JMC

Joint Mathematical Council
of the United Kingdom

Executive Summary
Digital technologies and mathematics education

A report from a working group of the
Joint Mathematical Council of the United Kingdom
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September 2011

1. Scenario

What is needed in schools and colleges is student-led mathematical modelling and problem solving, which makes use of the powerful mathematical digital technologies that are widely used in society and the workplace.

1.1 In order to provide a context for the body of the report we invite readers to imagine they are travelling on a train together with students on their way to school. One student is finishing off his mathematics homework and struggling to solve some quadratic equations by factorisation. Another student, who has already diligently done her homework, is playing a realistic action video game on her smart phone. This scenario is, of course, designed to emphasise the stark contrast between the worlds of current (and past) mathematics education at school and the world in which many of our current students live most of their life.

The point about modern smart phones and other portable digital technologies is that they are not just phones. They are multi-purpose computers with built-in processors, memory, colour display, audio playback, wireless telephone and broadband communications, Global Positioning Systems and accelerometer sensors, still and video camera, touch screen input – and they also run a wide variety of Apps. These 'Apps', short for Applications, are what used to be called computer programs or software. The relevance of this choice of analogy is that the girl could quite as easily have been using an Internet browser to access mathematical information, or discussing her maths homework by phone with a friend, or using *Google Maps* and *Google Earth* to plan a cycle trip or using a powerful, free, mathematical tool such as *GeoGebra* to explore an interesting mathematical problem.

We can also look more deeply at some of the sub-components listed above. The microprocessor, which powers the first of the smartphones, and most of the current portable computing devices, was designed by a UK company and is a direct descendent of the knowledge and skills which went into developing the Acorn Archimedes computer in Cambridge. The aesthetic design and the engineering specification for this, and many other Apple products, come from a team led by a British born and educated designer. The encryption which makes secure mobile communications possible was developed by a British mathematician. The Internet is based upon the designs of a British computer scientist. Video games are a major source of income for the UK economy and require advanced skills of mathematics, physics, biomechanics and computer programming to achieve virtual reality. Global Positioning Systems and the Internet rely on communications satellites – a technology in which the UK is a world leader.

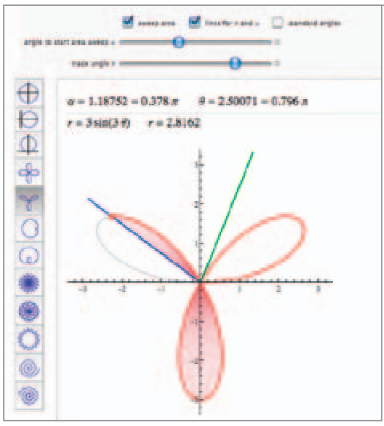
2. Introduction

Einstein famously said that his pencil was more intelligent than he was - meaning, that he could achieve far more using his pencil as an aid to thinking than he could unaided. There is a need to recognise that mathematical digital technologies are the 'pencils of today' and that we will only fully exploit the benefits of digital technologies in teaching, learning and doing mathematics when it becomes unthinkable for a student to solve a complex mathematical problem without ready access to digital technological tools.

2.1 The Joint Mathematical Council of the UK was established in 1963 to promote the advancement of mathematics and the improvement of the teaching of mathematics. It brings together representatives from societies and organisations which are involved with the processes and products of mathematics education. Its meetings are attended by academics and professionals concerned with pure mathematics, applied mathematics, statistics, operational research, higher education, research and commercial applications of mathematics as well as representatives from government departments and agencies together with teachers, advisers, inspectors and teacher educators.

2.2 Against a background of widespread concern about the UK's ability to meet the increasingly technological skills needs of major sectors of the economy, the JMC established a working group to consider the role which digital technologies might and should have in mathematics education, now and in the near future.

3 What are Digital Technologies?



3.1 Digital Technologies refer to a wide range of devices which combine the traditional elements of hardware (processing, memory, input, display, communication, peripherals) and software (operating system and application programs) to perform a wide range of tasks. They include: technical applications; communication applications; consumer applications and educational applications.

3.2 The generic term `computing' has been replaced with the term `Information Technology' (IT) in most walks of life. The National Curriculum introduced the term `Information and Communications Technology' (ICT) in the educational context – which became one of the core subjects. ICT in schools has concentrated on the use of generic software such as word-processors, spreadsheets and presentational tools together with tools for digital communication such as e-mail and the Internet. In order to avoid confusion with this interpretation of ICT the term 'digital technologies' is used throughout this report.

4. Why are Digital Technologies important to the economy and what contribution can education make?

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4.2 Policy makers at the European level state that increasing young people's interest in Mathematics, Science and Technology is essential for sustainable economic growth in Europe.

4.3 When comparing the UK to China and India Michael Gove said "It's rocket science – mathematics, engineering, physics and the other hard sciences which are driving innovation globally, and generating growth for the future" (Gove, M. *The answer is rocket science*. 2008; Available from: http://conservativehome.blogs.com/torydiary/files/gove_on_science.pdf).

4.4 There is a need to build on and improve the UK's capacity for technological innovation and creativity. Education at all levels has its part to play in engaging the interests and enthusiasm of young people so that they pursue education, training and career paths which contribute to the nation's needs while themselves achieving satisfaction and reward.

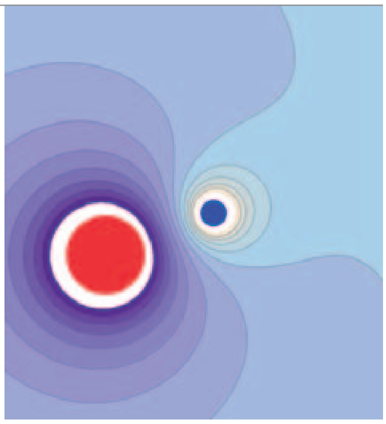
5. How are Digital Technologies impacting on mathematical practices outside school and college?

5.1 Mathematicians work on the important practical issues of their era, which have always required both the development of the subject together with the tools to support this. Pascal's and Leibniz's mechanical calculating machines, Napier's logarithms, Babbage's difference engine, Newman's Colossus and Turing's Bombe for crypto-analysis at Bletchley Park are just a few examples of computational tools which have been fundamental to the evolution of digital technologies to support mathematical developments. In this respect mathematics is, and has always been, a dynamic problem solving activity for which humans have continued to develop and exploit new tools.

5.2 New kinds of jobs are now open to people with mathematical qualifications, especially those with skills in the use of digital technologies. It is often argued that the number of mathematical tool users will outweigh many times the number of tool producers, with the implication that only a few experts need to really understand how to produce a mathematical tool. Such dichotomies are unhelpful as the workforce of the future will need to include a large number of mathematical tool modifiers. For the tool modifier, the central issue becomes the articulation of what the digital technology should do, designing a system to do it, and verifying that it will perform as specified.

5.3 The vast majority of young people are involved in creative production with digital technologies in their everyday lives, from uploading and editing photos to building and maintaining websites. They acquire many skills which will be relevant in their careers, but which are not drawn on during their time in school. They acquire new skills rapidly, and share their knowledge with their peers – but rarely in an educational context.

5.4 Whereas digital technologies are the 'tools of the trade' of the modern scientists, technologists, engineers and mathematicians, young people are not likely to use digital technologies for the creative production of science, technology and mathematics in their everyday lives.



Recommendation 1: For policy makers and teachers

School and college mathematics should acknowledge the significant use of digital technologies for expressive and analytic purposes both in mathematical practice outside the school and college and in the everyday lives of young people.

6. How are Digital Technologies impacting on mathematics education in the UK currently?

Recommendation 2: For policy makers
Curriculum and assessment in school mathematics should explicitly require that all young people become proficient in using digital technologies for mathematical purposes.

Recommendation 3: For policy makers
High-stakes assessment needs to change in order to encourage the creative use of digital technologies in mathematics classes in schools and colleges.

6.1 Ofsted reports have concluded that technology is underused within mathematics and that its potential is generally underexploited. Usage of digital technology within school mathematics has been predominantly teacher-led and mainly focused on presentational software such as PowerPoint and interactive whiteboard software.

6.2 Unless we can develop mathematics education in a more stimulating way, which takes into account the modern world and students' interests we are in danger of turning mathematics into an increasingly 'dead language' and alienating groups of students whose mathematical potential will remain undeveloped.

6.3 Rote learning of the current mathematics curriculum will not be sufficient to produce the problem solvers, independent thinkers and designers that the country needs.

6.4 The barriers to a more creative student-focussed use of digital technologies include:

- a perception that digital technologies are an add-on to doing and learning mathematics;
- current assessment practices, which do not allow the use of digital technologies, particularly within high stakes assessments;
- inadequate guidance concerning the use of technological tools within both statutory and non-statutory curriculum documentation.

6.5 Learning in science, technology and engineering in schools and colleges could be greatly enhanced if students were able to use digital technologies to perform mathematical processes, mirroring the types of applications used in STEM-based applications in the workplace. The benefit of using digital technologies relates both to the processing power afforded by the technologies and the opportunities to access real-world data, which is engaging for students.

6.6 There is already a wide range of existing 'mathematical' digital technologies which could readily be used by schools and colleges such as:

- Dynamic graphing tools
- Dynamic geometry tools
- Algorithmic programming languages
- Spreadsheets
- Data handling software and dynamic statistical tools
- Computer algebra systems
- Data loggers, such as motion detectors and GPS
- Simulation software.

6.7 With respect to the content of the new mathematics curriculum, it should include:

- the specification of the knowledge and skills required to use digital technologies within mathematical modelling and problem solving activities across a range of subject areas;
- student-led mathematical modelling and problem solving, which make use of the powerful mathematical digital technologies that are widely used in society and the workplace;
- a component of computer programming, interpreted in the widest sense of creating and communicating a set of instructions to a computer for a clear purpose.

6.8 Change to the mathematics curriculum and its assessment, although necessary, will not be sufficient to develop the classroom practices of teachers, many of whom have limited professional knowledge and experience of the type of digital technological tools being described in this report.

6.9 There will be a continuing need to update the skills of the teaching workforce, something which the subject associations and teacher education institutions working alongside industry and schools are well-placed to achieve.

Recommendation 4: For policy makers and school leaders

As the development of a technologically enriched student learning experience occurs at the level of the classroom, such change has to be supported by school leaders and accompanied by sustained professional development opportunities for teachers.

Recommendation 5: For policy makers

The UK Departments for Education and for Business, Innovation and Skills should establish a Task Force to take the lead in bringing together various parties with appropriate expertise to take forward the recommendations of this report and advise the Departments on required policy initiatives.

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Acknowledgements:
We thank the following schools for the photographs included in this report:
Davison CE High School for Girls, Worthing, West Sussex; Fairfield High School, Bristol; Bacon's College, Southwark.
We also thank Conrad Wolfram and Douglas Butler for providing images.
Design: cw-design.co.uk