

Developing capability in technology through collaborative approaches with mathematics and science

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This article is adapted from a paper developed for the CTC Trust and is based on the work of the ASE/DATA Science with Technology Project. The issues raised in this article have been fully recognised by the Royal College of Art Schools Technology Project and activities to support students in making effective use of their mathematical and scientific knowledge and understanding are included in the materials produced by the Project.

There are many aspects of design and technology that relate to work in mathematics, science and information technology. Helping students to make effective use of these relationships will lead to improved capability in design and technology. This article covers:

- the issues to be addressed when planning collaborative working in schools
- some strategies that can be used to address these issues
- the nature of the links between the subjects involved
- common areas of content and developing understanding
- the benefits of collaborative working
- a process for planning collaborative work
- the implications for design and technology

1. Collaborative working – the issues

There are issues to be addressed when planning any collaborative work in schools. These can be conveniently grouped as:

• *Logistical issues*

These include problems such as the timing and sequencing of the activities in each subject as well as timetabling and student grouping; these issues need to be carefully considered during the planning stage of the collaborative programme. Successful planning at this stage will usually involve key decision makers in the school.

• *Philosophical issues and subject cultures*

Within each subject there is an

understanding of the philosophical background to the development of the subject, the place of the subject within the overall curriculum, the subject's content and skills and the methods used to teach the subject. This gives each subject its own 'culture' which needs to be carefully considered during collaborative work. Often these cultures can lead to barriers and blocks that make planning collaborative working difficult.

• *Conceptual development*

In many ways this is by far the most important set of issues to be addressed. Students cannot easily transfer understanding from one subject to another; this is not the fault of the students. For example, often the way a topic is taught to achieve conceptual understanding in science does not lend itself to an understanding of the concept that can be translated into "knowledge for practical action" that is useful in design and technology. Mathematical skills are developed to serve the purposes of mathematics; students need to be supported if these skills are to be effectively transferred in order that they can be applied in another subject area. The transfer of knowledge from one subject area to another often involves a deconstruction and reconstruction of the form of the knowledge before the transfer can take place effectively. This needs to be taken into account during the planning stage of any collaborative programme.

2. Linking work in a range of subjects – some effective strategies

There are a variety of ways of developing collaborative strategies to link students' work in mathematics, science and technology in order to enhance capability in all subjects. These can be grouped into three broad areas:

2.1 Increasing **awareness** of the programmes of study used in each subject and taking this into account when planning schemes of work. This can be used to:

- make sure that particular concepts or skills are covered at an appropriate time

in order that they can be used in the other subjects

- cross-reference from one subject to the other and draw students' attention to links that could be used to improve the quality of their work
- build progression into the development of conceptual and procedural understanding in all subjects.

This increased awareness can be further enhanced through the use of common contexts and stimuli for pupils' learning.

2.2 Co-operative programmes using joint planning of a particular topic to provide a coherent and cohesive framework to develop activities. This can be used in two ways:

- with separate but linked activities taking place in each subject area but within the common framework with students frequently reminded or asked to make links; for example, a series of activities to develop understanding in science could also form focused practical activities to support design and make tasks in design and technology
- students given more responsibility for planning their work which is taken from one lesson to the next irrespective of the subject; they obviously need to plan the activities to make best use of specialist facilities and teacher expertise.

2.3 An integrated approach using a more holistic approach where the activities are planned making use of resources from all of the subject areas involved. The main focus will be an extended task with a range of resource activities to support this main task; these resource activities will cover all of the subjects involved. This type of activity can be carried out using a suspended timetable slot for two or three days or for a whole week or a planned timetable slot using a time allocation from each of the subjects involved. This approach can be used to take full advantage of industrial links, visiting 'experts' or local events.

2.4 One effective approach is to use a common context for all the activities with one major activity to which all of the subjects involved will contribute. A series of '**structured inputs**' can then be developed in the individual subjects to support the 'core' activity. These structured inputs will:

- provide data and information
- act as resource activities and focused tasks to develop skills and understanding
- include individual and group activities
- be matched to the individual requirements of the National Curriculum in the subjects involved.

This method allows for flexibility in the curriculum model adopted to deliver the collaborative programme. It also allows differentiation and progression to be built into the activity.

3. The nature of the links between the subjects

3.1 *Science and Design and Technology*

There are several ways in which the nature of the links between these two subjects can be viewed. From the point of view of design and technology the most useful view is that of 'science as a resource' for design and technology tasks. Science can provide:

- knowledge and understanding of appropriate concepts
- skills, techniques and procedures such as procedures for experimentation, investigation and research
- focused practical activities.

Design and technology can act as a context for work in science. For example, the area of 'products and applications' in design and technology includes the need for an understanding of the underlying scientific principles. This obviously requires the application of an understanding from science. However, it also provides the opportunity to develop interesting and relevant contexts for the pupils' work in science. Studying familiar consumer products such as personal stereos, sports equipment or fashion clothing provides

opportunities for students to learn about product design, meeting the needs of the intended users of the product, the use of materials, quality control and assurance procedures and marketing. It also provides familiar contexts for pupils to sort out, refine and develop and apply their scientific understanding. This can also be applied to investigating mass produced food products and food preparation and processing techniques, control systems and manufacturing systems. The use of anthropometric data in the design of products provides an excellent stimulus for work in science on human variation.

The reverse situation of science as a context for design and technology can also be exploited. For example, the science curriculum contains a number of references to the use of energy and the need for energy conservation and more energy efficient appliances, devices and processes. One useful starting point is to consider energy management in the school involving a series of science investigations to obtain the data and information needed to develop a range of strategies leading to reduced fuel bills and less environmental impact. During these investigations students will encounter many opportunities for the design and making of energy related products and devices such as temperature and lighting monitoring and control devices, automatic timing devices, the small-scale use of renewable energy, door and window closing devices and so on. These can be exploited in design and technology as contextualised, referenced or specific tasks allowing for differentiation.

3.2 *The role of mathematics in design and technology and science*

The mapping of mathematics onto the other subjects raises some difficulties; one area of mathematical knowledge or a particular mathematical skill will be useful in many areas of both design and technology and science. One way of dealing with this issue is to develop a set of 'generic' mathematics tasks that can be used to support a range of design and technology and science activities. These can then be incorporated into the collaborative project at appropriate points. These generic tasks could cover areas such as:

- 2D and 3D modelling
- using spreadsheets to develop mathematical models from investigative data
- calibration of devices and instruments
- analysing the relationship between two variables
- display and analysis of quantitative data
- using and interpreting graphical information
- reading scales and making measurements
- making scale drawings
- ratios
- assessing accuracy and reliability
- making estimates.

This allows abstract mathematical concepts to be developed through linking them with practical activities in the other subjects. It also allows a more mathematical and rigorous approach to be adopted in design and technology and science.

3.3 *The role of Information Technology*

Experience has shown that students develop more effective IT skills when these are learnt through a relevant context where there is a clear need for or advantage to using IT. Mathematics, science and design and technology all offer excellent opportunities to develop these IT skills and collaborative work will lead to the development of more relevant and meaningful contexts. In particular, there is great potential for the use of spreadsheets and databases in all of these subjects and the use of computer and mathematical modelling has a place in all three. Design and technology and science also provide opportunities for developing the use of IT in measuring, monitoring and control systems. CAD/CAM is also a key use of IT in design and technology.

Every attempt should be made to incorporate IT activities into the collaborative project but the guiding principle should be that IT is the best and most effective way of carrying out the activity and not contrived simply to provide an opportunity for IT.

3.4 Problem solving and investigation

'Problem solving' as a teaching technique now appears in the repertoire of almost every subject in the school curriculum. Mathematics, science and technology would all most certainly stake a claim in the use of the term. Similarly 'investigations' are carried out in all three subjects and there is some similarity in the processes used to carry out these investigations. Table 1 shows one analysis of these processes.

In all three subjects the stages used follow the pattern:

- Define the problem or situation
- Plan how to proceed
- Perform the investigation, making the product
- Review and evaluation.

This is not to suggest that the process used in these subjects is necessarily a linear one as opposed to a cyclical or even an iterative one; it is recognised that investigative approaches and designing and making activities do not fit easily into this neat process. However, these stages can generally be recognised in these activities even though the ways of achieving them may be quite different. The analysis is included here to show that there are common areas of process as well as content between these subjects. At first sight this appears to be an attractive area to use to develop collaborative work. However,

in the planning stage of the activity it is vital to establish a common language and understanding of terms such as 'problem solving' and 'investigation'. Further confusion can also arise over the meaning of 'open-ended' and 'closed' investigations. The meanings in science and mathematics for example, may be quite different.

4. Common areas of content across mathematics, science, design and technology and information technology

Identifying common areas of content between these subjects is not difficult. The following areas of design and technology all have clear links with Science:

- materials
- food technology
- energy transfers
- systems and control
- structures
- evaluating environmental impact of products and processes
- making risk assessments
- ergonomics and anthropometrics.

Examples of links with mathematics are:

- developing spatial awareness
- 2D and 3D modelling

Table 1

Mathematics	Science	Design and Technology
Identify a problem and plan an investigation	Making a prediction or propose a hypothesis and plan an investigation	Identify a need and plan the development of a solution
Build a mathematical model and select the maths to use	Design a suitable investigation to test the prediction or collect evidence to test the validity of the hypothesis	Carry out research and generate a range of designs/solutions to meet the identified need
Analyse the model using mathematics	Carry out the investigation/ collect the evidence	Implement the optimum solution
Interpretation and validation of the model	Interpretation of the data collected and check the validity of the procedure or hypothesis	Evaluate the effectiveness of the solution

- the use of spreadsheets as a design tool
- assessing accuracy and reliability
- display and analysis of data.

In many ways, more important than identifying common areas of content is the identification of strands of conceptual development to be built into a collaborative programme. As an example, the area of systems and control has been used to show how to develop common strands of conceptual understanding across mathematics, science and design and technology. The analysis shown in Table 2 can be used to develop a coherent approach building in the development of conceptual understanding allowing for both progression and differentiation. From this example a general process can be extracted which can then be applied to other topic areas.

- If collaborative work is used to develop pupils' understanding then it is vital at the planning stage to establish what the concepts are and to develop the strands and steps that lead to conceptual understanding.
- Where these strands cross the subject boundaries there must be a coherent strategy for their development. If parts of the strand are covered in different subjects the other subjects need to build in activities to support and reinforce the understanding and to aid the transfer from one subject to the other.
- Formative assessment strategies will need to be developed to collect the evidence needed to monitor students' progress and plan the next stage of their work.

5. The benefits of collaborative working in schools

The work of a number of projects with first-hand experience of working with schools, teachers and pupils highlights the clear benefits of collaborative work to both pupils and teachers. The key benefits to students are:

- enhanced learning through reduced confusion, greater coherence and linking

abstract work in one subject with practical activities from another

- increased motivation through a greater perceived relevance and personal involvement
- a reduction in the assessment load where shared coursework assignments are used.

This leads to clear benefits for teachers through:

- the benefits to students
- an improved understanding and awareness of other subjects
- better management of resources
- staff development, for example, through the discussion of teaching and learning styles.

6. A process for planning collaborative work

A process for planning collaborative work in schools has the following components:

Stage 1

Identify and agree a common broad area of content.

Stage 2

Identify the learning objectives – some of these may be common to the subjects involved; others might 'belong' to one subject but be dependent on the nature of the joint activity. This will also involve the identification of the knowledge, understanding and skills to be developed.

Stage 3

Identify strands of conceptual development that run through the subjects involved and employ strategies that support the effective transfer of understanding from one subject to another.

Stage 4

Discuss and agree teaching methods and approaches.

Different approaches to the same area of content or to a particular skill may be adopted in the different subjects. Each

Table 2 Progression in Systems and Control

Design and Technology	Science	Mathematics
	Need for complete electrical circuit. Use switches to control electrical devices. Ways of controlling the current in electrical circuits. Use circuit diagrams. [KS2]	
Use electrical switches to control devices.	Measuring the current in series and parallel circuits. [to understand the operation of sensors which are usually connected into a potential divider, measuring pd will need to be introduced here even though it is in KS4 Science.]	Understanding and using measuring instruments and units. Discrete and continuous measures. Design and use data collection sheets.
Use sensors in switching circuits.		
Interconnect mechanisms to achieve different kinds of movement.	Types of force. [KS2] Forces can cause objects to turn about a pivot. The principle of moments.	Use of letters to represent variables. Manipulate algebraic expressions.
Simple pneumatics systems.	Force, area and pressure.	
Systems have inputs, processes and outputs.	Measuring forces, movement, angles.	Explore a variety of situations that lead to the expression of relationships.
Systems are often made up of two or more sub-systems.		
Use systems that interconnect simple mechanical, electrical, electronic and pneumatic sub-systems.		
Design simple systems interconnecting different types of sub-system.		
Simple feedback systems.		
Analyse the performance of systems.	Conservation of energy. Energy is always dissipated. Efficiency of energy transfers.	Explore a variety of situations that lead to the expression of relationships Process and interpret data.



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subject will bring the collaborative project its own repertoire of teaching approaches. However, because they are part of a coherent and well planned activity this will reinforce students' understanding and capability rather than raising conflicts and confusion in the minds of the students. Discussions about teaching and learning styles also provides extremely useful informal staff development.

Stage 5

Plan for coherence and progression. A coherent structure and a co-ordinated approach to the topic needs to be developed even though the activities may be covered in separate subject areas.

7. The implications for design and technology

The work done by the Science with Technology Project and others raises the question of whether there is a body of knowledge and skills that is exclusive to design and technology. It is certainly true that developing skills in designing and making are at the heart of design and technology but the knowledge and understanding that contributes to this activity is heavily dependent on science; mathematical skills are an essential tool for both designing and making. However, the science and mathematics is rarely capable of being used effectively without undergoing significant re-working to make it appropriate to the designing and making task; in this sense, it becomes the property of design and technology. It is unlikely that students can undertake this re-working without a great deal of support through structured activities; the problems of transfer of understanding have been raised earlier in this article. This makes it imperative that a degree of coordination is established between these three departments in schools; the benefits to students' learning and development are clear. Unfortunately, the consequences of ignoring the issue can also be seen through students' work in design and technology; it was all too apparent in the work I saw in my role as a Chief Examiner for Technology.

References

The ASE/DATA SATIS *Science with Technology* Project

The Association for Science Education
The Design and Technology Association
Resources available from ASE Booksales, College Lane, Hatfield, Herts AL10 9AA.

The units on *Teamwork* and *Project Management* could be very useful for the planning team developing collaborative projects in schools.
The Science and Technology in Society (SATIS) project has produced a range of resources for science and technology covering the age ranges 8 to 14, 14 to 16 and 16 to 19. They are all available from ASE Booksales.

The Mechanics in Action Project, Department of Education, University of Manchester, Oxford Road, Manchester. (Resources linking work in mathematics with science and technology.)

Layton D. (1993), *Technology's Challenge to Science Education*, part of the Developing Science and Technology Education series, Open University Press

Sage J. *Developing relationships between science and technology in secondary schools*, IDATER 92 (International Conference on Design and Technology Educational Research and Curriculum Development), Loughborough University of Technology

Sage J. and Steeg T. *Linking the learning of mathematics, science and technology within key stage 4 of the National Curriculum*, IDATER 93 (International Conference on Design and Technology Educational Research and Curriculum Development), Loughborough University of Technology

APU (1991) *The Assessment of Performance in Design and Technology*

McLachlan M. and Williams J. (1993) *Collaborative work between Maths, Science and Technology in Stockport Schools* Stockport LEA and the Mechanics in Action Project

DFEE (1995) *The National Curriculum in Mathematics, Science, Design and Technology and Information Technology*

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