In praise of Armchair Science Education

Speech given by Jonathan Osborne, President of the National Association for Research in Science Teaching at the Annual Conference, New Orleans, April 18, 2007

And now to what I have to say. I suppose the first thing to say after last year's talk, is that this is a hard act to follow'…. May I assure you, just in case you are wondering, is not my intention to provoke you. Rather, my life is full of more modest ambitions – like hoping I have something of sufficient interest to stop you falling asleep after your conference lunch.

Today is an opportune moment to consider what is the state of science education and more importantly for this Association, the state of research in science education? To answer that question – the thesis of my talk is an argument in praise of armchair science education.

It is worth remembering that 50 years ago was 1957 – the year in which scientists and engineers in a country thousands of miles from here were about to have an impact on the lives of everyone then sitting in this room when, on October 4th 1957, the then USSR launched Sputnik 1, the world's first artificial satellite. The event, led directly and indirectly to many of the major changes in science education that we have experienced as students, teachers, researchers, curriculum developers or policy makers.

Fifty years later it is worth pausing and asking have we gone forward? Is the state of science education and is the state of research in science education in a significantly better state? The innovations that emerged from Sputnik – in this country, PSSC Physics; Chem Study; and the Biological Sciences Curriculum Study. At the elementary level, there was the Elementary Science Study, known as ESS; the Science Curriculum Improvement Study, known as SCIS, and Science-A Process Approach, known as S-APA. In the UK it led to new curricula in physics, chemistry and biology sponsored by the Nuffield Foundation. Did they succeed? As any Monday morning quarterback will tell you – hindsight is a wonderful thing. The answer depending on where you stand is possibly. If you want to take the optimist's view, working within the existing structures, they offered a new vision of what it was possible to do. Eric Rogers, the American architect of Nuffield Physics argued that what he wanted Nuffield Physics to do was to offer a vision of what it mean to be a 'scientist for a day'. There were two problem with his vision though – problems which I still think we suffer from today:

a) First his vision of what it meant to be a scientist was a very narrow one based predominantly in the exact sciences of physics and chemistry and a hypothetico-deductive methodology. Nobody who has studied the vast literature about the nature of science – what is now more usefully termed (at least in the UK) – how science works – can say that that is a comprehensive representation of science. As a research community, thanks to the work of many people such as Rick Duschl, Norm Lederman, Michael Matthews and others I think we do have a better vision of what might constitute an education about science.
b) The second problem embodied in his statement was a naïve conception of pedagogy. This was the assumption that the learning of science and the doing of science are one and the same thing. This is a dangerous assumption as they are clearly not. The practice of science is the search for knowledge to unanswered questions that we have about the material world. As James Watson, one of the discovers of DNA, so elegantly argued when explaining to his sister why the search for the genetic code mattered so much 'No one knows anything. This is off the map. Ch 1, page 1, life reproduced life. How? Secret of Creation. Worth a Nobel prize'. The task of science education is different. Its role is to construct in the young student a deep understanding of a body of existing knowledge. In doing so, it needs to show why this knowledge is valued; that is was hard won; and that science is a creative process – that it offers you the opportunity to free yourself from the shackles of received wisdom by creating your own knowledge. However, that is not the same as the doing of science and there is a clear line in the sand that needs to be drawn between the two activities – a line which I think the American emphasis on teaching science through inquiry (to use your

pronunciation – you say inquiry, we say enquiry) sometimes forgets.

However, let me give credit where credit is due. As well as exploring new ways of presenting science – predominantly through innovative practical work – many of these reforms at least attempted some innovative approaches to assessment. And why does that matter? As many of you are aware we live in an era of accountability – embodied in education by a nationwide program of high stakes assessment. Now don't get me wrong – I am not against the notion of being called to account – just against the notion of reducing the measure of a teachers' work to how his or her students perform on a one-hour test. In such a context, teachers are extremely rational beings – if that is how they are to be assessed, the intentions of the curriculum are read not from the curriculum documents but from the assessment items. Instead of assessing what's important, what's important becomes what's assessed. Anything extraneous to the test is marginalised. Students likewise are very rational. 'Is this on the test, they ask?' Understanding the rules of the educational game, they become performance learners where knowledge is acquired not for a love of learning and deep understanding but simply to be learnt by rote to be reproduced on a test.

So my message to us as a community is simple – if we really want to improve the quality of science education we must a) continue to show how the extant forms of summative assessment are harming that to which we aspire and b) develop methods of assessment which encourage the forms of pedagogy which we believe are more valuable. For instance, in the arena of argumentation in school science where I have worked over the past few years, much of our effort has been devoted to making a case for its value and showing that it is possible for students to engage in such work. Missing, however, is any work on how teachers might readily assess student competency with such practice.

So where else then, did the reforms of the sixties fail? My answer to that would be in the third of the triumvirate of curriculum, assessment and pedagogy that forms the basis of any teaching and learning experience – that is in the pedagogy. Many of the Nuffield notions of pedagogy rested on the oft repeated Confucian mantra – 'I hear and I forget, I see and I remember, I do and I understand' . Even the ideas of Piaget came too late to be influential on these reforms. Whatever you may think of it, the work of the past 40 years – the application of the ideas of Piaget, the constructivist revolution and now the turn to socioculturalism and discourse have all transformed the research community's notion of what it means to learn and thus to teach science. In simplistic form, what was missing from the notions of pedagogy is the reading, talking and writing that we now see as essential.

The real struggle, however, lies in the classroom where I think it is fair to say that school science is arguably one of the last surviving authoritarian socio-intellectual systems with a teaching style which is over-reliant on information transmission and, until recently, curricula whose primary social function was that of training and selecting a future generation of scientific research workers. Such a cultural practice does not naturally fit with the values and goals of young people. This is particularly true for students whose career aspirations lie outside of science, many of whom are female and who do not see science qualifications as a means of realising their personal goals or identity.

One of the most striking pieces of data about the state of school science is the survey undertaken by Svein Sjøberg for his Relevance of Science Education project of students' attitudes to school science in over 20 countries. Student ratings to the question 'I like school science more than other subjects' get increasingly negative the more developed the country. Indeed there is a 0.92 negative correlation between this data and the UN index of human development. Indeed, it is Norway, Svein's own country which has the most dramatic problem. What the data tell us though is that the 'flight from science' of contemporary youth is something deeply cultural.

Like all good research, some useful insights come out of this work. The questionnaire asks girls and boys to rate what topics, from a list of 108 items, they would most like to learn about in science. There were no less than 80 statistically significant differences. What were the boys top five? Explosive chemicals; how it feels to be weightless in space; how the atomic bomb functions; biological and chemical weapons; and black holes, supernovae and other spectacular objects in space. No surprises there then – other than to invite the question of what is it about the male of the species that they are so obsessed with death and destruction. What were the girls top five? Why we dream when we are sleeping and what the dreams may mean; cancer – what we know and how we can treat it; how best to perform first-aid and use basic medical equipment; how to exercise to keep the body fit and strong; and sexually transmitted diseases and how to be protected against them. Ask yourself which of these lists school science currently presents? The enduring failure to increase the participation of girls in the physical sciences remains one of the intractable problems that we still need good answers to. In essence, this is on of our holy grails.

So these are some of the failings that research has failed to answer, or at least contribute to an answer.

But this brings me to my final point. What I think we need to do is to a bit more is stand and stare, or – in the spirit of my thesis – just simply sit and stare. Basically, I want to make a case for a bit more armchair science education research. What I mean by that is epitomised for me by a student question to a colleague who is an educational psychologist – Guy Claxton – who had just given a seminar. If you have never read any of his writings or heard him speak then I would commend him to you. The strange thing about Guy Claxton is that he is an educational psychologist who has never collected one piece of data. At the end of a seminar, this student had the temerity to say – 'What you have just been talking about is really interesting – tell me, have you ever collected any data on that?' What was Guy's response? 'Good God know, there is enough data out there in the world without me going out there and collecting any more.'

In that statement, I think there is an important message. As you look around you will see our output grows. There is JRST which has, I believe, 300 extra pages this year, IJSE which now publishes 15 parts a year, Science Education, Science and Education, the International Journal of Science and Mathematics Education and now Cultural Studies of Science Education. Most of this we can only read selectively. Add to this, the voluminous Handbooks such as the one that Norm Lederman and

Sandy Abell recently edited and one begins to feel a bit like the Ancient Mariner – data, data everywhere and not a thought to think.

Out of interest, and in the spirit of my thesis, I collected, from my hotel room in Chicago last week, some empirical data from last 6 editions of three science education journals this year – JRST (of course), Science Education and IJSE. Looking at the abstracts and ignoring special issues, I categorised the papers as either reviews, empirically based, or theoretical/position papers. The findings? 3% were reviews, 88% were empirical and 9% theoretical position papers. The question I ask is - isn't it time as a field we engaged in a process of assimilating the meaning of what we have. Clearly such review papers are wanted. Put the words 'review' and 'science education' into Google Scholar and what are the top hits?

1. Pupils and Paradigms: A Review of Literature Related to Concept Development in Adolescent Science Students by Driver and Easley: 238 citations
2. Students' and Teachers' Conceptions of the Nature of Science: A Review of the Research by Norm Lederman: 344 citations
3. On the Role of Analogies and Metaphors by Reinders Duit: 166 citations.

Spend a little time searching for influential theoretical papers and what do you find?

Posner, Strike and Hewson's paper on Accommodation of a scientific conception: Toward a theory of conceptual change has 994 citations. Driver et al.'s paper on constructing scientific knowledge in the classroom in Educational Researcher – 487 citations. Michael Matthews book Science Teaching: The role of history and philosophy of science has 331 citations. Now the quick witted critic will recognize that having decried the significance of numbers as a means of assessing value I am doing just that. However, my point is not that – the community must decide the value of these pieces of work. What the citation counts show is that these are valued. These works serve as important points on the theoretical compass that guide the work we do. The fact that they are so highly used suggests, I would argue, that we simply do not have enough works of this kind. Are we as a community rushing to undertake empirical work when more time spent ferreting out secondary data, critically examining the theoretical ideas that guide our work might be more useful? In short, where angels fear to tread, fools rush in.

To give just one example, one of the most influential papers for my work this year – what little of it I have been able to do – has been the paper published in Science by Robert Tai et al which mined the data in the National Education Longitudinal Study begun in 1988 to show that, for the majority of students, the decision about whether to pursue a STEM related career had largely been formed by the age of 14. A paper has major implications for those of us working in the area of elementary and middle-school science, I should add

So – as we wend our individual ways home from this conference, I ask – to paraphrase Einstein whether:

Science education without data is lame, but is data without a good theory blind?

Basically, is it time to spend a bit more time in our armchairs more time picking over and thinking about what we do – to develop better theories about our goals and values in science education before rushing out to gather more yet more data?