Cross curricularity

David Barlex considers the developing relationship between science, design & technology and mathematics within the secondary school curriculum.

tools for change

STEM:
Science, Technology, Engineering and Mathematics

Within the curriculum STEM activities explore the interdisciplinary connections between the contributing school subjects science, design & technology and mathematics with special reference to those sorts of activities that might be termed engineering or have a strong engineering component.

Engineering is a very broad area of professional activity, hence the definition from the Royal Academy of Engineering as the knowledge required, and the process applied, to conceive, design, make, build, operate, sustain, recycle or retire, something of significant technical content for a specified purpose; a concept, a model, a product, a device, a process, a system, a technology.

An international movement

Over the past 25 years there has been agreement that cross-curricular activities involving science, mathematics and design & technology are an essential component of a balanced school curriculum. For example, in 1983, an expert group which conducted a comprehensive study of secondary education in America drew this conclusion:

While we recognize the integrity of the disciplines, we also believe their current state of splendid isolation gives students a narrow and even skewed vision of both knowledge and the realities of the world.

Ten years later Project 2061, also based in America, reinforced this view by stating:

The basic point is that the ideas and practice of science, mathematics, and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others...

This endorsement for cross curricular activity is not confined to America. In Israel technology education curricula in Israeli junior high schools (grades 7-9) were combined into one mandatory subject—'Science and Technology'. In addition, a new 'Science and Technology' national curriculum was developed, with collaboration between science and technology education as a central ideal justified as follows,

...Collaboration between science and technology is essential because of the growing linkage between scientific subjects and relevant technologies and also because of the unclear borders between them.

In England the specialist Engineering Colleges, catering for students aged 11 – 19 years, have the following as part of their vision statement:

Through a focus on enhancing understanding of the relationship between design & technology, mathematics and science, underpinning a broad curriculum, engineering colleges will raise standards of achievement for all students across the ability and subject range, leading to whole school improvement by providing increased diversity through opportunities for students to follow a wide range of vocational pathways.

The National Curriculum programme of study for design & technology to be implemented in 2008 in England includes the following statement promoting the use of cross-curricular links.

In ways appropriate to the product area, the curriculum should provide opportunities for pupils to:

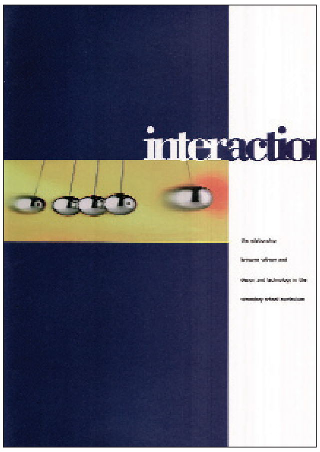
make links between design and technology and other subjects and areas of the curriculum. This includes using knowledge from other subjects and from outside the school when designing and making. It also includes using design & technology to give context and meaning to the application of other programmes of study.

However, despite the support for cross curricular activity and the explicit acknowledgement that the nature of design & technology lends itself to such activity, the reality of practice in secondary schools paints a different picture.

The relationships actual and potential

The Interaction Report written by David Barlex and James Pitt in 2000 painted a rather bleak picture of the relationship between science and design & technology:

In academia and industry the relationship is viewed by both communities as dynamic and influential whereas in secondary schools the relationship between science and design & technology is seen by both communities as almost non existent.




John Holman and Michael Reis in their report *S-T-E-M Working together for schools and colleges* paint a similar picture across the contributing subjects using the size of letters to indicate their relative significance as shown.

STEM	STEM
Inside the classroom: Science and Mathematics dominate curriculum time and resources	**Outside the classroom:** Technology and Engineering dominate the world of work

The isolation of individual subjects is understandable. The current accountability culture does little to encourage collaboration and any activity that does not immediately lead to improvement as measured by summative assessment and examination is likely to have low priority. This silo mentality is compounded by the high pressure existence of many teachers with little time available to talk to colleagues within their own subject specialism never mind those in other curriculum areas.

It will take considerable effort to overcome the barriers that currently prevent teachers from collaborating in genuine interdisciplinary STEM activities.

“

In Science there is so much to understand and remember

The course work component of D&T is so big

The cognitive demand of mathematics is too great for many pupils

”

... and we all have our A* - Cs to consider!

Yet there are strong arguments for a more collaborative approach. The Royal Society Report from John Holman and Michael Reiss identify the following benefits

- Marching in curriculum step – co-ordinating the sequence of work in the three subjects so that they can provide mutual support
- Painting a fuller picture of STEM outside the classroom – leading to increased motivation to choose the subjects and consider a related career.
- Showing the value of difficult subjects – enabling pupils to appreciate the contribution of these subjects to our lives
- Uncovering the engineering and mathematics that lie hidden in other parts of the curriculum – science and design & technology are replete with examples of engineering that have mathematics embedded and making these explicit will help pupils see the value of studying mathematics.

The report stresses that all members of the community need to be treated as autonomous players and that it will be necessary to foster a culture of co-operation not competition. The report also notes firmly that it is important to preserve the integrity and identity of individual subjects, as well as showing how the subjects support one another.

tools for change

Issues of understanding

It is here that the differences between the subjects needs to be understood by those in the STEM community who will be working together. Designing is a slippery activity, not at all like a scientific investigation. The designer's perceptions and understanding of the problem or brief change as he or she develops the solution and solutions initially conceived as appropriate are altered in response to this internal discourse. The whole exercise is underpinned by uncertainty. This is often misunderstood by those outside the design & technology community.

Bryan Lawson captures this nicely in his book *What designers know* with an analogy to playing chess:

Designing then, in terms of chess, is rather like playing with a board that has no divisions into cells, has pieces that can be invented and redefined as the game proceeds and rules that change their effects as moves are made. Even the object of the game is not defined at the outset and may change as the game wears on. Put like this it seems a ridiculous enterprise to contemplate the design process at all!

Marc deVries writing in his book *Teaching about Technology An Introduction to the Philosophy of Technology for Non-philosophers* gives a pithy summary of the difference between science and technology as follows:

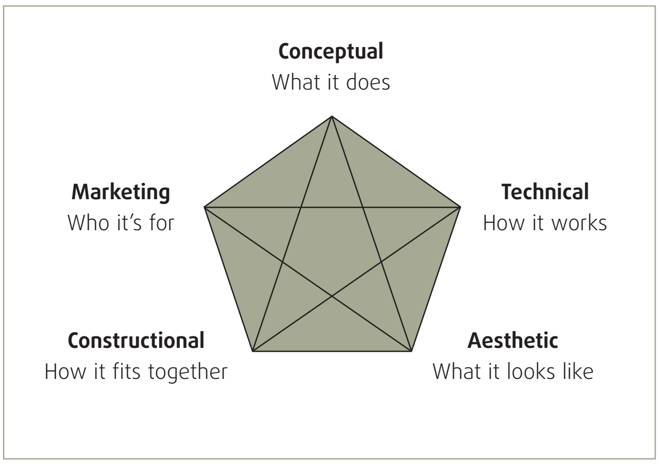
Science is primarily concerned with exploration and explanation of what exists developing and using declarative knowledge whereas design & technology is concerned with the conception of what does not yet exist and how it might be brought into existence requiring and developing normative knowledge

Don Ihde, another philosopher of technology, considers the statement from the National Rifle Association "Guns don't kill people, people kill people!" He argues that the human-gun relationship transforms the situation from any similar situation of a human without a gun. He than makes the analogy between the use of the gun by a person and the use of a technology by society arguing that at the level of mega technologies, it can be seen that the transformational effects will be similarly magnified. Don, along with other philosophers, has coined the phrase 'techno science' to describe the modern manifestation of technology. They argue that science and technology are so intricately related that their separation is really only useful for analytical purposes. So when we are discussing the impact of modern technology on society with pupils an important dimension will be the way science informs and interacts with the technology and this is to some extent what we want to happen with pupils in school the interaction of science (and mathematics) with the design & technology.

Within design & technology the main means of learning and demonstrating capability in the subject is through designing and making assignments (DMAs) in which pupils generate and develop ideas for products to the point where they are made to the standard of a good working prototype. At the heart of this process lie design decisions. For any particular product a pupil can make the following sorts of interrelated design decisions: Conceptual (what it does), Technical (how it works), Aesthetic (what it looks like), Constructional (how it fits together), and Marketing (who it is for).

This can be represented visually with each type of decision at a corner of a pentagon and each corner connected to every other corner. This inter-connectedness is an important feature of making design decisions. A change of decision within one area will affect some if not all of the design decisions made within the other areas. The design decision pentagon can be extended by asking three very important supplementary questions concerning the impact of the product resulting from the design decisions.

- What is the social impact?
- What is the economic impact?
- What is the environmental impact?



The design decision pentagon illustrates the range of decisions to be made, and their interconnection.

Teachers can use this diagram to audit their curriculum to reveal the extent of designing in their curriculum.

Pupils can use the pentagon to think about the design decisions that they make.

The designing, through making these decisions, is a purposeful activity in a way not encountered in most other areas of the curriculum. All areas of the curriculum have purposeful activities in the sense that their purpose is that of educating pupils in the subject at hand. Designing has another dimension to its purpose. It is aspirational in that the aim of activity is not only educational, but also to develop a product that will improve an existing situation or enhance the well being of a particular person. It is this dimension of purpose that makes designing such a powerful educative medium.

Within STEM activities the pupil's ability to make good design decisions can be enhanced by the application of relevant science and mathematics. This utility of science and mathematics not only improves pupils ability to design and the development of their capability in design & technology but also enhances the pupils understanding of the mathematics and science they use. Properly constituted STEM activities centred on designing represent a win-win situation for the contributing disciplines. The challenge for those of us committed to the interdisciplinary, cross-curricular STEM initiative is to demonstrate this enhanced achievement.

Developing interdisciplinary, cross-curricular STEM in the classroom

The first stage is the identification and clarification of a purposeful design activity to which the utility of mathematics and science can be used to enhance the quality of the design decisions made by the pupils. This is curriculum development. The second stage is to clarify the means by which pupils will be engaged with this purpose and utility. This will involve developing appropriate ways of teaching the curriculum – pedagogy development. The third stage will involve the teaching of the curriculum and the evaluation of pupil achievement.

This requires one or more small pilots. An immediate question now is "Who to involve in this process?" Many local authorities in England employ advanced skills teachers (ASTs) to provide professional support and guidance for other teachers. Collaboration between ASTs from design & technology, science and mathematics developing designing and making assignments with purpose and utility would be an appropriate and robust response to this challenge.

Interestingly this process is taking place in the Kent Local Authority and the preliminary results will be published in D & T News, early in 2008. Another interesting way of developing and evaluating potentially useful STEM curricular is through the activities of the newly constituted Science and Engineering Clubs. 250 schools specially selected by the DCFS have been given additional funding to develop extra curricular activities that inspire and engage KS3 pupils with STEM. The teachers involved are given professional development designed to enable them to collaborate effectively across the subject boundaries and there are plans for regional events in the summer term 2008 to celebrate the activities and achievements. These events will be co-ordinated and arranged by the STEMNET regional directors.

If you want to know more about Science and Engineering Clubs then visit:
www.the-ba.net/the -ba/YPP/Clubs/index.html and
www.stemnet.org.uk/teachers/After_School_Science_and_Engineering_Clubs.cfm

The need for nurturing

David Hargreaves has considered the development of activities that explore the interdisciplinary connections between school subjects as generating new professional knowledge. He argues that it is insufficient for schools to provide the opportunity for teachers to generate ideas but that in addition it is essential that there is support for this process as good ideas, especially when they come from new or more junior members of staff, are fragile and may need protection. An atmosphere of cynicism will kill knowledge creation. Developing STEM activities in schools will require those involved to show a generosity of spirit that prevents any such cynicsm.

Knot working is an interesting mechanism for facilitating the development of the new professional knowledge required to devise designing and making assignments with purpose and utility.

Knot working is an idea developed by Yrjö Engestrom. It involves solving urgent tasks where the combinations of people and the contents of the tasks are likely to change. The members of the group convened to tackle the problem are chosen on the basis of the experience in relation to the nature of the problem. In the case under consideration here such a group might consist of a design & technology teachers, a science teacher, a maths teacher and an ICT teacher. In such a group it will be important to put aside issues of status and position and concentrate on the task in hand, with each person making a contribution to cross-curricular STEM initiatives according to their relevant expertise. This may be an unusual activity, but the potential for curriculum development that enhances cross-curricular activity is high.

Vera John-Steiner (2000) has written at length about the issues facing those who wish to work across and within disciplines. She argues that it will require partnerships that thrive on dialogue, risk-taking and a shared vision. Such successful collaboration always involves trust and this has to be earned by those working together. Without trust it is not possible to reveal and overcome the insecurities and uncertainties that underpin all creative endeavours. Working with colleagues in this way requires those involved take the bold step of becoming dependent on one another. This dependence is not a sign of weakness, but of strength; a dignified interdependence through which those working together have mutual respect and can forge achievements far beyond their individual, isolated capacities. For example, design & technology teachers working with colleagues from other subjects in an endeavour to develop powerful designing and making assignments with both purpose and utility typifies the sort of collaboration that John Steiner has described. It is both professionally rewarding and personally exhilarating. The current revision of the Key Stage 3 curriculum initiated by the Qualifications and Curriculum Authority holds the promise that the cross-curricular activity required by STEM will become the norm rather the exception.

Further reading

Barlex, D. (2007) **Engaging with issues as a focus for technological literacy**
Presented at PATT17 San Antonio February 2007
Soon to be available in the Conference Proceedings at
www.iteaconnect.org/Conference/pattproceedings.htm

Barlex, D. (2005) **Becoming an Engineering College**
A report describing emerging and developing good practice,
London: Specialist Schools Trust

Barlex, D and Pitt, J. (2000) **Interaction:**
The relationship between science and design and technology
in the secondary school curriculum,
London: Engineering Council

de Vries M., J. (2005) **Teaching about Technology**
An Introduction to the Philosophy of Technology for Non-philosophers,
The Netherlands: Springer

Engestrom, Y. (2004) **New Forms of Working**
Accessed 23 April 2007 at
www.edu.helsinki.fi/activity/pages/research/newforms/

Hargreaves, D. (1998) **The role of teachers in the knowledge society**,
London, England: Demos

John-Steiner, V. (2000) **Creative collaboration**,
New York: Oxford University Press,

Lawson. B. (2004), **What designers know**,
Oxford, UK, Elsevier

Embedded links in this article

Royal Academy of Engineering
www.raeng.org.uk/

Interaction Report
www.engc.org.uk/documents/Interaction_Report.pdf

S-T-E-M Working together for schools and colleges
web.data.org.uk/data/news/index.php#stem

STEMNET regional directors
www.stemnet.org.uk/about_stemnet/meet_the_stemnet_team.cfm

D & T News
web.data.org.uk/data/publications/magazines.php

This article is one of a series available
on the Nuffield Secondary D&T website.

www.secondarydandt.org

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For further reading on key issues influencing the teaching of design & technology, see the recently published:

Design & technology for the Next Generation
a collection of provocative pieces written by experts in their field, to stimulate reflection and curriculum innovation.

Available from the educational publishers CliffeCo at
www.dandt-thebook.com