Review
Teaching STEM in the Secondary School

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Authors:	Frank Banks and David Barlex
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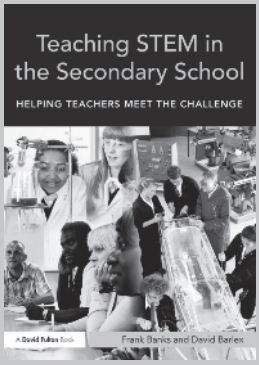

I'm sure most of us have read a lot about STEM (Science, Technology, Engineering and Mathematics) in documents such as research papers, journal articles, government documents and the media, but this book is different. While it draws on the authors' undoubted knowledge of STEM on an international front, with references to documents from numerous international sources, this book is more down to earth and is about STEM as it is in UK schools, with the added vision of how it could be if the opportunities where fully explored. The book is not written in the usual academic prose normally used for education books, it is written in what is best described as a 'conversational style'; at times I found myself asking questions such as 'what if?' and 'but can't we do that?' and, on several occasions, disagreeing with the authors by thinking 'no that can't be right!' Occasionally there is an element of humour which adds to the enjoyment of reading this book. This style of writing an educational text book is particularly welcome at a time when teachers and trainee teachers have become used to the usual list of bullet points and tick boxes. Part of this readability is achieved by the authors using case studies, cameos and examples thus ensuring the book is a realistic view of STEM in schools.

Who is this book for?
The text on the cover says '*essential reading for trainee and practicing teachers*' however I suggest that this book is also essential reading for senior leaders in schools such as head teachers and curriculum deputies who need to gain a very clear understanding about the educational opportunities available within STEM subjects.

Format of the book
In the introductory chapter about the nature of STEM the authors raise issues such as the relationship between science and technology, a topic that seems to recur periodically in the book and is not fully resolved. It is chapter two, where they start to show the way they think about STEM, the title '*A curriculum for STEM – 'looking sideways*' (page 25) says it all; numerous examples of good practice mainly from schools that introduce the reader to a range of educational initiatives that have, and are still influencing STEM implementation in schools. A section headed '*Sharing teachers' professional knowledge*' (page 33) includes a theoretical example of how STEM can help teachers gain an understanding of sharing the curriculum and yet establish a personal construct to inform their pedagogical practice. This is encapsulated in a simple but very effective diagram (page 34) that must be useful to anyone involved in teacher education.

It is in this chapter that an element of confusion creeps in as the previously discussed relationship between science and technology is exacerbated by the statement '*science and design & technology are so significantly different from one another that to subsume them under a 'science and technology' label is highly dangerous.*' (page 41). Perhaps this clarifies the confusion! At several points in this book I thought the authors, both with a science background, were talking themselves out of being scientists and into being technologists, but then the old problem of what design & technology is compared with technology (as used by many countries) raised its head. The authors, both with a thorough understanding of D&T through their international curriculum development activities and teacher education responsibilities, make a good job of trying to rationalise this but it remains an unresolved issue. This curriculum analysis chapter concludes with a statement that we could all take to heart. '*If teachers 'look sideways' pupil learning can enhanced.*' (page 46). A very true statement.

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Analysis of the each of the STEM subjects

As expected each of the subjects contributing to STEM is allocated a separate chapter each with an analysis using quotes from distinguished authors and published texts however what makes this book so useful is the inclusion of numerous examples of how the subjects can capitalise on STEM. These examples are realistic and achievable the theme being subjects cooperating in the development of teaching and learning materials. In the chapter '*Teaching Science in the light of STEM*' (page 48) the authors introduce the notion of teachers talking to each other. This becomes a strong thread in the book binding each section together. A second, but equally valid thread, is the importance of project work and project based learning (PBL) as these features in virtually every chapter. The science chapter starts with a short historical review with quotes from eminent authors and curriculum developers identifying the strengths and weaknesses of the way science is approached in UK schools. The possible relationship with D&T is a strong element in this analysis particularly with a recognition of the work by David Layton to the point of quoting the controversial statement '*the acquisition of scientific knowledge is inescapably tinged with dogmatism*' (Layton D, 1975) (page 50). Inevitably the examples given for consideration by teachers, and particularly suitable as STEM curriculum development, have a science base but are presented as being ideal for discussion with other STEM teachers thus demonstrating how '*dogmatism*' can be broken down. In the chapter dealing with D&T the subject is dealt with in a similar way with the addition of how D&T, through the D&T Association supported by higher education, design, engineering and manufacturing industries dealt with recent negative political interventions. Unfortunately the authors consider the starting point for D&T was in 1988 with the introduction of the UK national curriculum ignoring the fact that much of D&T curriculum development occurred prior to this in the 1970's and 80's supported by projects such as the Schools Council funded Modular Technology, Microelectronics For All (MFA) and Design & Craft. Similarly, more recent curriculum development initiatives such as the Digital D&T programme are not included although the Technology Enhancement Programme (TEP) gets a brief mention (page 161). Torben Steeg, an experienced educational researcher and consultant, (page 77) uses his in-depth knowledge of both science and D&T to provide an illuminating interview promoting interesting practical ideas for co-operation between D&T, science and mathematics. As with science the D&T curriculum development examples provide exciting opportunities for teachers and their pupils with no fewer than seven realistic examples of how D&T and maths could work together. While the text of this chapter, with the examples, encapsulates the learning embedded in pupil research and designing activities there seems to be a lack of recognition that making processes require similar levels of intellectual engagement as pupils use materials, tools, equipment and machinery to turn their ideas into reality.

I expected 'E' for engineering to follow next only to find it is 'M' for mathematics! (page 100) Engineering seems to be relegated to a later chapter titled '*Enabling the 'E' in engineering*' (page 151). The opportunities for mathematics within STEM are introduced using an amusing, but serious analogy, and then are dealt with in the same way as science and technology (D&T). The authors cite OfSTED reports and several eminent experts such Vorderman and Porkress (page 103) who paint a picture of concern about the lack of popularity of mathematics in schools and express major anxieties about the way it is taught. This is balanced by a discussion about initiatives such as the case study approach developed by the National Centre for Excellence in the Teaching of Mathematics (NCETM) until recently directed by Professor Celia Hoyles whose interview with the authors provides ideas for capitalising on the relationship between technology (D&T) and mathematics identified in an earlier chapter. As in previous chapters this is followed by examples of collaborative ventures between subjects although these seem to have a more scientific focus, this is recognised by the authors with the comment that science and D&T teachers '*will be able to identify many more examples*' (page 133). Surprisingly ventures such as Class Of Your Own (COYO), an emerging UK initiative, that focuses on mathematics in real life situations such as surveying in civil engineering and the construction industries is not included.
(http://designengineerconstruct.com/)

Eventually I came to the 'E' for engineering in STEM and this chapter is in an entirely different format. A major part of is a presentation by Professor Mathew Harrison, until recently Director of Education at the Royal Academy of Engineering, in which he presents a convincing case for engineering being a school subject backed up by recent facts and figures with quotes from numerous published reports. His main thrust can be summed up as engineering is the one subject in the STEM agenda that pulls together all of the subjects and these link into manufacturing and engineering industry. This is an impressive report on the recent history and successes of engineering in UK schools however it does raise the, controversial in the UK, question of whether engineering is a vocational subject. This is followed by the authors' discussion dealing with issues raised by Mathew Harrison,

again using their questioning style that effectively thus puts the reader in the position of decision maker. The USA STEM model, where engineering is seen as part of science, is explored with considerable detail and the authors make a convincing case that this model is unlikely to work in the UK and a collaborative model is more appropriate. A figure of '*more than 5,000 teachers*' (page 166) with engineering degrees is given as being the number employed in UK secondary schools mostly engaged in teaching STEM subjects. Surely they are ideal people to initiate or take part in discussion of this type at school level. The authors well balanced debate concludes that if engineering is to be a successful part of the school curriculum it will require considerable co-operation between science, D&T and mathematics teachers reinforcing, once again, teachers talking to each other. Unfortunately the authors deviate from their established format by not including examples of engineering project work and exemplary teaching and learning opportunities. Bearing in mind that until recently the UK had 70+ engineering schools under the Specialist Schools and Academies Trust (SSAT) scheme many developing outstanding STEM teaching and learning materials that are worthy of inclusion in this book.

A message that permeates the four chapters dealing with each of the STEM subjects is that curriculum development in the UK seems to be rather haphazard. For example in the mathematics chapter the authors enthuse about D&T project opportunities using four bar linkages as part of animated toy projects (pages 122, 123). This knowledge was part of geometric and engineering drawing (GED) some 40 years ago and did result in well motivated pupils engaging with interesting paper based design activities. Why was this abandoned? The authors are right - the four bar linkage with a mathematical analysis is an ideal opportunity for toy design in D&T providing it is updated to a computer aided design (CAD) based activity. To underpin this notion of updating important aspects of the curriculum the authors recount working with a group of science trainee teachers on acceleration using Fletcher's trolley which many readers may remember from their physics lessons. The task was to update this using data logging and IT to retain the learning but make it more accessible to pupils (pages 201,202). So science teachers were able to reinvigorate this essential learning. There is an interesting message in the chapter on IT that, in the light of STEM, the contributing subjects could revisit essential parts of their curriculum and update in a similar way.

Project based learning

The project based pedagogical thread mentioned previously is aligned with problem based learning (PBL) and brought together in a chapter (page 135) set out in an accessible format of question based headings such as '*How are successful project-based learning and related tasks organised*?' (page 144) and, important to the D&T teacher, '*Teaching knowledge when needed, or as structured development and the relative importance of skills*' (page 145). This chapter is particularly relevant to D&T trainee and practicing D&T teachers as it provides considerable detail about how to plan and manage design and make assignments, including assessment. The authors draw on the recommendations of the D&T Association to consider planning a programme of study using '*small tasks*' and '*big tasks*' (page 145) to ensure coherence in the learners experience. It is a comprehensive chapter concluding once again with the all important thread '*regular conversations with colleagues*' and the additional recommendation of '*teamwork*'.

Making STEM work

Several shorter chapters provide insight into how STEM can be pulled together in schools. The chapter titled '*The role of STEM enhancement and enrichment activities*' (page 175) is packed with fascinating information covering numerous examples of competitions and after school activities, many from overseas providing an international perspective about what is possible. The authors have done considerable research into this aspect of their book the result being a sort of directory of 'a good fun guide to STEM'. Particularly pleasing is the detail of more local initiative developed by a UK based D&T teacher who puts a 'D' into STEM providing design days and design camps for students. As a result of reading this chapter I found myself following up many of the initiatives searching for further information on the internet, I'm sure most STEM teachers would find doing this an inspirational experience as there are so many worthwhile schemes. The chapter finishes with a questioning conclusion of '*Why is the school experience so impoverished that stakeholders feel the need to initiate enrichment activities outside the mainstream school provision*' (page194). I'm certainly not sure about the answer but it is a question that teachers involved in STEM subjects could seek their answer. It is a point well made.

Similarly the chapter '*Computing and digital literacy, IT, computer science, TEL and STEM*' (page 197) is invigorating as it presents the reader with ideas for development. Headings such as '*IT and science*' (page 201) and '*IT and mathematics'* (page 207) are obvious but are supported by examples and cameos suitable for schools thus demonstrating the opportunities IT provides for teachers to develop creative teaching and learning situations for their pupils. For D&T and engineering the inclusion of '*systems for controlling artefacts*' (page 206)

is a comprehensive list of suitable soft and hardware followed a list of eight projects each starting with '*design and make*' underlining the importance of the making activity. A feature of these seems to be how systems and control can be harnessed by the 'pupil designer' rather than just learning about control systems and software.

Concluding chapters

While these chapters, '*Creating and environment for sustaining STEM*' (page 216) and '*Future vision for STEM*' (page 238), are important to all readers they are particularly relevant to school leadership teams as they provide insight to how STEM can provide a balanced curriculum. By presenting ideas such as '*considering mathematics*' and '*considering technology*' the authors précis the previous in depth commentary with additional material drawn from international sources. Amongst many examples I found two that are particularly noteworthy. The first is a long quote from David Hargreaves (page 233) who uses a gardening metaphor in a discussion about generating ideas and managing knowledge creation. This is particularly relevant to senior management teams in schools. The second is the STEAM (Science, Technology, Engineering, Arts, Mathematics) (page 252) movement in the USA which is likely to be of interest to some D&T departments in UK schools. (http://www.steamedu.com/). It would be easy for the authors to impose their vision for STEM but they steadfastly resist this saying '*Clearly we, as authors of the book, cannot and should not define the future vision for STEM. Any attempt would be futile and the fact is that it is your vision in your school that is important and only you can decide on and work towards that*.' (page 254)

Conclusion

This is the most comprehensive and interesting book about STEM in schools I have read. The style of writing ensures the wealth of research, information, ideas, and examples of good practice are accessible to teachers, trainee teachers and any educationalist involved in these subjects including those in education management positions. This book is a leap forward for STEM in schools. Enjoy reading this book and then heed the authors' advice and talk to colleagues about it.

Available from the D&T Association.
www.data.org.uk