Proceedings

# Development, Science Literacy and Education

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It may be fair comment to state that quite often, as in the case of health services, many people have unrealistic expectations from education and few can be said to be completely or even partly satisfied. Yet, there seems to be general agreement, both here and overseas, that there is a need for change, if not simply to improve the way science is taught in our schools.

There are many questions which could be raised. For example: What do we teach? How do we teach it? At what levels perhaps? Why do we teach science? What is science and what do scientists do? Should we as taxpayers pay for science?

I shall attempt to address some of these questions from my perspective as a working scientist. I shall argue that a competitive and productive science and technology sector is essential for progress in a small island state. I will do this by placing the issues connected with reform in science education in the broader context of science, society and development.

I do not for one moment doubt that the science we need to do must be good science. Therefore, we need to have a society literate in the sciences as much as we need to have well educated and trained research scientists and engineers. One of the main reasons for making such an emphasis at this stage of national development is that science must be considered an integral part of our economic development. A science intensive economy is almost obligatory for a small island economy in order to sustain future development internally, benefit from external innovations, increase productivity and at the same time remain competitive without impinging excessively on our environment.

As a professional organisation and a learned society, the Malta Chamber of Scientists wants to present the case for long term reform in science education, one that is robust beyond any quick fix, and one with the primary objective of high quality science literacy for all citizens. We would like to launch a debate between all interested parties to identify the limitations and the hurdles that our teachers and our students face in our education system from primary school to sixth form and to initiate the necessary changes. I am certain that the Malta Chamber of Scientists has a profound interest in these issues and it intends to participate as a catalyst in the reform process.

Admittedly, Maltese Society is not a scientifically literate society nor has there been any tradition, let alone a strong one, in science. It has been said that no record exists of a wheeled vehicle having been used in agriculture before the arrival of the Knights of Malta. Although many technologies must have been introduced in connection with the shipyards which may have contributed to our early steps in industrialisation, these do not seem to have kept pace with scientific and technological progress elsewhere. Today, they have been replaced, albeit on a limited scale, by newer technologies in other sectors such as electronics and information sciences. However, in other sectors, such as biotechnology and new materials, areas in which we might have strategic advantages because we could scale them down to our size, remain largely absent. It can be seen that there is still too little scientific space in the sphere of our economy to which our young people could be exposed and with which they could be favourably impressed.

However, there exist a few enterprises or institutions which could be involved to a greater extent in the popularisation of science and in education. Admittedly, the public sector is exposed to little science beyond that which is basic in health, energy, environment and agriculture and a few other areas where scientists might be employed. Nevertheless, there are significant opportunities, for example, in aquaculture, communications and water production, and which could be more closely involved with schools and higher education.

The private sector is increasingly occupied by service providers which make intensive use of information science and computer technology. However, it remains, as far as manufacturing is concerned, in need of considerable restructuring if it is to alter the present position of local companies from being little more than manufacturing subsidiaries of foreign corporations. In order to succeed, they depend on lower wages and intensive aid in a variety of forms. It is rare for them to employ scientists. A few companies whose activities are more technologically intensive do employ a small number of scientists in management, regulatory affairs and quality assurance but they do not engage them in any significant amount of innovative research and development.

Thirdly, in the sector of higher education and research, the science faculties including medicine and engineering still struggle with small numbers of experienced staff and a few committed students. This, in turn, is further compounded by the low spending on graduate education, training and research.

We do not know how the general public sees these issues or even if it perceives them at all.

We might ask whether Mr and Mrs Public understand that economic restructuring means a paradigm shift in the industrial sector from the predominant type which we have today, where there is little need for science, to an increased presence of businesses that depend on a continuous input from scientific research for their financial success. I have in mind a type of innovative research-based company which is a highly valued partner in economic production as much as in education, training and research. Such a company would provide the horizons to which students, and I should say their parents, can seek as suitably satisfying and remunerative careers. These research-based science careers would compete favourably with traditional professions such as medicine or pharmacy, or newer ones in engineering or computers. Such a company would indeed employ a large number of qualified and experienced scientists. Undoubtedly, an economy of this kind is vital to carry us into the 21st century.

Many developed and rapidly developing countries can boast of five to ten doctoral level research scientists and engineers for every 1,000 in their workforce. These statistics are not perfect, but, whichever way one tries to read these figures we are far from having the critical mass of fully qualified scientists. In the Chamber we have registered 40 PhD scientists. This is far below the comparable figures for countries such as those of the EU and North America or the tiger economies of South East Asia. The reasons may be found both in the economy as referred to above and in the educational system. Although we have substantial support for undergraduate education leading to entry level first degrees, we are probably unique in persisting in the grievous error of not supporting graduate studies at masters and doctoral levell. I think this is a fundamental mistake which needs to be remedied immediately.

Maybe, we should give Mr and Mrs Public some credit here for, at least, being consistent. The students do not see the availability of jobs in science and therefore they do not study science.

One may further ask whether the Maltese taxpayer would be willing to support national spending on research and development comparable to the two percent of Gross National Product which is, on average, spent in the EU, North America and South East Asia.

If one tried to answer these questions, one would find both positive and negative indicators. On the one hand, we are encouraged by the enthusiastic response to the science week organised earlier this year by the Malta Council for Science and Technology, by the readership of our own monthly Malta Science Report and by new initiatives such as the new investment in a small number of high technology companies at the Mosta Technopark, the prospects of Hambros and the Malta Development Fund and the new funding for research from the financial protocol that the government has signed with Italy. On the other hand, the injudicious choices that many people appear to make regarding lifestyle, health, leisure and environment and the small number of applications from students to enter science courses at the university remain disappointing. In particular, the number of graduates who pursue graduate level education in the Faculties of Science, Medicine and Engieering is far too small.

It is justified to conclude that the social and economic space occupied by science is small, that the level of science literacy is poor, and that the two issues are intertwined. Consequently, solutions must also be linked. For instance, research programmes must be linked with graduate education and with new business development which depends heavily on science and technology. Thus, we contribute by creating new positions for our graduates and the high value science intensive economy.

There is no doubt that the problems are complex. They bear on higher education and economic restructuring as much as on the school system, with many interfaces between the three. I have already addressed the links between education and the economy. To a large extent, the academic qualifications for entry into higher education determine what the schools do. Furthermore, school science teachers are the products of higher education. The relationship may somehow be linked with the hierarchy in the organisation of scientific knowledge. In fact, there may be useful parallels between the hierarchical organisation of science and of education.

In science, one often moves up along a scale from a basic level of general scientific knowledge, which may have a broad scope for lifestyle, work, leisure, etc. to a progressively narrower and more focused sector within a science discipline. The first, a basic general scientific knowledge, would ideally be owned by every member of society. While many educational experts would argue in favour of "science teaching" within the core curriculum of all schools, the subject matter itself may be limited to one of three lines of study in anticipation of further education at first degree level at university or at an undergraduate college. These are, firstly, the life sciences which could lead to further specialisation in enabling life science areas, or to entry into biomedicine, health and the various biotechnology applications (agriculture, animal husbandry, aquaculture, food, environment etc); secondly, there are the physico-chemical sciences which may lead to further specialisation in basic or enabling physics and chemistry but may also serve as a suitable entry into various engineering disciplines, such as energy or materials science, microfabrication, micro-electronics and others; and thirdly, that of information science, computer technology and mathematics.

Perhaps, given time, the new junior college of the university may develop along these lines, becoming an entry level undergraduate college.

Subsequent to this broad-based foundation in science education, there is the sector of graduate education. This is much more focused and specialised. It would lead either to higher degrees tightly linked with research programmes in front line or competitive basic or enabling sciences, or to professional qualifications such as the community may from time to time require. Spending on this science education would be pegged to objective parameters of national wealth.

Our school-leavers occupy the bottom of this pyramid. I think they ought to be the focus of any long term reforms in science education which we envisage for our schools.

Our counterpart organisations in other countries have of course preceeded us in promoting change of this kind. The changes already undertaken in the British school science curriculum are discussed elswhere in this journal. Another prominent movement for change is that of the American Association for the Advancement of Science. It is called Project 2061 or science literacy for all (in this case), Americans. Project 2061 has involved over 500 experts for the last 12 years and is now producing benchmarks for curriculum development. The two share much common ground: the need to diminish curriculum loading, to soften boundaries between traditional subjects and to match teaching with the ability of the students to learn. In principle, we are urged to teach less and take more time to do it, so that it can be done better and within the capabilities of our schoolchildren.

We would like to expect that those 16 to 18 year olds who leave school with a Matsec certificate at ordinary or advanced level have learnt at least enough science to be able to make informed choices about many aspects of career and lifestyle, both of which are increasingly dominated by science and technology.

About 80% of our school leavers enter the workforce or pursue vocational or technical schooling. This figure is too high. Neither these, nor most of the 20% or so who enter higher education will pursue any formal science education beyond this time. We do not think that this is sufficient to permit either a suitable level of scientific literacy in the population at large or to permit students to choose a career in science and technology.

By science literacy one understands that all students who leave school do so with a body of scientific knowledge which will enable them to make informed choices about health, diet and nutrition, exercise, sexual behaviour, reproduction / family planning, sexually transmitted disease, hereditary disorders / handicaps, environmental issues, waste processing, energy production and even politics, in other words, everyday things.

These issues are representative of a range of personal, social, economic and political decisions that each one of us has to make and for which a grasp of the increasingly complex scientific basis is necessary.

School leavers need to have acquired a judicious collection of knowledge from the worlds of life sciences, physico-chemical sciences and information sciences. Exactly what and how much will depend on the intrinsic importance of each topic within the hierarchical structure of scientific knowledge, as well as on the students' ability to comprehend the scientific concepts at their various stages of growth and development.

This concept of scientific literacy implies a need for softer boundaries between traditional subjects as well as new approaches to teacher training. It may be futile to argue about which is the best route to graduate science teachers, whether from a first degree in science or in pedagogy. What really matters is that the products are capable of teaching science in an attractive manner. In any case, the two paths may have to co-exist until a definitive effective pattern is eventually established.

The need to give both students and teachers a greater exposure to science in practice implies activities such as science clerkships in public and private enterprises as well as at the university. Other activities to consider are those such as the science week or a school science fair. Opportunities for scientific visits are present in government laboratories such as the forensic laboratory or the health service. In industry, physical science experiences may be found in the engineering / electronics / energy businesses; in life sciences, fermentors, beer, wine, food, medicinal products, vaccine production, aquaculture of fish and plants / algae. In the university, we tried this with biotechnology. Some of the outcomes will be demonstrated in one of the workshops.

We have to ask ourselves: "What can we do to bring the often abstract notions of science to life in the experience of both our teachers and our students?"

It is important that the practical emphasises the scientific method for it is this that distinguishes science from mere philosophy. In the proper design of scientific experiments one learns some skills which are useful also in management, as well as skills applicable to routine, mainly analytical laboratory work.

This brings us to the issues of curriculum content and method of teaching but also to the consideration of hurdles that may prevent our students from reaching the desired levels of science literacy. In this regard it may be important to ask whether there is a language problem. The number of students failing English at ordinary level appears to be high. Yet we expect most of our students to be taught and examined in a language that is not their mother tongue. While this may not be a problem for the few bright students at the top, it is not unlikely that a large majority could gain an edge if they were to be taught and examined in the language that they use daily. Having said that, I want to emphasise that this should not in any way diminish the importance of learning to read, write and communicate in good English. Undoubtedly, the language of higher education has to remain English, but I think one could make a case for altering the situation in our schools. There may be disagreement on this issue and therefore it should be thoroughly studied and debated.

In conclusion, I hope to have made a case for the pressing need for change in science education in order to satisfy our country's needs for science literacy and to facilitate social and economic development.

The issues are undoubtedly complex and as a first step the Malta Chamber of Scientists is inviting science teachers to join it in promoting the debate by becoming members. We need to know how we as scientists could help science teachers in planning and implementing reform. We would also urge all interested parties to join efforts in promoting well thought out and well managed long term reforms.


## *Membership*

Full membership of the Malta Chamber of Scientists is open to all individuals possessing a first degree in a science related subject. Candidate membership is open to students reading for a science related degree. Membership fees are due on the 1 June of each year.

Yearly membership fees: Lm10 for full membership (Lm15 for a married couple both of whom are members).
Lm5 for candidate members.

Benefits include:

1. Subscription to ***Xjenza*** (Lm5.00 per annum for non-members)
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3. Quarterly newsletter

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