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 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.

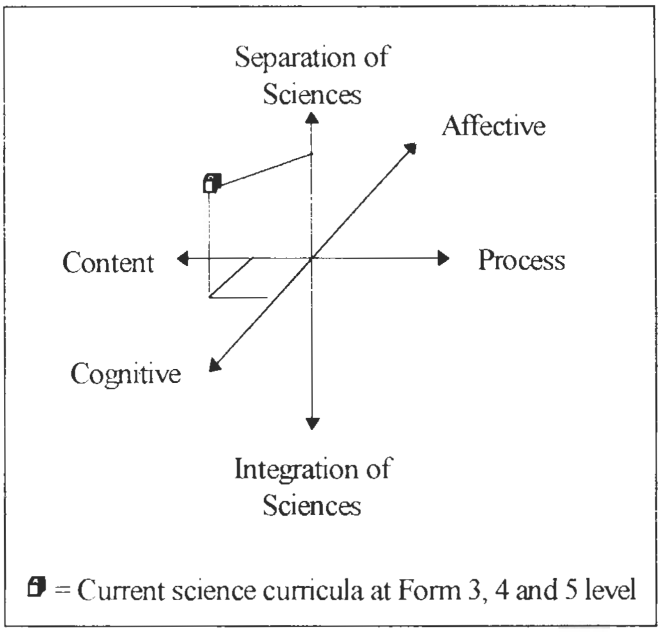

Figure 1. Dimensions of Science Content.

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 consis ent 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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