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ABSTRACT

It is important that young people are taught not simply to use technology, but to understand how it works and the principles on which it is based. This report explores the recent changes in science and technology, illustrates how and why science should be viewed as a basis for teaching technology, and considers why technology should be taught in relevant contexts. The main points of the report include: (1) the teaching of science and technology should be linked overtly to modern manufacturing processes and accepted improvements in management techniques; (2) there is great danger in the thinking that any teacher can teach any subject; (3) a clear definition of the scope of technology must be developed; (4) meaningful learning requires context, content, and process and none of them makes practical sense without the others, (5) there is a lack of scientific and technological understanding among investors and policy makers; and (6) if education and industry work together, a mutual understanding could emerge. (PR)

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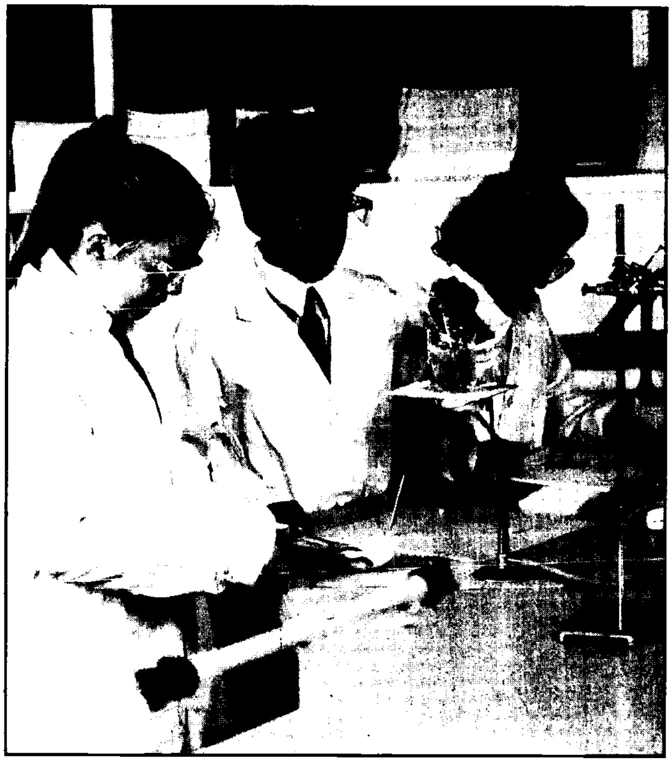

Technology, Science education and the world of work

Ian Lynch

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Technology, Science education and the world of work

Ian Lynch

Number 9 in a series of CTC Trust publications
General Editor Dr Helen Sharp

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The author

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Preface

The percentage of children who attend a City Technology College will always remain small. The success of the CTCs must therefore be judged, not only by the benefits to their own pupils, but for the inspiration and leadership they can provide for the whole of the secondary educational system. Ian Lynch's paper is a major contribution towards this end.

Technology, like motherhood, enjoys – and deserves – universal acclaim. But whereas the latter is readily definable and well understood, the former can mean so many different things to different observers or even different participants. I have always maintained that 'engineering' is not so much an identifiable discipline as a state of mind. Its key is the motivation to win utility by the application of science to tangible problems. 'Technology' shares many of the attributes of engineering though, as the author points out, it is not congruent with it – technology applies to activities where the engineering and indeed the scientific component may be a small part of the whole.

Nevertheless, for most endeavours in Technology, Science and Mathematics provide the essential foundation, with the greater emphasis on Mathematics – the idea of thinking in quantitative terms. The Mathematics needed for a technological mission may be very elementary, but it is almost always a key component. This is a theme which is here carefully and succinctly developed. What is intended is a million kilometers away from Craft, Design and Technology, where so often one saw projects entirely innocent of numbers and hence remote from the real possibility of application.

Ian Lynch also focuses on the question of how best to form links with industry. It is no easy task – it tends to be an expensive endeavour on both sides of the fence. But it can be done, and the author guides us on an exploration of means. It is the more valuable since it so clearly comes from direct experience of the challenges and difficulties of putting it into effect.

It is perhaps possible to be an inspiring teacher of French whilst remaining an island unto oneself. Such a person can inspire and encourage, can illuminate literature. It is much harder to imagine a solo performer succeeding in the development and success of Technology teaching in a school. Technology represents an itegration of many different branches of knowledge, understanding and skills. They are not within the province of a single individual. Technology studies have to be regarded, at least in some respects, as a team enterprise. And teams need management. Here again, Ian Lynch provides analysis of what is needed and experience on how it can perform.

Reading the paper will not in itself assure a successful end to the journey for anyone embarking on the responsibility of Technology and Science teaching in a school – but there could be no better starting point.

Professor Sir Eric Ash CBE
Rector of Imperial College of Science, Technology and Medicine

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Acknowledgements

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The photograph for the front cover was supplied by ADT College.

Ian Lynch
Curriculum Development Director
(Science)

Glossary

The following abbreviations are used in this document:

ASE	Association for Science Education;
AT	Attainment Target (National Curriculum);
BTEC	Business and Technology Education Council;
DES	Department of Education and Science (renamed Department for Education in July 1992);
EIU	Economic and Industrial Understanding;
GNVQ	General National Vocational Qualification;
HMI	Her Majesty's Inspectorate;
IT	Information Technology;
KS3	Key Stage 3 (National Curriculum);
KS4	Key Stage 4 (National Curriculum);
NC	National Curriculum;
NVQ	National Vocational Qualification;
SCISP	Schools Council Integrated Science Project;
SSCR	Secondary Science Curriculum Review;
TVEI	Technical and Vocational Education Initiative;
UCLES	University of Cambridge Local Examinations Syndicate.

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Summary

It is important that the young people of today are taught not simply to use technology, but to understand how it works and the principles on which it is based. In a rapidly changing world the scientific principles underlying technology are stable and less susceptible to rapid obsolescence. These principles therefore are a good foundation for transferable skills.

The Science and Technology curricula have undergone many changes in recent years, and continue to undergo changes. These changes must be managed carefully and the staff development necessary to re-educate teachers into new ways of working must be planned carefully.

This report explores the recent changes in Science and Technology and it illustrates how and why Science should be viewed as a basis for teaching Technology, and Technology should be taught in relevant contexts. The main points highlighted in the report are given below.

- The teaching of Science and Technology should be linked overtly to modern manufacturing processes and accepted improvements in management techniques. This is to ensure that students are motivated by seeing the practical application of their subjects in the world of work, and to ensure that they gain the skills necessary to enter useful employment after leaving school;

- Qualified teacher status in England and Wales is not subject-specific and there is great danger in the idea that any teacher can teach any subject; opportunities to teach Technology throughout the curriculum should be identified;

- A clear definition of the scope of Technology must be developed. If this does not emerge, it may be more appropriate for Technology to be absorbed into the rest of the curriculum;

- Meaningful learning requires context, content and process and none of them makes practical sense without the others. Industrial contexts should be used at all stages;

- There is a lack of scientific and technological understanding among investors and policy makers;

- In planning the Technology curriculum, the Mathematics and Science Orders should make a stable base on which to build;

- If education and industry work together, a mutual understanding could emerge. This would allow education to understand better the skills needed by young people when entering the job market, and help educators to provide to employers appropriate information about potential employees;

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- CTCs are contributing to this through:
  - Developing strategies to bring Science and Technology curricula closer together;
  - Investigating schemes for delivering core skills through 'A' level Science assignments which can be transferred to vocational awards;
  - The City and Guilds Technological Baccalaureate, developed with and piloted in CTCs, contains a central core of Science specifically related to Technology;
  - Concentrating on providing well-planned staff development programmes;
  - Developing curriculum materials in partnership with industry;
  - Developing a technological ethos which pervades the curriculum (details of this are contained in *Essential Educational Characteristics*, from the CTC Trust).

I. Introduction

Technology is perhaps the most controversial area of learning. The natural links between technology and science which lead people outside education to talk about science and technology in one breath, have been under-represented in the subject-based curriculum of the secondary school.

There are many technological perspectives, but this paper is written by a technologist with a background in Science and Mathematics education and recent training in industrial and education management, therefore the perspective is clearly scientific. This paper addresses the issues which will determine effective learning of science and technology so that those working in the manufacturing industries of the future will be better able to make effective use of an increased scientific and technological capability.

The key issues to be addressed are:

1. Defining which skills and knowledge are needed for long-term technological capability;
2. Managing the change from previous systems to make sure that young people learn effectively in the domain of technology.

These two issues are closely linked. Associated with the first one is the need to understand that subject definition requires the three elements: context, process and content. This highlights the problem that what students need to learn is not necessarily matched by what teachers have been trained to teach. This mismatch can be made particularly acute when subject labels and title roles become more important than capability. If a truly broad and balanced capability in technology is to be achieved by young people at school, task-focused team approaches to teaching Technology across the curriculum need to supersede role-dominated cultures. A key area in realising success, therefore, is change management related to staff training, selection and development. Science has a fundamental part to play in providing the transferable technological expertise necessary for this approach.

Background

Along with mainstream educational change, Science and Technology education has been through several stages of rapid evolution in the recent past. Change has followed a path of disjointed incrementalism which, owing to the inertia of existing pedagogues and financial constraints (Shipman, 1984) has not been uniform, planned or all-encompassing. In her paper *Post-16 provision in CTCs: bridging the divide* (Jones, 1992), Ruth Jones provides an outline of the historical background which has

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culminated in the current educational situation, particularly with regard to Science and Technology in vocational contexts. Although she concentrates on the post-16 situation, her thesis is also pertinent to pre-16 education: the attitudes and aspirations of higher education have had a profound effect on the teaching of these subjects pre-16 through both the examination system and teacher training. The division between academic and vocational progression routes is mirrored in the division between Technology and Science. Indeed it could be argued that one is simply a manifestation of the other. Alan Smithers and Pamela Robinson have illustrated some of the associated problems (Smithers and Robinson, 1992a). For example they argue that for a career as a professional engineer, 'A' levels in Mathematics and Physics are much more important than an 'A' level in Technology.

Since the 1944 education act the 'modern' education era has produced numerous studies and views of how things should be done with respect to the content of Science courses and teaching methodologies. Although some interest groupings have exerted pressure which has ensured an unprecedented change in some demographic aspects of provision, there are still many areas in which education has changed very little over the years. For example the 'balanced science' movement has succeeded in ensuring that all students are provided with an education involving the main areas of Science up to the age of 16 through the National Curriculum. However, academic 'A' levels, suitable for only a minority, remain predominantly the acknowledged route for further study of Science post-16. It is rare to find joint approaches to Science and Technology curricula between Science and Technology faculties pre-16 or at 'A' level and even rarer to find joint planning of work which also relates directly to work contexts.

It is not the intention at this stage to put a value on the merits or otherwise of the changes which have or have not taken place, but merely to point out that the context of this document is one of unprecedented change initiated from a wide range of loosely coupled sources. The rate at which change is embraced has been recognised as a major factor in the success or failure of its implementation.

> A final source of difficulty identified by the staff was the rapid speed of innovation that seemed to characterise the school. Reform project after reform project confronted them... (Dalin and Rust, 1983, p99)

The pressures for change are based on both political and educational perspectives which result in a rather confusing melée of signals for the classroom practitioner. It is also important to realise that curriculum planning is by its nature medium to long term and simple initiation and adoption are not enough to ensure success.

> Bureaucratically speaking then, the political and symbolic value of adoption is often of greater significance than the educational merit and the time and cost necessary for the implementation follow-through.
> (Fullan, 1982, p51)

Since education is essentially a labour intensive activity – teachers are its most expensive resource – structural changes to management organization, syllabi, and hardware will make only marginal differences if they do not enable classroom teachers to re-educate to new ways of working. Large numbers of teachers are expected to teach in unfamiliar areas of the curriculum due to a number of factors, mostly related to recent reforms: the Craft teacher teaching Electronics, the Physics teacher teaching Biology and the English teacher teaching Information Technology. Well-intentioned change will do more harm than good if the teacher is not adequately prepared and essential reform may be brought into disrepute when the outcomes appear negative.

Qualified teacher status in England and Wales is not subject-specific and there is great danger in the idea that any teacher can teach any subject effectively, even before Key Stage 3 (KS3). Some might be able to, but they are rare and we need to consider the art of the possible for the majority in raising global standards. For example, there are relatively few teachers who could answer the following question.

> Ile wody zuywa dziennie twoja rodzina?

The question asks how much water do you and your family use each day at home? The language is Polish and there is no guarantee that even a qualified languages teacher would recognise it. This might seem to be an extreme example, but there are many unpredictable instances where specialist knowledge in a variety of subjects is important for everyday classroom activity. Although non-specialist teachers might be able to deal with some things, statistically the specialist will waste less time, be more efficient and less prone to disseminate misinformation. Increasing breadth across the curriculum is desirable but an assumption that specialist skills and knowledge are no longer needed or that everyone is capable of becoming a specialist in all fields is not founded in rational analysis. The future is about management and the strategies which can be adopted in order to ensure that the student receives balanced provision from expert staff working together.

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II. Science and its relationship with Technology

Changes in the Science curriculum

The wide scope of influence on the Science curriculum is illustrated by some of the main sources of reform in recent years. From the teacher's side, curriculum innovations such as Nuffield Science and the Schools Council Integrated Science Project (SCISP) provided the pointers towards new teaching philosophies in Science. From the political side, in 1976 James Callaghan raised the profile of education in his Ruskin Speech and the so-called Great Debate was initiated.

The Secondary Science Curriculum Review (SSCR) which was a direct result of the Great Debate took place through the early 1980s and provided an opportunity to review practice and report on many unconnected innovations in Science teaching across the country. This resulted in a plethora of courses, materials and information which were documented in the form of a directory of resources and other books in the *Better Science Series* published by the Association for Science Education and Heinemann (ASE, 1987). More recently, attempts have been made to distil the best practice which emerged from these developments and this lead to a statement of policy for Science from the DES in 1985 and more recently criterion-referencing for GCSE Science, and *Science in the National Curriculum* (NCC, 1989). This latter document has itself undergone a major revision within the first three years of its life.

The Science curriculum has thus undergone dramatic change over the last decade, with strategies for management of change being key to their success. Slater (1985) suggests two approaches to the management of change: political and rational. In practice, though, things are less clear cut. The professional and political pressures for change are not discrete from one another and both have contributed in complementary as well as contrasting ways. In the final analysis, despite all the changes, Science has maintained a core of familiar content which has at least enabled teachers to approach development from a foundation which is familiar. This is less true of Technology where a plethora of interpretation from different perspectives can still cause confusion.

The emergence of Technology

In the recent past, technical subjects had been strongly associated with craft skills. Before comprehensive schools, secondary modern and technical schools offered lessons in subjects such as metal work, wood work and cookery, while it was not uncommon to find grammar schools which offered none of these subjects at all but concentrated on pure science.

The problem with developing specialist craft skills is that they take enormous quantities of time to perfect and are not necessarily widely applicable or transferable; added to this is the increasing tendency for machines to take over tasks which were previously only capable of being done by people. Deciding which skills to teach and which not to teach requires a combined knowledge of new technology, old technology and educational purpose which is very sparse both in educational and industrial circles. There is tension between highly job-specific vocational skills epitomised by National Vocational Qualifications (NVQs) on the one hand and broad generic processes epitomised by National Curriculum Technology on the other.

The timing of comprehensive reorganization which just preceded the new technology revolution is a significant factor in the way Technology has emerged as a subject. When modular Technology courses were introduced, they included subjects such as electronics, pneumatics, structures and mechanisms. The nearest traditional subject discipline to these was Physics, and it would seem natural that teachers of Physics would have had a major influence in the teaching of modular Technology courses. However, the status of Physics teachers in secondary schools was high and Physics specialists were in demand, so there was little incentive to change from the pure science approaches which predominated their own training. Therefore, most Technology courses were taught from the pure science perspective, although some Science teachers did use technological contexts. Where more technological and applied science approaches grew from teacher interest in areas such as microelectronics, these were largely developed on the teacher's own terms and were rarely compulsory core elements common to all syllabi.

On the other hand, teachers of the craft and domestic skills, many formerly based in secondary modern schools, did not enjoy high status. It was natural for them to embrace Technology as their own since it carried more academic weight and promised to raise their morale and status as well as to attract additional funding through sources such as TVEI and British Schools Technology.

Teachers of technical subjects have had a major stake in the development of more recent Technology curricula. Business Education and Information Technology (IT) are intertwined under the technological heading in the National Curriculum but there is no reason to believe that Business Education teachers, often from office practice backgrounds, or IT teachers, often with little formal specialist training, have any particular expertise in technology as it is understood by most employers and people outside education.

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The lack of training of Technology teachers was a difficult problem to resolve until the technological *process* became Technology's main educational goal. Dropping the need for in-depth knowledge of content, contexts and skills in favour of a simple general process was a good way of mitigating against the need for training specialist teachers of Technology and for existing Technology teachers to maintain their positions without having to upgrade their skills. But the rational problem-solving process is not unique to Technology: it is used in English to structure essays, in Mathematics to apply algorithms to calculate results and in Science to make deductions. It has been argued that there are subtle differences between the processes found in different subjects and that this makes them unique to the subject. However, the validity of this argument is doubtful.

Before balanced science was introduced, Chemistry and Physics teachers often taught atomic structure separately and without reference to one another. At best this could be regarded as reinforcement, but arbitrary repetition is both inefficient and, from the students' point of view, often tedious. Technology provides a more serious dilemma. In the absence of an agreed definition of its scope, interpretation is left to individuals so that the potential for duplication of work in other subjects, lack of consistency between schools and sheer irrelevance is far greater. This is even more likely if teachers have little recent work experience of modern technology and have little direct training in technological subject matter.

The strength of a subject-based organization is in accountability, familiarity, targeting of expertise and administrative convenience. It is impossible to have this focus without definition and definition inevitably means some restrictions in scope. There therefore needs to be an agreed definition of the scope of Technology in education. If this does not emerge, then it may be more appropriate for Technology to be absorbed by other subjects in the curriculum.

Technology as a subject

There has been a movement recently to restrict the scope of Technology to engineering. However, engineering-based technology is not the only technology important to manufacturing industry and wealth generation and in any case, engineering is itself not without its problems of definition. For example, computer programmers call themselves software engineers; there is a world of difference between a graduate electronics engineer and the engineer who comes to repair the video. Most people use the word technology in a broader sense than just engineering.

From an educational perspective, it is difficult to define a subject called Technology which can serve to promote broad and balanced technological literacy and yet fit into a severely constrained time slot. Broad interpretations of Technology provide contexts (and an almost infinite diversity at that) where people manipulate their environment through a myriad of processes, both rational and phenomenological, in order to produce useful products from components about which there is some existing knowledge. The difficulty in providing an elegant and easily understood definition of Technology stems from the fact that it does not exist as a closed entity and it does not have the tradition of a stable set of generally-agreed axioms, as is the case with Science and Mathematics.

Meaningful learning requires context, content and process and none of these makes practical sense in the absence of the others. The corollary of this is that teachers must have knowledge and experience in relation to these areas in order to make learning meaningful to their students. Technology cannot be learned efficiently as a set of discontinuous activities: progression and transfer of capability would not happen and considerable repetition is likely.

Take, for example, two technological activities: designing an electronic circuit for a car ignition and designing next year's wall paper pattern. Both tasks are technological and with industrial relevance but one task would be best tackled by an electronics engineer with a physical science background, the other by a graphic designer with an arts background. In the world of work it is very unlikely that there would be any transfer between the two and it is unreasonable to expect an individual teacher to be expert in both areas. Broad coverage of technology can only be realised by harnessing expertise which already exists across the curriculum, particularly in the Science, Art and Design areas.

If the whole curriculum were to become technology-oriented, specific areas or contexts which are recognised by the rest of the world as technological must be identified (for example electronics, biotechnology, industrial food processing, textile production or computer-based graphic design) and a technological approach must be taken where appropriate in other subjects.

Science as a basis for Technology

Despite the reforms intended to rid education of the social divisions outlined by Ruth Jones (Jones, 1992) and the initiatives of bodies such as the ASE and the joint Science and Technology training programmes of British Schools Technology, problems associated with the practical versus intellectual divide remain. The polarization of Science and Technology as separate entities continues and inappropriate matching of teacher expertise to subject matter persists. In *Better Science: key proposals* the following statement is made on page 4.

> [The Science curriculum] should contain sufficient technological content to provide a bridge to the Craft, Design and Technology curriculum which all should also experience. (ASE, 1987)

One only has to compare the original National Curriculum Orders for Science and for Technology to highlight the lack of a cohesive and integrated approach. The Orders are completely different even at a structural level. Opportunities for building bridges undoubtedly exist but it takes people to see them, make them, and walk over them before they have any real value.

Instead of being seen as opposite poles, however, Science and Technology should be considered as interdependent: Science is the basis for technological understanding (see Figure 1).

The results of the application of scientific knowledge and techniques to improve material well-being through technology are in evidence everywhere. Although other animals are capable of some amazing feats of construction, for example the spider and its web, humans are unique in their ability to apply learned principles to produce large quantities of very reliable products through a diverse set of technologies. There are technological artefacts which are created with little scientific input and it is possible to work in some fields of technology with comparatively little training in science, but the most sophisticated technologies are usually based on the rigorous and systematic application of the fruits of scientific research. The crux of the matter, therefore, is whether or not we believe that there is value in learning some of the fundamental principles on which the technologies that we use are based.

In a rapidly changing world the underlying science is more stable and less susceptible to rapid obsolescence and it therefore remains a better foundation for transferable skills which, in the current climate of change, is vitally important. Unfortunately, many of the underlying scientific and technical principles are difficult conceptually, particularly if divorced from a familiar context. This is why the symbiosis of Science and Technology is an important factor.

Science education

The purpose of teaching Science is central to any rational approach in deciding how Science and Technology education should be organized. Scientific awareness and capability are an essential part of our development as human beings, for example understanding our environment requires scientific knowledge. Science can also be intrinsically pleasurable in an

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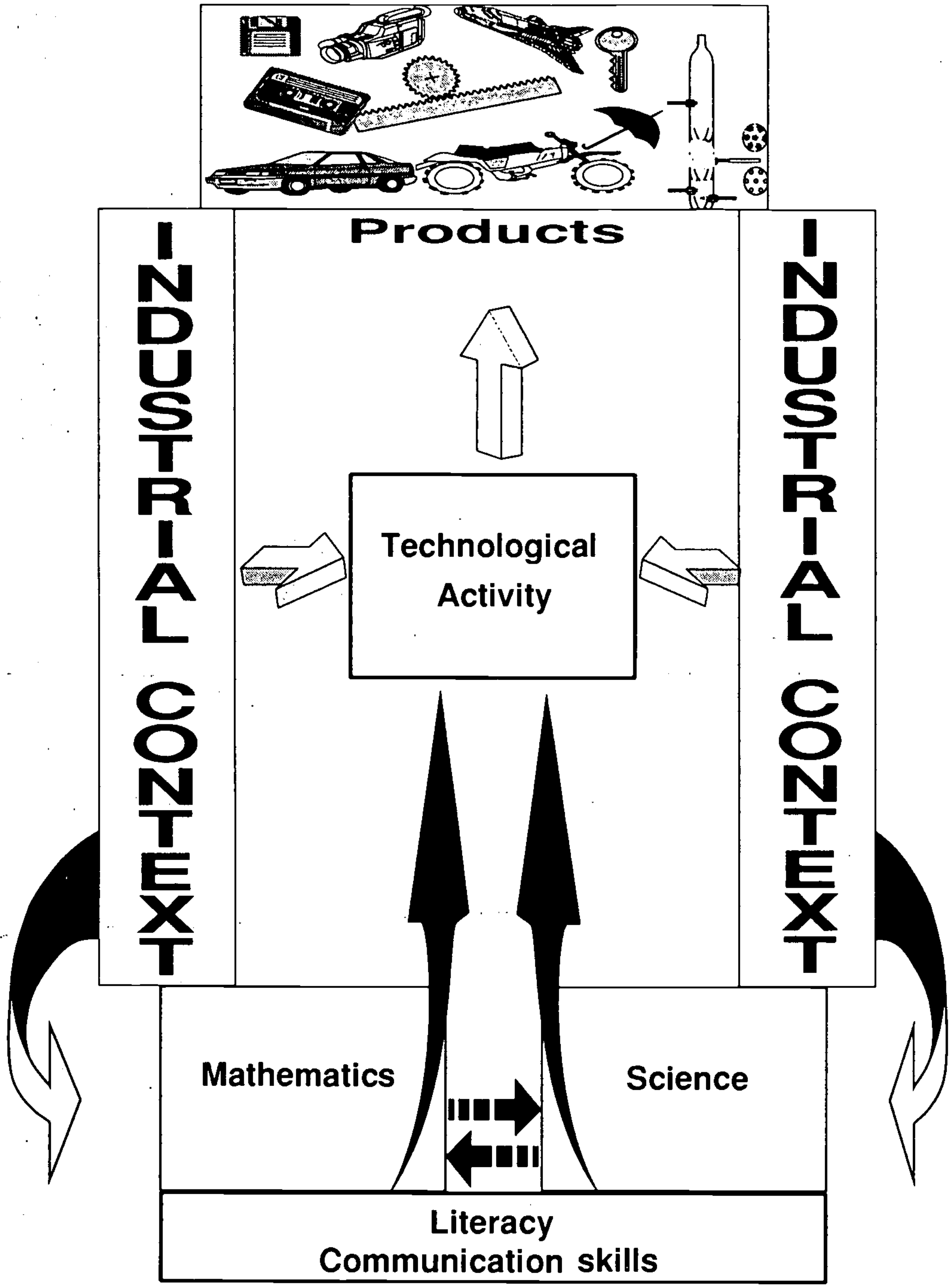

Figure 1. *Model for technological foundation*

aesthetic sense, with an appreciation of scientific elegance being no less rewarding than a study of Shakespeare or Rembrandt. If we require specialist scientists we undoubtedly need at least some of the population to be well versed in science. However we also need technicians who are prepared to update their skills from a solid foundation of general principles, managers who can make the right strategic decisions from the strength of understanding and investors who can back the winners of the future with hard cash. Better knowledge and understanding lead to better decisions in many fields.

A fundamental role of education is to prepare young people for adult life both in appreciating the aesthetic value of science and in providing a basis for improving the material quality of life for everyone. This inevitably means broad foundation laying in the early years with increased detail and opportunities to specialise later. However, broad foundation does not mean divorce from application or specific contexts and education should actively seek to bring examples from the workplace into the classroom whenever it is appropriate to what is being taught. For example, at Leigh CTC, industrial processes from the textile industry are used in modular Science GCSE at Key Stage 4 (KS4).

Contexts from the world of work have been used in this way in schools a great deal in recent years and it is clear that there is potential for Technology learning not only in Science but in other subjects too. As Michael Young points out:

> The result is that both the world of work and understanding technology, though often enthusiastically taken up by pupils and their teachers, have been taught separately from the mainstream curriculum subjects like English, History and Geography. (Young, 1989)

Leigh CTC have a cross-curriculum team specifically dedicated to developing larger scale Science and Technology projects which can incorporate elements from other subjects. In Year 7 these projects involve the opportunity for students to take part in the CREST (Creativity in Science and Technology) awards which staff have found particularly motivational for students, and for girls in particular. Motivation is a particularly under-estimated aspect in achieving greater participation in Science and Technology and the potential for providing this through other subject contexts has not been realised. As Paul Black points out:

> Concerns with effects of 'context' and 'motivation' are essential, but treatment of them as marginal trivializes a central issue. (Black, 1989)

A paradox of the fact that Science is seen by the population at large as difficult and the domain of 'boffins' may lead to lower uptakes in large sections of the population, but it is also responsible for the fact that a

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Science qualification is perceived as an indication of cognitive ability and such qualifications are therefore useful currency in gaining employment. In this sense, although heretical to some, a legitimate and pragmatic purpose for learning Science at school is to pass an examination which confers a certain amount of esteem and status within society. This reputation for difficulty has also guaranteed that formal study of Science beyond the age of 16 (and until recently pre-16) has been almost exclusively restricted to an intellectual closed shop capable of clearing the 'A' level hurdle.

Increasingly, however, vocational courses in technological subjects are inclusive of a foundation Science component and it may be that apart from academic specialization, the subject called Science is not needed post-16 if the foundations are laid through the National Curriculum pre-16 and specialist support science directly related to technological need is an integral part of other courses. The role of education is about preparation for future life and it is this preparation that is essential rather than just the cultural heritage of academic education and its associated labels.

CTCs are tackling this difficult area of post-16 education by considering the links between 'A' level and vocational courses through the International Baccalaureate, BTEC awards and GNVQ. Leigh CTC are, for example, looking at the delivery of core skills through 'A' level Science assignments in order to provide a basis for credit transfer and a more cohesive approach to the vocational and academic curricula with a view to keeping student options open longer.

Science and Technology education

Problems with fitting learning to the current legal assessment framework lead to fundamental questions of how Science and Technology should be taught. There are two views of the nature of Science:

1. Science is a body of knowledge built up over the centuries and continually expanding;
2. Science is a process and the methodology by which more knowledge and understanding is gained.

Views of Technology are more diverse because the word is used in many different contexts. However, as indicated earlier, Technology does basically have a process 'camp', reflected in the National Curriculum order, and a content 'camp' reflected in the Smithers report (Smithers and Robinson, 1992b).

Despite extreme views from some parties involved in the debate there is a reasonable consensus that broad and balanced Science, in terms of content and process, is the best route. Context has often been ignored in this debate, but it is no less important and is the main vehicle for generating curriculum links between Science and Technology and indeed other subjects.

The real problem is ensuring that teachers are able to make sound judgements about the construction of courses which reflect this balanced approach when they themselves have had little training in balanced Science and Technology.

- Contexts are nearly always specific, so what are the criteria for judging those which are most suitable?
- The knowledge base is vast, so how do we discriminate between the vital and the peripheral?
- Process is conceptually the most difficult, so how is it related to skills, knowledge and context?

This is compounded by lack of contextual experience amongst teachers and the continuing confusion about what Technology is and its relevance to the rest of the curriculum. All this is unlikely to foster the atmosphere needed to start more dialogue and strategies for co-operation between teachers of Science and Technology which HMI have identified as 'vital if a damaging and unnecessary division between Science and Technology is to be avoided' (HMI, 1985).

Despite these problems, the current generation of school leavers are probably the most scientifically and technologically literate young people that there has ever been. However, there is room for improvement and there is certainly no reason for complacency. With this in mind, CTCs are making some progress towards resolving the Science and Technology divide. Example strategies from ADT College, Dixons Bradford CTC and Macmillan College are provided in Appendix A.

CTC Science, Technology and the National Curriculum

CTCs are experimenting with ways of making the Science and Technology curricula less compartmentalized but at the same time being cautious about global constraints such as a National Curriculum which is geared towards a discrete subject model. The balanced science approach adopted by all the CTCs is evolving into a balanced science and technology approach in keeping with their curriculum emphasis with Science as a foundation for technological achievement. However, CTCs are as dependent as everyone else on central curriculum leadership and they are as concerned as others not to damage their students' interests by driving up curricular blind alleys.

Despite the extent of work done in the late 1970s and through the 1980s, the outcomes and interpretation of what constitutes good practice are still not unanimously agreed, but in contrast with the situation in Technology, there is a large consensus in the Science education community and among informed employers that certain ways of working are generally desirable. Some development pointers necessary to achieve this good practice are:

1. A better balance between scientific process and knowledge;
2. More learning through experimentation and discovery;
3. More emphasis on the student as a scientist;
4. A more balanced approach to scientific disciplines from 5 to 16;
5. More opportunities for scientific problem solving;
6. Better relating of Science to Technology and industrial processes.

These points are expanded and others included in *Science for all: SSCR recommendations* (ASE, 1987).

National Curriculum Science and Technology

Despite the effects of many influential factors, the National Curriculum remains the main agent for change in the Science and Technology provision for maintained schools. It could be argued that the National Curriculum has come at a good time in that the reaction to older knowledge based and didactic practices had already polarized some people to an extreme where there is a belief that process is the only way forward and that specific knowledge, understanding and context is not needed. National Curriculum Science attempts to bring about a balance whereby knowledge, skills and process are all important and the key to good education is getting the balance right.

National Curriculum Science is causing restructuring and reappraisal of schemes of work and teaching methods. This process should be beneficial to Science education as a whole and if successful will more than compensate for the problems of change everyone now encounters. As far as Technology is concerned, using the stability of the Science and Mathematics base as a starting point in planning the curriculum would be a sensible approach for two reasons:

1. The Mathematics and Science Orders have been revised and have had the most time to settle down;
2. All students must cover the core subjects (which includes Mathematics and Science), elements of which have direct relevance to Technology.

The technologists would be assisted greatly by such a move since they would have a foundation in place leaving them time to plan imaginative and appropriate contexts for learning. The student would then be provided with a more coherent curriculum across Mathematics, Science and Technology and from this base Technology extension into other areas

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could be planned at a pace with which teachers could cope. This idea is supported by an example model in Appendix B.

In the debate concerning breadth, balance and entitlement, time and experience will help improve consistency as teachers become more familiar with new methods through experience and training but they will be helped greatly by strong leadership and a sense of direction from within their own organization. The National Curriculum will ensure a common base but it is entirely right that there will be different emphases in different organizations.

Science and Technology in CTCs

The very title, City Technology College implies that a technological ethos pervades the curriculum and it is vital that the Governors, Principal and staff share a common perception of what this means. In CTCs at least, part of the dilemma about the purpose of the curriculum is resolved. By definition, a CTC curriculum should foster practical technological capability by taking every opportunity that the curriculum offers to involve technological artefacts, methods and process in students' learning. The technological input will vary and will have certain characteristics in different subjects but scientific knowledge, mathematical and design techniques, which are the prerequisites of quality outcomes, are specifically mentioned in all documents relating to curriculum emphasis in CTCs. The aim is that all areas of the curriculum are geared to supporting the achievement of technological capability and awareness through a sound scientific and mathematical base. Furthermore, since CTCs are bound to take students across the ability range, courses in Science and Technology must be appropriate to this wide range.

Within these parameters, all CTCs are autonomous and consequently there is no such thing as a typical CTC in terms of the particular details of organization. Each CTC is accountable to its Board of Governors and parents. However, an emphasis on some curriculum areas is implicit to CTCs as outlined in the CTC Trust publication *CTC Essential Educational Characteristics* and it is therefore possible to paint a broad picture of the scientific ethos in the existing colleges based on their common aspirations and management methodology.

Pre-dating *CTC Essential Educational Characteristics*, the DES booklet *A New Choice of School* which was published prior to the opening of the first City Technology College in Kingshurst emphasized the following areas of study:

- Business understanding and personal development;
- Design and its realisation;

- Mathematics and Science;
- Technology.

The original report of the industrial action team which was consulted in the setting up of Kingshurst CTC also stated the crucial nature of

> the acceptance of the importance of the application of knowledge and skills in any staff appointed.

This implies that CTCs would seek to recruit practical and applied scientists rather than theoreticians. It is relatively easy for CTCs to show increased priority for Science and Technology by making more time available for it than is usual (Lynch, 1992). However, it is more important that the quality and contexts of learning for CTC Science and Technology should be the basis of judgement rather than simplistic measures such as time allocation. It is in the relationship between Science and Technology that one should look for CTCs to demonstrate their character.

CTC Science, Technology and the world of work

In Science, there is a need for a greater emphasis on the application of scientific method and knowledge to solve technological problems and to explain how modern technological devices function. The difference needs to be made between experimental work in Science which is often termed practical, and practical work meaning the application of Science in Technology. Experimental school science is still in many cases pure science rather than applied science and is often divorced from practical contexts in the work situation.

> ...everyday contexts are profoundly different from the research or the teaching laboratory, and yet are both the origin of what pupils bring to education and the destination for what they take away. (Black, 1989)

The experience of individual teachers in work outside teaching is not vast. Therefore, Science teaching which reflects modern, technological application from a point of view of experience is difficult to provide. Such perspectives can be extremely useful in bringing realism to subject matter as is illustrated in the experience of Alan Tolhurst of Thomas Telford School (Appendix C).

Although there is on average nearly 3 years of work experience outside teaching for each member of CTC Science staff (Lynch, 1992), this is not enough to provide a broad perspective of a wide variety of industries to individual students on its own. Indeed, even those working in industry probably have a limited perspective which is constrained by their immediate experience in their own environment. An appetite for keeping well-informed is essential and the number of opportunities for teacher work experience needs to be increased. One of the CTC curriculum aims is to redress this situation by making Science teaching more relevant to Technology through application. For example, Bacon's College have appointed a Science teacher who is trained in Technology and who has responsibility for co-ordinating and developing links with Technology.

In a CTC-style curriculum the technological element builds upon the balanced science platform and extends into other areas of the curriculum. This provides CTCs with a development pointer beyond the details of the National Curriculum. Rational scientific approaches to problem solving are extended into the Technology curriculum in order to make things which people will find useful. Likewise, the details of technological artefacts are fed back into the Science curriculum so that the way in which they work is better understood. Thus there is a balance between scientific and technological process development and a progressively increasing base of knowledge and understanding. From this baseline consideration for the effects of technology on society and the broader implications of technology on lifestyle can be picked up in humanities subjects. When this starts to be pervasive throughout the organization, there are the beginnings of a scientific and technological culture.

> Separated from the humanities and social sciences, Technology becomes no more than a combination of artefacts and specialised knowledge.
> (Young, 1989)

III. Science, Technology and industrial relevance

Education – industry partnership

If the purpose of education is to prepare the young for later life, industry must have a special significance in the education process if only because most people spend a large part of their lives at work. The world of work is a customer to education and has a legitimate right to certain provision, but it is not the only customer and this is where tensions can begin to arise. There are different perspectives which can inevitably lead to heated differences of opinion which are not helped in instances where each side is ignorant of the other's *modus operandi*. One of the most useful aspects of industrial and educational co-operation is the promotion of mutual understanding from which a true partnership can develop with both sides contributing as equals.

Science and Technology education offer a variety of services to industry already. Equally, there is much that Science and Technology education can learn from industry. Both education and industry can learn from each other when considering appropriate management systems.

It is reasonable to require all people to have access to a broad appreciation of scientific methodology and knowledge; those who do not are culturally and aesthetically impoverished. There is, however, a second reason for fostering scientific and technological capability: the economies of the Western Democracies are fundamentally dependent on manufacturing industry which is itself based on increasingly complex technologies, many if not most of which are founded in scientific advance. In his article 'Sun sets over Silicon Valley' (*New Scientist* 19th September 1992 p33) Ian Ross describes the effect of different cultural attitudes to science and business in Japan and the Far East compared to that in the West. For example, the decline from 100% to 40% in the USA's supply of the world's semiconductors.

There is no doubt that economies based on modern 'hi-tech' manufacturing need capable and specialist scientists who can support the 'hi-tech' infra-structure. Yet, from the picture presented by Ross, it could well be argued that the number of innovative scientists with specialist skills is currently sufficient and that it is lack of scientific and technological understanding amongst investors and policy makers which is the limiting factor. This is also apparent from other sources.

> ...the limited understanding of many European managers of the nature of technological innovation and its human resource implications could become a main obstacle for the successful adaptation of European industry. (EC, 1992)

It is clearly unscientific to assume that 'more means better', whether in terms of specialization or breadth without first analysing the needs of the problem. However, it seems clear that there is a need for greater scientific and technological investment in all areas of management.

> ...all evidence points to a greater need for engineers, scientists and technicians in the future. (EC, 1992)

The need for scientific understanding from a cultural and human perspective is less divorced from the need to develop specialist skills in industry than many would think. The two are inextricably intertwined.

Industrial awareness in Science and Technology curricula

Although the National Curriculum Council have begun addressing the issue of Economic and Industrial Understanding (EIU) across the curriculum by publishing a series of EIU documents, there is a lot more work to be done if the relationships between Science, Technology and manufacturing industry are to be appreciated fully. The Science Orders themselves do not preclude industrial and economic contexts, but neither do they make them explicit. Given current pressures to put in place what

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is statutory in their own subject areas, teachers of Science and Technology may well see cross-curricular themes as peripheral issues and there is a great danger that significant EIU will be missing from many schools' Science offerings for some time to come.

Industrial awareness is broader than the economic component and there are several ways in which industrial companies contribute to the curriculum.

Historically, industrial companies have made a significant contribution in the field of curriculum materials production. A good example of a materials pack related to industry is *Understanding Our Environment* developed by Conoco and Du Pont with the help of the CTC Trust, individual CTCs and other educational agencies. This resource combines the knowledge of experts in industry and education to produce an up-to-date, factual account of environmental problems in a low cost easily accessible resource pack which is translated into several languages and distributed worldwide. Further details are included in Appendix D. Other examples include:

- The TASTE project under Dr Peter Chamberlain formerly of Redbridge TVEI unit and Bacon's College is another example where industry-related materials have been developed in response to the needs of GCSE;
- Lloyds Bank Headway materials of which the technology of hot air ballooning is a recent addition are used in schools throughout Britain. For this project, the physical model for the computer-based flight simulation was developed at the CTC Trust; Kingshurst CTC and Thomas Telford School have been involved in developing and trialling materials;
- Recently-developed software supporting a scientific approach to food and life styles is being trialled at Thomas Telford School on behalf of the Milk Marketing Board.

All of these projects are examples of education and industry working in partnership in order to produce materials which neither could have designed on their own. The National Curriculum has added a new dimension to this type of collaboration because it focuses the effort from the previously rather haphazard approach, and encourages a more co-ordinated effort to demonstrate how innovative materials development can also cover the mainstream programmes of study.

Materials production can improve the industrial perspective presented to the student through the curriculum, but there are in addition many other ways of doing this. For example, specific links with industrial partners provide opportunities for two-way interaction. Leigh CTC use a link with their co-sponsors, Wellcome Pharmaceuticals, to illustrate the importance

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of genetically engineered materials in Biotechnology at KS4. The author has had personal experience of working with managers at GKN Technology Ltd and Hardy Spicer Ltd when at Kingshurst CTC. These personal links help erase the mystique of industry for educationalists and provide up-to-date contexts for curriculum delivery. They are also important in raising the levels of understanding of modern educational approaches amongst industrialists, most of whom find enormous improvements in the interest and practical approaches now in operation compared to when they were at school.

This type of co-operation is essential if curriculum development is to reflect the needs of industry but at the same time maintain its appropriate educational purpose. Getting an industrial perspective inevitably means more than just talking with people working outside education and for industrialists to understand modern education they need to be involved at grass roots level.

Practical strategies are needed to make it attractive for teachers to incorporate more industry-related material in their schemes of work. In this respect good relationships with industry are vitally important as are the meaningful inputs to curriculum materials.

Motivation is one of the most significant factors affecting both educational and industrial performance. In a survey carried out in CTCs and a random selection of state schools (Lynch, 1991) teachers of Mathematics, Science and Technology were shown to be more motivated by working with their students than by their subjects' intrinsic interest. This suggests that effective change is more likely to be brought about by identifying that which is in the best interest of students rather than for reasons which are intrinsic in the subject itself. There was also an indication that teachers did not feel particularly strongly supported in keeping up-to-date in their subjects. It would be reasonable to surmise from this that teachers will only make up-to-date exemplars from industry a high priority in their teaching if they are readily available and they are linked to examination courses or other criteria that the teachers perceive to be of interest and use to their students.

Industrial management techniques

The team approach to subject areas, discussed earlier, fits in with modern ideas on staff motivation and it is difficult to see how Technology education can be tackled in any other way. A successful example of this is illustrated by Sony (*New Scientist* 18th July 1992) who have moved away from the accepted mass production assembly line model and have adopted an approach employing small integrated teams producing a complete appliance. Specific skills and high quality are still essential, but there is more co-operation between related areas to decide how best to deliver their skills in the most efficient way and without the constraints of demarcation.

If this style of management can be incorporated successfully in the teaching of Science and Technology, education will perhaps have learned its most salutary lesson from manufacturing industry. It is not that education and industry are the same, but that motivational factors in both work forces can have some common elements. Although we cannot guarantee that certain ways of working will be universally successful, it does appear that greater opportunity to take responsibility in a small collective for final identifiable outcomes is a factor in high quality production. Technology is at a watershed where better team work between different curriculum groupings is essential if quality outcomes are to be realised.

The difficulties for education or industrial companies reforming management practice towards the Sony model stem from a long cultural history. Management structures in organizations are founded in the size and complexity of the organization and the context and history of the company. Large and complex organizations are usually bureaucracies exhibiting the characteristics of a role culture.

> They are co-ordinated from the top by a narrow band of senior management, the pediment. It is assumed that this should be the only personal co-ordination needed, for if the separate pillars do their job, as laid down by the rules and procedures, the ultimate result will be as planned. (Handy, 1976)

This quote describes the idea of classical role cultures which fits traditional school management models with the pillars representing subject departments. In these cultures the role is more important than the individual and the individual acquires status from his or her role in the organization. Performance beyond the role is rarely required and can sometimes be viewed as disruptive. The role organization succeeds best in stable situations where this year's rules are carried over to next. Classic examples are the civil service, banking, the oil industry, IBM in the computer industry and many secondary schools. Interestingly the model in primary schools is often similar but the class takes the place of the subject as the pillar of the organization. Role cultures have problems in times of rapid market change because they tend to carry on in their own image. This results in collapse or change of the pediment through new management or take-over. Role cultures offer security and predictability and an opportunity for advancement with low risk.

Task cultures are more suitable for small units and are less hierarchical. Work is assigned on a project-by-project basis and workers are judged more on expertise and effective results than on their age or role status. Modern small hi-tech manufacturers in competitive markets often operate as task cultures. The problem with task cultures is that they are difficult to sustain in complex bureaucratic organizations. It might be possible to manage a school as a task culture by reorganizing the curriculum into smaller project-based groups, but success will probably be elusive without considerable efforts in staff development.

> ...[a task culture] is not always the appropriate culture for the climate and the technology. If organizations do not embrace this culture it may be that they are not just out-of-date and old-fashioned – but right. (Handy, 1976)

It is likely that a move to the team approach and task-oriented ways of working in schools will only be developed successfully from a limited start which can be integrated along with other current changes. City Technology Colleges have been experimenting with flatter management structures in order to facilitate this process but the results will take some time to emerge. Altering culture is a good deal slower and more difficult than changing the technology.

As far as learning Science and Technology is concerned, it is arguable that the task culture approach is the only possible way forward for successful and efficient reform. However, we must be aware of the constraints imposed by history and legislation.

Education as a supplier of information

One of the things that education does on behalf of industry is to provide information about the suitability of potential employees. This is done partly through the examination system and partly through the system of references. If educators know more about the industries that are potential employers of their students they are more likely to be able to give quality advice. In terms of modern technology, this form of updating is particularly desirable owing to the rapidly changing and diverse needs of employers. The whole issue of standards and their measurement and value is both emotive and commonly misunderstood.

Contrary to popular belief, there is no absolute measurement for standards of Science and Technology attainment. Comparison of the examination results of present day students with those of the past is simply scientifically unsound since there are too many uncontrollable variables. Even if we could find identical questions on a paper from 1952 and one from 1992 and look at success rates it would not be a fair comparison since the emphasis on what needs to be known and understood now has shifted radically in 40 years with many additional areas of learning.

Paper and pencil examinations are a convenient way of providing motivational targets and are an inexpensive selection tool allowing a degree of objective comparison at a particular point in time. There is great danger in extending their validity beyond this. The real reason for the persistence of emphasis on paper and pencil both in the teaching of very young children and in the examination process is that they are still a lot less expensive than the alternatives in terms of equipment, teacher time and training.

Science and Technology are most usefully employed in practical contexts which are difficult to test using traditional academic methods, and written communication (particularly handwritten) is becoming a less significant requirement. Industry needs people who are good at making things and selling them. This is why, despite the expense, practical courses must have experienced people evaluating practical capability. The epitome of this is in the case of NVQ assessments in the workplace which are related to job-specific tasks.

Assessment suitable for testing job-specific skills in the workplace is not appropriate for teaching Science and Technology in the secondary school. In the latter context, highly specialized and job-specific training is less desirable owing to problems of skill transfer. However, the principles of practical assessment and assessment of capability rather than theoretical knowledge are equally valid in GNVQ assessment and records of achievement promise to make a big difference to the quality of information that is available to employers about the practical capability of employment candidates.

Employers look to 'A' levels and then degrees as the normal route for professional scientists, engineers and technologists, but vocational courses also supply industry with large numbers of technicians and, increasingly, professional level personnel. 'A' level and BTEC philosophies are not particularly comfortable partners and are based on very different premises. Nevertheless, a lot of work has been done in the CTCs to try and achieve as best a fit as possible within the constraints of the available examining system. More coherent approaches are becoming increasingly important as the number of those seeking post-16 education grows and the ability range widens.

Thomas Telford School and Brooke College, for example, are actively planning courses leading to accreditation through BTEC and UCLES (in the form of modular 'A' levels). These courses require reference to industrial processes and work experience which is far in excess of the traditional 'A' level and resit GCSE model found previously in many school VIth forms. The pilot of the Technological Baccalaureate in Djanogly CTC, Harris CTC, Dixons Bradford CTC and Brooke College in conjunction with City and Guilds will break new ground in accreditation. In this award, Science, specifically related to Technology, is a compulsory element.

In the final analysis, education and employers working in partnership is a key feature. It may be that employers like 'A' levels not because of their intrinsic merit, but because they understand them, being the examination for which they themselves prepared. If the nation is to provide an education system with modern assessment methods which are cost-effective and meet the needs of employers, partnerships will have to be broadened and strengthened to a far greater degree than at present.

IV. The challenges for Science and Technology curriculum development

Theoretical discussion and modelling are all very well, but what can individual organizations do to promote excellence in Science and Technology? The main factors are discussed below.

1. There must be an acceptance that the main issue is one of management. Management is about the deployment of resources in the most effective way;
2. The most important and expensive resource is the classroom teacher who has a range of skills and supporting knowledge, including the ability to manage learning;
3. Subject labels such as Technology are less important than the ability to deliver programmes of study effectively. Team approaches are needed if achievement against statements of attainment is to be optimized;
4. Industrial contexts should be used at all stages to illustrate the link between scientific and technological progress and wealth creation, providing motivation for learning.

CTCs are contributing to the resolution of each of these challenges.

Managing a corporate culture

> ... schools can be more effective and successful than they sometimes are but to achieve this those given the task of running them will need to think much more urgently and imaginatively about their cultures and structures as organizations. (Ribbins, 1985)

The purpose of teaching is learning and efficient and effective student progress is the only reason for there being a teacher: the curriculum is what is learned, facilitated by those who teach. The National Curriculum

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provides a statutory base line for this curriculum but it does not specify the character and style of its delivery, nor does it preclude augmenting the curriculum beyond National Curriculum statute. It is up to the organization to determine whether the National Curriculum is to be regarded as the lowest common denominator or the highest common factor.

The immediate criticisms of this line of argument stem from the limitations in the time available for all the subjects. Despite some genuine difficulties, it is a great mistake to assume that the mechanics of the National Curriculum are in themselves the main problem. It is the cultural shock of change, the pressure of statute and short time scales leading to a lack of corporate direction which provide the real challenges.

The following points, which are drawn from CTC practice, provide a checklist for effective management of the Science and Technology curricula.

- Strong leadership in Science and Technology as a unified concept;
- The authority to overcome resistance to change;
- The credibility to provide educational leadership;
- A vision of the over-arching goals of the organization for Science and Technology communicated to the rest of the team;
- An appreciation of the importance of teacher attitudes and motivation;
- An appreciation of the need to build from the familiar;
- An ability to identify common strands in Science and Technology;
- An ability to prioritize educational tasks effectively.

Experience shows that finding teacher/managers capable of working to these criteria is not easy.

- It is likely that such a person will need substantial teaching experience preferably in more than one school;
- Qualifications gained ten years ago may not be a reliable indication of up-to-date knowledge particularly in Technology and more so in IT;
- The candidate will need some experience of teaching both Science and Technology which, given the polarization of the subjects, is not common;
- Management experience is essential and a management qualification highly desirable because it is management ability more than anything else which will determine success;
- The candidate must be credible in the eyes of both colleagues and students if he or she is to provide the leadership required to overcome years of polarization in attitudes; this is why it is very unlikely that

someone without considerable teaching experience would be suitable.

The selectors must have enough experience to ask the right questions and interpret the replies in order to make sensible decisions. Appointing the pleasant personality with the right degree is no longer enough in a situation which requires expertise in strategic management coupled with technical know-how.

The difficulties in making good appointments highlights two further crucial points.

1. Change must be planned at a pace which reflects the current ability and knowledge base of the staff;
2. A staff development programme which is prioritized to the main goals of the organization must be planned.

The importance of staff development

People are the most important single factor in improving Science and Technology teaching. Good management requires good managers and the most expensive resource in the management equation is the professional teacher. The concept of the teacher/manager is well-established in CTCs with titles such as Area Manager or Teacher Manager replacing more common terminology in an attempt to reinforce the view that teachers are managers of learning rather than simply subject specialists. The terminology and labels are not sufficient by themselves to ensure changes in practice, however.

The case for staff development is overwhelming. Even so, the constraints are severe. Not only have staff to find time to internalize the mechanisms of the National Curriculum, but few have had training to identify development needs. There is also major concern for the disruption to students' education by taking teachers out of the classroom for training.

Appraisal is a vital element, but it can do more harm than good if it is not well-understood and does not serve the organizational development needs of the institution. Science and Technology have additional overheads in terms of safety and the management of practical equipment. Practical lessons are more complex to manage and there are issues of keeping up-to-date with modern technological developments and of developing industrial partnerships. If all this was not enough, there is evidence that the fundamental approach of teaching based on traditional paradigms is questionable.

> ...the professional expertise which is needed to change the development of pupils is so radically different from that required to teach knowledge

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and skills on their present understanding that if the potential of early adolescents is eventually to be realised teachers will have to relearn their craft. (Shayer, 1989)

The key to success is to prioritize, starting with those factors which are most likely to reduce workload in the medium term. Savings gained from better co-ordination of the teaching of Science and Technology are most likely to result in added value through broader teacher expertise and is therefore a low cost vehicle for staff development. Without staff development there is unlikely to be meaningful curriculum development, the two are inseparable. Once the organization has tackled curriculum overload it can then move on to improving quality through appraisal and other mechanisms of evaluation. Specific development projects can be introduced providing a focus for improvement. By drawing staff from different disciplines closer together, the work presented to students is more likely to reflect more realistic scenarios associated with the world of work and staff can broaden their expertise from the confidence of a familiar foundation. The two things to avoid are entrenchment and stagnation at one extreme and chaos induced by innovation overload on the other.

An excellent example of a well-planned staff development and appraisal programme is employed at Leigh CTC where staff development is an integral part of the organization's mission statement, and staff development is for all staff (Hagedorn and Sharp, 1993).

Subject labels

The simplistic way to prevent subject departmental structures dominating management is to abolish them, but this is not a realistic management option. Industrial management is not based on formlessness and most people need defined parameters within which to work, particularly in complex bureaucracies. Teachers need to know who they are accountable to and where the resources they need to operate effectively are channelled. Structures allow targeting of specialist resources where they are needed most and ensure accountability. The skilful manager uses structure to identify those areas where economies can be made and facilitates communication between areas where it is useful. The problem in traditional school organizations is not the structures themselves but the power bestowed to them and the attitudes of those working within them. History and tradition have failed to provide the motivation to transcend the academic boundaries on a large scale but managing the National Curriculum effectively makes a change in attitude necessary. It is essential that the most senior member of staff responsible for the curriculum is able to bring together departments in order to realise corporate synergy without sacrificing specialist expertise.

Difficulties in dealing with the original Technology Order highlight these problems particularly well because the original Technology Order implied fundamental structural reorganization and redeployment of staff. The contents of the Order are not specific to the skills and training of many teachers and therefore leave scope for role ambiguity. This is a well-known cause of stress leading to a lowering of performance. The less familiar the ground the greater the sensitivity. If the territory is uncertain and not tied to anything which is well-understood, it is doubly difficult to achieve meaningful change. Tinkering with the Order will not in itself solve this problem other than by facilitating regression to the status quo. The route to a real solution starts with a decision on the organization's curriculum perspective by establishing a corporate culture for Science and Technology.

The task of senior management has moved on from delegating responsibility to department and faculty heads to actively achieving synergy between the various structures in the organization. Detailed planning is the initial key to success with the Science and Technology curriculum being approached from a team perspective with skills and expertise deployed to the areas where it is most effective irrespective of roles and titles. The National Curriculum provides the planning tool and despite being a constraint is also a great help because it is statutory and there is therefore reduced debate about the merits of specific content. Where there are identified gaps, staff development programmes need to be initiated to solve the problems or in some cases it might be possible to make a new appointment. Once a workable system has been established teachers can be introduced gradually to related but new areas so that more flexibility is achieved and development can continue.

At the time of writing, the Technology Order is being revised and within the remit for the revision it is likely that the essence of the process-based attainment targets will remain. In the original Order there was no clear difference between the style of the statements in the programmes of study and those provided as statements of attainment and it is the lack of coherence between Science programmes of study and those in Technology which is particularly problematic.

The logical step for curriculum development for CTCs beyond the National Curriculum is therefore to extend the programmes of study to provide technological teaching contexts which present Science as it is used in such contexts. For example, in Science Attainment Target 3 (AT3), KS4 'They should be introduced to the idea of composite materials, illustrated by some common examples...' would lead straight into the idea of structures and building technologies where further work in Technology based on what had been learned in Science could explore design in a civil engineering context and its social impact. Since the published programmes of study are statutory, curriculum planners must make sure that any system they devise fulfils the statutory requirements of the Technology Order.

Contexts for learning and industrial partnership

Context is a vital element in understanding anything practical and this can only really be provided by exemplars or experience. Most modern text books are very helpful in this respect. Improvements and lower production costs have resulted in high quality reprographics being standard.

The challenge for Science and Technology is not simply to produce curriculum materials based on industrial practice, but to make sure that materials are kept up-to-date in a rapidly changing situation and the expense of re-issuing text books is an inevitable constraint. Perhaps the best indications of a successful education – industry partnership will be when teachers and industrialists genuinely understand each other's point of view and there is an acceptance that the purpose of education is to prepare young people for later life, a major part of which involves working to provide a better quality of life for future generations through scientific and technological progress.

Appendix A: Strategies for making links between Science and Technology

ADT College

ADT College is firmly committed to an educational philosophy which makes scientific technology a priority. There are several initiatives which take advantage of a new outlook for management structure as well as an increase in the length of the school day and five term year. Three of these initiatives are outlined below.

EAST

EAST (Economic Aspects of Science and Technology) is a curriculum development initiative which involves cross-curricular units of work promoting economic aspects of Science and Technology in industrial and information handling contexts. It is supported by the CTC Trust curriculum development unit and led by Bernard Abrams at ADT College.

Five units have been proposed initially with examples covering the breadth of the Science National Curriculum. Examples of units are: seed germination and market gardening, electromagnetism, materials and badge design. Students may be required to set up a business plan and to produce a product with the product development taking place in the context of scientific investigation. The units identify learning objectives related to Science, Technology (including IT), Mathematics, English and the cross-curricular theme Economic and Industrial Understanding (EIU).

The support materials for teaching the units will include work cards and computer software. There will also be support for recording achievement and there is an emphasis on individually centred learning with students working in small groups. The materials are designed to be of use in current courses but there will inevitably need to be some reconsideration of planning across the Science and Technology curricula.

Industrial Studies

Industrial Studies is a curriculum development initiative led by Peter Jones at ADT College. It involves two hours of timetabled work facilitated by the longer school day. The initiative is a response to an identified need for time to establish cross-curricular work involving themes such as EIU, citizenship and external links which actively involve students. Although work in the Industrial Studies project does not involve exclusively applications of Science and Technology, a significant amount does. For example, in the field of telecommunications, work involving the science

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of sound integrated with technological applications using optic fibres, analogue and digital signals has proved popular and other projects related to applications of electromagnetism and an energy theme involve input from scientists and technologists; wider involvement at the development stages allows creative and expressive input to the programme.

Physics at work

In October 1992, ADT College, supported by the Institute of Physics, CTC Trust and Wandsworth LEA organized a series of visits for local schools which were attended by employers who make use of physical science as a major part of their work. The purpose of this exhibition was to provide an opportunity for students to see how the physical science that they are learning at school is related to the world of work in industries such as gas supply and electronics.

Dixons Bradford CTC

Dixons Bradford CTC have identified a need for Science and Technology teachers to become more familiar with each others' work, particularly in the fields of classroom organization and teaching methods. They also want to emphasize that students should be applying scientific knowledge to projects and work in Technology.

They have initially concentrated attention on the following course units:

Measurement and control	particularly with reference to AT5 in the Technology order and ATs 1 and 4 in Science;
Nutrition	and its relation to Food Technology;
Logic and systems	using a scientific systems approach to solve problems and a design approach to build technological solutions;
Mechanisms	the study of gearing linkages and levers as a basis for building mechanisms to solve problems;
Materials	investigating the properties of materials in order to solve specific problems.

In order to provide a greater focus for joint work, a one hour period per week was put aside specifically to promote Science and Technology links in Year 9. The course has been very successful and is to be extended to an hour per week across the whole of KS3 in August 1993.

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Macmillan College

Macmillan College divides the entire curriculum from age 11 to 18 into Heritage and Futures sections, each managed by a Curriculum Director.

The Curriculum Director for Futures has within his section Mathematics, Technology and Science. The three departments work closely together in the 11 to 16 phase. Present development work includes an audit of KS3 provision in order to link related topics in the Mathematics, Science and Technology curricula. For example, materials and their properties studied in Science will be related to the use of materials for practical application in Technology; major and minor projects will have specialist input from various areas of the curriculum with careful planning to ensure progression.

In the post-16 phase, the College will offer a restricted range of 'A' levels of direct importance to the industrial employment base on Teesside. Out of the eight subjects on offer, Electronics, Technology, Physics, Chemistry, Mathematics and Biology will be delivered by the Futures section, with Geography and Economics being delivered by the Heritage staff.

Electronics at 'A'/'AS' level will be delivered jointly by the Technology and Science staff operating in laboratories and workshops.

The Futures section is also currently preparing BTEC First and National courses in Materials Technology and Science.

The Materials Technology courses at National level will involve Macmillan College in working closely with Further Education colleges at Sandwell and Ebbw Vale. It will be delivered jointly by the Technology, Science and Mathematics departments working with local industry, who will be providing three month structured work placements to each student to complete off-site work-related Materials Technology assignments of 300 hours.

The College is currently developing a metallurgy/materials laboratory integrated into the Technology and Science area to deliver BTEC courses which will begin in September 1994.

Appendix B:
A model for establishing cross-curricular links

At the time of writing, the Technology Order is in the process of revision. The exercise presented here has involved a re-writing of the Technology programmes of study for KS3 to be more consistent with those in Science and Mathematics. The principle of providing a starting point for a collective approach to Mathematics, Science and Technology is believed to be more important than any specific detail in this example. Additionally, no attempt has been made to reference specifically Art and Design which also has a significant role to play in graphical aspects both in terms of conventional drawing and computer-based representations. This adds further weight to the notion that Technology is not a subject but an inter-disciplinary activity.

A similar exercise for KS4 points to the need for the provision of opportunities for more detailed study in some specific aspects of Technology, eg food, electronics, textiles. However, the principle of a foundation in the Mathematics and Science which are statutory still holds good. Information Technology is appropriate in any area with some specificity of application, but skills in the use of generic graphic design tools, particularly vector applications rather than the predominant bit map editors currently used in many schools, are of significant importance in industrial design. If business and economic understanding are to remain part of the Technology Order there should be more rigour in the presentation of marketing techniques such as how to approach clients and accepted techniques for closing a sale. This would ideally be linked to English, Drama and other languages departments and is therefore beyond the scope of this paper.

If this can be demonstrated successfully, and if allowed to, GNVQ could eventually become as significant a route from 14 as GCSEs are now.

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Maths

AT1 Level 3/4

Explaining work and recording findings systematically.

Investigating and testing predictions and general statements

Selecting materials and mathematics to use for a task.

Planning work methodically.

Recording findings and presenting them in oral written or visual form.

AT2 Level 5/6

Using trial and improvement methods. Estimating and approximating. Using imperial and metric units. Working out fractional and percentage changes.

AT3 Level 7/8

Constructing and interpreting graphs of linear functions: flow diagrams with and without loops.

Interpreting graphs which describe real-life situations and contexts.

Science

AT1 KS3

Pupils should be encouraged to develop investigative skills and understanding of science through activities which:

are set within their everyday experience and in wider context, and which require the development of their investigative skills and the use and development of scientific knowledge;

use an increasingly systematic and safe approach;

require increasingly precise quantitative approaches to the measurement of key variables;

require them to make strategic decisions about the number, range and accuracy of measurements;

require them to select and use increasingly complex apparatus and instruments to enhance observations and measurements;

involve the use of secondary sources as well as first-hand observations;

Offer opportunities to develop computer skills to store, process and retrieve information and to control and collect data during experiments.

Encourage them to appraise critically their investigation and suggest improvements to the methods.

Technology

Planning and research

Pupils should be encouraged to develop planning skills and understand their role in technology through activities which use an increasingly systematic and detailed approach. These activities should start with their everyday experience such as the technology used in the home, and progress to wider contexts such as technology employed in the leisure industry eg playgrounds, theme parks and toys and then to industrial technologies. The contexts should become increasingly complex and require increased use of mathematical, scientific and aesthetic skills in line with other NC orders thus providing identifiable progress throughout the key stage. The use of IT in the planning process should become a routine matter with pupils using a variety of software applications as readily as paper and pencil.

Pupils should demonstrate an ability to:-

Level 3/4

Find an interesting technology from books or magazines and describe why it is of interest in their own work consistent with the requirement of level 3/4 in the English Order.

Take existing technologies such as a playground roundabout and describe one design aspect in broad terms, e.g. safety implications.

Make plans for the design of a simple device such as a desk tidy which clearly demonstrate prior thought and consideration before the work is started. Achieving specification for higher levels of attainment with continual help and guidance.

Be willing to modify plans when advised to do so based on feedback on their realisation given by others.

Present their plans with care using appropriate language and drawings. (In this aspect of the work the content and depth of its understanding are not relevant.)

Level 5/6

Find information about an interesting technology from more than one source and describe why it is of interest in their own work consistent with the requirement of level 5/6 in the English Order.

Take existing technologies such as a playground roundabout and describe more than one design aspect in detail, e.g. safety implications and cost.

Make plans for the design of a simple device such as a desk tidy which include drawings and revisions either on paper or computer together with a clear indication that major features such as material, cost, stability and aesthetic appeal have been considered. Follow simple flow charts for control systems.

Modify plans on their own initiative based on feedback from the realisation of the plans given by others.

Present their plans with care using a structured document with headings and content forming a cohesive whole.

Level 7/8

Find information about an interesting technology from several sources and describe why it is of interest in their own works consistent with the requirement of level 7/8 in the English Order.

Take existing technologies such as a playground roundabout and describe the interdependence of several design aspects, e.g. safety implications, cost, excitement.

Make plans for the design of a simple device such as a desk tidy which include accurate scale drawings on paper or computer together with a clear indication that major features such as material, cost, stability and aesthetic appeal have been considered. Devise flow charts for control systems.

Modify plans systematically on their own initiative throughout a project based on their own findings and the comments of others.

Present their plans with care using a structured document which makes use of computer graphics and typesetting.

Maths

AT4 Level 3/4

Recognise reflective symmetry. Understand terms clockwise and anticlockwise. Construct 2-D and 3-D shapes. Reflecting shapes in a mirror line. Recognising rotational symmetry. Perimeters, area, volume. Understanding language associated with angle.

AT4 Level 5/6

Measuring and drawing angles to the nearest degree, symmetry of various shapes, 2-D representation of 3-D objects, enlargement by whole number scale factor.

AT4 Level 7/8

Understand and apply Pythagoras theorem. Calculations in plane and solid shapes. Enlarge a shape by a fractional factor. Using sin, cos, tan in 2-D etc. Understanding and using vector notation including its use in describing translations.

Science

Pupils should explore the nature of vision, leading to an appreciation that vision occurs because light enters the eye and signals are interpreted by the brain. They should learn about the visible region of the electromagnetic radiation, and its uses. Pupils should study the behaviour of light, particularly its transmission, absorption, reflection, refraction and dispersion. They should learn how light is controlled and used in a range of common optical devices, for example, periscope, simple camera, projector, fibre optics. They should study the function of the eye, common defects and their correction, for example long sight and short sight.

Technology

Design Communication

Pupils should be encouraged to develop technical design skills and understand their role in technology. These skills should include established techniques such as computer aided drawing and the use of reflective and rotational symmetry as well as shading techniques which make 2-D drawings appear as 3-D shapes. These techniques should be used increasingly in the planning and realisation of technological devices such as 3-D structures, mechanisms and electronic circuits. The contexts should become increasingly more complex and require increased use of mathematical, and aesthetic skills in line with other NC orders thus providing identifiable progress throughout the key stage. The use of IT in the communication of design ideas should become a routine matter with all pupils using vector graphics drawing packages as readily as paper and pencil.

Pupils should demonstrate as ability to:-

Level 3/4

Make 2-D drawings of uncomplicated structures using simple instruments such as a variety of pencils, rulers, set squares and protractors. Drawings should employ plain paper and squared paper in appropriate contexts.

Use a 2-D vector graphics application to produce simple diagrams and plans consisting of lines, curves, rectangles, circles and text labels. Use other computer-based graphic tools to gain an appreciation of their different strengths and weaknesses.

Compile documentation under guidance, throughout a short project using diagrams, photographs and text to illustrate their design process.

Level 5/6

Make accurate 2-D drawings involving distances and angles related to simple objects or the components of more complex systems. Translate simple 2-D drawings into 3-D models in, for example, making a support for a bridge. Produce 3-D drawings of structures using isometric grids both on paper and computer.

Use a 2-D vector graphics application to produce diagrams consisting of several interconnected parts, with filled areas and to scale.

Compile documentation independently throughout a short project using diagrams, photographs and text to illustrate their design process through which a third party can understand the work.

Level 7/8

Make accurate 2-D representations of 3-D objects using different views, e.g. plan and elevations. Use shading techniques to produce rendered drawings to convey realism both on paper and on computer.

Use a 3-D CAD application to produce 3-D extrusions from 2-D vector drawings. Use bit-map editors to clean up scanned images and understand the issues of vector graphics and bit-maps when dealing with computer images in practical situations. Be aware of software applications for converting bit maps to vectors and their limitations.

Produce a comprehensive record of the design process involved in a short project where techniques such as computer generated diagrams, photographs and printed text are used independently to convey an accurate presentation of the work involved.

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Maths

AT1 Level 3/4

Selecting materials and the mathematics to use for a task using alternative approaches to overcome difficulties.

Checking results considering whether they are sensible.

Using examples to test solutions, statements or definitions.

AT2 Level 3/4 (most of this number work is appropriate)

Making estimates based on familiar units.

Using a wider range of metric units of length, capacity, weight, and standard units of time.

Recognising and using simple fractions in everyday use.

Recognising and understanding simple percentages.

AT1 Level 5/6

Breaking tasks into smaller, more manageable tasks.

Iinterpreting mathematical information presented in oral, written or visual form.

AT2 Levels 5/6

Using trial and improvement methods. Using imperial units still in use todaycalculating and using ratios. Using estimation and approximation to check that answers to multiplication and division problems involving whole numbers are of the right order.

Science

Pupils should investigate a wider range of components in electrical circuits and appreciate the means of controlling electricity using a variety of components such as variable resistors, relays, switches, diodes, capacitors, transistors and logic gates. They should make simple electrical measurements to develop understanding of the relationship between current, potential difference and resistance.

Pupils should investigate qualitatively the properties of magnets, electromagnets and the nature of magnetic fields. Their investigation should be in the context of everyday applications and devices including electric motors, electromagnets, dynamos, transformers, loudspeakers and circuit breakers. They should measure and calculate the cost of energy used by domestic appliance. Using a systems approach, pupils should have an opportunity to use logic gates together with input sensors and output devices in simple decision making and control circuits to solve problems.

Pupils should be introduced to the concept of energy transfer by thermal processes and to the principle of energy conservation. They should have experience of a wide range of processes involving energy transfers in domestic contexts and in familiar devices, such as electric motors and mechanically driven models. The joule should be introduced as a unit for the measurement of energy. They should explore the generation of electricity.They should be introduced to the idea of energy efficiency, etc.The rest of Science AT4 is all relevant as is a significant amount of AT3.

Technology

Working with materials and components

Pupils should be encouraged progressively to develop skills in building useful and aesthetically pleasing objects and systems. These skills should include experience of working with a range of materials and components and draw heavily on work done on the physical, chemical and biological properties of materials and components studied in science. Pupils should progress from working to sets of instructions and plans to more independent design, planning and construction. Pupils should progress from working to sets of instructions and plans to more independent design, planning and construction. Pupils should gain experience of applying modern control technology through the use of modular electronics boards such as MFA, Alpha, Kent etc and progress to controlling mechanical and pneumatic systems through computer interfaces and simple programming. Ideas such as sinking and sourcing current and digital voltage levels should be introduced in appropriate cases and related to work founded in science. Safe working practice should be emphasised at all times, together with an awareness of the cost of the materials they use.

Pupils should be able to demonstrate an ability to:-

Levels 3/4

Describe the materials used in simple technological devices and structures in broad terms saying why the material is suitable or unsuitable for its purpose, e.g. glass, wood and bricks in the construction of a greenhouse; a battery, LED and LDR in a simple circuit; binding agents and colourings in food.

Use materials appropriately in their design and construction and be able to give a sensible reason why the material was chosen when asked, e.g. it is strong enough for the job, it provides appropriate fibre or protein in the diet.

Cut out 2-D shapes in wood, metal, plastics, fabrics and food with reasonable accuracy to make the components for a project using simple cutting tools such as knives, scissors and saws safely, e.g. the shapes and components to make a pencil box given a set of templates. Cutting shapes in pastry to produce a specified decoration on top of a pie.

Put together predefined components to make a useful system working to a plan, e.g. following a simple circuit block diagram to make a rain alarm from circuit board modules; making a bread roll given a recipe; building a simple balsa wood model.

Construct simple workable structures, mechanisms, or systems to their own design with occasional guidance, e.g. a toy box, a powered vehicle from lego, a lighting system for a dolls house using an OR gate to switch lights on from two different locations.

Levels 5/6

Identify key materials in more complex technological devices, whose properties are critical to the correct functioning of the device. eg. the paper cone in a loudspeaker, high melting point metal in a light bulb filament. Self-raising flour in a cake.

Choose materials specifically based on certain properties in order to realise an effective design giving the advantages and disadvantages of the materials, e.g. polystyrene to insulate a solar panel, cardboard to make a container for eggs flame proof material for a night gown.

Cut out shapes in various materials to close tolerances such that the shapes make a good fit when assembled into the final object, e.g. the parts to make a pencil box, the fabric components to make a simple garment.

Put together pre-defined components to make a useful system working to a plan in more complex contexts, e.g. following a simple circuit diagram to make a working rain alarm from individual components; making a cake to a recipe; building a multi-component model.

Construct workable structures, mechanisms, or systems to their own design independently, e.g. a toy car from wood, a powered vehicle with gearing from lego, a security lighting system for a dolls house demonstrating appropriate mathematical and scientific awareness at this level.

Maths

AT2 Level 7/8

Recognising that measurement is approximate and choosing the degree of accuracy appropriate for a particular purpose.

Using the memory and bracket facility of a calculator.

Calculating fractions.

Science

Technology

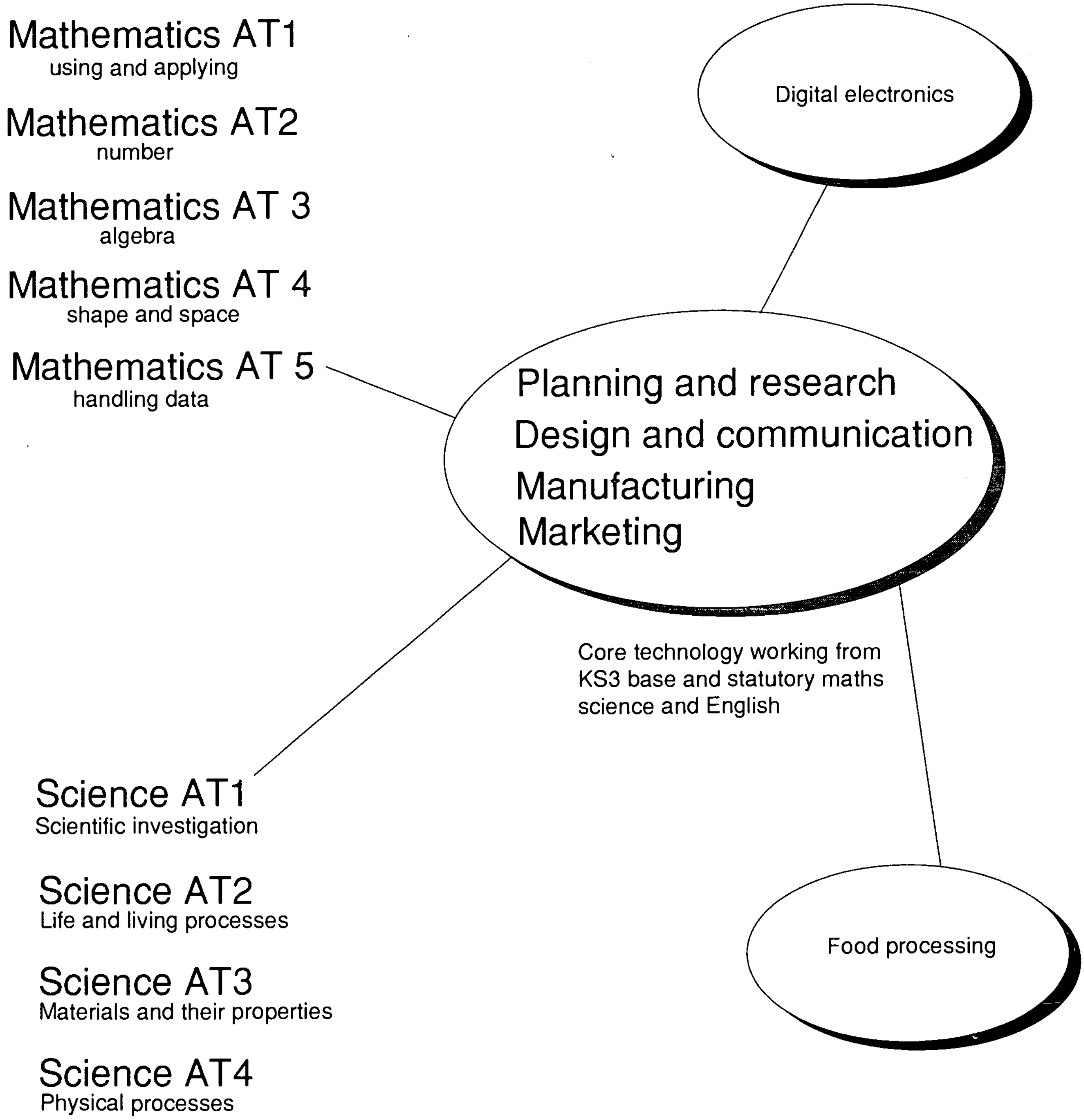
Levels 7/8

Discuss their design proposals based on the properties and aesthetic qualities of the chosen materials using scientific terminology such as tensile strength, brittleness, thermal and electrical conductivity, e.g. wool for making a sweater in terms of its insulation properties and texture compared with leather for a motorcycle jacket.

Modify existing designs by refining shapes, fitting components to a high standard of finish, e.g. designing and constructing a circuit from individual components to control the temperature in a model house. Take into account the need for accuracy based on purpose and cost.

Understand the terms analogue and digital as applied to control and interfacing of electronic and mechanical systems and use this understanding to design systems of control through a computer interface, e.g. write a simple computer program to switch on bit 5 on a digital interface for 5 seconds keeping all other bits with their original settings, in order to start and stop a motor.

Core skills in a vocational framework providing the basis for industrially relevant technological capability.



Appendix C: Extra-education experience

Alan Tolhurst is a mature entrant to the teaching profession having been educated through the vocational route and worked in industry and as an engineer in the Royal Air Force. Some examples of curriculum areas in which his experience in previous jobs has helped are given below.

Key Stage 3

At Thomas Telford School a cross-curriculum approach is adopted with team leaders for particular topics. Alan Tolhurst is the team leader for the weather module studied in Year 7. This module involves National Curriculum programmes of study in several subjects, but principally in Science and Geography. Experience of the significance of weather forecasting and its importance for flying when working as a member of aircrew provides relevant examples of the importance of knowing and understanding about weather in an exciting situation associated with the world of work.

The teaching of microelectronics and general electricity modules is more motivational when linked to practical high technology examples. Helmet mounted image intensifiers used by helicopter crews provide such an example in broad outline at this level and in greater detail post-16. The wide scope for the use of electricity in powering motors, servos and in switching and signalling devices in all air transport provides many opportunities for exemplars of practical importance across the age range not least in the field of safety where technological reliability can be literally a matter of life or death.

In addition to being scientifically and technologically trained, an industrial background also provides relevant input to the industry course in Year 8 where experience in the engineering and paper industries before joining the RAF is also useful.

Post-16

Thomas Telford School offer Cambridge Modular 'A' level Science courses and has found that the flexibility of the module system allows the structuring of a Physics course with a highly technological flavour. This flexibility has allowed previous experience outside education to be brought into the teaching situation to a far greater extent than was possible with conventional 'A' level courses and provides better opportunities for links with vocational courses such as GNVQ. The modules transportation, communications and instrumentation electronics which are taught at Thomas Telford School all have direct relevance to Alan Tolhurst's previous experience before becoming a teacher.

Students also have the opportunity to participate in the extended study programme post-16. Many of the projects which students undertake exemplify the application of Science as a foundation to Technology. Examples are the chemistry and physics of car tyres, crumple zones in car manufacture and the chemical and physical properties of bricks in the construction industry.

Appendix D: Understanding Our Environment

Description

This is a world-wide educational resource sponsored by Du Pont and Conoco. It has been developed in consultation with industry and education and consists of information and activity sheets together with overhead projector transparencies and a video cassette. The resources will provide help for teachers who are tackling the cross-curriculum theme Environmental Education, identified in the National Curriculum, as well as in relating specific subject areas such as Geography and Science to more detailed consideration of environmental issues. It is also envisaged that elements of the resources will be used in industrial settings to provide information. For example, Conoco Norway used an interactive computer program developed alongside *Understanding Our Environment* to highlight environmental initiatives being taken in the North Sea at the Environmental Northern Seas Exhibition, and this now has a place in the main Conoco building in Stavanger.

Aim

The aim of the resource pack is to improve objective understanding of environmental problems including the effects on the environment of over-population, manufacturing industry and technology. An integral part of the pack is a teacher's fact file which provides up-to-date information on major contributors to environmental problems based on current scientific understanding. The pack encourages consideration of sustainable strategies based on the current world situation.

CTC involvement

All the CTCs have had access to the environment resource pack pre-publication with the opportunity to trial the materials and feed back improvements. The CTC Trust has made several contributions in the production of the pack, particularly the teachers' fact file, foreign language translations and in associated software design. Foreign language versions of the materials in Spanish, French, Polish and Czechoslovakian will be available soon.

Partnership

A wide variety of partners from education and industry have been involved in this project, including Crystal Presentations Ltd, Du Pont, Conoco, Walsall LEA, Queen's University Belfast, University of Aberdeen, University of East Anglia, The British Plastics Federation, The OECD, and Living Earth Cameroon Environmental Education Project.

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