Developing relationships between science and technology in secondary schools

Developing relationships between science and technology in secondary schools

J Sage
Science with Technology Project, The Association for Science Education (ASE), The Design and Technology Association (DATA)

Abstract
The close relationship between science, technology and mathematics that exists in the world of practising engineers, scientists and technologists is not replicated in any significant way in many school situations. The National Curriculum has not encouraged teachers to undertake any developments that could change this situation. If Technology in the National Curriculum is to be seen as a rigorous and challenging subject the underpinning scientific and mathematical concepts and skills must be developed alongside the other essential elements of technology such as aesthetic sense, the ability to make and develop products and an understanding of values and human factors. Full technological capability can only arise from an interaction between all of these elements.

This paper will present a model for active collaboration between science and technology in secondary schools. It will explore areas common to the two subjects covering procedural capability and the development of conceptual understanding. The importance of establishing meaningful contexts for the work to be done by students will be emphasised.

What is technological capability?

In order to address the issue of how to develop technological capability it is firstly important to try to establish what it is. There have been many attempts over the years to define what is meant by technology. In all of these there is an underlying inference that technological capability involves the transformation of knowledge, understanding and skills (including scientific and mathematical) for practical application in the made world.

There is a view held by many in education and outside in industry that we need to find ways of working in schools and develop curriculum models and materials to allow students to more fully acquire this capability. This means finding ways of developing collaboration between technology, mathematics and science departments in schools.

Conversations with industrialists often include references to the 'seamless web' between these three areas in industry; an engineer, technologist or scientist does not differentiate between science, mathematics and technology. They draw upon the resources of all of them to complete the task or solve the problem in hand. There is a view that students should be able to work in this way, at least for some of their time, in schools. Technology provides the opportunity for this through cooperation and collaboration with science and mathematics as well as other areas of the curriculum. This paper will concentrate on the relationship between science and technology.

It is worth considering two models for achieving technological capability.

Professors Black and Harrison in 'In place of confusion - Technology and Science in the school curriculum'[1] proposed the well known TASK - ACTION - CAPABILITY model (See Figure 1). In this model a series of progressive tasks lead to capability. These tasks draw upon the resources of skills, knowledge and understanding. Successful outcomes from the tasks are achieved through the interaction of the tasks and these resources. It is this interaction that is the key to developing full technological capability. The resources can come from all areas of the curriculum and beyond but science is obviously a major contributor.

The increased motivation that will arise through students working on Technological Tasks that they see as interesting, meaningful and relevant will have benefits for related work in science; this can be used to develop further activities.

The full report of the APU Design and Technology Project 1985-1991[2] defines three categories which lie at the heart of capability in D&T.

Procedural qualities

- taking account of the issues related to the task;
- planning;
- developing proposals;
- developing product for user;
- developing product for manufacture;
- appraisal;

- development of the proposal as the task develops.

Communication qualities

Conceptual qualities
- understanding and use of:
materials,
energy,
aesthetics,
- understanding and awareness of people/users.

The report also makes it clear that there are further qualities involved in the interaction of these, in addition to the interaction between the active and reflective aspects of D&T, leading to full D&T capability.

We can now see that full technological capability will result through tasks that encourage and support interaction between skills (procedural and communication qualities), knowledge and understanding (conceptual qualities) and what we might call 'values', an awareness and understanding of the impact of technology, an aesthetic sense and a consideration of 'human factors'. Where will these skills, the knowledge and understanding and the appreciation and consideration of these values come from?
Obviously all areas of the curriculum can make a contribution but, again, science obviously has a great deal to contribute.

Technology in the National Curriculum

If we now move to Technology in the National Curriculum it is possible to identify areas common to science and technology (see Table 1).

Table 1 Areas common to Science and Technology in the National Curriculum

materials including textiles
energy
structures
control
electronics
electricity
fluids including pneumatics and hydraulics
nutrition
food technology
ergonomics and the use of anthropomorphic data
mechanisms
process technology - understanding a range of manufacturing processes and their control including food processing, biotechnology, chemical processes etc.
the impact of technology - environmental, human
IT - its use in measurement, monitoring, control, modelling, CAD, CAM as well as databases, spreadsheets, WP, DTP.
data collection, handling and presentation
measurement
communication skills
safety
investigative and research skills
modelling
use of mathematical processes such as equations, algebra, ratio, number patterns
graphical skills
follow procedures

	Design and Technology (AT1-4)	Mathematical modelling (AT1)	Scientific investigations (AT1)
Problem Definition:	Identifying needs and opportunities	Identify a real problem, plan an investigation	Develop a statement or hypothesis that could lead to an investigation
Entry:	Generating a design	Build a model; select the maths	Design the investigation including consideration of the variables
Attack:	Planning and making	Analyse using maths	Perform the investigation
Review:	Evaluating	Interpretation and validation	Interpret the results; check against original hypothesis or statement

- assembly and construction skills
- teamwork
- decision making
- project management
- economic and industrial awareness and understanding

However, before they can be used in Technology scientific concepts need to be defined in a technological, as opposed to a scientific, sense. They need to be turned into knowledge and understanding that can be used within a technological task.

It is also possible to identify a common process, for example as used by the Mechanics in Action Project, University of Manchester Department of Education [3].

One problem of trying to point out the common features of these processes is that of time scale. D&T activities covering all four ATs tend to be much longer that those in science and mathematics. However, if one accepts the 'Russian Doll' model of technology. That is that every large holistic tasks contains a number of smaller holistic tasks each of which contains a number of even smaller holistic tasks etc. then this becomes much easier. The timescale of these smaller tasks will be similar to that of school scientific investigations.

Another problem of this model is the assumption that D&T is a linear, or at best, a cyclical process. The processes involved in technological tasks are more complex than this and can often involve using all the aspects identified by the Attainment Targets at the same time. However, it is useful to identify these stages in the process as it provides another framework for collaboration between the two subjects.

The problems of collaboration

Having established the need for collaboration and that the responsibility for developing technological capability also rests with others outside the technology department, it becomes necessary to look at some of the problems of collaboration.

Professor David Layton[4] has succinctly highlighted some of the problems of collaboration between science and technology. Much of this can be applied to collaboration between other subjects as well.

The essential problem is the change of role of science (in this case) acting as a service subject to technology and having to fulfil a dual role; its traditional role of autonomous subject with its own aims and objectives, and the additional one in relation to technology. This gives rise to some practical difficulties.

Firstly, there is no single mandatory body of science knowledge for technological activities. Any front-end loading of students with the scientific knowledge, prejudging the science they are likely to need, could well influence the definition of the problem and close down solutions. However, it is extremely likely that without some scientific understanding of the problem, the available solutions will be extremely constrained.

Secondly, there is the problem of timing and sequencing; the need for specific knowledge may arise in technology before it is covered in science or mathematics. A programme of study aimed at students achieving conceptual and procedural understanding in a particular area of science or maths may not be compatible with development of progression in technology. This is a problem already very familiar to science and maths colleagues.

Lastly, the form of the scientific knowledge and understanding as developed in science, may not be in the best form for it to be transferred and applied in technology.

A solution to these problems needs to be found. To quote Professor Layton:

> *'My argument has been that this notion of transforming scientific knowledge for practical action has some interesting implications for science in the National Curriculum. ...... One question for science education is whether this new curriculum neighbour* [Technology] *is to be a partner or competitor. If the answer is partner - the consequences of the alternative could be disastrous for both science education and technology education - the nature of the new relationship has to be negotiated.*

Quite clearly technology and science should be partners but we need to make this partnership effective. We need to overcome these problems so clearly identified by Professor Layton.

The need for collaboration, between science and technology in particular, has been widely acknowledged and was recognised as being essential, but problematical, by HMI[5], amongst others, in 1985.

> *'Science and technology courses should seek to ensure that scientific principles and knowledge are taught in conjunction with technological problem solving.'*

'Another contributory factor to good quality work was close cooperation between science and technology departments which made available to pupils a wide range of expertise and resources that would otherwise have been the case. Such interdepartmental cooperation is not easily achieved, but as technology is a multi-disciplinary study employing skills and knowledge developed by many subjects, more attention needs to be given to cooperation between departments.'

This is still true today. If anything the introduction of the National Curriculum has made the task even more difficult as teachers and departments struggle with their own subjects putting collaboration with others some way down their priority list.

There are also implications for assessment; for example, it is quite possible for a student to achieve a higher level for part of science within a technology activity than they do in science. Who is responsible for validating and recording this? I suggest it should actively involve the student; but this is beyond the scope of this paper.

How can we achieve this collaboration?

There are a variety of models for curriculum cooperation.

1 Integrated work - the work of the students is integrated into a course, a project or a task in which there is a seamless web of work.

2 Collaborative work - productive collaboration between teaching staff in the organisation of a coherent programme of study for students. The separate subjects retain and maintain their separate identity but work is passed from one teacher and lesson to the next to provide coherence and continuity.

3 Coordinated work - a sequencing of activities in the different subjects to give coherence to the whole. There may be a common context for the different activities. However, there is no overall coherent programme of study although students are encouraged to make connections between the lessons or topics.

4 Awareness - an awareness of what is going on in the other subjects so that reference can be made and links indicated to students.

A Technology led model

I am going to propose a Technology led model where it is useful to identify three levels of support from and collaboration with science.

Essential science
This is the science that is firmly embedded into a technological task and essential to achieving successful outcomes from the task.

This may be so well integrated into the task that students may not even realise that they are learning science. However, these tasks need to be written by science teachers. This is to avoid the dangers of accepting, for example, that some science is needed, but the teacher simply giving the answer to the student so that they can get on with the task.
They must be tasks written to help students achieve understanding in science.

Useful science
This is science useful to the task. These tasks could be written as separate science activities identifiable by students but have relevance and validity because of their close association with the technology task. They could be taught in science lessons.

Opportunities to develop further work in science
Building on the relevance and motivation of the technology task to further develop science activities within the science programme of study.

The model

The model which brings all of this together is not a complex one and relies on existing tried and tested ideas. It assumes that increased motivation and perceived relevance arises from setting students activities into meaningful contexts.

See diagram 2 A model for achieving full technological capability

The essential features of this model are that it allows the interaction between Technology Tasks and the resources needed for success in those tasks and by setting both in the same context the motivation the students have for the Technology Task will be utilised within the more focused Resource Activities. These Resource Activities could include essential and useful activities as well as develop further opportunities for work in science and mathematics. The model can be used at any of the levels of collaboration. It also allows students to behave more as technologists, engineers or scientists do in industry.

One of many examples of using the model is using the context of 'Development issues - the response of technology'. This involves identifying needs through information about a community in a developing country; eg. a village in Southern India.

A possible task is supplying the electricity needed by the Health Centre to run a refrigerator to store vaccines and to provide distilled water. Students would need to investigate the feasibility of using biomass, solar, wind, small scale hydro power based on real information and data. This would need some scientific resource activities and could involve designing, making and testing models or even full scale devices.

This is a model that I believe can lead to full technological capability but, the responsibility rests with other areas of the curriculum, not just technology. The role of science is paramount.

To develop curriculum materials of this nature requires the collaboration not only of technology and science teachers but also of business and industry working with schools and curriculum development projects, to provide the authentic and authoritative information and data they need and also to present positive messages to students.

This view is supported by the Advisory Council on Science and Technology[6].

'Employers might achieve more by providing teachers with scientific [and technological] *resources and project materials and helping teachers deliver the National Curriculum by assisting in the development of attractive and balanced courses* [and curriculum materials].

Brian Woolnough in 'The Making of Engineers and Scientists'[7] recommends that:

> *'The role and type of practical work should be reconsidered to ensure, particularly, that it is not wasting time on trivial exercises and that it does give the student an opportunity to experience how a scientist,* [technologist] *or engineer works through genuine scientific investigations* [and technological tasks].

This is well supported by the evidence of research into why students lack motivation in science; this is exactly the sort of arguments put forward by the students themselves.

Conclusions

There is no doubt in my mind, and that of many others both in education and in business and industry, that we must work to achieve a higher level of technological capability in all youngsters. This involves increasing the status of technology in our schools; improving the motivation of students in science and mathematics and raising students awareness and aspirations regarding careers in industry. This must be seen as the responsibility not only of technology, science, mathematics and other teachers, but also that of the business and industrial community.

References

1 Black, P and Harrison,G *In Place of Confusion: Technology and Science in the School Curriculum*. The Nuffield-Chelsea Curriculum Trust and The National Centre for School Technology, Trent Polytechnic, (1985).

2 EMU *The Assessment of Performance in Design and Technology: The full report of the APU Design and Technology Project 1985-1991*. SEAC (1991).

3 *Mathematics, Science and Technology in Schools: A Cross-Curricular Conference Report.* Mechanics in Action Project, Department of Education, University of Manchester (1991).

4 Layton, D *Inarticulate Science? Text of the department of Education Lecture May 24th 1990* Occasional papers No 17, University of Liverpool Department of Education (1990).

5 T*echnology and school science: an HMI enquiry*. DES (1985).

6 *Science and Technology: Education and Employment.* Advisory Council on Science and Technology (ACOST). Cabinet Office. HMSO (1991).

7 Brian E Woolnough T*he Making of Engineers and Scientists: Factors Affecting Schools Success In Producing Engineers and Scientists.* A report for The Institute of Physics, The Institution of Electrical Engineers and National Power. Oxford University Department of Educational Studies. (1991).

Figure 1

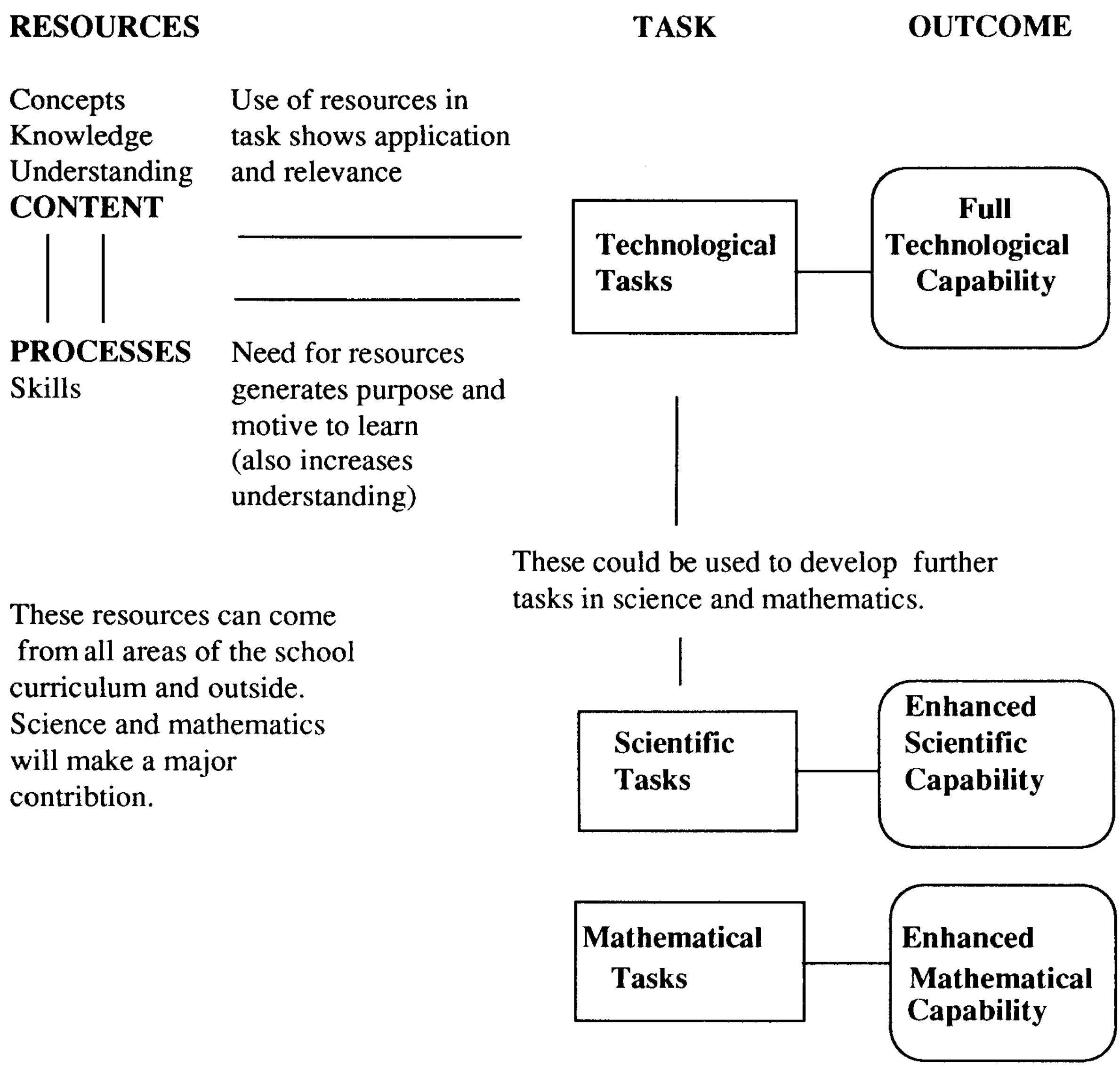
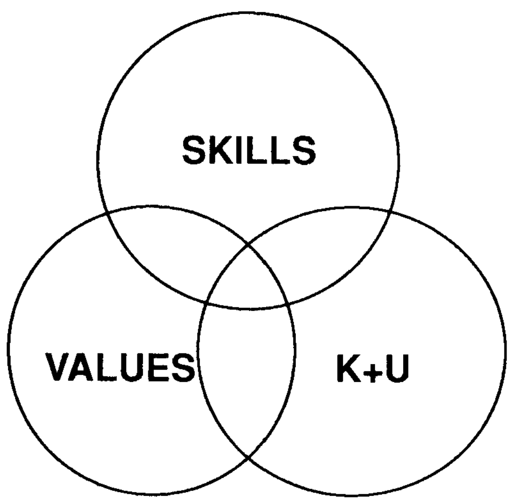

RESOURCES
TASK
OUTCOME
Concepts
Knowledge
Understanding
CONTENT
Use of resources in
task shows application
and relevance
Technological
Tasks
Full
Technological
Capability
PROCESSES
Skills
Need for resources
generates purpose and
motive to learn
(also increases
understanding)
These could be used to develop further
tasks in science and mathematics.
These resources can come
from all areas of the school
curriculum and outside.
Science and mathematics
will make a major
contribtion.
Scientific
Tasks
Enhanced
Scientific
Capability
Mathematical
Tasks
Enhanced
Mathematical
Capability

Diagram 2

Full technological capability will aise from an interaction of skills, knowledge and values through the performance of technological tasks.

investigative
research
planning
making proposals
implementation
evaluation
communication
IT
thinking
decision making



aesthetic
economic
moral
environmental

materials
energy
structures
control
etc.