Technological Education and Science in Schools

*Association for Science Education**

We reprint, with acknowledgement excerpts from a recently published occasional paper of the ASE.

Commitment to Technological Education
The ASE believes that all pupils, both boys and girls, are entitled to a balanced technological education throughout their time in compulsory schooling.

Rationale for Technological Education
This technological education should form an integral part of every pupil's liberal education, through which they would develop an appreciation of their world and its culture, build up problem-solving and decision-making skills and gain a personal maturity which would enable them to play an active part in being in control of their environment. Such an education, developing the pupils' self-confidence, interests, skills and sensitivities would also provide an appropriate preparation for adult life and employment, both in industry and in the service and caring professions.

Aspects of Technological Education
The technological education of each pupil should consist of four distinct but interrelated strands. Some of these strands should be experienced through existing subjects and areas of study; others would necessitate a discrete time allocation in the curriculum. The ordering of these strands is not significant and no sequential hierarchy is to be inferred.

a) *Technological Literacy*
Each pupil should be made familiar with the content and the methodologies of different technologies. There is a range of technologies, not just one, containing different knowledge and approaches, about which all pupils should know and understand. (As we are familiar with talking about the arts, the humanities and the sciences as plural, collective terms, so we should envisage the technologies.) It would be inappropriate for the ASE to seek to define the content of this strand of technological education; indeed it might well change with time and with the local context. However, we would envisage that it would include a broader range of technologies than the traditional ones associated with mechanical and electrical engineering; it would also include those relating to the production and utilisation of textiles and food, to the provision of housing and health, and to both 'high technology' and alternative technologies. Good exemplars already exist for much of this in the existing curricula of CDT, home economics, computer studies and science departments. We suspect, however, that more work needs to be done to produce a comprehensive, co-ordinated curriculum in this area, and to make much of the existing material less gender-biased. For pupils to be technologically literate in modern society, all should have a sound appreciation of these aspects of our culture.

(b) *Technological Awareness*
Along with a knowledge of the different technologies, each pupil should be made aware of the personal, moral, social, ethical, economic and environmental implications of such technological developments. Such an awareness should be developed in the context of most subjects and areas of study — through history, geography and English as well as through the sciences, home economics and CDT. In science, this technological awareness is being developed through 'social, economic and environmental' implications of the science taught and is being reinforced by the National Criteria for GCSE awarding 15% of the marks for it. Resources are becoming available through such initiatives as SATIS (Science and Technology in Society), Science in Society and SISCON (Science in a Social Context).

(c) *Technological Capability*
In addition to being different technologies and aware of their implications on society, all pupils should be encouraged to develop their own technological capability in tackling a technological problem, both independently and in co-operative action with others. Such a capability would tackle realistic practical problems which require consideration from a variety of perspectives; technical, scientific, aesthetic, economic, social and moral. It would utilise knowledge, both explicit and tacit, from a variety of disciplines and incorporate the use of the 'technological process' with all its inherent humanity of 'trial and error' based on personal experience and creativity, feedback and evaluation. This would involve active engagement with technological tasks, and would require a significant amount of time to allow for an adequate response. A technological task might, for instance, be to increase the energy conservation in the school, to develop a kit to prevent old people getting hypothermia, to design and construct a game or a teaching aid for handicapped youngsters, or to research and design an ergonomically efficient kitchen. These activities would be synthetic, bringing together the knowledge, experiences, resources and skills acquired in other subject areas. As such they would differ from the traditional subject-based approach adopted in many secondary schools, being more similar to the interdisciplinary, topic-based work of the primary schools. Though it is possible to develop technological capability in other subjects, notably CDT, home economics and science, it is likely that the most effective approach will necessitate a more interdisciplinary structure.

(d) *Information Technology*
Each pupil should acquire competence and confidence in the technological handling of information during their school life, both as a preparation for life in modern society and also as an important skill required for developing technological capability. We believe that this should be taught as an integral part of different subjects, or as appropriate to a particular task, rather than as a separate subject. In science, for instance, computers should be in the laboratories for normal and regular use in data handling, simulations and interfacing with practical experimentation.

Technological Ethoc
Beyond the technological education that pupils receive through these four strands in their formal curriculum we believe that each pupil should receive their education in a school ethos which regularly encourages technological activities. This might include technological clubs, inventors and 'great

egg race' type competitions, fashion design shows, displays of technological projects, school plays, Young Enterprise and CREST ventures, and activities in PSE. The school administration should also be seen to be utilising modern technology. While much of this ethos can be part of the experience of all pupils, other extra-curricular activities involving only a minority of the pupils can also have a beneficial and stimulating effect on the whole school, and should be encouraged. Science teachers have, as they have demonstrated in the past, an important contribution to make to this aspect of a technological education.

It will be seen that the technological awareness and the information technology aspects of a technological education are multidisciplinary, and should be experienced through all subjects, or through the areas of study in the primary schools. Technological capability depends on skills and knowledge acquired through many subjects but, because they need to be brought together in synthetic activity focused on a technological task, and because of the considerable amount of time required for pupils genuinely to engage in such work, this aspect would need a separate time allocation. In the primary schools this will most appropriately be integrated with the science teaching. Similarly, for technological literacy to be developed coherently through teaching the technologies, periods specifically allocated to them will be required. If Technology is to be considered as a separate subject, it would include these two aspects of development technological competence and acquiring technological literacy. A technological ethos should permeate the whole school.

Ownership of Technological Education

The question of who takes responsibility for the technology education in a school raises important practical and political problems. The obvious possibilities are the science department or the CDT departments, though home economics and IT might be considered possible candidates too. Whilst there are many successful examples throughout the country in both science and CDT, both alternatives have traditional problems associated with them. The science department runs the risk of limiting technology to a particular form of scientific problem-solving in investigational practical work, coupled with the applications and implications of science through 'Science and Society' type activities. The CDT department might bias the teaching towards a rather narrow, male-orientated model of technology exemplified typically by some of the GCSE courses for CDT or the Schools Council Modular Technology Course. Neither tradition encompasses all the aspects of a technological education as outlined above. A third possibility is that a technology co-ordinator (or consultant) be specifically appointed to the school hierarchy to take responsibility for 'technology across the curriculum'. Such a post raises the question of why such special pleading should be for technology alone; similar considerations could, and should apply to many other aspects of the curriculum. The most satisfactory solution is for each school to develop a 'whole school curriculum policy' for all aspects of the entitlement curriculum, including a consideration of 'technology across the curriculum'. Thus the technology co-ordinator might be responsible to an ad hoc steering group set up to establish such a policy. In primary schools the team leader would probably co-ordinate the science and the technology together. Such a curriculum, co-ordinating all aspects of the pupils' learning, including the technological education, needs to be developed by senior management in each school, taking account of local initiatives and policy from the LEA and guidelines from the DES National Criteria.

The Organisation of Technological Education

In the primary schools, the characteristics of the scientific and the technological approach are not easily distinguished and they are normally, and appropriately, taught together. Other areas of study will contribute to technological awareness from the natural extension of their own work. Much of the best work in the primary school will be developed not through 'subjects' but through integrated, interdisciplinary, investigational topic-work of a type which lends itself naturally to development of a technological education.

In the secondary schools, a strong reliance on discrete subjects taught regularly, and independently, throughout the school can impose constraints on the development of an integrated technological education. Though it can facilitate the structuring of an ordered progression in technological capability, it would be a mistake to think that such an appearance of hierarchical development represents the reality of the way that technological problems are solved. Too much reliance on any particular technological or design method, often imposed on reality post-hoc, can be delusory, premature and inhibiting. Technological education, above all, needs freedom of expression and a variety of opportunities for different approaches. Currently, little is known about the way that pupils, and technologists, solve problems, but we are convinced that success and progress in technological capability can best be judged sensitively by the originality and appropriateness of the solution rather than against any mechanistic application of criteria in preordained sub-skills.

Where technology is taught as a separate subject, considerable care needs to be taken to ensure that all aspects of a technological education are covered either in that subject or in others. The dangers of overlap between the science and the technology 'departments' in the ownership and teaching of such subjects as electronics, energy and structures can be eased by the organisation of a single 'science and technology' department responsible for, say, 30% of the timetable. This, however, causes unhelpful separation at the other end of the curriculum spectrum, divorcing technology from its other relatives in craft, design, home economics and business studies. It is helpful to organise the timetable so that blocks of time of different lengths are available for different aspects of technological education. Some units, or modules, would require only a short time; others, particularly the technological project work, would require a long, extended time span. Such modules of work would not, as a general rule, be optional (option systems based

on a free 'pick and mix' principle lead inevitably to unbalanced, unco-ordinated and gender-biased uptake) but would have the advantage of flexibility in time allowance and distribution. For instance, it might be argued that all pupils should study *modules* in electronics, in keyboard skills, and in household management, whereas it could not be argued that every pupil should, or could, study whole *courses* in electronics, information technology and home economics. Similarly, the introduction of blocked periods of time, such as project weeks, or regular whole days, would enable the interdisciplinary aspect, the community involvement and the individualistic nature of technology education to be developed. There is evidence that much very impressive work is being done in schools where such frameworks have been established.

Overall, we believe that technological education should be organised according to a whole school curriculum policy set in the context of a largely common curriculum. We would want all pupils to have equivalent experiences in developing technological awareness and technological literacy, and though the tasks through which they develop their technological capability may differ, such variation should not be determined by traditional gender stereotyping. We would expect boys and girls alike to be involved with the same technologies, including those associated with food, textiles, electronics and 'high technology'.

If the technological education is arranged as outlined above, it is likely that about 10% of the curriculum time will be required for acquiring technological literacy and developing technological capability. This could be timetabled as a subject called Technology. Preferably such an allocation will include longish periods of time, such as project weeks, to allow for extended, co-operative work. The distribution of teaching resources is likely to be most effective if some use if made of curricular modules, and if the science, the home economics and the CDT teachers work in the closest co-operation. This blending of the science and the technology departments together is particularly important if the best use is to be made of teachers with skills in both areas. If faced with the alternative of teaching science in the science department or technology in a technology department, such a teacher may well opt for the latter, to the detriment of balanced science teaching in the former.

Contributions of Science to Technological Education

The scientist can make a considerable contribution to each aspect of the technological education of all pupils, as the relationship between science and technology is inextricably entwined. Science teachers will be able to contribute to the pupils' technological education both through the teaching of their own subject and as members of a multidisciplinary team working on technological tasks.

Many science teachers will be able to increase the pupils' Technological Literacy by using their own expertise in such areas as electronics, computing, home economics, biotechnology and industrial methods. They will also be able to act as consultant and resource to other teachers, a role well established in many primary schools.

The Technological Awareness of pupils will be enhanced as the science is taught in its 'social, economic and environmental' context, considering the applications and implications of science in our technological society; this is at the heart of 'science for citizens' and is central to all the science courses for GCSE.

Aspects of Technological Capability can be reinforced by the use of investigational practical work in science. The model of 'science as a problem-solving activity', as developed by the APU, has many similarities to the technological process, the fundamental aspect being the involvement of the pupils in planning their own investigations. Though most scientific investigations are more constrained by time, resources and intention than technological tasks, the process of working for the pupil will be similar. The scientific knowledge and understanding that the pupils have gained through their science lessons will provide a vital resources for solving technological problems. Similarly, as science lessons increasingly include simulation exercises involving value judgements and societal implications, practice in such decision-making will also provide important experience for tackling technological problems.

Science teachers should encourage the pupils to become familiar with computers as a normal part of their science lessons, using them as a basic teaching aid. Thus the pupils will gain confidence and familiarity with the use of information technology. All science laboratories should have the ready use of computers on a permanent basis.

Science teachers can enhance the technological ethos of the school through their normal teaching, through posters and displays, through science, photographic, animal and electronics clubs, through design and invention competitions, and through the use of visits an industrial and business experience for their pupils.

Summary of Recommendations

1. All pupils should receive a balanced, co-ordinated technological education throughout their years of compulsory schooling.
2. This technological education should consist of acquiring a technological literacy and technological awareness, and developing a technological capability through involvement with extended interdisciplinary technological tasks.
3. Every school should establish a whole school policy for technological education, and should appoint a technology co-ordinator responsible for the technological inputs across the curriculum.
4. Technology and science should be taught together in primary schools.
5. Balanced, co-ordinated technological literacy courses should be developed, incorporating a broad range of technologies. These should build on the strengths of courses, or course units, existing in technology, CDT, home economies, electronics, IT and science, but not be limited to them. Such courses should pay attention to the relevance of the technologies to the pupil and the local community, and ensure that each topic is equally suitable to boys and girls. Such co-ordinated technology courses should be less restricted than existing GCSE courses for CDT.

6. All pupils should, as far as resources allow, receive the same, or an equivalent, technological education. Options between different types of technology should not be offered, as this encourages gender polarisation and discourages discrimination in curriculum planning.
7. Technology should be given a separate time allocation in secondary schools to provide adequate time to develop technological literacy and technological capability.
8. Extended periods of time should be allocated for developing technological capability through projects on technological tasks.
9. Technological awareness should be encouraged in the teaching of all subjects and areas of study.
10. Information technology should be an integral part of the normal learning experience of all pupils.
11. Science departments should review their own policy and practice with regard to contributing to the technological education of all pupils, both through the teaching of the sciences and through co-operation and co-ordination with other departments.

The Delivery of a Technological Education

In considering what might be the most appropriate way to help schools deliver their technological education, we recognised that different schools have their own particular strengths, constraints and resources, and that this prevents any single curriculum pattern being recommended. We realised that the differences between schools, and the very innovative nature of technology itself, meant that what would work well in one school, with its traditions, staffing and structures, would not easily transfer to another with a quite different history. At the present time, when strategies and policies for teaching technology are changing so fast, we felt that it would be most helpful to highlight the key principles and encourage each school to work out their own co-ordinated policy as appropriate to the needs of their pupils.

It was clear, however, that whereas there was no national consensus about the way that technology should be taught, there was an increasing number of counties in which the advisory team was advocating, and resourcing, a clear policy for their schools. We were not conversant with developments in all countries, but were particularly impressed by the support, the resources and the guidelines produced by Staffordshire, Wolverhampton, Hampshire, Sheffield and Gloucestershire, where teachers were helped to work co-operatively together in sharing ideas and experiences. In many areas the TVEI schemes were encouraging schools to reconsider their technolgical provision too. Similarly, the work by the Technology Education Project based at St. William's Foundation at York, Sheffield and Leeds, and SITE (Science in Technology Education) based at KQC London and NCST Trent, was supporting teachers in their development work, teaching technology in an inter-disciplinary manner. Further details of these schemes are available from Professor D. Layton at Leeds University and Professor G.B. Harrison at Trent Polytechnic.

Perhaps the best way forward for a school seeking to establish its own co-ordinated policy for delivering a balanced technological eduation to all its pupils is for each school to seek its own answers to questions such as those below. The questions have been set under headings of different approaches which might be incorporated. Most schools are likely to utilise something from most of them.

Discrete Subject Enrichment

- Which subjects will receive a 'technological flavouring'? Science? English? geography? home economics? CDT? all of them?
- What changes are necessary to provide such enrichment?
- Should different subjects incorporate different aspects of technology?
- How will the progression in technological enrichment ensure that it is appropriate to pupils of different age and aptitude?
- How much co-ordination is necessary between the subjects?
- Who will do it?

There is much evidence of most subjects becoming more, but not excessively, technologically enriched.

Collaboration between Subjects

- How formal should such collaboration be?
- Which departments should collaborate?
- Would the formation of a single Science and Technology Faculty help?
- Would the linking of technology with science separate it unhelpfully from its other relatives in the creative arts departments?
- Can the curriculum be satisfactorily co-ordinated without the closest co-operations between different departments, with their different cultures and traditions?
- Who is responsible for the co-ordination?

It is clear that much constructive work has been developed in schools where the science and the technology departments work closely together, often as a single faculty, though other combinations of subjects can also prove successful.

Structured Courses called Technology

- Which of the published courses would help to prepare for which GCSE course?
- Should the GCSE course be a Mode 1 from one of the examination groups or a Mode 3 to produce an appropriate course within the GCSE criteria? (We were impressed by a Mode 3 submission from Sheffield, which was structured under five complementary headings of Technology and the Individual, Technology in Home and Community, Technology and Industry, Technology in a Changing World, and Global Perspectives; such a comprehensive curriculum emphasises the values as well as the skills involved.)
- Should a technology course be approved under the CDT criteria or as a science, as LEAG offer?
- Can a technology course be linked to a balanced science course to produce

a co-ordinated package in about 30% of the time? This would increase efficiency through co-ordination and enable a single extended project to be developed which satisfied the GCSE requirements for both subjects. (Such an arrangements is being developed in some schools.)

- Should introductory technology courses consist of pupils rotating around woodwork, metalwork, textiles and home economics rooms, or should integated courses be developed centring on less restricted problems?

Free-Standing Projects

- Should the school set aside some time and resources to establish projects centring on the needs of the community, which bring together groups of pupils and staff to work apart from the constraints of the normal curriculum?
- Should the timetable be restructured to allow for extended periods of time to work on such projects?
- Is technology best taught through dribble or dunking, i.e. through short periods of time, regularly throughout the school year, or through more total immersion in longer periods of time, less frequently ? Some schools have had success by devoting afternoons regularly, or one whole day per fortnight, or a project week at the end of term, to such work. Some schools have organised joint projects with local industry, or other groups in the community.

Modular Curriculum

- Should all, or some, of the curriculum be based on a modular structure?
- Would the synthesis of courses involving modules from both technology and science utilise subject specialisms most efficiently?
- How much choice should pupils have in forming a balanced and sensible whole for themselves?
- Can a modular structure with pupil choice avoid gender stereotyping in the options?
- Could such courses be accredited for GCSE?

Currently many schools are experimenting confidently with such a structure and finding ways of having it accredited through such schemes as the Oxfordshire Credit Bank, organised by the SEG.

Hidden and Informal Curriculum

- How far is the hidden curriculum of the school conveying positive messages about technology?
- Are the products of technological activities adequately celebrated in the school?
- Is the technological message set firmly into a moral and compassionate context?
- How far does the informal curriculum include clubs and competitions such as CREST or Young Enterprise initiatives which stimulate the inventiveness and creativity of the pupils and involve adults from the local community as a resource?

In many schools the excitement and commitment generated by such activities is recognised as a central part of technological education which permeates the whole school. A danger is that if technology only comes through the informal curriculum it will be perceived as having secondary importance, and involve only a minority of the students.

We believe that each school can progress most profitably by answering such questions in the context of its own situation, building on the strengths and within the constraints of the local staffing and resources, and including where possible the opportunities and talents of the local community. There is no standard package of Technology that can be bought off the shelf, no single solution suitable for every school. Perhaps, at this time when England and Wales are moving towards a National Curriculum for all schools which would include a programme for Technology, it would be unwise for a school to invest too much in developing their own brand of Technology. But by building steadily towards a co-ordinated policy throughout the school, and increasing the technological component of different aspects of the curriculum, the technological education of all pupils will be enhanced.

Epilogue

Throughout our discussions, we were aware of the danger that our technology, as our science, could become mechanistic and divorced from the values and goals of the community it was intended to serve. Technology, indeed a rationale for introducing technology into schools, could be perceived in utilitarian terms, aimed at providing for the short terms needs of a materialistic and aggrandizing society. But technology without humanity and compassion would become dangerous. Technology without knowledge and skills would become ineffective, merely sentimental. Our challenge is to ensure that the teaching of technology with science in our schools encourage the development of moral and responsible attitudes for citizenship, as well as developing the skills which will enable informed compassion to be turned to good effect.