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THE DECLINE IN THE STUDY OF PHYSICS

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Dedicated to Professor Boran Leontić on the occasion of his 70th birthday

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This paper draws attention to the diminishing number of students studying physics both at schools and universities despite its enormous importance for a modern technological society. One possible reason is that many teachers do not convey fully the fascination and excitement of physics and hence fail to inspire young people. A possible way of overcoming this is to place emphasis on "hands-on" experimental work which can be carried out using simple and inexpensive materials which are readily available. Examples of this are given.

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"Physics is an incredibly rich discipline: it not only provides us with the basic understanding of the laws of nature, it is also the basis of most of modern high technology,.... If a nation wants to become wealthy, it must acquire a high degree of expertise in physics, both pure and applied" [1].

These words were written by Abdus Salam, one of the 1979 Nobel prize winners in physics, in a book devoted to the centenary of the birth of the great Austrian physicist Erwin Schrödinger. They could well be used as a mission statement for encouraging people to enter university to study physics and then pursue a career in it. Salam himself was brought up in Pakistan, one of the poorest countries in the world. He played an important role in the founding of the Institute of Theoretical Physics at Trieste close to the Slovenian border, and was its director for many years. A major aim of the Institute is in the training of young physicists from third-world countries.

It is interesting that Salam associates the wealth, and hence the power of a nation, with a high degree of expertise in physics. Perhaps it is no coincidence that around one hundred years ago, at the height of the Austro-Hungarian Empire, saw the flourishing and untimely death of Boltzmann and the birth and formative years of Schrödinger, Pauli and Wigner, all of whom came from within the boundaries of the Empire. For many years, Zagreb, and much of Croatia, formed part of the Austro-Hungarian Empire. Salam's statement is also consistent with the marked decline in the United Kingdom as a world power from about 1960 onwards, coinciding to a lessening of its scientific prowess relative to several other countries.

Despite the almost self-evident nature of Salam's statement, all is not well with recruiting young people from schools to study physics at university [2]. Possible reasons why this might be so and how it can perhaps be remedied form part of the theme of this article. There is no doubt that many young people regard physics as a "difficult" subject at school - much harder than almost any other. Very worryingly, they look upon it as "boring", and the subject appears frequently to be very badly taught, particularly since many science teachers have little or no training in physics: few physics teachers are trained, and so the downward spiral continues.

A further reason for the unpopularity of physics might be that young people frequently regard physics and physicists as a threat to the future of the world. This compares with the situation some thirty or forty years ago when science and technology, mainly based on physics, were regarded as the key to future prosperity. The Chernobyl nuclear reactor disaster in 1986 has wreaked havoc over world confidence in the nuclear industry as a safe provider of energy, and the industry is unlikely to flourish again for many years. Today the threat of nuclear war has receded, but certainly not gone away. Physicists are heavily involved in the arms race with the production and development of ever more lethal devices. In summary, physicists are often regarded as uncaring, irresponsible and hell-bent on the destruction of the environment and its population.

What do we do to counter this poor perception of physicists? Much of it, we believe, is based on ignorance and a failure to appreciate the type of work carried out by most physicists. Physicists also need to develop their skills at communicating the essential fascination of the subject, and stimulating the curiosity of people - especially young people - about the workings of nature.

In addition, there is not sufficient emphasis on the enormous achievements made by physicists in improving the quality of life for the bulk of the world population. Perhaps three examples will suffice. At the start of this new millennium, so much in everyday life is taken for granted that it is easy to forget its origin. A good example is electricity. Most of us take for granted that we get light when we flick a switch in the home or work place. Few will ever think of the pioneering work of Michael Faraday who discovered the principles behind the first electric motor, dynamo and transformer in the 1830's.

Perhaps an apocryphal story is that shortly after his pioneering work, Faraday was asked by the prime-minister of the day about the use of his inventions. Faraday is said to have replied "I know not Sir; but I dare say that one day your government will tax it" and, on another occasion, he is said to have retorted "of what use is a baby?"

Towards the end of the nineteenth century, Thomas Edison and the Croatian-born Nikola Tesla in America, and Sebastian de Ferranti in England, and others, used their physics knowledge to develop practical electrical distribution networks allowing electric power to be available for the first time in the home and workplace. It is difficult to underestimate the enormous effect that this has had in improving the quality of life for tens of millions of people. Again, developments in vacuum technology allowed Edison in America and Joseph Swan in England to produce the first electric light bulbs. It has been argued that the availability of the electric light bulb has been the single most important item responsible for the educational development of first-world countries, enabling millions of people to study after nightfall.

A second example, which people throughout the world often take for granted, is the enormous increase in global communications. Few people think twice about being able to watch sporting and other events on television from anywhere in the world. In that sense the global village has arrived; however it has only become possible through enormous technological achievements, such as satellite communications. Much of this is ultimately based on the work of physicists "both pure and applied".

A third example is the development of the World-Wide-Web, the use of which is beginning to mushroom, and is likely to revolutionise the way in which we acquire information. This was the brainchild of the English physicist Tim Berners-Lee who works at CERN in Geneva [3].

The above three examples illustrate the enormous contributions which physicists have made to advancing our society and perhaps also that what they have invented and developed is frequently far too easily taken for granted. They serve to illustrate the need for a constant stream of gifted scientists capable of making far-reaching discoveries some of which will ultimately benefit the mass of the population. Physicists are very much in the forefront of this work.

This still leaves the original question as to why fewer young people today wish to enter university to study physics and pursue a career in this subject. It is perhaps doubly strange in view of the many sources currently available which convey the wonder and excitement of science especially physics. Compared with some thirty years ago, there are nowadays a huge number of well written popular books on physics, particularly in the areas of elementary particles, cosmology and astronomy. In addition, at least within the United Kingdom, there are excellent television and radio programmes devoted to science. A further important area for the promotion of science has been the "Hands-on Science Centres" or *Exploratories*, the numbers of which have increased rapidly throughout the world since their first introduction with the San Francisco Exploratory in the early 1980's [4]. These have proved immensely popular and provided valuable sources for science education, many of the exhibits having a strong physics content.

So, where does this "swing away from physics" start? There is no doubt that we need to inspire young minds, to attract them to science in the first place, and that it is the job of the teacher to do this. The UK government's initiatives on introducing science in primary schools are indeed very wise, and we are fortunate to live in an era when science features strongly in the media, on the Web and in the flood of books on popular science which find themselves on bookshelves alongside Stephen Hawking's best-seller: there is an informed and educated public. There has never been a better time for positive image-projection about physics.

Yet, as we all know, the numbers of physics students continue to fall, and physics departments are closing, perhaps because of the trends in education itself (dumbing-down?), or the perception that physics is a "hard" subject, and that success and material rewards are less likely than in other subjects which students choose at A-level and university.

So, how do we inspire people, and "turn them on to physics"? One traditional, and honourable medium has been the lecture demonstration, which Charles Taylor, in his excellent, concise, classic book on the subject [5], has traced back to the seventeenth-century. Taylor quotes Sir Lawrence Bragg, in 1974, claiming that scientists:

"are often singularly inept at explaining to non-scientists what they are doing"

and that those who give "popular" talks are sometimes regarded by their peers as:

"actors, aiming at popular applause, who cheapen science by over-simplification and spoil the diginity of its aloofness" [6]

Since the days of Bragg, himself a master of the art of the lecture demonstration, much intelligent thought has been given to the popularisation of science, with exciting initiatives from UK bodies as diverse as the Royal Society, the Institute of Physics [7] and many universities, who perhaps have a vested interest in halting the decline in their science intake. Heads of university physics departments have wisely started to channel the talents of some of their staff not just towards the traditional "extra-mural" teaching, but to the often arduous "road-show" (such as the "Liquid Nitrogen Show", given many times by one of the present authors, PJF), where cardboard boxes bristling with curious apparatus are stuffed into the car-boot, *en route* to the local primary school or Women's Institute.

But, reading Taylor's book, one can be over-awed by the sheer sophistication of the lecture demonstration as an art form, of which luminaries such as Faraday, Tyndall, Bragg, Laithwaite and Taylor himself - all incidentally connected with the Royal Institution in London – were masters. From the 1970's onwards, the Open University too has been broadcasting physics demonstrations of a very high quality. There is no doubt that these lecture demonstrations were backed up with hours of preparation and technical support, which is simply unavailable to the average science teacher or lecturer, especially in this crazy world, where educators seem to spend more of their time justifying themselves to their inspectors, and where paper-work seems to matter more than pupils.

However, as both having had the experience of making and demonstrating simple, home-made and eye-catching physics demonstrations, the present authors would like to state the case for all science educators to "get back in the lab", and re-kindle their own curiosity by once more experiencing the joys of "hands-on" science. If our students see around them, in the lab or classroom, simple examples of home-made apparatus, which can be developed from everyday materials, we have a chance of convincing them that physics is all around us, and that everyone can be involved. It is up to us to try to de-mystify the subject.

In doing this, we are no doubt following in the hallowed footsteps of Faraday himself, who refined his physics understanding by the process of "learning with the hands". For several years before his breakthrough discovery of electromagnetic induction in 1831, he is said to have carried a magnet and a coil in his pocket, and would handle them and ponder over them in thoughtful moments [8]. As teachers, we can keep both our curiosity and our subject alive by making the time to try out simple, and perhaps novel, experiments in the laboratory (using only simple, everyday apparatus). In this way, we will develop the "feel factor" which will inform and inspire our teaching with the keen edge of research, rather than the dulled repetitions of text-book platitudes, which wrongly portray even "classical" physics as a dead subject.

R.D. Edge, in his 1981 book *String and Sticky Tape Experiments*, reminds us that

"We live in a vicarious age, often having our experiences through the medium of television, rather than doing the touching and feeling ourselves .... Physics is an experimental science, and only by doing 'hands-on' experiments - messing about with the equipment - can you get a feel for it" [9].

Here is a subtle point: perhaps it is precisely *because* the media-based science demonstrations are so slick and sophisticated, that they alienate ordinary folk, even teachers, whose understandably under-rehearsed efforts seem to pale into insignificance. We certainly cannot compete with the masterly and impressive magic shows we see on television; but where we *can* score, and really involve the students themselves, is to set them the example of making their *own* physics experiments, using cheap, everyday, safe materials. Edge's book, for example, gives a wealth of inspired ideas for physics demonstrations, which are simple and cheap enough for all our students to make and try themselves. Despite the every-day nature of the materials used, the experiments range from primary school level right up to university physics.

In contrast to this "hands-on" approach, it is greatly to be regretted that the Bristol Exploratory which, for many years had inspired and challenged the minds of local people interested in science, has been forced to make way for what many critics regard as a "virtual reality" palace in the city, where computer monitors and video screens have taken the place of sturdy, well-made and imaginative demonstrations [10]. Perhaps this is a mirror of our age; but, whilst it might well inform and inspire - and we certainly do wish it well - it cannot take the place of the "learning with the hands" referred to above.

The Nuffield Science courses in the 1970's paved the way for an investigative and heuristic approach to physics education, and some of us had the privilege of training for physics teaching in this mode. Over the years, however, only a minority of schools and still fewer colleges adopted the Nuffield courses, for a variety of reasons. Some teachers reported that students apparently seemed to prefer being *told* what the "correct" physics was, rather than "discovering" it for themselves, and that it was harder for the average student to achieve as good an A-level grade in the Nuffield courses as in the more "traditional", didactic syllabuses.

However, the year 2000 marks the launch of new A-level syllabuses in the UK, and there is hope of many schools adopting courses which have some of the flavour of Nuffield, updated to the IT age. Two examples of these are the Salters Horners Physics course [11], and the Advancing Physics course, produce by the Institute of Physics [12]. Both courses seek to emphasise the applications of physics and the connections between physics and everyday life. They have backup from industry, teachers are fully supported, with well-planned resources, via the Web and electronic media, such as CD ROMs, and there is an overall aim of attracting more students, and motivating them.

Whist these trends are encouraging, we must also seek to foster links across physics, both formal and informal. The present authors have been involved in developing links between local universities, schools and colleges in the Bristol and Bath area, and this must surely benefit the mutual understanding and practical support between practitioners at various academic levels, which leads to a clearer perception for our students of the progression pathways in the subject. A short research or development placement in a local university physics department can greatly enrich the knowledge and confidence of an otherwise isolated physics teacher. One of the present authors (AJW), who teaches physics at City of Bath College, (a Further Education college), was granted such a privilege during July 1999, and used the time to try out and develop simple electrostatics apparatus, with a view to using it in lecture demonstrations. Having time to "play and ponder" in the lab., temporarily released from the demands of modern educational bureaucracy, is of infinite worth, since it brings the practising educator back to the reasons for which s/he came into science in the first place, and of which we so easily lose touch, the sheer beauty, elegance and fascination of the subject we are privileged to convey to young minds.

In the course of this short placement, it became apparent what a wealth of physics education material is shared freely on the Web by physics teachers throughout the world. This is indeed an inspiring example of international co-operation and, far from leading to the passive acquisition of information, can stimulate and further one's own ideas and researches. One of the Web's treasures, discovered this summer, is the work on electrostatics by William J. Beaty, who worked for a while at the Museum of Science at Boston, USA where, he reminds us, van de Graaff's original high-voltage generator resides [13]. Clearly, Beaty is passionate about physics, and he ably conveys this in his prolific practical papers on the notoriously "difficult" and weather-dependent subject of electrostatics. His optimism and enthusiasm, his passion for physics are an example to us all. As the result of enthusiastic - almost obsessive - experimentation, very much in the style of Faraday, he has built up an impressive body of knowledge which is freely available to the world. Far removed from the sterile world of textbooks, (which often propagate myths, since no-one has ever bothered to challenge some of their statements passed -in Aristotelian fashion - from generation to generation), he "boldly goes ..." , and reveals some of the spark of genuine scientific enquiry, prepared to risk embarrassment along the way:

"Rather than courting dishonesty in order to avoid embarrassment, we should constantly pursue embarrassment in order to avoid dishonesty." [14]

It is this risk-taking, this spirit of enquiry which will inspire our students. If, in our teaching, perhaps by means of apparently imperfect experiments, which might not be very sophisticated nor work as the text-book might suggest, we can convey this enthusiasm, and "fly by the seat of our pants", we could convey the excitement and wonder that should be part of this beautiful subject.

As an example of Beaty's work, his "pop-bottle electrostatic motor" was constructed, by a helpful school pupil, as part of the summer project referred to above [15]. Made from three plastic pop-bottles and some aluminium foil, it vividly shows how apparently *static* electricity can become very much *dynamic*, and forges links akin to Franklin's classic (but very dangerous!) demonstration that the "electric fluid" from lightning is identical to that produced on the earth. Powered up either from a van de Graaf, or from one of Beaty's far simpler electrostatic generators [16], we have demonstrated the device at Open Evenings and similar events, and challenged the viewers to explain how it operates.

In conclusion, as we have reached the end of the twentieth century, we can be reminded, by Bill Beaty of what Albert A. Michelson said near the end of the nineteenth century:

"The more important fundamental laws and facts of physical science have all been discovered, and these are now so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is exceedingly remote." [17]

If, even in so-called "classical" physics, there is much more to explore and to explain, and in which, by imaginative teaching, we can convey some of the spirit of excitement and enquiry which is the life-blood of physics, how much more is there still to discover about this wonderful world, if we can but make our physics more fun?

DEDICATION

This article is a contribution to the Festschrift for Professor Boran Leontić, to mark his seventieth birthday. Over many years, Professor Leontić has been heavily involved in the physics education of a large number of Zagreb students, as well as playing a prominent role in research. PJF recalls with pleasure working in his department from February 1972-October 1973. During this time, he worked with several people in the Physics Department at Zagreb University on the electrical resistance and thermoelectric power of some spin glass materials. Spin glasses was then quite a "hot topic" in condensed matter physics. The research involved a fruitful collaboration with Professor John Mydosh at Jülich in Germany, who was one of the pioneers of spin glasses.

References

1) Abdus Salam, *Overview of Particle Physics*, in *Schrödinger - Centenary Celebration of a Polymath*, ed. C. W. Kilminster Cambridge University Press (1987) p. 180;

2) The numbers of students taking "A" (advanced) - level physics in the UK declined from about 46000 in 1988 to 33000 in 1996. See *Physics World* 10 (May 1997) p. 57; in the last three years in the UK, some 10 physics departments in the Higher Education sector have closed, due to lack of students;

3) See James Gillies, *Weaving a better tomorrow: the future of the Web*, CERN Courier **39** (7), 26-28 September 1999;

4) The first of these in Europe was the Bristol Exploratory, pioneered by Richard Gregory, Emeritus Professor of Neuropsychology, and Director of the Brain and Perception Laboratory at the University of Bristol, UK;

5) C. A. Taylor, *The Art and Science of Lecture Demonstration*, IOP Publishing, Bristol (1988);

6) op. cit., p. 4;

7) See, for example, *Securing the Future of Physics*, IOP Publishing, Bristol; The Institute of Physics has a web site: http://www.iop.org, which is well worth visiting;

8) Much has been written on Faraday's use of experimentation by Prof. David Gooding, also of the University of Bath. His *Experiment and the Making of Meaning*, Dordrecht, Kluwer Academic Publishers (1990) is a good starting point;

9) R. D. Edge, *String and Sticky Tape Experiments*, Am. Assoc. Phys. Teachers, Maryland (1987), Introduction;

10) *Scandal at the Exploratory*, Nature **400** (26 August 1999) p. 801 and *UK centre "drops science for sensation"*, ibid p. 804, with a defence by Gillian Thomas, the director of "Explore" (the successor to the Exploratory), Nature **401** (9 September 1999) 111;

11) More details on the Salters Horners physics course, to be examined by EDEXCEL, which "places physics into social, industrial, environmental and historical contexts (and thus) makes it more relevant and appealing to students can be obtained by e-mailing: reed.educational@bhein.rel.co.uk

12) More details on the IOP *Advancing Physics* course, to be examined by OCR, can be obtained from its web-site: http://post16.iop.org

13) Try, for example, this web address: http://www.eskimo.com/ billb/emotor/stathint.txt

14) W. Beaty, *Physics Sermon*, http://www.amasci.com/amateur/physerm1.html

15) Full constructional details can be obtained from:
http://www.eskimo.com/ billb/emotor/emot1.html

16) See: http://home.earthlink.net/ lenyr/stat-gen.html

17) Albert A. Michelson, speech at the dedication of Ryerson Physics Lab, University of Chicago, 1894, quoted on Beaty's site:http://www.amasci.com/.

SMANJENJE STUDIJA FIZIKE

Upozoravamo na smanjenje broja slušača fizike u školama i na sveučilištima usprkos ogromne važnosti fizike za suvremeno tehnološko društvo. Možda je razlog što nastavnici ne prenose čar i uzbuđenje fizičkih otkrića i propuštaju oduševiti mlade ljude. Moguć način za prevladavanje stanja je da se stavi naglasak na osobni eksperimentalni rad koji se može izvoditi jednostavnim i jeftinim pomagalima, i koja su lako dostupna. Daju se primjeri.