Xjenza

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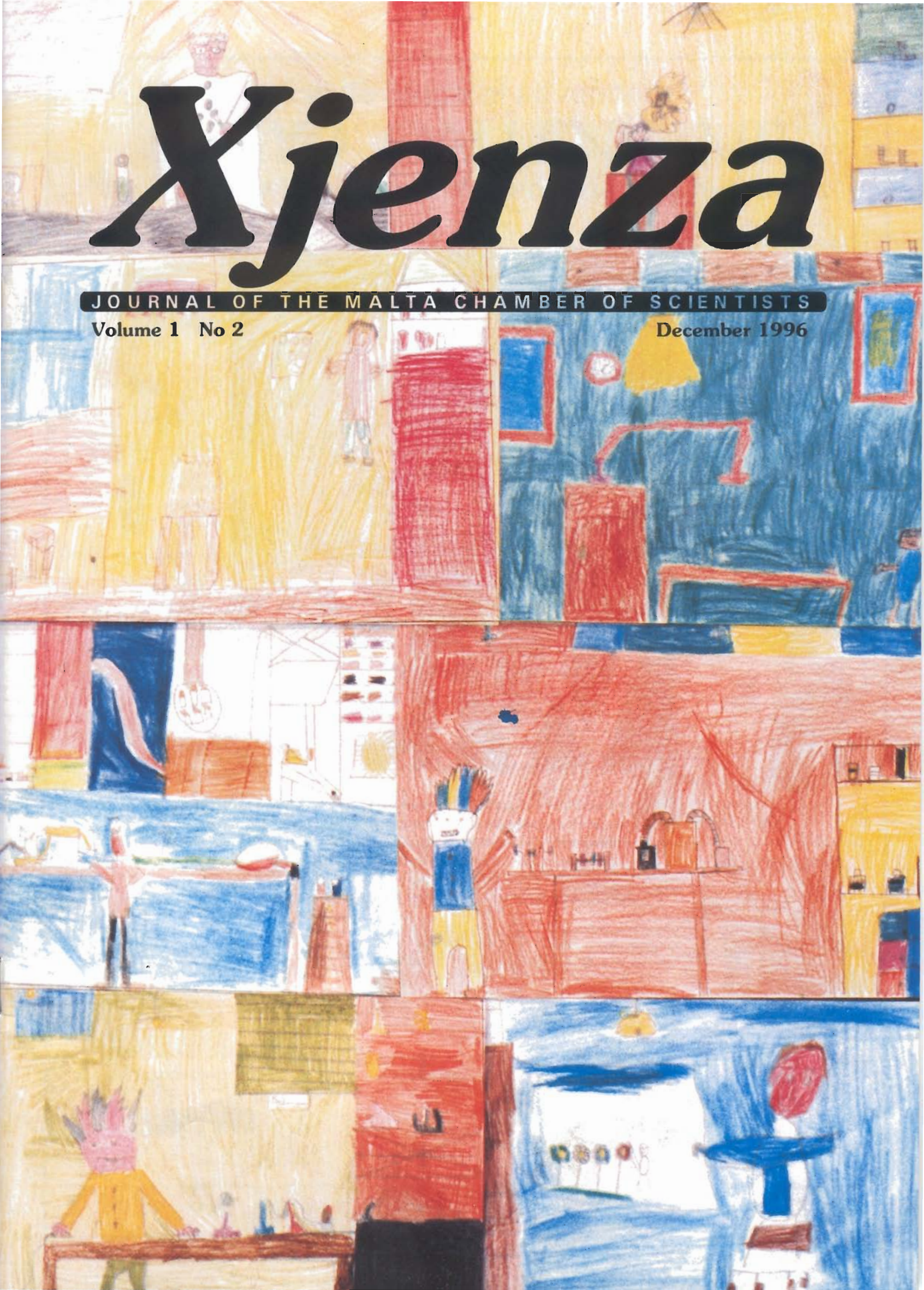

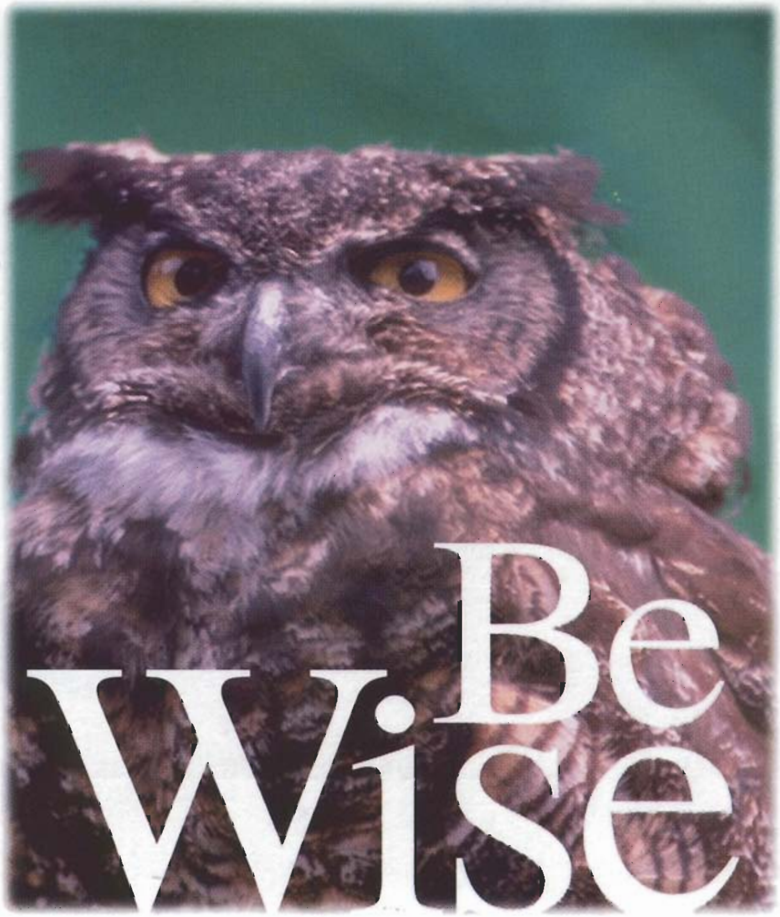
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Xjenza
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Cover Picture: Children's impressions of a scientist at work, drawn by seven year old boys (Prep 3x) from St. Edwards College, Cottonera, Malta.
Picture by: Charles Borg Galea

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Editorial

Science Education in Malta - into the 21st Century

Welcome to the second issue of Xjenza. This issue is dedicated solely to the Proceedings of the Malta Forum for Science Teachers which was held between the 16-18 September, 1996. This Forum was organised by the Malta Chamber of Scientists in collaboration with the Faculty of Education and the Faculty of Science from the University of Malta, and the Education Division. There were three British Education Consultants invited to take part in this Forum, namely Dr. Susan Tresman and Ms. Elisabeth Whitelegg from the Open Universtiy, and Dr. Jan Harding. These speakers were guests of the British Council and I would like to take this opportunity to thank the British Council for their sponsorship, without which it would not have been possible to hold this event.

The problems facing science education in Malta need to be articulated and solutions proposed now if we are going to be heading into the 21st century with a defined long range science policy which makes sense for Malta and which is the object of a national consensus. The aim of the Science Forum was precisely that. Identifying the problems involved in science education is the first and most important step in this exercise.

The crucial problem to be addressed is "Why do so very few students opt for the sciences in our country? What is it that puts students off the sciences at such at an early age, which as things stand in Malta at the present time, is the determining factor in the choice of a career?"

Let's start by looking at science in primary education, or rather the lack of it. The importance of compulsory science teaching at primary level cannot be overlooked. Science should be made part of the core curriculum for 7 to 18-year olds. If science is introduced early enough then it will be possible to introduce a culture of science in our youth. Teaching science that is fun, that is related to everyday life, that generates interest in students and thus imparts lasting enthusiasm for the subject which would encourage them to further their scientific studies beyond post-secondary levels, is of utmost importance.

One of the invited speakers, Dr. Susan Tresman from the Open University, directs the programme of training for teachers of primary science in the U.K. In the Workshop she gave (refer to article on page 33), she talked about the method used for compulsory primary science in the U.K., about the curriculum that has been developed and the way training of teachers for primary science is being carried out. The Open University in the U.K. is the world's leading distance-learning centre. We need to follow up this established contact. Dr. Tresman showed an interest in advising on changes required to be brought about in Malta if primary science education is to be developed. I am not saying that we should follow the U.K. blindly but there already exists a programme which has been developed after careful research and which can be started immediately after the appropriate training in teaching skills is given to the teachers. The curriculum has also been developed. Perhaps as a starting point. in order not to waste any more precious time, we should get going and if any changes need to be done to make the curriculum more relevant to our islands, then it can be modified accordingly.

But let's make a start. let's not waste more time talking. We have talked enough. Action is now what is required. I believe we should seek opportunities for collaboration with the OU to share the expertise they have developed. Let primary school science be a starting-point. As Dr. Tresman rightly emphasised in her talk in the final plenary session of the Forum, funds are required to be directed towards release time for teachers if the primary science programme is going to work. Teachers need to be given time to work on the programme, away from contact and the pressures of the classroom. There also needs to be a means of validation, perhaps a diploma which needs to be financed as part of in-service teachers' training. We have to encourage the right attitude towards science so that science is established as part of the core curriculum at primary level together with mathematics and other subjects.

Introducing compulsory science, rather than compulsory physics at secondary level only, will serve to improve science literacy in the next generation. In the context of compulsory science, should we be looking at an integrated or rather a broadened and balanced science subject or should we stick to the rigid divisions of Chemistry, Biology and Physics? A possibility would be for all students to do compulsory science at secondary level, while Chemistry, Biology and Physics would be studied by students who favour a science-related career.

The very wide curriculum content of science subjects taught at secondary and post-secondary level in schools is resulting in overloading and therefore cramming and is making the learning of science in our schools very difficult. This should not be the case. One should perhaps be talking about altering as well as reducing the curriculum content. There should be less teaching done in schools but it should be of better quality, in which the thinking and creative skills of the students are brought out rather than their ability to cram (see Mr. Pace's article on page 42).

This brings us to the important issue of teachers' training. The introduction of an integrated science subject, as has been introduced in other countries, would need a reculturing amongst teachers. One would change from being a Chemistry or Biology or Physics teacher to being a Science teacher. This would, of course, entail a change in the way teachers are being trained and requires careful thinking. The introduction of a compulsory science subject at Intermediate-level for entry into University is definitely a step in the right direction, but perhaps the way this is being implemented is not (refer to Prof. Vella's paper on page 44).

Science teachers need to be provided with adequate resources and technical support to be able to carry out their teaching duties well. All schools need well-equipped laboratories where pupils can perform hands-on experiments in small groups from a very early age. More field-work needs to be encouraged. Only in this way can we move away from science teaching purely from text-books to science teaching that is alive and relevant to the world around us. With this aim in mind, there should be more pre-service and in-service teacher training of the right type.

It could well be the language problem that is keeping students from taking up science. The fact that science is taught in English, using text-books that are written in English, does not encourage students to opt for the sciences when the standard of English is falling in our schools. This perhaps calls for some rethinking to be done. Should there be special courses in scientific English given to both teachers and pupils at secondary level and beyond for better communication in English? Since graduate teaching and scientific research is all in English, would it not make more sense to improve the standard of English in our schools, so that students can cope better with any subject that requires a command of the English language?

Another issue is that of gender. Why is it that so very few girls are opting for a science career in Malta? Dr. Jan Harding in her paper (see page 20) mentions that perhaps "humanising" the teaching of science would attract more girls to the subject. There is also the problem of culture. We keep hearing the phrase "Science is not for girls. It is far too difficult and technical for them. Girls would do better opting for the Arts." How true a statement is that? There is nothing to show, in fact, that girls who opt for the sciences are doing less well than their male couterparts. Again this calls for a reculturing amongst, perhaps, the career guidance experts, parents and teachers themselves, so that girls are encouraged to opt for a career in science. Dr Whitelegg in her article (see page 39) refers to "the traditional image of Physics which is one that is unappealing to many girls." It is this traditional image of science that requires changing, if we want to encourage more girls to take up a science career.

The final point I would like to make concerns increasing science literacy amongst the people, that is popularising science. Science Week, organised by the Malta Council for Science and Technology in March, 1996, was definitely a step in the right direction. The Malta Science Reports in The Times, which are monthly features edited by Dr. Richard Muscat for the Chamber, are also helping the lay people understand what scientists do in Malta. Perhaps translating these articles into Maltese and featuring them in a Maltese newspaper might be of use to those readers who are not comfortable with the English language. Radio and television programmes on science should also become a regular feature in Malta. Adult science education could be a possibility. We are here talking of tackling the problem of science illiteracy amongst Maltese of all ages. In Britain, great strides are being made in communicating science to stimulate society's comprehension and appreciation of science and technology through the "Public Understanding of Science" initiative. The Malta Chamber of Scientists could launch a similiar initiative in Malta, given the appropriate funding and resources. If an effort is made and speedily so, perhaps the picture that will emerge in, say, 5-10 years' time will be one of encouragement and achievement.

ANGELA XUEREB
EDITOR

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.

Proceedings

The Problems of Science Education in Malta - A Brief Overview

Charles Mizzi
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I believe that the problems of Science teaching in Maltese Schools are the fallout of two main factors, namely, the relatively recent historical development of the introduction of a science component in the core curriculum, and, the byzantine divisions among "science" teachers who through their personal background and training, owe "allegiance" to one branch of science rather than to a holistic heritage of scientific knowledge.

I propose to give, in this article, a brief commentary on these two facets. As it contains personal interpretations, I do not mind being judged by the reader as having been "subjective", for that is exactly what I am going to be. I would be more than happy if the article gives rise to an exchange of views with interested parties whose perception might be different.

The introduction of Science in the Maltese curriculum
When I entered the Lyceum in 1954, I was exposed to two lessons of "Science" per week in the first two years of my secondary education. *(Needless to say, Science had no place in the Primary curriculum).* The syllabus in Form I was made up of a skimpy overview of flora and fauna. The syllabus covered in Form II ensured that during the first term, we covered the features of the Bunsen burner - "a very efficient burner" which we never saw.

In Form III, I happened to choose Physics as an optional subject. *(Most students would bypass the study of science thereafter. Their knowledge of carnivores, herbivores, omnivores and Bunsen burners being deemed as a sufficient scientific preparation for life).* The Form III textbook was a skimpy one covering solely "Heat Energy." The Form IV syllabus covered rudiments of Optics. In Form V, the rest of the GCE Physics Syllabus was supposed to be covered in six months. No wonder so many students detested Science, particularly Physics! No wonder so many failed to pass their GCE in Physics!

One interesting evaluation of the situation prevailing at the time, that I came across from a third party, was that "syllabi at the time were of the right length so as to be adequately covered in private lessons during the summer months when Lyceum students had to sit for their supplementary examinations, once they had failed their annuals."

The reason for making such a song and dance about the situation at the time, is that we may easily forget that many who have occupied command positions in the intervening years, had an inbuilt perception of the validity of science education founded upon their interpretation of their formative years at school. Thus, as an example, one should not underestimate the influence that say a female head of school who had received her education pre-1955 and has an inbuilt conviction that she has got by very comfortably without any science education, might have had on her students and their perception.

In 1958, things started to change. Science education became a serious proposition and pursuit. Females were offered the opportunity to take up science as an option. Science was no longer regarded as being fit solely for males. GCE Ordinary Level syllabi were updated and were no longer risible. A sixth form course in the sciences based at the freshly opened secondary technical school at Corradino was launched, leading to the (then) recently set up GCE Advanced Level examinations. Yet, science education was the province of only a small minority of the student population - the "cranky ones" of whom I was one. From being one out of an original six, I have seen the numbers building up bit by bit, until years later, a critical mass of science educators scotched the perception of a science education being solely fit as an option for a few freakish kids.

In 1976, a new development took place. A top-down edict established Physics as a core subject of the secondary curriculum. The innovation was not, to put it mildly, introduced in the most felicitous of manners. Its introduction as a core component was concurrent with the introduction of Arabic. The two subjects displaced the teaching of one foreign language, geography and history from the core curriculum. It was thus perceived as a threat to a group of teachers with allegiance to these subjects within the schools. Antipathy to the "impositions" was rife and made rational judgement of the situation rather difficult. The measure became controversial with political overtones in a polarised situation.

The two questions which were asked at the time were "Why should Science be a compulsory subject on the curriculum and not remain an option for those who are willing to take the plunge?" and "If there has to be a compulsory science component in the curriculum, why on earth should that component be exclusively Physics?"

It is interesting to note that twenty years on, the first question has receded into oblivion. Maltese society has accepted that an all round Secondary education necessitates meaningful exposure to science in the formative years. It is also worth noting that in the past twenty years, the administration of the Island has changed hands twice. Arabic has been dropped, but, curiously, Physics has survived.

For the record, I wish to report the authorities' point of view regarding the issue of Physics as a compulsory subject, at the time of its introduction. Physics was then perceived as a vocational subject - a subject which would entice students into the fields of engineering and medicine. An engineering career required a good foundation in Physics and Mathematics. A medical career required a good foundation in Physics, Biology and Chemistry. In line with the philosophy at the time that career choice should be left to as late a stage as possible, Physics was perceived as the common factor between the two careers. Compulsory Physics would entice students to science oriented careers, leaving the choice between engineering and medicine until the age of sixteen. This perception may now have been superseded with the introduction of the Matriculation examination. On the other hand, considering the special requirements of the various Faculties, it may not have been superseded at all.

Perception is changing from a position of science being a "vocational subject" to science being an integral part of a general culture and education.

It may be the case that the time is ripe to address the following three issues:

(i) Is Physics being taught in Maltese secondary schools in a vibrant enough manner?

(ii) Should the exposure to a science education be broader than the constraints of an exclusive Physics syllabus would allow?

(iii) Should a meaningful exposure to science start at Primary school?

The fragmentation of Science in three distinct fields

Is there any such thing as "a teacher of SCIENCE", in contrast with a teacher of Physics, a teacher of Chemistry or a teacher of Biology? If we were to address the issues raised in the last paragraph of the previous section, would the "teacher of combined science" find difficulty in changing from being a teacher of a branch of science? The question certainly begs investigation.

Irrespective of what might have been surmised from the reading of the article this far, the author (as a teacher) was not a science teacher. He was a teacher of Mathematics. In that discipline, it never occurred to him that he should teach Arithmetic exclusively ...... or Algebra exclusively ...... or Geometry exclusively. Neither did it occur to anybody that an integrated syllabus in Mathematics was a softer option than say a syllabus in one of the branches of Mathematics.

Such does not seem to be the case in the science field. There is a general perception that "Science" or "Integrated Science" is far easier than "Physics", "Chemistry" or "Biology"? Why is it that a subset is seen as easier than the whole?

I do feel that these are a few issues that have to be resolved before we decide on which course to adopt in the future. Obviously, there are many other issues to be considered, which I have not touched upon here as I know that other contributors are dwelling upon them in their contributions to this forum.

At present, the Ministry of Education is undertaking a review of the National Minimum Curriculum (3 to 16 year olds), which exercise it has delegated to the Department of Curriculum Development of which I am the Director. The exercise is going to be based on widespread consultation and will last up to March 1998 - to enable initial implementation of the new curriculum to take place in September 1998. It is the apposite time for stakeholders in Education to participate in this general and radical rethink by proffering their contribution and participation.

Proceedings

Raising Questions: the Why? Who? What? & How? of Science. Why Should Science be part of the School Curriculum?

Jan Harding
Gender in Science and Technology (GASAT).

Science is a human endeavour through which we try to make sense of the world. It can be a source of wonder and delight; it can provide the basis for a greater personal sense of competency in a world increasingly dominated by science and technology and can lead to more secure and abundant living.

Science is also used instrumentally, as a basis, together with associated technology, for national (or corporate) wealth and development. This can lead to 'choice for use' and to an élite, academic science for 'scientists' and a limited science for trades, with gender differentiation based on cultural expectations of males and females.

Science can also be used exploitatively. A new pre-university physics syllabus in Queensland, Australia, starts with preamble: 'Physics enables us to control the world'. In this we find the WHY of physics based in the greater power it affords to humans, to control and manipulate materials and events. This can lead to exploitation of the natural environment, the world becomes less safe, the powerful live more plentifully but the disadvantaged may suffer greater deprivation.

The WHY we have in mind when we design science curricula and present them for learning will inevitably influence the mind-set of our students. It is essential that we think through and can justify, morally and ethically, the WHY of science.

WHO should participate in science education?
If science is a human endeavour, and so part of our cultural heritage, we have no right to exclude anyone, by expectation or by curricular manipulation, from the delights and the greater sense of competence that its study can bring.

If science leads to skilled and relatively well-paid employment, again we have no right to exclude anyone by expectation or curricular manipulation.

WHEN should science education begin?
Science should have a secure place in the primary curriculum. Exploratory science fosters and develops the natural curiosity of the child. It contributes to the development, not only of skills useful in the study of science, but also of language in communication and mathematical skills of classification, ordering and pattern-making.

WHEN should science education end?
In a democratic society, where the culture is dominated by science and technology, it is essential that its citizens feel competent to contribute to decision-making about their uses. This requires facilities for adults constantly to update their understanding of science and technology. I have been working in the UK with COPUS (the Committee on the Public Understanding of Science) and the National Federation of Women's Institutes to break down barriers that separate most women from science. On September 10th, 1996 the new structure of Regional Science Coordinators and County Federation Science Representatives for Women's Institutes was launched at the British Association's Annual Meeting.

So-called cognitive tests from many parts of the world suggest that there is no built-in cognitive difference between males and females. This means that if there is gender bias to the male in the recruitment of scientists, science will be deprived of talent and a national economy will suffer. Moreover, a gendered society maps different characteristics and experiences on to females and males. The characteristics of nurturance and social responsibility ascribed to women will be largely absent from the pursuit of science.

The WHO of science as a human endeavour needs the whole range of human resources for its development, and requires the response 'SCIENCE FOR ALL (from the cradle to the grave!)'

WHAT should go into the science curriculum?
The content of a science curriculum in compulsory schooling depends on the objectives accepted for science education. I firmly believe these to be 4-fold:

1. to lay foundations across all the sciences on which life-long-learning may build;
2. to provide the challenging and rewarding experiences of exploring the natural and manufactured world that will lead to personal commitment to continued learning;
3. to develop skills, to expand and extend knowledge;
4. to reflect on the nature of science and its social implications.

The processes of practising science (such as observation, interpretation of data, data analysis, the design and evaluation of an investigation and how these vary from one science to another) should form an important element in the curriculum.

The question of the knowledge component in the foundations laid in schooling has to be negotiated. There is a tendency for the content of science curricula to expand at an alarming rate as knowledge extends. 'Pruning' has to take place within an understanding that what is presented is not exhaustive. To make sense of the world around us needs foundations in not only physics, chemistry and biology, but also earth science and astronomy. Real problems presented to the scientist know no subject boundaries. This leads me to support a broad and balanced science course for all throughout compulsory schooling. Later, the student may specialise with higher education or a trade in mind.

The WHAT of Science should recognise the vital role science plays in the world of today.

HOW should science be presented for learning?

To establish personal commitment to science it is important to demonstrate its relevance to the student's current interests and concerns.

The literature contains many accounts of successful learning in science. I will illustrate using examples from primary, secondary and post secondary education.

A 7 year old boy was 2 years behind in reading, but a perceptive teacher noticed he gravitated to the science table and played with batteries, wires and bulbs. On questioning him, it emerged that the boy's father worked as a technician with an electricity company. The teacher began to lace simple instruction cards by the equipment. It became important for the boy to read them. In 3 months he had caught up on reading and science was his favourite activity.

The students in a mixed secondary class were required to keep a science diary within an integrated science course. This enabled the teacher to identify the topics of main interest for each student. Individuals became recognised as 'experts' in their own topics. If a question arose in class it was referred to the 'expert' who researched it with support from the teacher. Girls as well as boys were listened to with respect by their peers.

A Level 1 BTEC physical science course (roughly equivalent to GCSE 'O' level) recruited young women returning to education with little science background. Eighty per cent dropped out of the traditionally taught class. A newly-appointed woman head of department reorganised the course around modules, each entered through a question relating to health care (e.g. Does it matter how high the drip-feed bottle is placed?). Responsibility was passed to the next intake of students to seek answers using references to the same standard textbooks used before. Collaborative and mutually supportive learning was encouraged. No students failed the module, although personal circumstances caused two students to withdraw from the course.

The Salter's Chemistry Course of the 1980's which was based on the everyday experiences (extended by the media) of young teenagers, has had phenomenal success. It has been followed by an A level course and a Salter's Science Course based on the English National Curriculum.

In the early 1980s also, assisted by graduate student teachers, I developed a 'Chemistry from Issues' course which started from issues where our use of materials (chemicals) hit the headlines. It generated considerable interest among local teachers in whose schools the students trialled the modules. (A workshop on this approach was presented later in the Forum).

The HOW of science will determine the level of personal commitment generated. It should start from where the student is.

Proceedings

Science Education in Malta: Raising Questions

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Introduction
The beginning of modern science teaching in Malta can be traced back to the late 1950s and early 1960s. At that time, Chemistry and Biology were added as separate subjects to the secondary school curriculum, which already included Physics; a government sixth form and a university Junior College were established to teach Advanced level sciences; and the university science departments were given a new life with new curricula and the recruitment of expatriate staff. Over a few years, the increase in the number of students studying science, and the building and equipment of school laboratories was so remarkable that, in 1964, Prof. P.C. Lewis commented that 'The progress has been such that it is doubtful whether the word "expansion" is sufficient to describe it - "explosion" would perhaps be better' (Lewis, 1964). This spectacular progress was not simply a local phenomenon. It reflected the world-wide interest in science at the beginning of the space age, which sparked off science curriculum development in the USA and in the UK, and which influenced all subsequent science curricula elsewhere.

It would be interesting to examine the causes and the conditions that stimulated that great interest in science locally but this is not the proper place to do so. Reference can be made to three historical studies that have already outlined the growth of science education in Malta and sought explanations for its vicissitudes over the years (Sciberras, 1991; Farrugia, 1994; Pace, 1994). The reason for referring back to the 1960s is because I believe that the decisions which were taken at that time and the curricula which were drawn up, still determine to a large extent what science is taught nowadays in schools, and how it is taught and assessed.

A Basis for Renewal
Many educators now believe that the time is ripe for a thorough review of science education at all levels (Project 2000 + Steering Committee, 1994). I believe that five reasons form the basis for the call for curriculum renewal. These hinge on relatively recent developments in the following interrelated areas of knowledge and the change in social and economic conditions:

(a) *a better understanding of what is meant by science and the process of scientific inquiry*
Very briefly, the research by Popper and co-workers in the philosophy of science has shown that science is not simply the carrying out of experiments to arrive at laws or theories. Neither is it just experimentation to *prove* hypotheses. Scientific inquiry is a much more complex undertaking in which social interactions between scientists play an important role in the construction of scientific knowledge (Chalmers, 1982). Consequently it has been realised that the 'hands on' approach of the early curricula is not sufficient. It should be coupled with a 'minds on' approach and a greater attention to the role of social interactions between the individuals involved in the scientific inquiry, and particularly to the discussion of ideas.

(b) *the development of a new learning theory that explains how children learn scientific concepts and which has implications for effective science teaching*
Theoretical work on concept formation, knowledge structures and learning generally along with extensive empirical work on children's ideas has led to what is known as the theory of constructivism (Bodner, 1986). This theory attempts to explain how children develop their own ideas about physical and biological phenomena which are often in conflict with accepted scientific ideas (Driver *et al.*, 1994). It also explains why children's ideas are resistant to change and provides insights into more effective methods of teaching. In particular, it emphasises active participation by students in discussing their ideas, doing experiments together, interpreting the results, and reflecting on how their thinking changed as a consequence of learning.

(c) *a greater awareness of environmental issues and the world-wide commitment to link education to sustainable development*
During the UN Conference on Environment and Development (the Earth Summit) held in Rio de Janeiro in 1992, many nations including Malta committed themselves to the idea that education should be reoriented towards sustainable development. In particular, the conference document, which was described as a blueprint for global action as we move towards the 21st century and aptly entitled Agenda 21, suggested that one of the objectives of education and training should be the integration of environment and development concepts in all educational programmes (Quarrie, 1992). It seems to me that it is the duty of science curriculum developers to address issues concerning environment and development in the light of this global commitment.

(d) *the impact of information technology on learning and teaching science*
There is little doubt that information technology promises to become a valuable tool for science teaching and that it has already been used sporadically by innovative teachers for the retrieval and presentation of information, analysis of the results of practical work, and links with laboratory equipment. However, I am not aware of current science curricula that integrate IT in a systematic way. I believe that the new curricula should capitalise on the immense potential of information technology and other new technologies without letting them deflect our attention from the main task, which is that of teaching science.

(e) *the local economic and industrial scene is different from that of the 1950s and 1960s but science is still regarded as a priority for economic progress*
In the 1950s, industrialisation was needed to avoid dependency on expenditure by the military establishment in Malta and employment with the Services. At that time, science and technology were seen as a national priority and a programme of modernisation of curricula and the development of human and physical resources were undertaken in earnest. The outlook today is different as we enter a post-industrial age. However, in a recent speech during an 'information day' on European Commission programmes, the Prime Minister of the day stated that "Our future welfare and economic solvency depends on an expanded programme of industrial development and services based on advanced science and technology". For this reason, the role of science and technology had again been given priority on the government's national agenda coupled with the conviction that "unless the country continues to invest heavily in this sector, it will not only lose the momentum it has established in a variety of economic and social fields, but will undergo a systematic process of deterioration, leading to economic dependence" (Fenech Adami, E., 1996; Malta Council for Science and Technology, n.d.). It is important that the commitment to improve science and technology in schools spans both sides of parliament. New science curricula must therefore consider carefully the implications of the national economic aims, and science at all educational levels must use wisely the promised resources.

And now for some questions.

Who should learn science?
Is it still important to insist that all students between the ages of 5 and 18 should study science? This is not a frivolous question because our answers, which will influence the aims of science teaching to different age groups, can easily be adopted as the objectives of our curricula. Usually, the arguments, brought in support of the claim that all students should study science, fall under the following headings, which are expanded upon in Table 1: the needs of the individual, the needs of society, and the needs of the environment and future generations. The arguments are not universally accepted and they have been seriously questioned, for example, by Chapman (1991) who holds that there is no evidence that education is directly related to economic performance, and even if it is related nobody really knows what the curriculum for economic prosperity in a post-industrial, information-technology-based society should be. Furthermore, the survival of the planet depends on issues that demand an education in economics, politics and sociology rather than science and technology. Given these counter arguments, it would be worthwhile to spend some time to assess our arguments for compulsory science in order to make them more persuasive.

The main reasons concern:

1. The needs of the individual
- scientific skills to develop powers of observation, analysis and evaluation
- scientific knowledge to improve his/her quality of life
- scientific literacy to participate meaningfully in the workings of a modern society

2. The needs of society
- science education for the preparation of scientists, engineers and technical personnel
- scientific literacy for decision-makers and the general workforce

3. The needs of the environment
- knowledge of the scientific principles that regulate the local and the global environment to understand the need of sustainable development
- understanding of the social, economic and cultural impact of science on society and consequently on the environment, in order to take action to support sustainable modes of living

Table 1. Why Teach Science to all?

Following the general question about science for all, one can consider the priority of our objectives according to the students' age and ability. Thus, what priority, if any, should be given to the needs of the individual, society, and the environment in the case of students in the different age groups: 5 to 11 years (Primary), 11+ to 16 years (Secondary), 16+ to 18+ years (Post-Secondary)? More importantly, for the 11+ to 16 year group (Secondary), should we differentiate between students who would like to follow a science-oriented career later in life and others who do not? In other words, should we ask students to select an option at the end of Form 2 or Form 3 and then provide an intensive science course for those who opt for a science-oriented track and a less intensive one for the others who opt for a different track? I know that many educators argue against the choice of options when the students are only 13 or 14 years old and favour a choice at age 16 (Sammut, 1996; Darmanin, 1996; Consultative Committee on Education, 1995). The removal of that choice would constitute a radical change in the secondary school curriculum and we have to consider all its implications before a decision is taken one way or another.

What science should we teach?

A decision to teach science to all students of all ages leads to two questions, at least. What science would be suitable for each stage of education? What proportion of teaching time should be devoted to science in the case of each group: primary, secondary and post-secondary?

The selection of content depends to a large extent on our objectives. It also depends on whether the content is presented as separate chunks of science (an atomistic approach) or as an integrated whole (an organic approach) or as a mixture of both. Whichever approach we take, modern science curricula are bound to be more complex than earlier ones because they must take into consideration several dimensions, three of which are shown in Figure 1. One dimension refers to alternative ways of presenting science, starting from separate sciences, where scientific knowledge is considered as consisting of self-contained packages of knowledge labelled 'biology', 'chemistry', 'physics' and so on without overlap between them. At the other end, science is seen as an integrated body of knowledge with little distinction between the traditional sciences. Another dimension ranges from emphasis exclusively on content (facts, concepts, principles, laws and theories) to exclusive emphasis on scientific processes (observation, experimentation, interpretation, communication, problem-solving and related processes). A third dimension refers to the cognitive - affective axis. Curricula with an emphasis on cognitive skills give priority to developing skills in recall, understanding, analysis, synthesis and evaluation. Other curricula promote affective objectives, such as interest, enjoyment, curiosity, responsibility, sharing, tolerance of other people's ideas, honesty, trust and other attitudes and values.

Issues concerning gender should also enter the discussion of the selection of content and the way it is presented as this can attract more females to science at post-secondary level and beyond (Ventura, 1992; Cauchi, 1996). Similarly, we should decide whether the history of science should feature in the curriculum. And if so, we ought to decide how, for whom and to what extent.

A related issue is the general concern among many science educators about the extensive syllabi which compel teachers to force-feed their students with masses of notes. A reduction of content would allow time for more educationally sound methods of teaching. However, what are the implications of reducing content for subsequent stages of school education and for university courses?

How should we teach science?

The developments in learning theory mentioned earlier allow us to arrive at a number of principles that can

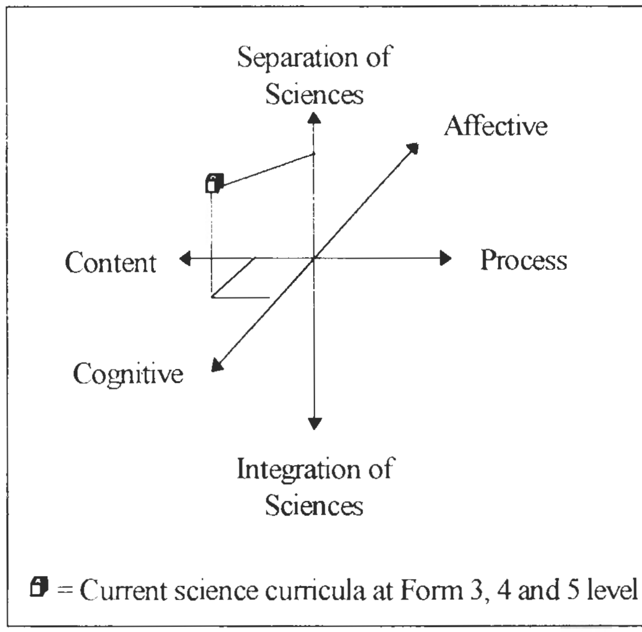

Figure 1. Dimensions of Science Content.

inform us about effective teaching. A very useful concise statement of these principles is found in *Science for All Americans: Project 2061*, a publication of the American Association for the Advancement of Science (1990) which presents recommendations for science curriculum development.

1. Learning is not necessarily an outcome of teaching
2. What students learn is influenced by their existing ideas
3. Progression in learning is usually from the concrete to the abstract
4. People learn to do well what they practice doing
5. Effective learning by students requires feedback
6. Expectations affect learning
(Adapted from AAAS(1990) *Science for All Americans: Project 2061)*

Table 2. Principles of Learning.

These principles (listed in Table 2 and Table 3) are based on the understanding that students should participate fully in all lessons by carrying out practical activities and discussing their ideas freely. It is in this respect that we have to consider the role of language and whether we should establish a language policy for science teaching. Any decision to teach science wholly in English or in Maltese or in a mixture of both has implications for textbooks and assessment, and it is bound to have repercussions on the attainment of students of different abilities and their preparation for studying science at higher levels. Of course, the availability of resources and technical support is another pre-requisite for effective science teaching.

1. Teaching should be consistent with the nature of scientific inquiry ◆ Start with questions about Nature ◆ Engage students actively ◆ Concentrate on the collection and use of evidence ◆ Provide historical perspectives ◆ Insist on clear expression ◆ Use a team approach ◆ Do not separate knowing from finding out ◆ De-emphasise the memorisation of technical vocabulary **2. Science teaching should reflect scientific values** ◆ Welcome curiosity ◆ Reward creativity ◆ Encourage a spirit of healthy questioning ◆ Avoid dogmatism ◆ Promote aesthetic responses **3. Teaching should counteract learning anxieties** ◆ Build on success ◆ Provide abundant experience in using tools ◆ Support the roles of women and minorities in science ◆ Emphasise group learning **4. Science teaching should extend beyond the school** **5. Teaching should take its time** (Adapted from AAAS(1990) *Science for All Americans: Project 2061)*

Table 3. Effective Science Teaching.

How should we prepare science teachers?

Science teacher education courses in Europe adopt either the sequential approach by which prospective teachers first obtain a science degree and then proceed for a course in teaching methods, or a parallel approach by which they follow science and education courses contemporaneously (de Vries, 1994). Allow me to say that in Malta we make little miracles because we offer both approaches at the same time in the same Faculty with the same members of staff. This puts us in the advantageous position of knowing the strengths and weaknesses of both approaches, as well as the academic and administrative advantages and disadvantages of both. Over the years we have adapted to the changes occurring in the university and it seems that we are at a point where we need to reconsider the structure of the BEd(Hons) course for science teachers as the Faculty of Science has added an extra year to its undergraduate course, which now runs over four years and leads to a BSc(Hons) degree. The main question that arises is 'What is the proper balance between content and methodology for prospective science teachers?'

Continuing science teacher education is an equally important issue. The Education Division runs in-service courses for teachers in July and September for which sometimes staff of the Faculty of Education are invited to address teachers. While these compulsory courses have their merits, we should ask what alternative attractive and effective methods of continuing education can be offered and what opportunities can be devised so that practising teachers are motivated to upgrade their qualifications in science and their professional knowledge of science teaching.

How do we evaluate our science education?

Up to some years ago, our students' performance in the GCE O- and A-level examinations of foreign examination boards could have been taken as a rough measure of the standard of our science teaching. The standards of performance that the students needed for a pass were set externally and presumably independently of our education system. This is no longer the case as the standards for achieving passing grades in the Secondary Education Certificate (SEC) and Matriculation Certificate examinations are set locally with the consequence that the general public is less likely to accept the students' performance in examinations as a reliable indicator that the levels reached in science are comparable to those of other countries. This situation raises two questions concerning internal and external standards. Firstly, how are we going to ensure that the quality of science teaching is kept high? Secondly, what measure can we use to compare our standards with those of other countries? The answer to the first question depends on our willingness to establish criteria for good science teaching and form a team of evaluators to assess and advise about current practice. An answer to the second question is that we can participate in the international surveys carried out periodically by the reputable International Evaluation Association (IEA). These surveys, when carried out according to accepted international criteria, can provide a reliable measure of standards of achievement in science (as well as in mathematics and other subjects) of students of various age groups (Comber and Keeves, 1973; IEA, 1988; Rosier and Keeves, 1991).

Conclusion

In conclusion, reasons have been presented for the renewal of school science curricula. Rather than accepting past responses to the challenges of curriculum development concerning aims, content, teaching methods, and evaluation, a number of questions are asked in order to stimulate a debate about some important issues that have to be settled before new curricula are proposed. Past experience, locally and abroad, has shown that changes in the curriculum are unlikely to succeed if teachers' views are disregarded. The forum for science teachers was an excellent opportunity to make the teachers' views known and to start off the debate. Of course, one cannot expect to arrive at a consensus during the three days of the forum but the large attendance augured well. A proper follow-up with wider participation is even more important.

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Proceedings

Getting Science Out of its Masculine Strait Jacket

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Gender in Science and Technology (GASAT).

Summary. *School science becomes masculinised through: the predominance of males working in science; the way science is "packaged" for teaching and learning; classroom interactions which reinforce stereotyped expectations and the way science itself is conceived and practised. Each of these aspects is expanded in this paper and suggestions made which may couteract masculinising effects and enable girls and women more comfortably to pursue careers in science. These involve taking steps to make women scientists visible, to teach science in a social context and to encourage problem solving, collaborative working and discussion.*

Keywords: science, social-context, person-orientation, gender-stereotyping, strait-jacket.

What does it mean to say science is in a strait-jacket? A strait-jacket implies confinement and loss of freedom. To label it masculine implies that confinement arises from science taking on masculine characteristics. What evidence is there that science is in a masculine strait-jacket and what can we do to extract it?

As a result of a major four year action research project in England (the GIST project: Girls into Science and Technology), Kelly (1985) argued that secondary school science becomes masculinised in four chief ways:

- Numbers

The scientists students meet, in texts, media, in person and among teachers are usually men;

- Packaging

Examples used in text-books or by the teacher, are more usually drawn from activities that boys, rather than girls, engage in;

- Interactions

In a co-educational class, boys claim laboratories and workshops as their territory;
Students and teachers reinforce gender-stereotyped behaviour;

- The Nature of Science

The way science is practised: its principles, concepts and methodology are biased toward the male.
Let us look in more detail at each of these, for each contributes to the confining of science within a masculine framework.

The Predominance of Men
The position today, where there are many more men than women scientists, is a product of past gender-stereotyping, which first deliberately excluded women and later failed to remove obstacles to women, such as gendered expectations of the appropriate roles for men and women in the world.

But there are women working as scientists at all levels. We need to make them more visible. Text-book publishers should ensure that men and women are equally presented doing serious science, with as many women as men identified in leadership positions and as many men as women in support situations, such as technician or secretarial/administrative roles. All careers information should show females and males participating in each occupation featured.

The GIST Project invited women scientists and technicians into the project schools to teach pieces of science related to the work they were doing. But they found that unless attention was drawn especially to the fact that they were women, many of the students, particularly boys, did not remember the presenter was a woman. In another project in Wales, a woman airline pilot and a woman chief steward were both remembered by girls as air hostesses! *Such is the strength of stereotypes.* To change them, we need both to make women scientist/technologists visible and continue to refer to them in these roles.

Packaging
An analysis of text-books, especially in the physical sciences, show that while illustrations feature more males, in many, few people are included. Collings and Smithers (1984) showed that boys have significantly lower person-orientation than do girls, and the student scientists of each gender score less on a person-orientation scale than those choosing arts subjects. By presenting science in an impersonal way we may be attracting into it young people, mostly males, who have little concern for people.

The situations or technologies used to explain topics in science more often reflect the way boys are connected to the world (e.g. football, machinery, ballistics etc.). While boys and girls do express different interests there are aspects of science that both genders would like to know more about (Whyte, 1986; Lie and Bryhni, 1983). These common aspects may vary between cultures. Surveys need to be carried out in Malta to discover components of these common interests.

On the other hand, the problem may lie in the motivational or entry point. In the UK, electronics is one of the least popular subjects with girls. We were surprised, therefore, when we investigated young people's entries to a National Design Prize Competition, to find a majority of girls and boys who entered were using microprocessors in some form of control technology situation. But the gender difference emerged in the way they defined the problem they had worked on. For the boys, the problem was a technical one, they were improving a device; the girls, however, saw a social problem (helping a young child to learn or a disabled person to be more independent). Once the girls recognised that electronics could help them solve this problem they had no difficulty working with it (Grant and Harding, 1987).

A pre-university course in Victoria, Australia, requires physics to be learned 'in context'. The structure of the atom can be investigated either through the debate over nuclear energy or through the atomic bomb. If students choose the latter, the brief runs like this: *'you are asked by a group of non-science students, who plan to visit Hiroshima, to fill them in on the development and use of the atomic bomb'*. The physics content of this course is traditional but, in the first two years of its use (1992/93) students have shown a substantial increase in A grades gained. This is particularly marked for females (Hildebrand, 1996). By relating science to people's needs and placing it in a social context we can remove many of the masculine constraints on science.

The dominant behaviour of boys and the need to breakdown stereotypes

The effect of the behaviour of boys on girls' learning in science classrooms is irrelevant in the single sex environment of Maltese secondary schools, but stereotyped expectations of both girls and boys may operate in these settings. I understand that different curricula are available for girls and boys in the 'area secondary' and trade schools (Darmanin, 1992), although all curricular areas are theoretically open to both sexes. In common with other national governments, Malta has signed the 'Platform for Action' agreed at the 1995 UN Fourth World Conference on Women. This places special emphasis on widening girls technical and vocational education and on educating boys in home-crafts.

Early stereotyped experiences may strongly influence relative achievement of girls and boys in a number of topics of the science curriculum (Harding, 1996; Johnson and Murphy, 1986). Electricity is one such topic - and was chosen, for this reason, by Parker and Rennie (1985), in an action research project in Western Australia, which addressed three issues with grade 5 teachers: the development of skills and attitudes relating to the teaching of electricity; the development of positive teachers' attitudes towards the participation of girls in the physical sciences; and the development of skills in creating and maintaining a non-sexist learning environment. This project enabled ten-year-old girls to achieve parity with boys in the assessment of work in electricity.

In the co-educational context of Maltese primary schools also, teachers need to develop skills to create and maintain a non-sexist learning environment, especially when presenting science topics for learning.

The 'ideology' of science and implications for science education

A common perception of science is that it consists of a set of immutable laws which are generalised and abstracted from contexts. Too often science education consists of the presentation of these laws for practical demonstration and their use to solve paper-problems. Objectivity is assumed to require separation of the observer or experimenter from the object or system investigated. Emotions have no place in the pursuit of science.

The effect of these perceptions on recruitment to science was investigated by Head (1980, 1985). He reviewed studies of the personality of practicing scientists (all male) carried out since the Second World War. He found that scientists emerged as more authoritarian, more emotionally reticent, more imbued with the Puritan work ethic and less person-orientated than their male peers. His investigations of teenagers found that the boy scientists were among the least mature of their age group, whereas the girls choosing science, though fewer in number, were among the most mature. He argued that a girl had to have a certain maturity to make what was then an unconventional choice, whereas science, presented as law-bound, unemotional and reliable could provide the less mature boy with the certainty that spelt security.

How does this selective recruitment affect the practice of science?

Both Keller (1985) and Harding (1986) argue that the differential nurturing of males and females develops different psychological, emotional and cognitive needs (if not abilities). Keller sees the male's greater need to dominate and control has led to the dominance of the master molecule concept in biochemistry and genetics. This, she argues was a factor in the delayed recognition of the work of Nobel Prize-winner, Barbara McClintock. For McClintock, the most important principle was variation and difference, not generalisation and abstraction. Neither did she strive to distance herself from the systems she studied. She felt she was down in the cells with the chromosomes. She had 'a feeling for the organism' and would say *'Let the material tell you what to do'*. In this way she was able to observe the transposition of genetic material between chromosomes when ideologically it could not happen.

Keller argues that the history of science demonstrates that science has been pursued, and knowledge generated, in many different ways. By allowing science of the 'Enlightenment' to become the dominant way, with its strongly masculine overtones, science is constrained in a strait-jacket.

Could science be different if more women were involved? It is difficult to say, as most women who remain in science have adapted to the system. But if we modify the way we teach science we may enable more women, and males with different psychological and cognitive needs to pursue it.

Removing the strait-jacket

The following factors have been found to associate with girls' greater enjoyment and success in science:

- the placing of science in the social context;
- the avoidance of vocabulary, technical terms and meanings that derive from a peculiarly shared masculine experience;
- the integration of **their** experience of the world into the learning process;
- the use of a framework that allows them to recognise complexity and ambiguity;
- the opportunity to reflect, work collaboratively (and therefore discuss) and to define a problem in their own terms;
- the expectation that they will participate and achieve success.

Ventura (1992) reported that Maltese girls were less successful in 'O' level physics than were boys and that Form 4 girls performed badly across all sciences in secondary schools. Perhaps the masculine strait-jacket is operating and presentation of the sciences at this level does not take the above factors into consideration.

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Proceedings

Adolescent Girls' Views On Science: A Maltese Study

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Summary. *This study was carried out in Malta in an area secondary school for girls. It is an ethnographic investigation of the adolescent schoolgirl culture from the girls' own perspective. The paper focuses on the girls' ideas and opinions on science, what they think about science, why they think science is more appropriate for boys than for girls, and what interests them in science.*

Keywords: adolescent girls, science interests.

Introduction
Girls view science, particularly physical science as masculine (Klein, 1989). Despite the fact that girls view science as predominantly masculine, they are still interested in and want to learn more about science. The problem exists not in trying to find out why girls and boys have different science interests or how to make what is considered to be "masculine" science more appealing to girls but rather to identify what in science interests girls and to build on these interests. As Whyte (1988) states "women have a particular contribution to make to science by virtue of their being women".

Girls are more interested in the biological sciences than in the physical sciences. They are interested in subject matter related to health, nutrition and the human body especially when the subject matter is placed in a context related to daily life or to society. Girls are also excited by science lessons which emphasise practical 'hands-on' experiences (Peltz, 1990).

As a result of my early experience of teaching girls, aged eleven to thirteen, in an area secondary school in Malta, I was interested to learn which topics in science the girls wanted to cover and what they themselves really wanted to learn. The main purpose of this study was, therefore, to explore the students' own views, ideas and opinions about the way in which they were learning science.

Methodology
In this study, the students were allowed to express their own ideas and opinions, in line with what Davies (1982) stated: "children have been written about from many perspectives, and for a multitude of purposes but rarely have they been asked to speak for themselves". This study was therefore intended to "lay stress on the study of everyday life and on the actors' own interpretations and definitions of the situation" (Delamont, 1978), and thus an ethnographic style of research was selected.

The study was carried out in the school where I had previously taught. As in Pollard (1985), I decided that "I could positively use the shared experience and rapport which I had built up previously to the advantage of the research". The five students enrolled for this study all came from working class families and were described by the headmistress as "students who do not shine in their work". Starting in September, I met these girls for about an hour every day. The meetings were in the form of informal group interviews. We would sit around one of the laboratory benches and talk, and I would interject at intervals with open-ended questions. Throughout the interviews a relationship of trust and understanding was established with the students. Within the 'we-relationship' (Davies, 1982) which was developed, the students actively sought to help me see things their way. They felt that they could be open with me and for them, ".... You were like a friend to us.... more than a friend.... you were like a sister not like a teacher...".

All the conversations with the girls were recorded and later transcribed. In the process of transcribing, some patterns started to emerge. The transcripts were divided according to the themes which were emerging, for example, a section relating to science interest, one to teachers, the school and so on. Following through each section until a clear picture of what was happening started to emerge, in turn resulted in a narrative of what the girls had told me. A prepared plan of action and preconceived ideas initially formulated changed as the relationship with the students developed, and consequently the way in which the data was interpreted.

Girls' Views About Science
When the students were asked to write down the first thing that came to their mind when they heard the word science, the following words emerged: animals, chemicals, personal care of body, growing up, nature, feeding of animals, what things are, environment, laboratory, experiments, our life, medicine, how things in the world work, discovery about things, our body, what things have inside. These descriptions only relate to the biological and chemical aspects of science. There was

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Proceedings

Why Physics Seems to Be Beyond Some Students' Grasp

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It is quite common for many students to complain about having to study physics. Some clearly state that it is not a subject of their interest, and even more find understanding physics to be beyond their capability.

The rate of failure in the subject is quite high. As can be seen from the results in the SEC physics 1996 May session, about half the students (47%) did not get the required pass mark to proceed with their studies. In addition, most of the grades were in the 4-5 region, showing that performance was not of a high standard (Table 1).

Grade	No. of Candidates passing	% candidates passing
1	55	2
2	82	3
3	136	5
4	652	25
5	483	28
6	454	27
7	240	9
U	543	21

Table 1. Grades obtained in SEC Physics exam in May 1996 Session (MATSEC, 1996) No. of Candidates: **2645**; No. of candidates opting for paper 2A: **1097**; No. of candidates opting for paper 2B: **1548**.

What is it that seems to hinder students' performance in physics? Science educators, teachers and politicians have always shown concern for the problem with physics, and a number of possible reasons have been put forward. The major arguments involve the difficulty in understanding concepts in the subject, teachers' professionalism and pupils' ability.

- **the nature of knowledge of physics:** The knowledge of physics tends to be objective, involving considering mechanisms and physical phenomena around us. However useful these things may be to the commodity of our everyday life, they do not seem to be of such great interest to young teenagers, especially girls who tend to be more interested in the social rather than the physical aspect of our society (Head, 1980, 1985). On the other hand, boys seem to be enthusiastic initially but interest wanes at the end of secondary education.

- **the level of concepts involved:** Many of the concepts involved in physics are abstract in nature and not easy to understand. Relationships often involve more than two variables and some ideas cannot be visualised. Concepts like density and acceleration involve a combination of three variables, while magnetic fields and field lines are difficult for students to conceive.

- **teachers' professionalism:** One may easily blame teachers for poor teaching ability as one major cause of the problem. While this argument may hold in some cases, it may be possible that even with the best teachers the problem lies with the students. There must, therefore, be other factors involved.

- **students' ability:** Likewise, the understanding and absorption of the concepts covered is often attributed to the students' mental ability. Teachers very often witness students trying to make sense of physics with no success. If so, what level and what type of mental ability is required, and what can we do to help students?

The main argument of this article concerns the demand of concepts found in physics and whether Maltese students in secondary schools have the required mental ability to grasp such concepts.

Cognitive development in adolescents

Most of the major work in cognitive development was carried out by the famous psychologist Jean Piaget, who developed the levels of cognitive development through which students evolve during their childhood (Inhelder and Piaget; 1958). The main levels of development of interest at secondary level are the ***concrete operational*** and ***formal operational*** stage.

Concrete Operational Stage

At this stage, thought is very much tied up with concrete situations. Unless the pupils have the apparatus in front of them, or a diagrammatic representation of the situation, they will not be able to formulate thoughts about it. In addition, at this level, children cannot consider more than two variables at one time. So, as Inhelder and Piaget (1958) first reported and Shayer and Adey (1981) later described, students considering the reason why some objects float and others sink, may reason in terms of whether an object is light or heavy, rather than use the concept of density.

Formal Operational stage: At this level thought is considered to be hypotheticodeductive. This means that thought does not need a concrete situation to occur, but rather the other way round. A developed formal operator, or abstract thinker, will be capable of, not only to think out an idea, but also to consider all the variables (more than two) and devise a fair test to test out his/her hypothesis. In the same example cited by Shayer and Adey (1981), students will now be able to consider the combination of mass with volume in density and to be able to devise an experiment, controlling the variables, to test it out.

It is important to point out that the model is developmental in that students have to go through the concrete operational stage before reaching formal operational thought. In addition, it is a slow process, and development occurs gradually.

The Physics Syllabus

One need not have a background in psychology to realise the curriculum demand of the subject. At this stage one may pose the question of how cognitively demanding can physics actually be? What is the minimum cognitive level of development required to be able to understand the basic concepts? The various sections of the physics SEC syllabus are considered and their average level of demand noted. Table 2 lists the minimum cognitive level necessary to just follow the course as compared to that

Topic	Minimum level of cognitive development required to follow	Maximum level of cognitive development required to fully understand
Structure of Matter & Kinetic Theory	**3A** Abstract model used to explain behaviour of gases gas expands due to greater vibration.	**3B** Understanding of gas laws - manipulation of pressure, volume & temperature.
Energy	**2B** Work as using energy Energy has many sources.	**3B** Heat can only be partly converted into useful energy. Different energy needed to stop cars of different velocity.
Waves	**3A** Equation v=fλ known as an algorithm light as part of electromagnetic spectrum.	**3B** Understanding difference between longitudinal & transverse waves. Relating velocity to wavelength & frequency.
Charge & Current Electricity	**2A** Bulbs light when connected to batteries Bright bulb has more energy than dim bulb.	**3B** Meaning of potential as work done in transfer of energy between two points.
Pressure	**2A** Force = Pressure. Same force acts more over a small area than a large one.	**3A** Can understand that pressure in liquids depends on height, not on cross-sectional area.
Linear Motion	**2A** Intuitive notion of speed. Speed & position of departure not differentiated.	**3A** Acceleration qualitatively understood as rate of change of velocity.
Magnetism & Electro-magnetism	**2B** Can understand that like poles repel, unlike poles attract.	**3B** Understand nature of fields ; effect of motion & current in magnetic field, motor, generator.
Optics	**2B** Light travels in straight lines Angle of incidence = Angle of reflection.	**3A** Can use lens laws (ray diagrams) but as algorithms.
Electronics	**3A** Gates : known as algorithms.	**3B** Understand the use of gates in practice : alarms etc.

Table 2. Minimum and Maximum levels of cognitive development required to follow Physics SEC course. (adapted from Shayer & Adey,1981) (2A - Early Concrete operational; 3A - Early formal operational; 2B - Late concrete operational; 3B - Late formal operational)

necessary for fully understanding physical ideas and their implications. If one would like students to understand physics, formal operational thought is required in most cases, as is indicated in Table 2. Physics includes many concepts which are abstract in nature. Often mental models are used to explain phenomena. A topic like kinetic theory involves the use of a mental model to represent particulate structure and is all abstract in nature. No wonder it is one of those topics many students fail to grasp. Other instances of abstract notions like magnetic fields, electric charge, cutting of flux etc., form the basis of physics throughout, and unless students have the mental ability to manipulate such ideas, their level of understanding will be limited to simple one way relationships and mechanical manipulations of formulas. Students may still manage to get through the SEC exam but a very limited insight would have been achieved.

This leads to the question of whether Maltese secondary school students have developed a basic level of abstract thinking to understand physics and if not, is it one of the reasons for their difficulty with the subject? Several pilot studies have been carried out (Andrews, 1979; Attard, 1989; Busuttil, 1981), but although similar trends have been obtained in the UK, all three studies seem to indicate that Maltese students lag behind in development. However, the samples considered each time were small and non-representative, and have to be interpreted with caution. The results of the research considered here include a greater student population and thus may give a clearer picture of the situation in general.

The sample used for this study consisted of 814 Form IV students from Junior Lyceum schools, of whom 458 were girls and 356 were boys. The test used was the Science Reasoning Task, the pendulum having an internal consistency 0.83 (Shayer and Adey; 1981). The instrument was devised and tested by Shayer and Adey (1979) and used in a study involving about twenty five thousand students in the UK The pendulum task was chosen as it differentiates between late concrete and formal operators, and was therefore suitable for our sample. The test consisted of twelve items, was held in class, and involved a class demonstration using the apparatus. Each question was explained and the students wrote their answers on the questionnaires. Care was taken to explain the questions in Maltese to avoid language difficulties. Table 3 below outlines the results obtained.

Level of Development			% Students at Form IV
2B	:	Concrete	31.3
2B*	:	Mature Concrete	47.3
3A	:	Early Formal	19.8
3B	:	Mature Formal	1.6

Table 3. Level of Cognitive Development in Form Four Junior Lyceum Students.

As one can easily note from Table 3, only about 20% of Form IV students achieved some form of abstract thinking. The rest of the students were still at an earlier stage of development. Taking Junior Lyceum students to represent the top 55% of the student population for that year, the results obtained show that Maltese students are at a similar level of development to that of students in the UK (Shayer and Adey, 1981). This result differs from other small studies mentioned above, and is believed to be more indicative. However, one must not forget at this stage that only Junior Lyceum students were tested, and that a significant percentage of students attend private, church or area secondary schools. The sample considered is, therefore, probably not representative of the whole top 55% of the student population in that year.

Another implication of the findings, relevant to the argument in question, is that less than a quarter of students in Form IV have developed abstract thinking and that the conceptual demand of many topics in physics is beyond the mental ability of our students. A more interesting result transpires when level of development is considered across gender. As Table 4 below shows, girls in Government Junior Lyceum schools are at a higher level of cognitive development than boys of the same age.

Level of Development	Boys (%)	Girls(%)
Concrete	36.2	27.5
Late Concrete	47.5	47.2
Early Formal	14.9	23.6
Formal	1.4	1.7
Total	**100**	**100**

Table 4. Level of Cognitive Development in Form IV Students across Gender. χ^2- 12.6; $p < 0.005$.

One must note here that the population of boys in government schools is less than that of girls, and since a significant proportion of the total Form IV students go to church or private schools, one cannot extrapolate these results to the whole population. What can be said is that girls in Junior Lyceum schools are at a more advanced level of development than boys in Junior Lyceum. T-test analysis carried out on the actual scores showed that the means for boys and girls were 6.11 and 6.31 respectively, and found to be statistically significant ($p < 0.001$). If the subject matter seems to be too demanding for the students, does it lead to the conclusion that the curriculum needs to be changed to fit the students' ability? The question of matching has been debated in the UK in the '80's and the general consensus that has emerged is to stick to what we have.

Another possibility, to tackle this mismatch, is maybe to help students develop abstract thinking so that more students would be able to grasp the concepts. Researchers from King's College, London claim to have managed to achieve this throughout a programme known as Cognitive Acceleration through Science Education (CASE) (Adey, 1992). Would the implementation of this programme solve all our problems?

It would be wiser to look at the ways and methods included in such projects and to learn about the approaches and methodology employed. However, two main points need to be considered, the first involves what level of subject matter needs to be taught, and the second is how this subject matter is going to be taught.

Following Vygotsky's (1978) idea of zone of proximal development, subject demand should be just beyond the students' present level of development. According to Piagetian theory, a student at a concrete level of development will never be able to grasp concepts requiring abstract thinking, however hard she/he tries. This line of thought would negate all possibility for teaching physics successfully at secondary level. Vygotsky's argument, however, runs differently. According to Vygotsky, there is a difference between what the student is able to do on his/her own, and what she/he can do with the help of a teacher, or a mediator. The difference between these two levels is known as the **zone of proximal development**, and teaching should be pitched at this level. The implication is that if at the age of 13-15 students fall mainly at the late concrete operational stage, then teaching should be at the early formal level. So, physics can, and should, be taught to students at secondary level.

Learning and development are not two separate things and one cannot wait for development to expect learning. On the contrary, learning and development go hand in hand. As students learn, development occurs, promoting further learning. Teaching science is not solely the vehicle to promote scientific knowledge, but is also a powerful tool to help adolescents undergo cognitive development.

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Proceedings

Learning Journeys in Science for Primary Teachers: A Case Study from the Centre For Science Education: Open University, United Kingdom, *'Primary Teachers Learning Science'*

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Summary. *The introduction of the National Curriculum in Science in England and Wales has resulted in a series of new professional demands being made on primary teachers to manage and deliver the science curriculum when they frequently have limited knowledge, confidence and experience of the subject. This has led to significant changes in the emphasis and content of courses which offer opportunities for professional development in learning and teaching primary science. A collaborative initiative between the Centre for Science Education (CSE) at the Open University (OU) and the BBC Education has developed a range of materials to support professional development opportunities in this area. Recent work at the CSE has focused on researching, developing and implementing the first presentation in 1995/6 of a post graduate course based on OU/BBC resources which has been delivered nationally in partnership with Local Education Authority Teams, mentored by CSE members. A workshop at the Maltese Forum for Science Teachers in September 1996 provided opportunities to consider the impact on teachers of the course 'Primary Teachers Learning Science' via the course resources and its assessment strategy. Participants were able to examine course materials and the assessment guide, and to work closely with copies of marked assignments which had been presented as part of the Certificate awarded by the Faculty of Science, Open University.*

Keywords: primary teachers, professional development, science curriculum.

The Open University/BBC Primary Science Project

Over recent years, the CSE of the Open University has gained considerable experience in the in-service education of primary teachers in science with the development of the 'Science for Primary Teachers' course (Tresman et al, 1994; Tresman and Hodgkinson, 1994). The initiative utilised the distance learning techniques of the Open University, in a framework of Government sponsored short course arrangements using Local Education Authority advisory staff.

In developing this course, the project team were building on the OU's experience of teaching science to adult learners with limited formal science background in undergraduate courses such as the 'Science Foundation Course' and 'Science Matters'. This experience had alerted the Primary Science project team to the possibility that mixed media study programmes could be designed which provided science knowledge for the teachers and constructed frequent and explicit bridges between that knowledge and strategies for teaching. In this way, teachers' experiences of learning science could impact on primary practice in a sustained and durable way.

The plans for the new media resources of the BBC Primary Science appeared to complement the CSE's plans for a new course in 1995, so a collaborative team was set up to coordinate the production of all aspects of the teacher's professional development resources. Examples of the full range of resources were introduced through a series of activities at an additional workshop provided at the Maltese Forum for Science Teachers in September 1996.

The Course

Designing a course which is both accessible and challenging to experienced primary teachers requires explicit links to be made between appropriate selected content and practice, so that the teachers' investment in time and effort in the course will be professionally relevant.

Six workbooks are provided that focus on key areas in science in the primary curriculum:

Life: Diversity and Evolution
Materials: Chemical and Physical change
Forces and Energy
Electricity: Making connections
The Planet Earth
Ecosystems

These are linked with the BBC broadcasts for teachers and children. The Course Team advises Local Education Authority groups on planning training programmes around the materials. Tutorial support is offered to assist teachers' preparation and planning for assessment.

Each workbook takes the reader through a learning process of exploring, planning, implementing, and reviewing in a reflective learning cycle. Such a model for learning aims to assist teachers to process information, gleaned during the course, and insights gained with experiences during the course to move forward into new learning. The assessment woven into the course is a key element in establishing whether new learning has occurred and whether teachers have been able to graft this onto established practice. Two strands can provide evidence in this respect: personal learning and associated learning strategies and the impact of these on practice in the classroom and school.

Within the opening section of each workbook, explicit statements are offered on general and subject specific outcomes expected after studying it. Performance criteria relevant to each specific outcome are given and guidance on how to use them to map out an appropriate route through the workbook.

Teachers are asked to compile a learning file (supplied as part of the course materials) to enable them to keep a record of their learning journey, through notes, responses to activities, pieces of children's work, results of reflections, group discussions, marked and returned assignments.

Assessment Strategy

Self assessment plays a leading role in evaluating learning. Within the workbooks are embedded activities which develop teachers' skills in interaction with new concepts and ideas in science and science teaching introduced in the text or associated broadcasts. 'Core Skill Activities' develop skills that underpin all learning and are intended to assist evaluation of learning. Responses to these activities may contribute in the process of planning and structuring tutor marked assignments which form the summative assessment of the certificate course. Other activities are concerned with specific concepts linked to the subject areas covered in the particular workbook. These are structures to develop knowledge and ideas, reinforce understanding and provide opportunities to practise using and applying newly acquired concepts.

The Summative assessment comprises two assignments and one end-of-course project. They have a dual focus: on personal learning; how the processes of learning as an adult occur and on professional learning; the use which is made of the subject knowledge within the context of primary teaching in science.

The assignment tasks relate to the aims of bridging personal learning of science and children's learning and classroom and school based activity. The first two are studies of learning and teaching, the third is a project on an aspect on the role of the science coordinator. The coordinator has responsibility for planning and coordination of the science curriculum in his/her school. The first presentation of the course is now complete and the examiners of these assignments reported on the first two tasks as follows:

'Through these assignments, teachers were able to articulate their lack of knowledge and skills at the start of the course and many demonstrated improvements in their first assignment (completed after three months). They described a variety of methods for identifying pupils' existing ideas in science, but many had difficulty selecting effective methods of developing detailed learning objectives for each child in their selected group'.

'In the second assignment, teachers were able to describe the strategies they had developed to increase their knowledge in science and confront difficult concepts. This helped them to identify with pupils as they were meeting new concepts. Teachers revealed increasing confidence in planning and teaching, using their wider knowledge of science to provide a broader spectrum of appropriate classroom activities. Many recognised the beginnings of change in their practice, moving away from 'telling' information and providing highly structured activities, towards more effective questioning and probing children's ideas which diagnosed misconceptions and could be used to plan effective programmes of learning for the children'.

The classroom based research project represents a shift in the level of demand to build on previous work and provides a challenge in the context of whole school science.

A choice of three contexts is provided:

- to write a report on the development of a portfolio of assessed and moderated children's work in one area of science for use in school
- to write a report of a project to plan science in the curriculum over a range of time scales
- to write a report on the planning, running and evaluation of a science school-based in-service training session.

In each case, teachers are required to demonstrate through evidence, how they have translated their own science knowledge and understanding to inform practice in the chosen area.

Since these have not yet been marked, outcomes of the project will be reported in a later paper.

The Workshop

A workshop was provided at the Maltese Forum for Science Teachers in September 1996. An introduction gave a brief overview of project resources and identified needs of primary teachers and how these had been catered for in a series of training programmes and partnerships established between the Open University and Local Education Authorities throughout England and Wales.

The participants were then split into two groups to engage in two activities. A period of 20 minutes was allocated for each activity. Each group of participants was asked to report on one of these activities in a brief plenary at the conclusion of the workshop.

Activity 1
Participants were asked to review course materials, in particular the six workbooks and comment on opportunities contained therein for guiding teachers' learning about their own and children's learning in science in these key areas of science.

Activity 2
Examples of assignments produced by teachers participating in the first presentation of the course were made available for study. Participants were asked to compile a list of up to six important issues raised by these assignments in the areas of personal learning about science and six illustrating impact of the course on teaching science as demonstrated by the teachers' responses to the assignment tasks.

On reflection
Given the widely contrasting backgrounds of participating teachers in knowledge of science and experience of teaching it within the primary curriculum, evidence of substantial progress from the starting points of individuals studying 'Primary Teachers Learning Science' has been demonstrated during the first year of presentation, 1995/6. This progress has been in terms of enhanced knowledge of science concepts and how to teach them effectively, an increased appreciation of the processes involved in learning science as an adult and as a child, greater awareness of the organisation problems of effective teaching and planning in school and improved knowledge of resources and equipment and confidence in how to use them.

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SCIENCE TEACHERS' SECTION

The Malta Chamber of Scientists is setting up a Science Teachers' Section. This section shall be responsible for matters concerning the teaching of science in Maltese schools. It shall also be responsible for the organisation of seminars, forums, training courses and publications related to science teaching. Any teachers of science in Malta, from primary to tertiary level, who wish to join, please contact the Secretary of the Chamber at the address below:

P.O. Box 45,
Valletta B.P.O.,
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Proceedings

Empowering Primary Teachers to Work With Confidence and Expertise in Science: Workshop Presented to the Malta Forum for Science Teachers; September 1996

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Summary. *In the United Kingdom, young children are usually taught science by non-specialist teachers who not only frequently lack confidence in the subject, but often bring their own misunderstandings to the classroom. How to break this cycle has exercised the science establishment and the Government for some years. A range of initiatives have been introduced, culminating in the English/Welsh National Curriculum, with its Northern Irish and Scottish counterparts. Since September 1995, a joint initiative between the Open University (OU), Centre for Science Education (CSE) and BBC Education has offered substantial training opportunities to support the teaching of primary science. A workshop, presented at the Malta Forum for Science Teachers 1996, provided opportunities to view, explore and discuss television broadcasts for teachers and investigate aspects of the OU workbooks which form the basis of a Certificated Course in Primary Science (located within the MA in Education Programme) at the University.*

Keywords: primary science, curriculum, teacher training, workbooks.

Introduction: Primary Science
Since the introduction of science as a core subject of the National Curriculum in 1990, all children of primary age are entitled to experience and be taught science within their school. The areas of science are determined by Programmes of Study established within the following strands: Life Process and Living Things, Materials and their properties, Physical processes. Contexts derived from these should be used to teach pupils about experimental and investigative methods. However, few primary school teachers have a science background beyond 'O' level or GCSE level (at 16+), and although science has been a focus of In-service training for the primary sector in the last five years, it is still an area in which many primary school teachers say they feel the need for support.

Over the recent years, the Centre for Science Education has made a considerable impact into the primary science area with the development of the '*Science for Primary Teachers Course*' (Tresman and Hodgkinson, 1993; Tresman et al, 1994; Tresman and Fox, 1994; Hodgkinson and Tresman, 1994; Tresman and Hodgkinson, 1994). Similarly, BBC Education has a long standing valued reputation for the production of broadcast materials for primary schools and in more recent times for In-service training materials.

A collaborative venture forged between the CSE and BBC Education has produced materials to enhance and develop teachers' own understanding of science and to support and impact on their professional practice (Tresman et al, 1994). A major thrust of the training programmes based on these materials is to develop teachers as reflective learners and practitioners of science. A summary of the project is shown in Table 1.

Teachers' notes support the effective use in the classroom of four series of broadcasts for pupils aged 5 - 11. Teachers' manuals support the planning of appropriate activities and schemes of work in science and suggest opportunities for assessing children's understanding of science .

The series of six *Teaching Today* broadcasts focus on key areas in science that research had shown pose particular problems for teachers. Each programme has three elements woven into its treatment of the subject:

- children learning science
- adults using science
- pedagogy eg. teaching strategies or educational research.

The programmes and notes for tutors are designed to be used in school-based science In-service training.
Workbooks following the six themes explored in the *Teaching Today* broadcasts and produced by the Open University, contain substantial background knowledge in science and provide a route to teacher certification from the Science Faculty: '*Primary Teachers Learning Science*'.

Current government funding initiatives allow for Local Education Authorities (LEA's) to contribute substantially to the costs incurred by primary schools in retraining their teachers to develop their science teaching. Providers of training courses in science have to be approved (appointed as 'Designated Providers' by the Department for Education) and work in partnership with LEA's to establish training programmes of between 5 and 20 days' duration.)

- **T.V. Broadcasts**

  For Pupils

  Cats' eyes for 5-7 year olds, 4 x 15 mins, 8 per term for 5 terms.
  The Experimenters for 7- 9 year olds, 20 x 20 mins, 4 per term for 5 terms.
  Science Zone for 9-11 year olds, 20 x 20 mins, 4 per term for 5 terms.
  Space Ark, 24 x 10 mins, 4 per term for 2 years.

  For Teachers

  Teaching today - 6 programmes, 1 per term for 2 years.

- **Printed Media**

  For Pupils

  Two series of highly illustrated information books for 5–7 and 8–11 year olds.

  For Teachers

  Teachers' notes on pupil broadcasts for 5–7, 7–9, 9–11 year olds, including activities, assessment and planning guides.
  Teaching Today notes x 6: ideas to support professional development in key science areas.

  Kits

  Collections of practical activities for teachers, on key topics.

- **Professional Development Course**

  Open University workbooks leading to OU certificate.

- **CD interactive**

  Teachers' resource for exploring the pedagogy of investigations, and content and issues in science teaching.

Table 1. Primary Science: Details of the project.

'Primary Teachers Learning Science' qualifies for designated status which has allowed widespread negotiations between the CSE and LEA's throughout England, Wales and Northern Ireland to establish training programmes which are based on the workbooks and associated assessment. These training courses are administered and tutored locally with LEA Science Advisory staff, backed by validation and specialist guidance and mentoring from the Project Team at the Open University.

Training Courses: Local Partnerships

Government initiatives in the area of primary science are aiming to make a response to research findings e.g. Tobin and Garnett (1988). These showed that, while primary teachers could manage their classrooms, get activities in science started, monitor their pupils engagement and probe children's thinking, they experienced severe difficulties in a number of key areas:

- could not assist pupils to develop the science content from the curriculum
- could not ask the crucial questions to focus children's thinking on what was learned
- did not always know what children were supposed to learn from an activity
- were unable to diagnose partial understanding and misunderstandings from children's responses
- failed to focus on content and concept development.

The Open University experience of teaching science to adult learners with very limited formal science backgrounds, convinced the Project Team that sustained improvement in primary practice in science could be achieved through teachers acquiring a personal knowledge base in science and providing opportunities for them to reflect with colleagues on how this newly acquired knowledge could impact on their teaching.

Members of the BBC and OU staff met with a wide range of science advisory staff from around the country explaining how to use the Open University/BBC Education resources to set up Government funded training schemes. The Project Director from the OU, CSE with responsibility for Academic Liaison offered detailed support in establishing appropriate training programmes based on the OU Course, backed by the wealth of programme and print resource from the BBC. A high level of interest and many models of provision were forthcoming, all characterised by the partnership between LEA teams and the OU. An example of one

TERM 1		BBC/OU RESOURCES
June	Pre-course twilight - introduction to proposed course, staff etc., attended by course participants and Headteachers	
late September	2 day introduction to course Ways of studying the workbooks OU assessment for the Certificate	Workbook 1: Life: diversity and evolution Assessment booklet
	Introduction to the learning file and assignments Audit of science skills of course participants Diversity and Evolution tutorials and workshop Investigative work in science, reporting on and recording children's achievements and experiences	Teaching Today Broadcast and notes
October	1 day, tutorials and workshop on Materials	Workbook 2: Materials: Physical and Chemical changes Teaching Today Broadcast and notes
late October	1 day in school researching tasks with children and preparing for course assignments 1 and 2 (with supply cover)	
November	1 day, tutorials and workshop on Forces and Energy	Workbook 3: Forces and Energy Teaching Today Broadcast and notes
	ASSIGNMENT 1 DUE NOVEMBER	
early December	1 day workshop and tutorials Continuing Forces and Energy	Workbook 3: Forces and Energy
	Differentiation in primary science Working with colleagues, school based INSET - strategies for and evaluation of (production of A4 resource sheets by course participants to be shared amongst all members of the group)	Workbook 2, Section 4
TERM 2		
January	1 day workshop and tutorials on Circuits and Magnets Planning for science, providing equal opportunities for science (5 minutes presentation by course participants)	Workbook 4: Electricity: Making connections Teaching Today Broadcast and notes
	ASSIGNMENT 2 DUE MARCH	
February	1 day workshop and tutorials The Planet Earth Resourcing primary science	Workbook 5:The Planet Earth Teaching Today Broadcast and notes
late February	1 day in school (with supply cover) researching tasks for assignment 3	
March	1 day workshop and tutorial on Ecosystems Assessment in science	Workbook 6: Ecosystems Teaching Today Broadcast and notes
twilight late March/ April	Exhibition mounted by course participants in local professional development centre for Heads, Colleagues, Pupils, future course participants	
	ASSIGNMENT 3 DUE AUGUST **AWARD BOARD MEETS NOVEMBER TO OFFICIALLY AWARD CERTIFICATES**	

Table 2. An example of a training programme.

such training programme was shown and discussed during the workshop and is included here in Table 2.

Tutors, one for every group of 12 or so participating teachers, are generally drawn from the Local Education Authority Advisory Staff, but alternatively may be drawn from the Open University academic staff. The award of the post graduate certificate is made on successful completion of two assignments and an end of course project. Tutors are supported by training, the provision of tutor notes and monitoring of their marking of students work by the Project Team and other Science Faculty staff at the OU.

During the first two presentations of the course, more than 600 teachers have studied courses based on the OU materials. Based on these levels of interest, the OU/BBC collaboration is the largest provider of training in primary science in England. Some teachers have applied to the OU individually, to study within a network of groups established and tutored by the Open University. These individuals encompass returners to the profession, supply teachers, teachers currently taking a career break to raise families and others keenly motivated to enhance their qualifications in science but unable to obtain government funding. Some individuals and groups have purchased the workbooks directly from BBC Education and have designed training programmes around them.

Workshops

There are a range of potential uses of the Primary Science package of resources in the professional development of teachers. The Project team has developed a series of workshops for key staff in the field. These include advisers, advisory teachers, teacher trainers and those with responsibility for science within schools. The workshops are designed to be both an experience of professional development, and a tool for the dissemination of the project's potential roles.

Such a workshop was provided at the Malta Forum for Science Education, September 1996.

An introduction covered the ground of the first two sections of this paper. The participants were then split into three groups to engage in three activities. Each of these provided opportunities to explore the potential of different resources contained within the project for supporting training in science for teachers of primary aged children.

A period of 30 minutes was allocated for each activity and each group of participants was asked to report on one of these activities in a plenary session to the workshop.

Activity 1

Participants were asked to review a broadcast aimed at the professional development of teachers in the area of Life, Diversity and Evolution, and study comment on the effectiveness of the '*Teaching Today*' notes, which support and extend the broadcast.

Activity 2

Participants worked through a series of activities and reading contained in the Open University Workbook 5 using associated rock samples from a kit supplied with Workbook 5.

Activity 3

Participants had the opportunity to explore the full range of 6 Workbooks, plus the associated assessment material, and attempt to design a training course based on these materials which could provide appropriate training opportunities for colleagues in their schools.

Guidance notes were produced for each activity and are shown in appendix 1.

Background To Activity 1

***'Teaching Today'* Television series and associated Teaching Today notes**

The *Teaching Today* booklets, together with the associated television programme, offer help with ideas and concepts relating to six key areas of science for the Primary Curriculum.

Life : Diversity and Evolution
Materials: Chemical and Physical Change
Forces and Energy
Electricity : Making Connections
The Planet Earth
Ecosystems.

The booklets provide suggestions on how to organise and run training sessions within your school, which would cover these areas of science.

Background To Activity 2

The Open University Workbooks

There are six themes forming the structure of the professional development resources in Primary Science, they are:

Life: Diversity and Evolution
Materials: Chemical and Physical Change
Forces and Energy
Electricity: Making Connections
The Planet Earth
Ecosystems

Each theme has a Workbook and a *Teaching Today programme* associated with it. Each Workbook focuses on a key area of National Curriculum Science for the primary age range. Experimental and investigative science is embedded throughout the course materials. The Workbooks underpin and extend some of the ideas covered in the BBC Teacher's Files. Each Workbook enables the teachers to develop their own science knowledge and offers strategies to enable them to use that knowledge to enhance their own professional practice, both within the classroom and within the school. Complemented by the Teaching Today broadcasts and science kits, each module of study consists of text, video and hands-on investigative material.

Within each Workbook, the text is structured into four sections. Workbook 5 is used in the workshop and used here to give the context for each section.

Section 1: About this Workbook. In this opening section, course participants are introduced to techniques of reflective study and the implication for them of embarking on a learning journey in science. The wide range of BBC Primary Science resources are indexed along with statements of outcomes and performance criteria for the Workbooks. Advice on how the materials can be studied and record keeping of the learning journey through completion of the Course Learning File is given. The assessment is introduced.

Section 2: Learning about The Planet Earth. This section offers opportunities for the learners to develop their own knowledge and understanding of the particular concepts stated, and develop and improve their competence in defined skills.

Section 3: Teaching about The Planet Earth. Here the focus is on developing teaching and learning in the classroom, encouraging the development of strategies to enable the teachers to use their own science knowledge to impact on their practice.

Section 4: Assessing children's learning in science. Topics and issues that have been included in Sections 2 and 3 are covered in greater depth in a science context.

In the workshop, the particular focus for study falls on workbook 5, Section 2 (see Appendix 1).

Background To Activity 3

Resources of the course "Primary Teachers Learning Science"

Copies of all the resources provided to teachers who enrol on the course in the United Kingdom as students of the Open University were provided for participants to examine and discuss.

OU workbooks covering the six key themes were:

Life: Diversity and Evolution
Materials: Chemical and Physical Change
Forces and Energy
Electricity: Making Connections
The Planet Earth
Ecosystems

The structure and detail of the assessment framework was presented in the Course Introduction and Assessment Guide, together with examples of assignments produced by participating teachers.

Some complimentary resources produced by BBC Education were also available for examination.

Related documents covering the National Curriculum were displayed, together with some recent research publications by the author.

The Assessment Strategy For The Course

There are two assignments and one project for the OU Course: 'Primary Teachers Learning Science'. All are included in the Course and Assessment Guide, and examples of this were available for workshop participants to look at. The assignments and the project are designed to meet the following aims:

1. To assess teachers' understanding of the course material, and how they have applied those ideas in the context of their developing practice in school.
2. To provide teachers with feedback on their progress on the course.
3. To assess in the project, their knowledge, understanding and professional competence in the teaching of science in the primary curriculum and school.

Local Education Authority or Open University Tutors have responsibility for providing tutorial support and planning for the assignments and the project, and for marking them. The tutor also helps teachers to have access to a range of services from the OU if this should prove necessary e.g. counselling. Tutors meet all students face-to-face at least once during the course for the mandatory contact. This enables the OU to verify that the final project report is the teachers' own work - in conjunction with verification from a colleague, usually a headteacher. The final project is double marked, once by the tutor, and also by a script marker. There is no written examination. The foci for the assignments are as follows:

Assignment 1

To present a personal skills audit (30 marks) and to present findings about children's ideas in a particular area of science to use in planning science work in the classroom (70 marks).

Assignment 2

Include an evaluation of personal learning in one area of science (20 marks). Evaluate approaches to teaching investigative science and collecting and reporting evidence to demonstrate progress in children's ideas (70 marks). Plan the project (10 marks).

The Project

In addition to the three options outlined below, (worth 85 marks) all candidates were required to answer a question about their own learning as a result of studying the course, and make an evaluation of how their new knowledge in science is likely to make an impact on their practice (15 marks).

Option A Present a report of a project to develop a portfolio of assessed and moderated children's work in science for use in your school.

Option B Present a report detailing the planning, delivery and assessment of science in the school for a particular age range over a two-year period, for example, 5-7, 7-9 or 9-11 years. The report should consider planning over long, medium and short term scales.

Option C Present a report on the planning, running and evaluation of a science school based training session.

The workshop concluded with the opportunity for a wide ranging debate on the relevance and transferability of this initiative in an international context.

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Appendix 1

Maltese Forum for Science Education
Workshop Resource:

Using a Teaching Today Programme and associated teachers' publications.

Activity 1 : for 30 minutes.

For 20 minutes.
View the programme on Life, Diversity, Classification and note down examples of the following elements you see that would be useful in professional training on this topic.

- Scientific knowledge for Teachers.
- Processes and skills of science.
- Examples of how children learn science.
- Relevant contexts for using new knowledge gained by teachers.
- Ideas that could be used for school-based training sessions for colleagues you might run.

For 10 minutes.
Look at examples of Teaching Today booklets and assess their degree of relevance and usefulness to staff training in science in your area.

Combine as a whole group to present your findings to the plenary of the workshop.

Using the Open University workbook : The Planet Earth

Activity 2 : for 25 minutes.

Using the rock cards and relevant sections of the text (copies provided), in groups of 2 or 3, annotate the copies of Table 5 and Figure 22 provided.

For 5 minutes.
Combine as a whole group to reflect on applications of this type of work to the science you teach in the primary classroom. Share these thoughts during the plenary of the workshop.

Exploring the course resources for 'Primary Teachers Learning Science'

Activity 3 : for 30 minutes.
'Primary Teachers Learning Science' is a Certificate Course from the Science Faculty at the Open University.

For 20 minutes.
Examine the course materials – the workbooks, learning file, assessment guide and examples of assessed work. Look at the complimentary materials provided.

For 10 minutes.
On the basis of what you have examined, produce a programme for a training course based on the needs of your colleagues as you perceive them in the area of primary science. Include a consideration of who would deliver the training and where and when the sessions would be held.

Proceedings

Motivating Physics for post-16 Students

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Summary. *There is a new curriculum development project, the Supported Learning in Physics Project (SLIPP), based at the Open University which aims to tackle the problem of decline in the numbers of students opting for Physics at post-secondary level. This project focuses on control over and use of contexts for learning.*

Keywords: Supported Learning in Physics Project, SLIPP, post-secondary physics, context and control.

Science education in the UK has undergone considerable change in recent years. With the introduction of the National Curriculum, students have an entitlement to science teaching and learning during the years of compulsory schooling - 5 to 16 years, and in all State schools (the majority of schools in Britain) students must by law study all the sciences up to GCSE (the 16+ examinations), rather than select one or two science subjects out of three. Some schools teach the sciences as separate subjects and students must do all three, others teach them in an integrated way as broad and balanced science. However, this compulsion to study science, and physics in particular, has not led to large numbers of students deciding to continue with these subjects at post-16 level and the decline in numbers of students taking physics at post-16 level has continued despite the introduction of the National Curriculum in 1988.

The reasons for this persistent decline in the numbers of students taking physics post-16 has been widely reported and need not be repeated here. However, it may be useful to draw some parallels between some of these reasons and some similar issues that I am aware of in Malta.

In both educational systems, students are more used to a transmission mode of learning, to being spoon-fed by teachers, and so they are unused to taking responsibility for their own learning and for finding things out for themselves. Sometimes the teachers themselves are under-qualified to teach at this level, or perhaps are de-motivated after several years of teaching to students who are not very committed. Physics has a particular image of being a difficult subject and it also requires quite a high level of mathematical ability, so parents may suggest to their children that there are easier routes to a qualification than via physics. The traditional image of physics is also one that is unappealing to many girls (Whitelegg, 1992).

In addition, in Malta, there are the problems of poor communication skills, particularly the requirement to learn science in a foreign language (English), over-large classes, and lack of practice in learning through investigative work.

These issues can lead to poorly motivated students, who are unlikely to counter the trend of declining numbers and opt for a subject that they will have to struggle with, rather than something that holds more of a guaranteed route to success.

This is a multi-faceted problem that contains fundamental issues that are grounded in economics, demographics and society's image of science and scientists, (and physics in particular), so there is only so much that can be done to improve the situation by particular educational initiatives.

However, in this paper, I wish to outline one particular initiative that is being developed in the UK that aims to have some effect on this decline in the popularity of physics, and which I hope may also be of interest and of use in the Maltese situation where similar issues confront students and their physics teachers.

The Supported Learning in Physics Project

Considering all the factors that contribute to this poor uptake of physics at post-16 has led me to the conclusion that a key issue that can be tackled by educational initiatives is students' *motivation* for learning physics. A new curriculum development project, the Supported Learning in Physics Project (SLIPP) based at the world's leading distance learning university - the Open University in the UK, aims to tackle this key issue in two ways.

Firstly, the A-Level Information System (ALIS) based at Durham University, UK, has found that A-level students have greater motivation if they are given more control over their own learning. Secondly, students are also more likely to be motivated by a subject if it relates to activities and hobbies that they are interested in during their out-of-school activities. This latter factor is particularly true for girls who have been found to pay much more attention to the context a science problem is set in than do boys who tend to disregard context and treat problems in more abstract ways (Murphy, 1994).

SLIPP has focused on these two factors - control over learning and use of contexts for learning, as a means for increasing motivation for learning physics and has designed a learning programme for post-16 students that makes use of these two factors.

SLIPP is a package of self-study materials that covers the core of the physics A-level. It is also appropriate for those taking the new post-16 vocational programmes (General National Vocational Qualifications - GNVQs). SLIPP consists primarily of text-based resources which develop physics learning through self study of the materials using active learning strategies developed by the Open University. It consists of eight units of supported self study material and incorporates some CD-Rom activities and other audio-visual resources where appropriate (these are commercially-available materials which must be purchased separately). The recommended mode of use of the SLIPP materials is for teachers to plan routes through the materials with their students and to manage a time-table for study with the students. However, after setting targets for the students' learning, teachers should then withdraw and allow students to study the materials independently but arrange to meet students for small group or individual tutorials and problem solving sessions. This approach frees the teacher to help those who are struggling and to develop more advanced work with others who need further challenges. Practical work is integrated into the texts and although full instructions are given for the majority of experiments students are encouraged to hypothesise, plan and carry out experiments for themselves and the end-of-unit projects encourage this in particular. For safety reasons, teachers should supervise the practical sessions and be available to offer help when asked. However, teachers should not be delivering the learning, the study texts do this, so teachers should develop more of a tutoring role offering advice and assistance when requested and withdrawing at other times. Obviously teachers must monitor students' progress at regular intervals and the material contains lots of questions of different sorts - both to develop and to test students' understanding. A teachers' guide offers advice on the way to use the materials and contains tests which teachers can administer to their students to check their learning at the end of a unit.

The second feature of the project is the way the physics content is introduced and developed. Each unit is written around a real-life context, a context which we hope will be interesting and attractive to young people and one that is inclusive of girls' interests. The physics learning is embedded within these contexts and so the contexts determine the order in which the physics concepts are covered. This leads to a rather non-traditional coverage of some of the physics concepts and also some concepts being covered in more than one context so appearing in more than one unit. This is felt to be a positive feature, we do not all learn everything first time around, and presenting energy transfers for example in the context of transport and in the context of rock climbing will help reinforce that concept and appeal to a diverse range of students in different ways. The eight units and their associated contexts are listed below:

Title	Context	Content
Physics, jazz and pop	Listening to a concert in a modern concert hall	Oscillations, s.h.m., Waves, ideal gases, communications
Physics on the move	Safe transportation of people and goods	Statics, dynamics, energy, kinematics, Newton's laws, forces
Physics for sport	Rock climbing, springboard diving, scuba diving	Forces, vectors, oscillations, s.h.m., Ideal gasses, energy transfers, materials
Physics on a plate	Cooking and eating food	Thermal physics, electromagnetism, geometrical optics, energy, electricity, structure and properties of solids
Physics of space	Space exploration and images of science and scientists	Quantum physics, light, nuclear processes, geometrical optics, radioactivity
Physics phones home	Development and use of the mobile phone	Electromagnetism, electric and gravitational fields, electricity
Physics in the environment	Energy use, recycling, pollution, life and death of the car	Thermal physics, fission and fusion, nuclear processes, electricity
Physics of flow	Measurement and control of fluid flow	Fluid flow, electricity, electromagnetism

The materials are currently in various stages of production and the first one, *Physics, jazz and pop* is due for publication this November. The others are scheduled to follow over the next few months and all should be available for use by the start of the next academic year. The materials are being marketed by Heinemann Educational Publishers and will each cost about £8.50. For further information please contact the author at the address above, or for information on availability of the materials or to order inspection copies please contact the publishers at Inspection Department, Heinemann Educational, PO Box 380, Oxford, OX2 8BR, England.

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Proceedings

Science Education in Malta: *Quo Vadis?*

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The low number of students who choose science and who eventually pursue a career in science (Cauchi, 1996) is a clear indication of the need to revise our present policy regarding science education. In our strategy to improve the situation we should be extra careful not to waste too much energy on attempting to cure the symptoms of this problem. What we really need is to recognise our responsibilities, be bold enough to address the deep rooted causes of the problem and to do our utmost to resolve them even though solutions might imply radical changes in our present educational policies.

A major issue that emerged during this forum was the need to rethink the decision making processes that influence the curriculum. We are aware of decisions that were hurriedly taken and which had adverse repercussions in schools. Besides, fostering a piecemeal approach to curriculum development, management by crisis and remedying mistakes that could have been avoided, involve a waste of energy and resources, not to mention a waste of opportunities when one considers the number of students being influenced by these decisions. Curriculum development should be a participatory exercise with representation from a variety of educational sectors - especially teachers who will eventually be entrusted with the task of implementing the innovations. Particularly important for the development of the science curriculum is the formation of partnerships with industry. Traditionally, industry's involvement with students starts once they have left school, making full use of the skills and knowledge developed by students throughout the years of schooling. A close partnership with industry would ensure that schools continue to supply industry with an efficient workforce, and that industry shoulders this responsibility by financing particular educational projects and offers its resources for use by the various educational institutions.

Science education has been defined as a process which "*develops an enquiring mind and a scientific approach to problems*" (Schools Council, 1977). Therefore, when judging proficiency in science one should be aware of the process of learning rather than just its end product. Unfortunately, our educational institutions - think otherwise and a lot of importance is attributed to examination grades. Evaluation is predominantly of the summative type and syllabi abound in endless lists of isolated chunks of scientific knowledge with examinations, more often then not, testing students on their ability to recall these facts. At times, particularly at tertiary education level, the main objective of examinations is to measure what students do not know rather than what they do know. It is a well known fact, among university students, that the prestige of certain science courses is measured by the percentage of students failing the course. A high percentage of successful passes is considered as a '*watering down of expectations*' or a '*softening of course content*'. It is no wonder that students do not choose science as they associate it mainly with a lot of hard work requiring a lot of study and memory work (Cauchi, 1996).

In schools, science teachers have to struggle between finding time to allow their students to discover, discuss and assimilate concepts while trying to cope with an overloaded syllabus. Hence, for most of the time the teaching mode adopted is of the expository type (Abela and Buhagiar, 1993). Learners are rarely engaged in 'time consuming' investigations which induce them to apply learnt knowledge and to devise solutions. Most of the science being done in local educational institutions (ranging from primary schools to university) is of the recipe type - where learners are expected to follow instructions and fit in their observations into expected and previously predicted answers. It has been shown that this is one of the major sources of dissatisfaction in science (Gatt and Vella, 1990; Cauchi, 1996). The tragedy of it all is that students, knowing full well what is expected of them at the end of the course, accept the situation and end up demanding this examination-oriented pedagogy from their teachers (Abela and Buhagiar, 1993).

This distorted view of proficiency in science might be the symptom of an underlying ideology, which has certainly influenced teacher recruitment and certain educational policies, that considers a sound knowledge base as the most important requisite for making a good teacher. Besides undermining teaching as a profession, this ideology continues to shift attention away from what is really needed We need to recognise teaching as a profession with its particular line of expertise, and with its own specific training programme. This awareness is surely hindered by attitudes which consider students, who opt for the teaching profession, as lying at the *trailing end of the spectrum of science* or at the shallow end of the dream pool.

Without diminishing the importance of a sound knowledge base, this ideology is the remnant from a time when teaching was characterised by mere transmission of knowledge. However, we are now in an era in which knowledge is continuously evolving and hence education should strive to develop independent learners. Hence, teachers need to be equipped with the skills that would help learners to actively participate in their learning. We have already sought to improve science teaching by exposing science teachers to more science content with no significant improvement to the situation. What we need to do now is to recognise the crucial role of pedagogy in effective science teaching and be ready to invest in teacher education programmes which provide a sound pedagogical base.

However, training science teachers to adopt a more learner-centred approach is not enough. There is an urgent need to balance this training with adequate support that would alleviate some of the problems of everyday teaching. For example, this support could include:

a) an effort to ensure that all laboratories are specifically designed and well resourced to facilitate science teaching,
b) a reduced number of students per teacher to facilitate the organisation and management of practical sessions, and
c) a restructuring of syllabi in order to reduce the amount of topics to be covered and increase the possibilities for investigative projects.

Certain changes in teaching conditions may be delayed by an apparent lack of science teachers. The problem could be alleviated by a more coordinated deployment exercise of new recruits between the Education Division and the Faculty of Education. Concurrently, efforts should be initiated to achieve a balance between supply and demand. The present course structure of the science content units in the B.Ed. (Hons) programme deters students from choosing particular science main subject combinations. The result is that the product of the teacher education course is not quite what is required in our schools.

The issue of subject choice is not solely restricted to the tertiary level of education. Students are expected to make a subject choice, which will determine their future career, early in their secondary education. In most cases, children experience problems in making the choice and rely heavily on their parents' advice as well as their guidance teachers (Gatt and Vella, 1990) who may not always be aware of the career opportunities available for science students. Opportunities are further reduced by certain subject combinations that still have inherent gender bias. Furthermore, the latest innovation concerning science in area secondary schools is such that students cannot dream of covering the MATSEC science examination syllabi, except maybe through private lessons, hence making it more difficult for them to take up science at post-secondary education.

Schools should be sites of opportunity and hence, subject choice and specialisation should be deferred till the end of secondary school, when students are more capable of making better and more informed choices. The need for specialisation really starts at the post-secondary stage. A truly integrated science course could replace the present specialised science courses. Care should be taken to avoid a fragmentary type of programme, made up of bits of biology, chemistry and physics and to propose a truly integrated course based on multidisciplinary themes. Besides exposing learners to a better concept of the scientific method of discovery, an integrated science course allows students to explore and experience a wide range of possible career opportunities in the scientific world.

Such an innovation in the educational system would certainly require some additional support before it is fully implemented. MATSEC examination syllabi will need to be revised to suit a more flexible style of science teaching. Syllabi will probably consist of a compulsory core that would introduce learners to basic scientific principles and a set of investigative projects which can be chosen by the learners depending on their interests. In order to create further opportunities, the MATSEC examination board will also have to rethink their present policy of offering 2A and 2B papers and start offering a single paper catering for a wide spectrum of abilities and offering a whole range of grades. Pre-service and in-service teacher education programmes will also need to be revised. The main emphasis of these programmes should be that of equipping teachers with the methodological skills required to help them teach in an integrated fashion, rather than focusing on imparting very specific and isolated scientific knowledge.

If we are going to be offering a relevant educational setup, which would allow students to deal with the challenges of the 21st century, we need to develop skills to rapidly adapt to new situations and to be able to build up new structures which would help us to satisfy our needs. However, we should also be equally ready to tear down these structures in order to build new and improved ones which would satisfy our needs better.

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Proceedings

Science Education in a Restructured Sixth Form

Alfred J Vella
Department of Chemistry, University of Malta, Msida.

I wish to share with you some reflections on the recently introduced changes to the sixth form curriculum. These reflections are not based on empirical data (it's still early days for the new system) but rather they derive, if you will, from an application of first principles to the recent experiment in pre-university education.

The 2 Advanced level plus 3 Intermediate level subjects plus Systems of Knowledge system has, potentially, two types of impact on the science education picture in Malta: a positive impact, because now all sixth form students will be taking some science (albeit at 'I' level); and a negative impact, because students in the science streams will suffer a loss of one science subject at 'A' level in exchange for one 'I' level science and two 'I' level arts subjects.

I think the teaching of arts subjects, and particularly that of English language, to science students will have a salutary effect on the latter's ability to communicate better and more elegantly than at present, even and especially in matters of a scientific nature.

On the other hand, the reduction in background content, equivalent to 2/3 of that of an advanced matriculation science subject, will have to be addressed by the various faculties (e.g. medicine, engineering, architecture and science) who offer courses to such scientific matriculates. The general entry requirements to university have been modified in order to take account of these curricular changes. However, as far as I know, the various faculties whose study programmes may be affected by this science content reduction have not been formally alerted and requested to harmonize course contents with the requirements of their future students.

How does the syllabus content of an 'I' level science subject compare with that of the corresponding syllabus at 'A' level? I was involved, with others, in the drawing up of the 'I' level syllabus for chemistry and I wish to share some of the problems that we had in that area: I suspect that colleagues in other science subjects had similar experiences.

There was the problem imposed by the time available for teaching the course programme: 2 hours per week for about 60 weeks over a period of 2 years: i.e. a total of 120 hours of course work. Compare this with the time available for teaching 'A' level chemistry, which is 360 hours and that for 'SEC' level chemistry which is about 270 hours. This constraint had a number of repercussions. Firstly, we were obliged to kickstart the course at a point equivalent to that of a completed 'SEC' chemistry programme. Yet, I am informed that students are allowed to follow 'I' chemistry even when they have no 'SEC' chemistry background. Almost certainly, this is going to create a lot of difficulty for these students and, in my view, it would have been wiser to disallow students such a choice.

Secondly, in view of the limited time afforded to teaching the subject, we could not allot time to any laboratory instruction. So while exhorting teachers to use laboratory demonstrations as often as they could, we did not formally request them to organize a practical component for the course. A similar decision was taken by the syllabus setters for physics, biology and environmental science. Incidentally, these panels were not acting in concert and this same conclusion was arrived at in an independent manner.

Thus, a situation developed where all 'I' level science programmes were shorn of their practical component, and this in sharp contrast with corresponding teaching programmes at 'A' and 'SEC' level. To my mind, this situation has automatically impoverished the quality of the learning experience for intermediate level science students. Of course, there was the advantage for the school administrations, that, in this manner, the syllabus was easier and cheaper to teach. Indeed, in retrospect, I wonder what would have happened had we decided to establish a practical component in the course. Was the problem of laboratory provision for all students at sixth form considered when the decision to start 'I' level sciences was taken? Or did this minor detail escape the attention of the planners?

Another problem which has also emerged and which should have been highly predictable at the planning stage, concerns the question of textbook availability.

In chemistry, the course was designed to cover a similar width of subject area as that covered by the advanced level course but each area was to be developed to a lesser extent. In other words, we reduced the course content in depth but not in breadth. I guess this was conditioned by the desire on our part to ensure that no major areas of the 'A' level syllabus remained completely unvisited especially since we perceived most of the 'A' level topics as being of fundamental importance to higher studies at university.

Now, of course, while a few good texts exist for both the 'A' level and the 'SEC' level courses, these being similar to corresponding courses in British schools, no texts are specifically designed for our home-grown 'I' level course. Teachers will, no doubt, manage this problem by employing the current 'A' level texts and advising students to use them judiciously, i.e. to skirt around certain topics, to leave out some chapters completely and so on. Clearly, this is not an ideal situation.

Future syllabus setters might consider to steer clear of the current course content structure and to adopt an approach similar to that followed by North American textbooks designed for the freshman year at US universities. The main advantage in this approach would be that many superb texts exist for such a programme. However, the linkage of such a syllabus with that of 'SEC' chemistry may not be completely congruent.

Similar problems are likely to exist for the other 'I' level sciences although rather than discuss these here I want to end my brief contribution with a few words about the new subject introduced at (and only at) 'I' level, namely environmental science. More to the point, I will focus on the manner in which this new science subject was born to the curriculum.

It is my understanding that environmental science is currently being touted as the likely most popular science choice for the arts stream at the sixth form college. Presumably, students will choose environmental science either because this is perceived as the softest option in science or, more appropriately, because they will wisely decide to stay clear of 'I' chemistry or 'I' biology because of a lack of 'SEC' background in these subjects.

Students should not choose environmental science or any other subject by default. If the cultural base of the nonscientific sixth former is to be enriched with some science, and this is a very good thing, I do not know if environmental science is the best vehicle to use for such enrichment. And having chaired the syllabus panel set up to produce a first syllabus for the subject, please note that I am not making this statement lightly.

Indeed, one could reasonably argue that a study programme consisting of selected topics from the various scientific disciplines and connected by a common theme could well provide a better medium for teaching science to the nonscience major at sixth form. Moreover, other approaches suggest themselves.

But, then, it is not my intention here to evaluate the merits of these different approaches.

Rather, since we are discussing *"planning for the future"*, I feel that it would be better for me to use this very recent experience as an object lesson in *"how not to plan curriculum changes in future"*.

To my mind, such an important decision as to what type of science should be taught to pre-university nonscientists should have been taken after substantial discussion with the various players in the educational field. Not least, one should have involved practitioners and teachers of science. There is no evidence to suggest that the matter was discussed at all outside of a tight circle of persons, who, needless to say, were apparently more concerned with the overall picture than the nitty gritty details of its component bits. After all, the nitty gritty could always be sorted out later, somehow.

Even as we bemoan the manner in which, in the past, physics was imposed on the system as the science subject for the secondary school masses, we, today, see similar impositions being inflicted on the post-secondary science sector with the same abandon and apparent relish as in the past.

I plead with the decision-takers of this land: please inform your minds before you make them up. Look before you leap. The context of any decision should consist of a set of options each of which is accompanied by attendant repercussions and these have to be thought through and agonized over, if need be, before any conclusion is arrived at.

I do not think that all the implications of the recent curricular changes for an ostensibly better sixth form were scrutinized quite in this manner.

At this point one counsels patience and perseverance with the new system. In the spirit of science, we should observe the new model, give it time to produce results and after due process and in the light of the data gathered, modify the model with caution, respect and a great love for the student body of the coming century. It is their necks that risk getting broken if we do not look before we leap.

Profiles

Jan Harding Ph.D.

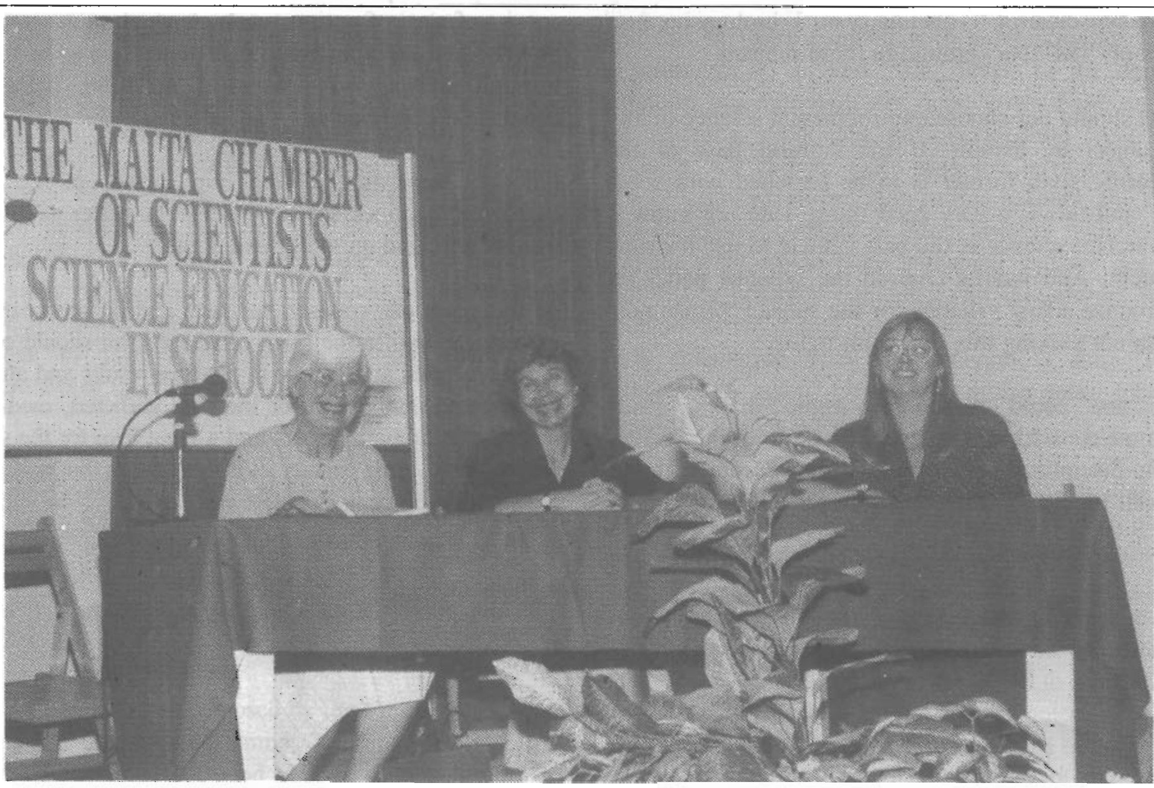
Jan Harding is currently an equal opportunities consultant and chairperson of GASAT (Gender in Science and Technology). She has devoted her career to promoting Science and Technology among women and as a result has cultivated an international reputation. She completed a research fellowship which led to a Ph.D. at the University of London in 1975. She has contributed to, or organised numerous courses for science teachers, workshops and conferences aimed at promoting women in science all over the world. She is a member of the Fawcett Society Education Committee, external examiner at a number of Universities and an elected Fellow of the Royal Society of Arts.

Elizabeth Whitelegg B.Sc.

Elizabeth Whitelegg is a lecturer in Science Education and Director of Research in the Centre for Science education at the Open University. During her 21 years experience working at the Open University, she has contributed to numerous OU courses for undergraduates, postgraduates in physics and in women studies and more recently she has written materials for the professional development of teachers in physics. She is now the Director of the major curriculum development project for school and college students - the supported Learning in Physics Project. She is a member of the Collaborative Learning in Primary Science Research Project and a founding member of the Northern European Gender and Science Network.

Susan Tresman Ph.D.

Susan Tresman has worked for the Open University since 1981 as member of Central Academic Staff based at the Walton Hall Campus. Her Ph.D. is in Vertebrate Palaeontology (King's College, London). She is a qualified teacher holding a Post Graduate Certificate in Education in Biology with Physics from the University of Cambridge. She directs the largest Government funded programme of training for teachers of primary science in the UK, with many partnerships between the Open University and Local Education Authorities. Dr. Tresman is collaborating with Science Educators in Australia to spearhead similar programmes in New South Wales, Queensland and Western Australia. Her present position is Programme Director of the taught M.Sc. in Science, and Director of Teaching in the Centre for Science Education.



The three invited foreign speakers during a session of the Forum for Science Education in Schools organised by the Malta Chamber of Scientists. From left to right, Jan Harding, Susan Tresman and Elizabeth Whitelegg.

Correspondence

Maltese Scientists in the USA

1st August, 1996

To the Editor - Congratulations! You have done a commendable job for a project that I believe would be most important for the Maltese scientific community and those individuals wishing to learn more about on-going research.

I would like to introduce myself to you. I am a science writer and the associate editor of *Chemical Engineering Progress*, a magazine for chemical engineers. I write technology-related articles for the magazine. I have an undergraduate degree in Biology and more than twenty years experience as a writer. My family is Maltese but I was born in the States.

I am also writing to let you know that if you would like an article written about Maltese scientists doing research in the United States, I would be most happy to interview those individuals and prepare the articles.

I also hope you decide to sell *Xjenza* subscriptions to college libraries here in the States. I believe this is important so more people will be acquainted with Maltese scientists and researchers.

Again my sincere wishes for continued success with *Xjenza.*

Claudia M. Caruana
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Science Education and Language

30th November, 1996

To the Editor - Allow me to start my letter by expressing a few words of praise for the recently launched scientific journal, *Xjenza*. It is indeed a journal of good calibre produced by Maltese Scientists for Maltese Scientists. It not only serves as a "local outlet for their work" but more importantly as a launching pad for the younger generation scientists who are having their first go at producing a scientific write up and who subsequently aim to publish in international journals. The sections are well balanced and the subjects cover a broad spectrum of topics which serve to arouse the interest of the majority of scientists.

I would also like to comment on the 17th Business and Science Meeting: Science Education which was held at the University of Malta on Thursday 28th November, 1996

The emphasis laid on the importance of science education was definitely a step in the right direction. Science is the keyword in today's technologically dependent world. It was very encouraging to hear the Education Minister, the Hon. Mr. Evarist Bartolo, M.Ed., express parallel opinion on the subject. During his first month in office, he has repeatedly and emphatically expressed his concern on the need for improvement in science education.

The Malta Chamber of Scientists, is actively striving towards the promotion of higher levels of science education. Activities like the Forum for Science Teachers into the 21st Century: Science Education in Schools, and the Science Education Business Meeting are evidence in this regard.

At the latter meeting, it was remarked that students taking examinations in physics scored low marks because of difficulties experienced in comprehending the linguistic presentation of the questions, which incidentally happened to be in English. This problem was claimed to have been resolved, or thought to be so, by restructuring the questions to include less English phrases and make more extensive use of diagrams. This line of approach offers cause for concern. If students are accepted to operate with a mediocre level of English, they will undoubtedly come to face problems in communicating on parity with other scientists and in drafting and comprehending scientific literature. The inherent ambition of students should be to enhance their linguistic potential which will prove to be most useful in furthering their scientific education. Lowering of standards is not to be condoned in any way. Students should optimise their advantage of being multilingual rather than dispense with the need for a good command of English.

Thank you for allowing me space in your journal to express my views. I reiterate my congratulations to you and the Editorial Board for your good endeavour in producing an outstanding Maltese scientific journal.

Well done!

Dr. Marilou Ciantar B.Ch.D.(Hons), M.Sc.(Lond)
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Malta.

Erratum

Motor Vehicle Accidents: Analysis of Casualty Department Data, St. Luke's Hospital, Malta.

Maurice N. Cauchi
Department of Pathology, University of Malta Medical School, Guardamangia.

Xjenza 1996; 1:1 35-38

1. In Table 1 (p35), Table 2 and Table 5 (p36), of this article, the columns labelled 'Total' may be slightly higher than the sum of 'Male' and 'Female' patients. This results from the fact that where the gender of the individual patient was not clearly stated in the hospital Casualty Department Data, it was entered as a missing value, and would therefore appear in the total but not in the individual male/female columns. This was inadvertently omitted from the text.
2. In Table 6 (p37), the total number of patients from M'Scala should have read 15 and not 10. The percentage figure is, however, correct.

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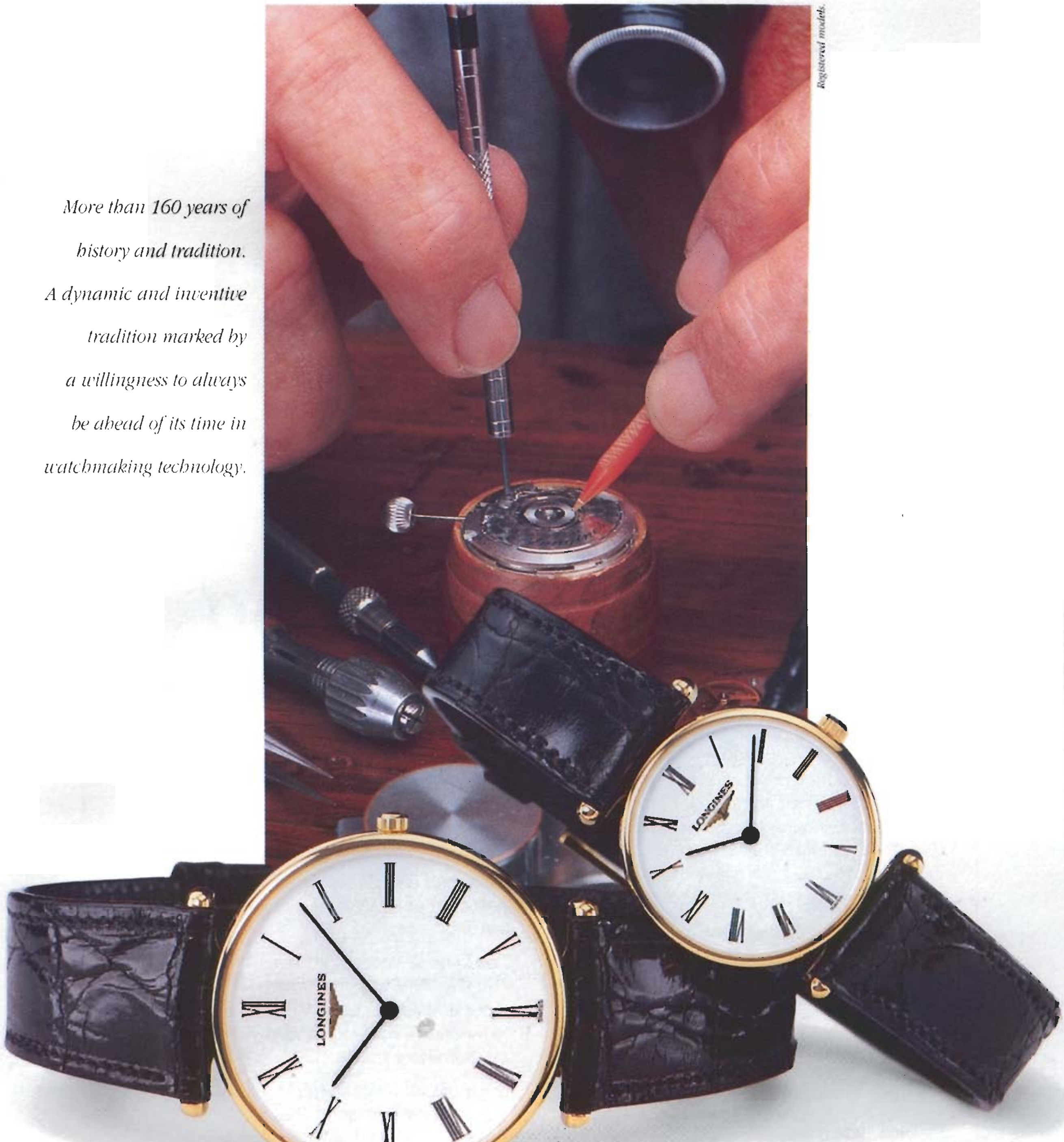

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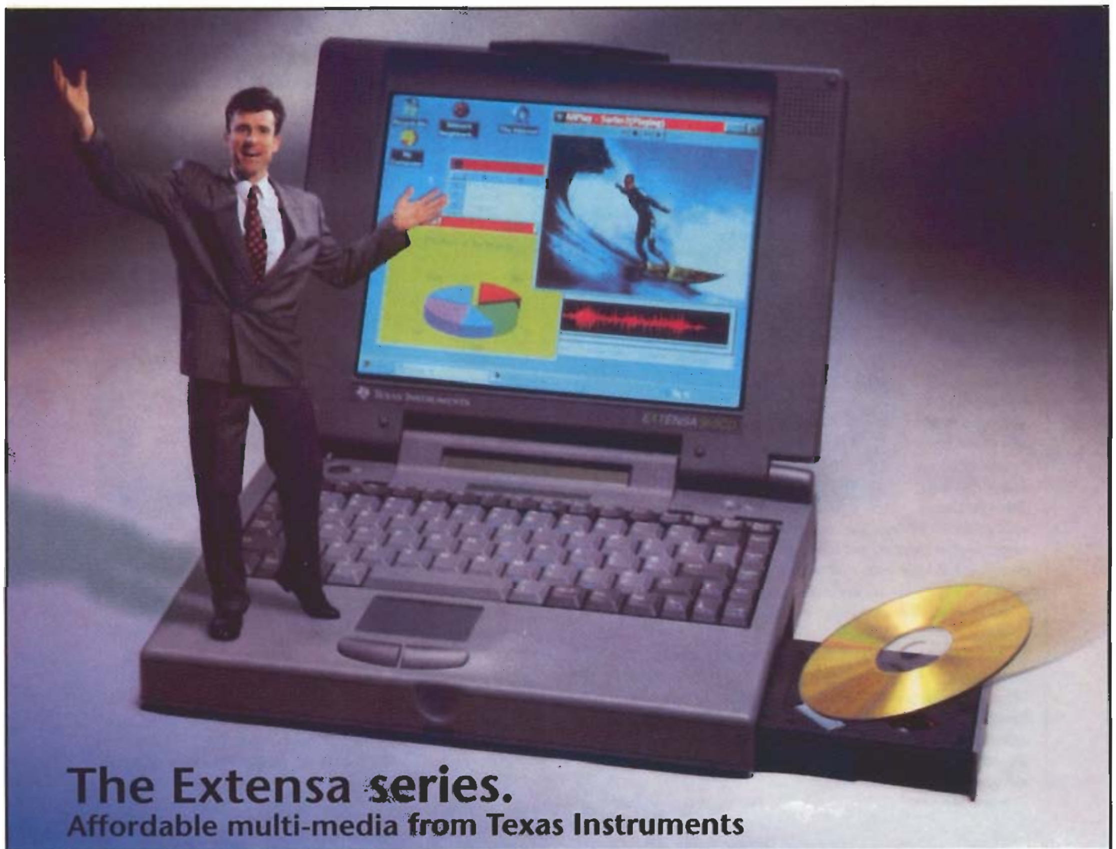

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