideas have proven useful to science teachers in a range of teaching environments. It has been suggested that non-majors' science *is* inherently an exercise in cross-cultural education, that everyone teaching non-majors is teaching across cultures. In an age in which science education must reach out to the ordinary citizen, if certain scientific initiatives are to survive politically, then too parochial a view of science teaching may be counterproductive.

Working within these parameters, the Course Team sought to devise distinctive, and in some cases markedly innovative, teaching methods that would address the "science wars" divide (which C. P. Snow in a gentler age had called 'the two cultures'): the arts and the sciences and indigenous modes of knowing were to be compared directly in relation to their ways of seeing and understanding nature. The idea was not to seek final resolutions, or to prove one way of knowing better than another, but to explore the cogencies and contributions of each along with the problems and limitations of each.

In order to encompass so many disparate aims, often with few precedents in the literature, and to cater for the multiplicity of student backgrounds and teaching/learning environments, flexibility of format became key in preparing all the teaching materials the unit produced. Within twelve years, more than thirty textbooks had been published by members of the Course Team. Two of these books received Australian National Book Awards, and in general the books were favorably received in international journals such as *Isis*, *Social Studies of Science*, *Technology and Culture*, *Science*, *Technology and Human Values* and *Metascience*. One reviewer enthusiastically described the University as located 'on the periphery of the periphery, but in the development of teaching materials in the Science and Technology Studies field, it must be viewed as the center' (Bindon 1983, p. 548).

THE IMAGINING NATURE PROJECT

Without doubt the most radical restyling of academic pedagogy is seen in what became known as the Imagining Nature Project. All seven books published in the *Imagining Nature* series attempted to break new ground in the teaching of social and cultural studies of science and technology, (Chambers 1984a–e; Turnbull 1993; Watson et al. 1989).[4]. All offer cross-cultural and interdisciplinary treatment of such fundamental concepts as perception and representation, order and chaos, models and metaphors, objectivity and subjectivity, measurement and approximation, classification and rationality, theory and experimentation.

Richly illustrated with color reproductions from the history of science and the history of art, the title volume, *Imagining Nature* (Chambers 1984a), is the most conventional in format, providing a brief historical and philosophical introduction to the series. Although this book does not tackle any scientific concepts as such, it examines the boundaries traditionally drawn between nature and culture, nature and nurture, the natural order and the social order. It pursues the various historical meanings of the word nature and explores the notion of naturalistic representation. In the six remaining volumes these issues are visually argued and documented in relation to the arts and the sciences. In short, the series as a whole attempts to construct a working introductory framework within which students may address a selection of real world situations in which technical, social, moral, intellectual and political judgements about nature and about science are made.

Throughout the series, science is depicted as one way of knowing among many, but as the most powerful of all knowledge traditions. In this manner, the stage is set to explore the sources of authority and instrumental utility, which characterize science and technology in both local and global contexts. At the same time indigenous knowledge is also shown to be authoritative, systematic, intellectually satisfying and useful, when considered in particular local contexts, and able to make global contributions as well. Make no mistake: this is not a framework of "anything goes" relativism. Rather, it sets the stage for understanding from whence techno-scientific explanations draw their power.

TEACHING BY EXHIBIT

The remaining six books in the series are structured as virtual museum exhibits. They entirely eschew the didactic or authoritative tone and make little reference to philosophical or cultural theory; instead, they incorporate techniques designed to stimulate visual thinking and intellectual problem solving. This is accomplished in a series of interactive exercises based on paintings, drawings, photographs, film and audio clips, scientific diagrams and charts, dances and chants, landscapes and maps, animal and plant depictions, optical illusions, textual descriptions, and the numerical delineation of nature.

Why use the exhibit format? At their best, museum spaces remain one of the most effective instruments of science education.[5] A large number of educational strategies in the museum inventory are unavailable in the conventional classroom or textbook presentation, where explicit didacticism and authoritative pronouncement often deaden the intuitive sense of wonder and discovery that is at the heart of science or, indeed, at the heart of almost any intellectual exploration. Such considerations often become paramount when trying to reach those students who have no pre-existing cultural or intellectual commitments to the scientific enterprise.

In the Imagining Nature books, all of the basic themes of the course are introduced through juxtaposition of images and short texts. The aim is to make these issues come alive for students who may or may not wish to deepen their knowledge at some future time. We intend these techniques to be added to the science teacher's repertory, not to replace other tried and true approaches. Five principles shaped the Imagining Nature exhibits:[6]

1. *Primacy of the Visual over the Verbal:* Images should seldom merely illustrate the verbal text. Rather, the text enriches and develops ideas that are first presented visually. Much can be said about this approach, which builds on the assumption that students' visual literacy and visual abilities often exceed their verbal or numeric literacy. Pictures are often perceived to be more accessible and more interesting than a page of words. This principle lends itself to certain well known, and sometimes dangerous, museum strategies, such as the power of the aesthetic impulse in humans. That is to say, there is often no greater attention grabber than a beautiful object or a pleasing pattern. But to achieve the desired intellectual end, the aesthetically inviting image must be presented in a context that poses questions or sets a problem. Too often in museums, aesthetic considerations become the end rather than the means.
2. *Visual/Verbal Dialog:* The pictures question the words; the words question the pictures. Thus, a problematic image may be shown together with several equally plausible, yet incompatible, verbal explanations. Alternatively, a text may be offered together with an image, or series of images, which apparently contradicts the written word. For example, the term 'genus' may be defined as 'a taxonomic category of plants having certain common attributes'. This is accompanied by a host of illustrations of different species of the genus *Acacia* found in many parts of the world: trees, shrubs and prostrate forms, some so similar only botanists can tell them apart, others so distinctive they appear utterly unrelated. Another example might be an indigenous (or ethnobotanical) classification which makes more practical sense than that used by modern science. When other taxonomic puzzles, such as these, are brought together, in the end students are enabled to probe deeply into issues of the importance of convention, the nature and value of classification, and the social and intellectual uses of taxonomy.
3. *Problematic Juxtaposition:* Understanding the pictorial sequence should require an exercise in logical problem-solving. For example: 'why is that bridge next to that skeleton?' or 'why are there 26 different depictions of the rhinoceros?' or 'why is that Australian landscape painting next to an electron micrograph?' or 'why is the aboriginal dance sequence shown next to a European map of Sydney Harbor?'
4. *Non-linear, Multiple Station-point Narrative Structure:* In its simplest

formulation, this principle means only that stories are often told from a number of points of view; at its most complex, this principle means that multi-layered, seemingly contradictory, truths are sought out rather than avoided. That is to say, although consistency is a 'bulwark of rational thought,' it is also a 'hobgoblin of little minds'. If Resonance Theory can win a Nobel Prize for Linus Pauling, and if aboriginal bark paintings can depict nature at many levels of meaning, then students should understand that simple truths are not always easy to come by. Issues of the postmodern movement are embodied in the presentation for further discussion – without requiring the student to read a single word of abstruse theory.

5. *Participatory Democracy:* Interactive exhibits in museums do not work unless viewers act, rather than just observe, and think, rather than just act. In the exhibits in Imagining Nature, students are asked first to discover the questions, then to think about and discuss the answers. In some ways, this approach may be seen to democratize the educational process. Attention shifts from the authoritative voice of the expert to the common sense of the non-specialist. There is some truth in this observation, since teachers in the program are often kept on their toes in ways unlikely to occur in lecture/tutorial encounters. In reality, however, participation itself is the aim. The idea of democratized learning is, for the most part, illusory. Exhibits are as surely constructed to particular ends as are lectures and textbooks. If the didactic message is hidden, it nonetheless remains the educational objective, and the teacher will ordinarily make sure the 'proper' lesson is learned.

When students first browse through the six bound portfolios of exhibits, they are not given a great deal to go on. A quotation from Ezra Pound's wonderful little book, *The ABC of Reading*, gives student a clue:

> The ideal way to present the next section would be to give the quotations *without* any comment whatever. I am afraid that would be too revolutionary. By long and wearing experience I have learned that in the present imperfect state of the world, one *must* tell the reader. . . . The most intelligent students, those who most want to *learn*, will endear themselves to the struggling author if they will read the *exhibits*, and not look at my footnotes until they have at least tried to find out *what the exhibit is*, and to guess why I have printed it. (1960, p. 95)

Students are then enjoined to 'Explore this book in the spirit of Ezra Pound's instructions. Look through the items presented in much the same way you would attend an exhibition at a museum or gallery: linger over this, skip over that, and return to savor the best or to puzzle over the mysterious'.

As an exercise, I now invite readers to imagine that they are either a student or an instructor attempting to make the most out of the following three sample exhibits:

Exhibit One (adapted from Chambers 1984e):
a) photograph of the Firth of Forth bridge;

b) drawing of a fossil bison skeleton shaped like the bridge;
c) photograph by Max Yavno of two men turning a San Francisco cable car – their bodies arrayed in a symmetry produced by physical resistance to strain;
d) brief poetic passage from Rebecca West describing her pleasure in seeing a 'soft rosy girl' holding up a child in such a manner that the girl's limbs reflect the lines of the cantilevers supporting the Forth Bridge, 'a tremendous black diagram across the western sky behind her'; and
e) passage by Jacob Bronowski describing both art and science as the search for 'unity in wild variety'.

Exhibit Two (adapted from Watson and Chambers 1989):
a) quote from the 16-year-old Einstein asking, 'What would the world look like if I rode on a beam of light?';
b) engraving from a 13th-century treatise on optics showing the rectilinear motion of light;
c) short passage from the philosopher Stephen Toulmin asking what kind of a discovery is embodied in the notion that 'light "travels" in straight lines';
d) environmental assessment document describing toxic wastes "traveling" down the river;
e) picture of a traveler with a suitcase;
f) short philosophical essay on the role of metaphor in science; and
g) the following paragraph:
A tourist travels to the mountains; light travels in a straight line; news travels fast; wine travels poorly. In these contexts, what it means to travel is dramatically transformed. Does the travel metaphor diminish or enhance the ability of language to portray reality? What tacit assumptions are made about the nature of the thing which travels? When a member of the Bunitj people says 'Water important . . . Water is your blood . . .', how is the meaning of water affected? And what is assumed about one's relationship with nature?

Exhibit Three (adapted from Watson and Chambers 1989):
a) diagram from the journal *Science* charting alligator movement in and out of the water against time of day;
b) Pliny's accurate description (112 AD) of crocodile movements in and out of the water;
c) bark painting of a crocodile showing ecological associations;
d) photo of Aboriginal artist sitting on the ground painting above mentioned bark;
e) Topsell's 17th-century description of the crocodile and his movements in and out of the water;
f) naturalist Bartram's 18th-century florid account of the alligator going in and out of the water;

g) African wood carving of two crocodiles by a stream; and
h) poem by Aboriginal writer about the crocodile (Southern Cross) shown on the Australian flag.

For on-campus students the exhibits serve simply as a starting point for tutorial discussion, which may proceed in a number of different directions. The teacher may use slides, film and audio clips to spice up a lecture in which the possibilities of a particular exhibition are explored from several points of view. Although the materials are modular and require no particular trajectory, growth and development is stimulated by the frequent cross linkages, continual return to the basic themes of the course, and encouragement to tackle further reading once the student is motivated. Off-campus students are required to maintain a daily journal in which they record their thoughts as they work through the exhibits and readings. These journals are marked on a pass/fail basis; pass grades require evidence of growth of sophistication in relation to a number of themes and objectives that are clearly specified. Assessment of student work is based principally on essays and term papers exploring the course themes in greater depth. With these materials we find that participation in class discussion is an especially important barometer of student progress. Occasionally, exams have been given over the readings that accompany the exhibit books.

Because the exhibits are in effect modular building blocks, off-campus students study them in any order, which may be determined by the student's academic background, life and work experience, or simply personal interest. With regard to on-campus classes, the value of lock-step progression usually dictates an agreed upon regime. The exhibits' modularity enables teachers to structure a number of very different courses based on selection, order and accompanying readings assigned. Dramatic illustration of this point is found in the fact that the books have been used at other universities for courses in environmental studies, science journalism, physics, psychology, geography, architecture and design, history and theory of art, anthropology, history and philosophy of science, and aboriginal studies. They have also been used in different ways at both graduate and undergraduate levels as well as for secondary teaching.

Long experience of working with these materials and years of student review and evaluation give strong indications of where the program has been effective and where not. Unquestionably, on first encounter many students, and sometimes teachers as well, show some apprehension as to what is expected of them. Usually such fears soon pass. The program's greatest successes have been in the area of motivating learning with those students who have little interest in science and may even have substantial mental blocks against pursuing scientific questions.

Reaction of students to the course materials is almost entirely favorable, though the range of opinion is reflected in the following comments. One mature-age student paraphrased Moliere's *Bourgeois Gentleman* saying, 'I always thought I hated science, now I find I have actually been speaking it for forty years'. Another revealing comment came from an Aboriginal student: 'When I saw the diagram of the base pairs of the 'double helix' compared to the kinship linkages of the Yolgnu, I realized that they both had their places in the world'. Two final comments: 'Big deal, I worked through the whole thing in an hour!' and 'the journal took me three months but was the best educational experience I ever had'. Interestingly, these last two comments came from the same student, at the beginning of term and at the end of term. In other words, initially, students feel that the coursework is interesting and easy, almost self-evident. But as the term progresses they become more deeply involved and more acutely aware of the challenges posed in these materials.

Finally, the success of the Imagining Nature exhibits has been especially striking with indigenous students. Teachers report that the influence of the materials can often be seen in written assignments even in the final year of study. Most importantly, they also report that by recognizing the intellectual stature, cultural validity and continuing social utility of traditional modes of thought, students actually become more, rather than less, able to incorporate scientific ways of seeing and understanding. In other words, students no longer feel required to choose between expert knowledge and the wisdom of the elders. Similarly, a navigator in a traditional sailing boat is not asked to choose between the Ptolemaic and the Copernican view of the heavens. In the Imagining Nature project scientific knowledge and traditional knowledge are compared principally in relation to how the different systems function in their own cultural context.

THE NATIVE EYES PROJECT

The Imagining Nature project complements a proposed new academic major on the other side of the globe, at the Institute of American Indian Art and Culture: Indian Perspectives in Knowledge and Culture. Why should this interest a science teacher in, say, a large state university, perhaps without a single indigenous student? As suggested above, teaching science to non-majors always involves the difficult educational task of bringing disparate knowledge systems together in ways that are intellectually productive and helpful to students. Thus, it may be useful for all those who teach science to non-majors to think about the problem of teaching science to Native American students. After all, urban students who are not deeply schooled in the modes of modern science often have "folk" beliefs and styles of knowing in the mode of indigenous cultures. Thus the indigenous ways of knowing can provide the ordinary teacher insight into how their non-major students think and thus how to reach them – exploring existing patterns of thinking, while also showing the power of "Western" science. In this sense, science teachers should perhaps endeavor to understand how "science" functions in folk culture, as opposed to in the culture of academic science so familiar to researchers who also serve as teachers.

Taking such an approach involves the challenging prospect of redeeming knowledge traditions long dismissed in some quarters as nothing more than superstition and myth. Yet these mythic traditions are often intensely utilitarian, incorporating practical knowledge still being mined by the knowledge industries of the modern world. Furthermore, these traditions have enabled an array of hugely varied and deeply satisfying art treasures as well as richly complex and highly functional understandings of the natural world and of humanity's place in nature. These are, after all, traditions which have nurtured human values over thousands of years.

These days very few would attempt to advance Native American or Aboriginal Australian knowledge systems by opposing or trying to discredit the power and validity of modern science and technology. It is essential to equip indigenous youth to function effectively in the techno-scientific world of the 21st century. Indeed, several dozen outstanding programs in math, science and technology for American Indians (set up at the secondary level and funded by government agencies, such as the Bureau of Indian Affairs) embody this aim. The Native Eyes Project, on the other hand, is not so much about training Native American scientists. Rather, it is about rethinking the foundations of tertiary education in the face of countervailing pressures of globalization and indigenization. One of the most confronting and difficult educational challenges of the new millennium is bringing together disparate and largely incommensurable knowledge systems. Far from being an abstract intellectual debate, the problem goes to the heart of how different cultures view one another and how they interact socially and politically. Finally, the problem speaks directly to the issue of the future of traditional cultures, how they must move beyond mere survival into a productive accommodation with the modern world that does not sacrifice essential cultural values.

It is not anti-scientific to suggest that science, like any other human activity, is a social enterprise that bears the imprint and assumptions of the society of which it is part. Neither is it anti-scientific to suggest that traditional knowledge systems still have a substantial role to play in understanding the natural world, in aiding continued survival of the human race within that world, and in strengthening the integrity of Native American cultures. Yet, whenever science is compared systematically to any particular indigenous knowledge system (e.g., Lakota, Maya, Koori, Yoruba, or Sami), science is inevitably triumphant in the eyes of the world. This is due in part to the well known ability of science to reduce and co-opt those aspects of knowledge that it can utilize, while discrediting what remains as mere 'subjective belief' and mythology. Indeed, the contributions of indigenous knowledge to the databanks of modern science and technology have been immense, as great surely as the ancient antecedents of European thought on which historians of science have lavished such notable attention. In truth, the contributions of ancient Greece and medieval Islam must themselves be counted among the contributions of indigenous knowledge to modern science.

In recent years, there has been some recognition of the validity of balancing the reductionism of science with more holistic and deliberately moral approaches to the construction of meaning. For example, indigenous knowledge has a crucial part to play in the preservation of biodiversity and the management of natural resources. The desire to achieve environmentally sustainable development has prompted attempts to establish a dialogue between science and indigenous knowledge, combining the strengths and perspectives of each.

Some Proposed Courses

To properly present the issues, students need to see the strength and magnitude of the contributions to civilization of indigenous cultures across the Americas. Although a certain amount of tribal knowledge will be included, the course materials will not by any means attempt to supplant the teachings of the elders who are charged with responsibility for the transmission of tribal culture and knowledge. Similarly, while including a number of units with substantial scientific content, the new curriculum is not intended to replace the professional teaching of specific scientific disciplines. Rather in both cases, the aim will be to inculcate a significant degree of respect for, and understanding of, the role of different knowledge systems (including science and technology) and the context of their effective application.

Eight interdisciplinary courses are proposed for the Indian Perspectives on Knowledge and Culture major. All incorporate a certain measure of science content. The four courses briefly described below include a significant amount of science. Due to the interdisciplinarity of the subject matter, teacher manuals will be required in most cases, introducing the relevant scholarly and scientific literature, as well as the Native American perspectives:

Diversity of Expertise (integating Biology, Agriculture, History of Science and Technology, Ethno-science, Anthropology, Astronomy, Urban Studies). This important unit will examine some of the great indigenous knowledge traditions in terms of their present day interest, their sophistication and practical application in the past and present. Case studies will include: Pacific navigation, astronomy and mathematics of several cultures, nature tracking, the loom, agricultural technology, culinary development, architecture and urban planning, botany and drugs. It will raise questions of intellectual property rights, dispute resolution when experts disagree, and new social and institutional roles for Indian knowledge practitioners.

Bodies in Sickness and Health (integrating Health Sciences, Cultural Studies, Anthropology, History, and Sociology). Taken from four major scholarly literatures: sociology of health, history of medicine, cultural studies of the body, and cultural studies of sex and gender, this course will deal with issues of the perception of the body in cultural context, the body in sickness and health, medicine and alternative medical traditions, legal and illegal drug use, sex and gender roles in cultural perspective. It will also explore practical problems of health maintenance in Native American communities.

Perceiving Nature (integrating Geography, Taxonomy, Ecology, Chemistry, History, Fine Arts, Philosophy, Cultural Studies, and Psychology). Based on the Imagining Nature Project, described above, this course will examine the basic ideas of perception and representation, especially as they relate to the depiction of the natural world.

Environments, Cultures and Bio-diversity (integrating Ecology, Environmental History, Biology, Law, Politics of Development). Topics to be considered include: the cultural meanings of biological classification, the value of indigenous ecological knowledge, sanctuaries and totemism, animal behavior, fire in the landscape, bio-diversity conservation and environmental management. The significance of indigenous knowledge for bio-diversity conservation was recognized at the UN Conference on Environment and Development at Rio de Janeiro in 1992. The conference publication called for reevaluating the role of indigenous people in promoting environmentally sustainable development.

If we can engender a more sophisticated understanding of the worth of indigenous knowledge systems and their relevance to contemporary social, aesthetic, scientific and environmental issues, then we have gone part of the way to creating a broader acceptance of the values and practices of the earth's multiplicity of indigenous cultures. Similarly, if we can instill a working and sympathetic understanding of the nature of the scientific enterprise in a way which does not demean traditional knowledge, then we better gird indigenous youth for living in the modern world. We may even encourage some to go on to scientific and professional careers. And that may apply to teaching all non-scientists, as well.

NOTES

[1] The program flourished for twenty years, and many of the Imagining Nature textbooks and materials are still used by Deakin's Institute for Koori Education and by a scattering of course units in the Arts Faculty.

[2] The Native Eyes Project currently exists only as a highly detailed proposal for a revolutionary 'liberal studies' curriculum incorporating both traditional and modern approaches to the arts and sciences. The Institute's location in Sante Fe, New Mexico, places it within one of the most diverse concentrations of Native peoples in North America, at the heart of the nation's oldest multicultural community.

[3] Specifically members of the course team held graduate qualifications in Biochemistry, Biology, History, History of Science and Technology, Museum Studies, Philosophy, Political Theory, and Sociology of Knowledge. Additional consultants from these and other disciplines were invited to write and to review course materials prepared for the off-campus program.

[4] Many of these books are now out of print; for further information on how to obtain them, contact the author at: wade@deakin.edu.au.
[5] At their worst, it must be admitted, museums have much to account for. For an up-to-date review of relevant museological issues, see Hein (1996). Other contributions to the same volume are also highly germane to the philosophy of the Imagining Nature Project.
[6] The following discussion makes use of a number of examples which may seem trivial or incomplete when taken out of the larger context of the classroom or the textbook. These are offered here only to clarify certain points under consideration, not to stand alone without further discussion.

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