CROSS-CURRICULAR TEACHING AND LEARNING IN THE SECONDARY SCHOOL

MATHEMATICS

A David Fulton Book

ROBERT WARD-PENNY

SERIES EDITED BY JONATHAN SAVAGE

CROSS-CURRICULAR TEACHING AND LEARNING IN THE SECONDARY SCHOOL

MATHEMATICS

Why is cross-curricular work so valuable in the mathematics classroom?

Why can pupils sometimes draw graphs in mathematics but not in science?

What might mathematics teachers learn from the performing arts?

Cross-curricular approaches have much to offer the modern mathematics classroom. They can help teachers to present mathematics as a growing, relevant discipline that is central to much of modern life, and help learners to make sense of what they are doing and why. New contexts, new technology and new qualifications all make this an exciting time to be a cross-curricular teacher of mathematics.

But cross-curricular approaches are not always straightforward. Skills do not always transfer easily from one subject area to the other, and a number of important decisions have to be made. How should this type of work be planned, or assessed? How might it fit into the wider curriculum? Are all cross-curricular activities equally useful for learners? Does mathematics have something to share with all of the other curriculum areas?

This book tackles these issues head on, combining educational theory and contemporary research with practical ideas and suggestions. From the mathematics of molecular geometry, wind turbines and impact craters to mathematical haikus, Babylonian clay tablets and juggling, each chapter is packed with examples for use in the secondary classroom.

Key features include:

- discussion of key issues and debates
- case studies to show you how others have used cross-curricular approaches
- a wide range of examples and practical activities to help you develop your own practice
- example approaches for planning and assessment.

Part of the *Cross-Curricular Teaching and Learning in the Secondary School* series, this book is essential reading for all students on Initial Teacher Training courses and practising teachers looking to holistically introduce cross-curricular themes and practices into their mathematics teaching.

Robert Ward-Penny teaches on the Secondary PGCE Mathematics Course at the University of Warwick.

Cross-Curricular Teaching and Learning in . . .

Series Editor: Jonathan Savage (Manchester Metropolitan University, UK)

The *Cross-Curricular* series, published by Routledge, argues for a cross-curricular approach to teaching and learning in secondary schools. It provides a justification for cross-curricularity across the Key Stages, exploring a range of theoretical and practical issues through case studies drawn from innovative practices across a range of schools. The books demonstrate the powerful nature of change that can result when teachers allow a cross-curricular 'disposition' to inspire their pedagogy. Working from a premise that there is no curriculum development without teacher development, the series argues for a serious re-engagement with cross-curricularity within the work of the individual subject teacher, before moving on to consider collaborative approaches for curriculum design and implementation through external curriculum links.

Cross-curricular approaches to teaching and learning can result in a powerful, new model of subject-based teaching and learning in the high school. This series places the teacher and their pedagogy at the centre of this innovation. The responses that schools, departments or teachers make to government initiatives in this area may be sustainable only over the short term. For longer-term change to occur, models of cross-curricular teaching and learning need to become embedded within the pedagogies of individual teachers and, from there, to inform and perhaps redefine the subject cultures within which they work. These books explore how this type of change can be initiated and sustained by teachers willing to raise their heads above their 'subject' parapet and develop a broader perspective and vision for education in the twenty-first century.

Forthcoming titles in the series:

Cross-Curricular Teaching and Learning in the Secondary School . . . The Arts
Martin Fautley and Jonathan Savage

Cross-Curricular Teaching and Learning in the Secondary School . . . English
David Stevens

Cross-Curricular Teaching and Learning in the Secondary School . . . Foreign Languages
Gee Macrory, Cathy Brady and Sheila Anthony

Cross-Curricular Teaching and Learning in the Secondary School . . . Humanities
Richard Harris and Simon Harrison

Cross-Curricular Teaching and Learning in the Secondary School . . . Using ICT
Maurice Nyangon

Cross-Curricular Teaching and Learning in the Secondary School . . . Mathematics
Robert Ward-Penny

CROSS-CURRICULAR TEACHING AND LEARNING IN THE SECONDARY SCHOOL

MATHEMATICS

Robert Ward-Penny

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

This first edition published 2011
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

Simultaneously published in the USA and Canada
by Routledge
270 Madison Avenue, New York, NY 10016

Routledge is an imprint of the Taylor & Francis Group, an informa business

This edition published in the Taylor & Francis e-Library, 2011.

To purchase your own copy of this or any of Taylor & Francis or Routledge's
collection of thousands of eBooks please go to www.eBookstore.tandf.co.uk.

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
Ward-Penny, Robert, 1980–
Cross-curricular teaching and learning in secondary education-- mathematics / by Robert Ward-Penny. -- 1st ed.
p. cm.
Includes bibliographical references and index.
1. Mathematics--Study and teaching (Secondary)--United States. 2. Mathematics teachers--In-service training--United States. 3. Effective teaching--United States. I. Title.
QA13.W37 2011
510.71′273--dc22
2010024131

ISBN 0-203-83563-8 Master e-book ISBN

ISBN13: 978-0-415-57203-3 (hbk)
ISBN13: 978-0-415-57204-0 (pbk)
ISBN13: 978-0-203-83563-0 (ebk)

Contents

List of figures

Acknowledgements

Sincere thanks to all those friends and colleagues who have offered feedback, ideas and encouragement whilst making their way through various drafts of this book: Sarah Blyth, Ian Boote, Graham Charles, Isobel Chester, Jenni Ingram, Peter Johnston-Wilder, Sue Johnston-Wilder, Vicky Larner, Clare Lee, Christian Lockley, Jonathan Savage and Marian Ward-Penny.

Thanks are also due to all those who have helped to inspire and construct the case studies contained in this book: for the case study in Chapter 1, Jim Vinton and Sophie Fitzgerald of Farnham Heath School; for the case study in Chapter 3, Alex Hughes of Ninestiles School, Birmingham; for the case study in Chapter 4 and the use of Figure 4.2, Garry Redrup and Ashley Green; for the case study in Chapter 8, Nick McIvor and David Hall; and for the case study in Chapter 9, Peter Ransom. Details of the 'Maths Circus' discussed in Chapter 8 can be found online at www.davidhallworkshopsandshows.co.uk.

Special thanks to Peter Raedschelders for permission to use his art in Chapter 6. Further examples of Peter's artwork can be found online at http://home.scarlet.be/~praedsch/.

Abbreviations

2-D	Two-dimensional
3-D	Three-dimensional
A2-level	The second and final part of A-level study
A-level	Advanced level (consists of AS + A2-levels)
ASCII	American Standard Code for Information Interchange
AS-level	Advanced Subsidiary level
AST	Advanced Skills Teacher
ATM	Association of Teachers of Mathematics
Becta	British Educational Communications and Technology Agency
C Standards	Core professional standards for teachers
c.	Circa
CCTV	Closed circuit television
CLIL	Content and Language Integrated Learning
CSMS	Concepts in Secondary Mathematics and Science
CUREE	The Centre for the Use of Research and Evidence in Education
DfEE	Department for Education and Employment
DfES	Department for Education and Skills
EAL	English as an additional language
FSMQ	Free-standing mathematics qualifications
GCSE	General Certificate of School Education
GDP	Gross domestic product
GIMPS	Great Internet Mersenne Prime Search
GPS	Global positioning system
HDI	Human Development Index
ICT	Information and communication technologies
ISBN	International standard book number
KS	Key stage
MA	Mathematical Association
MDF	Medium-density fibreboard
MEI	Mathematics in Education and Industry

NCETM	National Centre for Excellence in Teaching Mathematics
Ofsted	Office for Standards in Education, Children's Services and Skills
PE	Physical education
PED	Price elasticity of demand
PGCE	Postgraduate Certificate in Education
PLTS	Personal, Learning and Thinking Skills
PSHCE	Personal, Social, Health and Citizenship Education
Q Standards	Standards required for Qualified Teacher Status
QCA	Qualifications and Curriculum Authority
QCDA	Qualifications and Curriculum Development Agency
RE	Religious education
STEM	Science, Technology, Engineering and Mathematics
VAK	Visual, auditory, kinaesthetic

CHAPTER

1 The context for cross-curricular mathematics

Of all of the subjects in the school curriculum, mathematics is one of the most ubiquitous. Skills taught in mathematics lessons are often fundamental to other subjects, and pupils' progress in other curriculum areas frequently depends on them being fluent in basic mathematical procedures. Many lessons in other subjects can be enhanced and made more meaningful through the use of mathematical methods and ideas, and mathematical thinking and problem solving is a critical skill across the curriculum.

However, mathematics often functions as a 'chameleon discipline' (Johnston-Wilder and Lee 2010), fading away against the background of whichever curriculum area it is supporting. Consequently, pupils often leave school without a real awareness of the scale of the power and relevance that mathematics has in modern society, and will continue to have in the future. For many pupils this lack of awareness is coupled with a debilitating lack of experience and confidence in applying mathematics in out of school contexts. A cross-curricular approach to mathematics is therefore both urgent and exciting, offering both teachers and learners a chance to engage with the subject in a way that is both more authentic and more motivating.

The book has three interrelated aims: to justify the importance of a cross-curricular approach to teaching and learning mathematics; to provide a wide range of examples; and to explore both the potential and pitfalls of such an approach. In order to meet these aims it will consider a wide range of issues. Some of these will be largely theoretical, whilst others will be purely practical; however all of them will ask you to reflect on and challenge your own practice. You may find it useful to have some paper and a pen to hand as you read, in order to note down your own thoughts and ideas.

Key objectives

By the end of this chapter, you will have:

- Considered what 'cross-curricular' teaching and learning might involve, and how it might be recognised in the classroom

- Reflected on your own views about, and experiences of, cross-curricular teaching and learning in mathematics
- Reviewed some of the recent curriculum changes and new qualifications which contain significant cross-curricular elements

Why is cross-curricular teaching important?

It is undeniable that we live in interesting and turbulent times, and that this century poses a number of challenges which are both complex and controversial. The Millennium Project (2009) identifies 15 global challenges currently facing humanity, including the following:

- How can sustainable development be achieved for all while addressing climate change?
- How can everyone have sufficient clean water without conflict?
- How can population growth and resources be brought into balance?
- How can the threat of new and re-emerging diseases and immune micro-organisms be reduced?
- How can shared values and new security strategies reduce ethnic conflicts, terrorism and the use of weapons of mass destruction?
- How can growing energy demands be met safely and efficiently?

It is clear that each of these questions involves knowledge, skills and understandings from more than one school subject area. For example, the issues surrounding the sourcing and delivery of clean water involve concepts typically located in a host of subjects including geography, biology, chemistry, technology, politics and economics. Each of these questions also draws heavily on techniques, ideas and thinking skills that are found in mathematics. In fact, mathematics is a fundamental element here and elsewhere; it is present wherever there is a call for quantification, measurement, modelling or logical analysis, and in this way it underpins the use of each of the other subjects mentioned. It is impossible to imagine any kind of approach to answering these challenges that would not use mathematics in some form. However, it is just as challenging to think of a way that mathematics could solve any of these problems as a stand-alone subject.

If we are to future-proof our pupils' developing mathematical facility, there is a need for us to present mathematics in a wider context and promote joined-up thinking between mathematics and other curriculum subjects. It is not only the future which is making this demand; there has already been a shift in the employment market, and new technologies and globalisation trends require flexible mathematical thinking as much as procedural competence (Hoyles *et al*. 2010). Cross-curricular approaches to teaching mathematics offer a range of ways of enhancing pupils' mathematical learning so as to address these needs and concerns.

Different organisations are beginning to recognise the need to rethink the way that mathematics is presented and delivered in schools, and at the time of writing there have been a number of significant changes in mathematics qualifications and curricula that involve, either explicitly or implicitly, cross-curricular perspectives on mathematics. Many of these changes are exciting ones that offer a range of new opportunities – and new challenges – to mathematics teachers. However, each has its own perspective on what 'cross-curricular' mathematics might entail, and so it is important to start this chapter by considering what you, and others, might mean by 'cross-curricular'.

What does 'cross-curricular' mean?

The term 'cross-curricular' is widely used by schools and educational organisations, but it can be quite difficult to formally define. Although 'cross-curricular' has an obvious semantic meaning, genuine cross-curricular activity transcends this: you would be unlikely to claim that an English teacher asking their pupils to turn to page 76 would constitute a genuine cross-curricular use of mathematics! So what does 'cross-curricular' mean?

Reflective task

Think about the term 'cross-curricular' and note down what it means to you. How might you recognise a cross-curricular activity in the mathematics classroom? When you have finished, put your jottings to one side, then review them once you have completed reading this chapter.

One way of answering this question is to suggest that a cross-curricular approach can be recognised not simply through an overlap in content, but through associated changes in both the teacher's pedagogy and the pupils' learning experience. It is in this sense that Savage offers the following definition elsewhere in this series:

> A cross-curricular approach to teaching is characterised by sensitivity towards, and a synthesis of, knowledge, skills and understandings from various subject areas. These inform an enriched pedagogy which promotes an approach to learning which embraces and explores this wider sensitivity through various methods.
>
> (Savage 2011: 8–9)

This definition moves beyond the immediate meaning of 'cross-curricular' to describe an approach that is in some sense *interdisciplinary*, combining two or more different schools of thought to address a problem. Tasks that fully satisfy this principle tend to be steered primarily by the nature of the problem, requiring new skill sets at different stages and a degree of criticality, self-reflection, and even metacognition on the part of the learner.

Savage's definition also contains a significant challenge for the mathematics teacher, as it encourages us to move beyond simply using scenarios from other subjects as decontextualised illustrations. For example, when teaching the topic of ratio, a teacher might draw two gears on the board, one with 18 teeth and one with 6 teeth, and ask the class how many turns of the smaller gear would equal one turn of the larger gear. This is a valid link to another subject area, but so far no knowledge, skills or understandings have crossed between subjects. The pupils merely have to extract the numbers and select an appropriate operation. To this end, the activity could be developed by introducing ideas from technology such as 'velocity ratio' and 'torque', or better still, by presenting pupils with a physically meaningful problem together with a set of gears that they could use to help devise and test a solution.

Another challenge arising from this definition is to separate off our understanding of 'cross-curricular activities' from the more prominent curriculum area of using and applying mathematics. Cross-curricular activity often uses skills of application and modelling, but in addition it is always informed (and often steered) by content and skills drawn from other subject areas. 'Using and applying' investigations, however, can sometimes be based around abstract mathematics, where enquiry can be steered purely by an interest in the structure and properties of mathematics itself.

Throughout this book you will find examples of many different types of cross-curricular activities, from using mathematics to investigate the effects of natural disasters to integrating performing arts techniques in order to explore the properties of quadrilaterals. Some of these examples could easily take place as a small part of a regular mathematics lesson, whereas others are more extensive, and might require extra resources or a wider level of school participation. In every case, what is important is that the blurring of subject boundaries impacts upon the pupils' experiences, the teacher's practice, or both. When these conditions are satisfied, activities can have a substantial impact, ideally developing pupils' understanding and motivating their study in each of the subject areas involved.

There are other ways in which 'cross-curricular' teaching and learning can be considered, and some of these will be touched upon in the discussion below. As you read through this book you will undoubtedly continue to develop your own understanding of the term 'cross-curricular', and the role of cross-curricular teaching within the mathematics classroom.

Why teach mathematics in a cross-curricular way?

Having established a working definition for what we mean by 'cross-curricular', the next step is to consider some of the different reasons why we might choose to teach mathematics in a cross-curricular way.

Authentic activity

Although many arguments can be made for the benefits of teaching mathematics in a cross-curricular way, the simplest, and perhaps most important, is that cross-curricular activities are more authentic. The vast majority of the actions that we perform as adults are cross-curricular, since they draw on a range of skills that have been traditionally taught separately in different curriculum subjects. When adults use mathematics, they often use it to provide one perspective on a problem that is then considered alongside many others.

For example, consider the following scenario. During his weekly shop, a father must decide whether to get three tins of Brand A (60 p for 500 g) or four tins of Brand B (45 p for 400 g). At first, this problem might seem like a purely mathematical one, as this problem can be 'solved' using proportional reasoning. Yet in reality, such a decision would be influenced by a number of other factors. Does his family have a preference for one brand or the other? Is one brand healthier than the other? When he cooks for his family, does he find a 500 g tin too big, and so does he create waste? Is one brand a fair-trade product, produced in a more ethical way? None of these questions devalue the importance of teaching proportional reasoning to our pupils, but they do demonstrate that whilst inside the classroom problems are often selected in the service of the mathematics, outside mathematics is more frequently utilised in the service of a problem.

Teaching mathematics in a cross-curricular way, then, can help to familiarise pupils with the idea of applying mathematics in context, encouraging them to develop the skills of selecting appropriate mathematics, applying it and critically evaluating its use against real concerns and limitations. The context serves to steer the mathematics, rather than just illustrate a mathematical idea. The Dutch mathematics educator Freudenthal wrote that: 'Viewing context as noise, apt to disturb the clear mathematical message, is wrong; the context itself is the message and mathematics a means of decoding' (Freudenthal 1991: 75). The ideal of preparing learners for the world by teaching them a contextualised, applied form of mathematics has clear links to many current initiatives, such as functional mathematics and work-related learning, which are examined below. The relationship between content and context, and the goal of developing skills that can transfer between situations and disciplines are both discussed further in Chapter 3.

It can also be argued that cross-curricular teaching offers the teacher opportunities to make the mathematics itself more authentic. If particular mathematical concepts were originally developed out of a recognition that a type of problem could be solved in a certain way, is it then disadvantageous, and possibly even disingenuous to remove the topic from its original purpose and not recognise its origin? Mason and Johnston-Wilder argue that:

> seeing topics arise from classes of problems suggests that the motivation for a topic can often be found in versions of the original problems that the topic resolves, and in the range of problems to which that topic can be applied in different contexts.
>
> (Mason and Johnston-Wilder 2006: 16)

Cross-curricular practice can help to embody this ideal.

Motivation

This idea leads onto a second argument that can be used to support a cross-curricular approach: that it is motivating for pupils to see how mathematics is used in other subjects and disciplines. The psychologist Bruner suggested that: 'The best way to create interest in a subject is to render it worth knowing – which means to make the knowledge gained usable in one's thinking beyond the situation in which the learning has occurred' (Bruner 1960: 31). Pupil motivation is a complex construct that is influenced by a wide range of factors and develops over time. However, educational research offers us some general principles which are relevant to cross-curricular teaching. Middleton and Spanias reviewed the research concerning motivation for achievement in mathematics and reached the following conclusion:

> Providing opportunities for students to develop intrinsic motivation in mathematics is generally superior to providing extrinsic incentives for achievement. To facilitate the development of students' intrinsic motivation, teachers must teach knowledge and skills that are worth learning. In other words, students must understand that the mathematics instruction they receive is useful.
>
> (Middleton and Spanias 1999: 81)

This is an important finding; it tells us that whilst extrinsic motivators such as grades, marks and prizes can encourage pupils in the mathematics classroom, pupils are more likely to be motivated if they can see the use in what they are doing. This idea is repeated further on: 'Last, and most important, achievement motivation in mathematics, though stable, can be affected through careful instructional design … Creating interesting contexts within which problems are situated stimulates students' imaginations and illustrates to them that mathematics is useful in various applications' (p. 82).

Teaching with an awareness of the wider curriculum allows the mathematics teacher to demonstrate the importance and relevance of mathematics, and to reveal the chameleon discipline at work. An instance of this is given in the report *Mathematics: Understanding the Score*, where a teacher is praised for the way in which they answered the question, 'Why do we have to learn algebra?'

> The teacher reminded the pupils that algebra is important in science because formulae are needed to express the laws of science; spreadsheets use algebraic formulae and are a very powerful tool used by thousands of businesses; and computer graphics require complicated algebraic methods to make sure that objects are portrayed correctly. He also pointed out the power of algebraic notation as a means of communicating within mathematics.
>
> (Ofsted 2009: 17)

Carefully constructed problem situations might even motivate the learner further, by giving them room to devise their own strategies, carry out their own methods and develop a genuine sense of ownership regarding their work. A compartmentalisation of the curriculum can work against this, as a pupil might feel limited to only using strategies and skills that they think are typical of a mathematics lesson.

Developing integrated skills

A third argument for the use of cross-curricular activity in schools is that it supports the development of skills that transcend traditional curriculum areas. These include practical skills, such as the appropriate use of technology to aid investigation, and reflective, metacognitive skills such as the ability to synthesise different techniques to develop a problem-solving strategy, and the capacity to think creatively.

An example of this type of skills-based thinking can be found in the PLTS (Personal, Learning and Thinking Skills) contained in the 2008 National Curriculum (QCA 2007). These are six groups of skills which teachers are statutorily required to integrate throughout the curriculum to support learners' development. The six groups are: