Introduction

There is food for thought in the fact that, after a decade of Labour Government, at the same moment that the Prime Minister was making a speech about how important he considers science, The University of Reading announced the closure of its Physics department. Now 30% of physics departments have either been closed or merged in the last 5 years. What is one to make of the deafening silence of Government ministers when last year, the small Sussex Chemistry Department - a fantastic department to work in where I had stayed for some 37 years and which has housed some 12 Fellows of the Royal Society, 3 Nobel Laureates and a Wolf prize winner since it was created in 1962 - was under threat of closure. It was only through the concerted efforts of staff and students that a U-turn occurred. Does no-one in the Government care or is there a hidden agenda? Some Government measures such as those that concentrated on the research/industry interface aimed at improving technology transfer and the encouragement of start-ups have been successful. However, nothing effective has been done by this or for that matter the previous Government over decades to improve matters on the science education front and indeed several measures introduced have exacerbated the problem – a conclusion supported by the crumbling of the cookie. The laissez-faire attitude to science education has now resulted in a disaster as exemplified by the fact that more young people are opting for media studies than physics. I presume that the highly vocal Simon Jenkins must pour a glass of his favourite claret each time he hears that yet another science department closes as a tribute to the success of the science education policy he touts. As a new five story chemistry building nears completion here at the Florida State University (where I was wanted!) the jaws of colleagues drop with incredulity as news crosses the Atlantic of each successive UK science department closure.

As I finish writing this article I note that - out of the blue - HEFCE has suddenly pledged support for strategically important subjects such as chemistry. Is it too little too late and will it materialize? One notes that according to the Broers' Report, the £200m previously pledged by the Government to improve school science facilities has '…yet to emerge'! If as the Minister for Lifelong Learning, Further and Higher Education claims that "they have significantly increased the numbers of science undergraduates and raised the numbers coming through teacher training in science subjects" why are science departments still being extinguished right, left and centre – something does not add up. A booklet published by the Government a few years ago entitled "Your Creative Career" promoted subjects such as photography (how many people can emulate David Bailey?) and media studies but science and engineering were presumably not considered creative by Tessa Jowell the minister who wrote the introduction. This Freudian slip may actually reveal the real the true attitude of senior Government to science and engineering. If the Government does not see the sciences as creative how can we expect our young to?

The Need for and Value of Science Education in General

The need for a general population with a satisfactory understanding of science and technology (S&T) has never been greater. We live in a world economically, socially and culturally totally dependent on S&T not only functioning well but being wisely applied. Unfortunately the numbers of young people opting for S&T training has dwindled frighteningly all over the developed world, not just in the UK. For information it is worth noting that over decades the US has been spectacularly successful in making up its home-grown S&T shortfall by draining first Western European scientists and now Eastern European and Asian scientists. Most importantly as well as trained engineers and scientists we desperately need a scientifically literate general population capable of thinking rationally *eg* scientifically – lawyers, businessmen, farmers, politicians, journalists, athletes etc. This is vital if we are to secure a sustainable world for our grandchildren.

The fact that a) we use in one year an amount of fossil fuel that took a million years to accumulate, b) we may be on the verge of climate change catastrophe of global proportions and c) powerful technologies may soon fall into the hands of disturbed individuals with minds riven

with those twin cancers nationalism and religious fanaticism, seems to concern the scientific community a lot more than politicians or the media (the latter seems more concerned about a wedding in Italy at present). As my Sussex colleague the Nobel Laureate Sir John Cornforth has written (cf www.vega.org.uk ) "…if you are a scientist you realize before long that if the world is in anyone's hands it is in yours".

The failure of our general science educational policy is manifest in the fact that so few are aware of the true level of our dependence on S&T or the truly humanitarian contributions that S&T have made to society; from raising the health of the population (half of all 18th century children died by the age of 8) to the advanced technologies which pervade our everyday lives (DVDs, the Internet and mobile phones being archetypal examples). Furthermore the personal reasons for S&T education are also overwhelming. A Royal Society of Chemistry/Institute of Physics study indicates that graduates with Chemistry and Physics degrees earn, for the most productive 15-20 years of their working lives, some £15,000 more annually than most other degrees (including psychology, that seductively popular subject which is diverting a large proportion of our best young people into dead-end uncreative careers). It is actually a triple whammy as in addition the Government gets greater investment return in tax from this better-paid workforce and furthermore there are S&T industries to enter (the Chemical Industry posts a 50 billion pound annual turnover with a 5 billion profit - which is more than can be said for Law). At a time when China and India are producing the hordes of scientists and engineers on which they know their futures depend all we hear from our government is that it is not its job to interfere with a secondary/tertiary education system that is graduating ten times as many psychologists, linguists, historians and media people than there are jobs for. Too bad if young people are not going to be qualified for careers available and/or commensurate with their abilities, forcing many to settle for poorly paid, uncreative jobs.

The Cultural Nature of Science

Many think of the sciences as merely a fund of knowledge and journalists never ask anything other than what are the applications of scientific breakthroughs. Interestingly I doubt they ever ask a musician, writer or actor the same question – I wonder why. In addition to numeracy the main values of a scientific education are the acquisition of the skills to solve problems and uncover new knowledge but more importantly to be "at one" with the modern environment which is suffused with wall-to-wall scientific inventions and technology as well as environmentally important issues. The "Scientific Method" is based on what I prefer to call "The Inquiring Mindset" in order to include all areas of human thoughtful activity which categorically eschews "belief", the enemy of rationality. This "Mindset" is a nebulous mix of doubt, questioning, observation, experiment and above all curiosity, which all small children posses in spades and indeed need in order not only to develop their talents and but also to survive. I would argue that it is the most important intrinsically human ability we possess and it is responsible for the creation of the modern "Enlightened" portion of the World which some of us are fortunate to inhabit. Curiously for the majority of our youth, the educational system magically causes this capacity to disappear by adolescence. Without it we have no instinctive ability to assess the importance of many of the technical issues that impinge on our everyday lives and are unable to accurately gauge the validity of fears over such issues as climate change, the immensity of the looming energy crisis or the socio-economic/humanitarian importance of new genetic technologies. Scientific education is by far the best training for all walks of life because it teaches us how to assess situations critically and react accordingly. It gives us an understanding based on reverence for our life-enhancing technologies as well as life itself. If we do not know how things work, how can we fix things, how are we going to use the powerful technologies wisely? It is this need for everyday scientific common sense and wisdom about our environment that our forefathers developed in order to survive and which in the modern context we shall need to improve if we are to survive.

Science Misunderstanding and its Dangers

The level of public misunderstanding of science can be gauged by the overwhelmingly negative response to GM foods (in the UK), stem cell research and nanoscience and nanotechnology (N&N). N&N is basically chemistry and thus as old as life itself indeed almost as old as our Universe. In fact that ardent opponent of GM and N&N, Prince Charles, is not only the result of an infinitely long sequence of genetic modifications but also the product N&N – atom by atom, molecule by molecule, bottom-up assembly on the basis of a DNA blueprint. The discovery of this blueprint is arguably the greatest advance in knowledge of the 20th Century and a British one at that. N&N is just a new name for a vast swathe of immensely varied Chemistry in fields where this discipline overlaps Physics, Biology and Engineering. The claim that N&N and GM are innately bad is as inane as saying any one or all of Chemistry, Physics and Engineering is/are bad for us. Those who campaign against N&N do not understand what it is and in any case there is no doubt that trying to stop N&N is a futile exercise. To paraphrase Moliére in "le Bougois Gentillehomme" – "Cor blimey Guv we've bin doin N&N since Dalton discovered it in 1803 and didn't know it!" If indeed it were possible to curtail N&N we are very likely to lose massive future advances. It would be comparable to having stopped all Chemistry in 1906, the discipline that led to the fertilizers feeding 70% of the world's population, penicillin, anaesthetics, plastics, silicon chips and computers, paint, pure water, false teeth and fillings (as well as the technology used by hunters to kill animals – presumably for pleasure). N&N promises comparable benefits in the 21st Century. Of course there are going to be serious attendant problems as all powerful technologies can be beneficial or detrimental, dependent on how wisely society decides to use them. However it seems more likely that a population with a good understanding of S&T is more likely to use the new technologies more wisely and ensure that the benefits outweigh the disadvantages than one that is ignorant of the sciences. Furthermore science is fundamentally based on doubt, a concept orthogonal to faith which is presently providing some motivation for certain disaffected individuals to undermine our moderately democratic world. Here in the US such ignorant "beyond belief" belief, unbelievably, is resulting in theme parks which encourage the scientifically illiterate to "believe" that human beings and dinosaurs inhabited the Earth at the same time!

The Multidisciplinary Problem

There is, however, a very serious problem that has arisen because of the ever increasing multidisciplinarity of much key 21st Century science - especially that labeled as N&N. Because many of the exciting advances in modern chemistry lie in the areas where this subject overlaps or underpins physics (e.g. molecular electronics, molecular physics) or biology (biological chemistry or molecular biology) or engineering (materials science), all areas of N&N, the traditional university infrastructure with separate chemistry, physics, biology and engineering departments is now highly counterproductive and greatly responsible for the demise of many science departments. There is no way that first class N&N can be carried out without a thorough grounding in basic chemistry which is more important today than ever before. The new fundamental sustainable technologies which we desperately need to develop to ensure our survival are overwhelmingly chemistry-based. As science departments close at an ever accelerating rate, the UK's ability to provide the training needed for N&N, from where the most sustainable new technologies will most likely come, is being seriously challenged. A good indicator of this overlap is the fact that almost half of recent Nobel prizes in Medicine and Physiology are indistinguishable from the prizes in Chemistry and some of those in Physics.

Reasons for the Disappearance of Science Students

There may be many reasons for the dearth of S&T students. One that I think is important is the fact that in my lifetime a profound paradigm shift has taken place in our everyday technologies. Mobile phones, digital watches, DVDs, camcorders, Ipods etc have become totally impenetrable to understanding without significant scientific background knowledge. That was not the case in the past when even young curious children could enter the world of S&T fairly easily to find out

how a clock, gramophone, telephone and even a radio worked. How could a child today be moved by the inner workings of that modern miracle - the digital watch - as was I by the elegant gold and silver inner workings of the pocket watch my father gave me - when I finally managed to prize the back off? As one TV, mobile phone or game player is ditched to be replaced by the latest version so our children have no chance of gaining understanding by fixing them and most importantly never develop reverence and awe for the technology they use incessantly. Whenever I see a young person on a mobile phone – it seems to me that most are never off them – I wonder how many ever wonder how they work. I was staggered to meet someone in science education recently (in the US but born in Britain!) who told me they did not care how mobile phones worked! Because I knew a bit about how they work, some years ago I wondered about the possible effects of a pulsed radio signal emanating from a source located a few centimetres from that delicate object called the brain and worked hard to put together a significant funding to produce a TV programme about the possible health hazards of mobile phones (cf www.vega.org.uk). It seems to me a good thing that some people do care about our technologies.

Why are there not hordes of UK students eager to follow in the footsteps of those British and Irish giants of Science, Mathematics, and Engineering: Newton, Hooke, Dalton, Watt, Brunel, Hamilton, Faraday, Maxwell, Whittle, Darwin, Dirac and Crick, some of whom have graced our money and our stamps? Perhaps we should not be surprised when obscene amounts of money are paid to ignorant media blabbermouths (with some notable exceptions) and supermodels as well as take-over moguls who dump workers deemed in excess of requirement on the State. No surprise when the media overflows with wall-to-wall sport, cooking, trivial quiz-shows and inane "so-called" reality shows. There are TV channels devoted to sport, religion and films but next-to-nothing of cultural value in general and science in particular. It is thus hardly surprising that there is very little incentive for our kids to get stuck into the demanding intellectual rigours associated with calculus, differential equations and the complexities of chemistry and physics subjects whose values only become apparent at a later stage. Everyone knows that education is the key to a healthy economy and a creative population and yet governments show their contempt for scholarship by not paying teachers anything like what they deserve and certainly not enough to ensure enough gifted people with a passion for science enter the profession. Not only is there is a serious shortage of trained science teachers teaching children during the pre-16 period when they start to make career choices but they are often up against teachers who have excelled in non-science subjects.

The Media War on Science

The problem is compounded by the media celebrities such as Mr. Connolly who makes truly pathetic jokes at the expense of his maths teacher (for every silly little Billy who disrupted their class at school who makes it as a celebrity a thousand don't and end up in dead end jobs) or that purveyor of pseudo-technical jargon Mr. Clarkson who also exults in his mathematical incompetence. Such people incite disdain for science and maths in our impressionable young. The interminable media glorification of so-called "powerful" celebrities such as Mr. Cruise, who is a scientologist, does not help! No wonder then that many nurses cannot put the decimal point in the right place so patients might get 10x too much or 10x too little medication than required (…if they're lucky!). There may have been many cases similar to a recent one in which a 10 times too high a concentration of salt solution was administered with fatal consequences. The smile would be wiped off the faces of such ephemeral celebrities (as well as Mr Jenkins) if they were to end up in a hospital where such a nurse attended to them. A highly influential US politician said his physics and maths lessons at school were a waste of his time, the teachers' time and a waste of space and that he would have been better off taking typing or music because at least the latter was good for the soul! I wonder whether such a dangerous ignoramus, were he to develop a gangrenous infection, would prefer to be serenaded by a violinist rather than have penicillin

administered. Such people need to decide whether they would prefer to lose an arm or a leg rather than their soul.

The Science Department Cull is a Direct Consequence of Present Science Education Policies

The situation is further exacerbated by present policy that actively encourages those VCs - who know the cost of everything and the value of nothing - to eliminate science departments in favour of trendy cheap courses. These VCs bleat about how important is their freedom to do whatsoever they wish with taxpayers' money and steer funds earmarked for the sciences into "softer" areas which students prefer. Just as cheap fast food has resulted in unprecedented levels of obesity, so this "McDonalds" approach to cheap trendy seductively soft courses designed for mass consumption in tertiary education has resulted in a plethora of students trained for nonexistent jobs. Another major factor, which the Government could change at a stroke, encouraging VCs to close sciences department even if, as at Exeter, they have plenty of students is the inadequate provision made by the Government to cover the real cost of science education. The unit of resource ratio for an arts graduate versus a science graduate is 1:2 when a more realistic ratio is at least 1:4. (Note that medical students who are (or were) rated at 4.7!! make no first order contribution to the GNP). It is thus no wonder that VCs who fail in their primary role – to bring in outside funds – are encouraged by such manifest governmental disdain for science education to eliminate science departments. I understand that at a university with which I am somewhat familiar, a building construction policy based on half-funding by Government, in the vain hope that matched funding would fall like manna from the heavens, has brought this once outstanding institution with outstanding departments across the arts and sciences and humanities to the brink of relegation to a second division arts college. There is a simple rule for universities: The first priority is to invest in the brightest young talent available and new buildings are nice to have but must be secondary.

The RAE/TAE Catastrophe

The problems are not helped by the disastrous Research and Teaching Assessment Exercises (RAE and TAE). These costly, time-consuming, misguided exercises have, more than any others, undermined the science base in tertiary education. The arbitrary assessment of research and teaching "quality" has led to the reduction in funding for some departments to below the level of viability. The results have given the green light to some VCs to cull science departments to save money. Simple common sense dictates what should have happened: The more poorly assessed departments should be helped to improve – those already doing well clearly do not need the extra money. The government has acted like a teacher who gives a struggling child an even harder time when what is needed is the extra support needed to catch up.

Science at undergraduate level cannot be adequately taught unless there is a serious research component. US colleges without graduate programmes which nevertheless involve undergrads in research projects show remarkable levels of success in science education compared with those without such projects. The teaching assessment exercise is equally ill-considered. When I was a student, some teachers I liked were disliked by others and vice versa. So after a lifetime in teaching I have learned that it is almost impossible to assess the merits of teachers in general. There are as many ways of teaching as there are teachers and there as many ways to absorb information as there are students. Furthermore teaching at university level cannot be assessed by anyone who does not do research professionally because unless one is in the business of discovery, although one may have a qualification in science, one cannot be called a scientist. We are also of course shooting ourselves in the foot as overseas students are unlikely to go to institutions deemed arbitrarily to be underperforming. The continual news of one science department closure after another without any obvious concern certainly implies that such closures are Government policy. There seems to be implicit faith in big ponderous institutions brimming with equipment, but battleships are not the only answer. The fact that all the sciences at Sussex have been so successful is a clear an indication that the present policy is flawed. A

football analogy would be: The likely demise of a league system with only a premiership division. I have seen the RAE and the TAE in action and they are flawed in concept, impossible to implement fairly or reliably and most importantly have been totally disastrous in their consequences for the science base. One major advantage of the US system lies in the fact that students do not need to specialise as early in their careers as we do in the UK. This means for instance that someone who has a first degree in say German could, with an appropriate level of science as a minor subject, go on to do medicine – something almost impossible in the UK. Furthermore because of this much more general approach to US tertiary education it is not possible at a major university to drop the sciences until the third year.

The Inanity of the Peer Review Process

I know few successful scientists who have a good word to say for the peer review process. The process in which a disparate bunch of overworked scientists has little choice but to plough for hours through piles of the interminably repetitive arguments inserted into ineptly designed research grant application forms in a vain attempt to asses the relative merits of the various proposals. (It is, by the way, no better here in the US – probably worse). I cannot believe these forms were constructed by an expert research scientist. Then a committee attempts to grade the applications on the basis of these assessments using some arbitrary numerical voting system - more ludicrous than that used to grade Olympic skaters and gymnasts. Often a tenth of a % can mean the difference between being funded and not. As a young scientist I once complained to an eminent elder colleague that it is impossible to construct a proposal for good research project which by its very nature must entail the unexpected. My colleague, in a tone that indicated I should know the bleeding obvious, told me to apply for funds for good research already done and use the grant for a new project!

Research funds should be downloaded to the university departments on some flexible scale which is graded to help the less well performing institutions that exhibit promise. The funds should be divided into three not necessarily equal amounts – the first to adequately support young people start up. The institutions have done the work in finding the young people on whom they have placed their hopes for the future so why not leave it to them to disburse the funds. They have done the work - why do it all again in such a half-baked fashion? The second portion to be downloaded to those whose last research projects have been rated excellent on the basis of the final research report. If they have done well once – there is a good chance they can do it again. This is basically the bookie's approach to backing race horses. The third amount to be distributed to part-fund researchers who did satisfactorily the last time encouraging them to trawl for matching funds garnered from other source – say industry. Some sort of peer review could be applied only for this group. This approach would save a LOT of precious time that is better spent actually doing the research. Something akin to this was at the heart of the dual support scheme that was responsible for helping me to make a start as a young researcher in the 60s.

Conclusions

Do I think there is any hope for UK? I am really not sure as we have a prime minister and a minister for education who appear to think a book written by people who thought the Earth was flat and the Sun rotates around it has some fundamental substance – presumably more than "The First Three Minutes" by Stephen Weinberg. It is beyond belief that in the 21st Century, Tony Blair and Ruth Kelly are diverting taxpayers' money to faith-based groups intent on propagating culturally divisive dogma antagonistic to the secular "Enlightened" philosophy that created the modern world. One need look no further than Northern Ireland to see the results of a sectarian segregated educational policy. It is a scandal that the present system is enabling a car salesman to subvert significant government funds to propagate dogma such as "Intelligent Design" in our schools. State funds are also being used to support some schools which abuse impressionable young people by brainwashing them into believing that non-believers (including Mr Blair and Ms Kelly!) will burn for all eternity in the Fires of Hell and that it is their duty to

undermine the last few democratic freedoms left in UK law. This policy is a perfect recipe for the creation of the next generation of home-grown and state-educated suicide bombers.

The resurgence of inter-religious prejudice and its incursion into education, politics, law and the media is as disturbingly anti-democratic as it is anti-scientific. Unless the UK (and the USA) wakes up to the imminent dangers not only will the Enlightenment be extinguished but also the UK's capacity to survive in a world that looks increasingly likely to be dominated by the Eastern Tigers who do not seem to have such ridiculous anti-scientific hang-ups. I think there is every likelihood that the lack of scientifically educated and aware young people in the UK will result in ever poorer performance on a global scale and a takeover by the next generation of young Chinese and Indians which is ravenous for the scientific spirit that will free them from the shackles of present poverty levels. This new generation is being actively encouraged by their Governments who see the future to lie in science education based on doubt and questioning (as opposed to belief). Paradoxically this philosophy, pioneered in the West since the time of Galileo and which is responsible for the modern way of life, is now being undermined by an ignorant anti-science movement. It is truly disturbing that a well-funded cohort of religious groups aided, abetted and condoned by this Government is undermining our science education (in the US also). If they achieve any more success in their subversion of the intrinsic secular safeguards embodied in our democratic institutions and our educational system there can be no doubt that there is major trouble ahead - so "Do Panic!"