Mathematics, science and technology teachers working collaboratively with ICT

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Abstract
Supported by the Partners in Learning Programme of Microsoft and the UK Teacher Development Agency (TDA), a group of five secondary schools from Hampshire are working together on developing collaborative approaches to teaching mathematics, science, technology and allied subjects including physical education and sports. Typically three teachers from each of the schools meet with the project team for a day every two months to share their ideas and experiences in activities which foster collaborative work among maths, science and technology teachers. Between these external meetings, teachers arrange their own in-school activities to support and encourage staff in developing innovative and cross-curricular approaches to teaching their subjects. The project will disseminate experiences both in developing the collaborative practice model used, and the activities, and accompanying resources, which have been developed. These will be made available on the Microsoft Innovative Teachers website. The schools have access to a variety of ICT tools including Interactive Whiteboards, computer suites, teachers' laptops and hand-held technology including graphing calculators and data-loggers.

1. Introduction

Hampshire is a large county in the South of England with some 70 secondary schools, mostly for pupils aged 11-16. It has a long history of supporting the use of ICT in teaching and learning mathematics and related subjects. These have included small scale but influential projects carried out under the auspices of the National Council for Educational Technology (NCET), the Department for Education and Skills (DfES), the Teacher Training Agency (TTA) and more recently the Qualifications and Curriculum Authority (QCA).
Since 1993 these have included:

- NCET `Pilot Portables Project' involving three schools evaluating laptop computers, palmtop computers and graphical calculators for mathematics teaching.
- DfES `Data-capture and modelling in mathematics and science' involving the mathematics and science departments in four schools using hand-held technology (Texas Instruments graphical calculators and data-loggers). [6]
- TTA `special project' using hand-hand technology in mathematics, science and Design & Technology in three secondary schools and a junior school.
- QCA `Algebra and Geometry' curriculum project using dynamic geometry software as a bridge between algebra and geometry in mathematics departments in four schools.

The TTA administered the national programme for 450,000 teachers' professional development in using ICT supported by the New Opportunities Fund (NOF) from 1999-2003. As part of the Needs Identification materials for this, in 1999 the TTA produced a pack of CDs with video case studies illustrating good practice using ICT in secondary school subjects – several of which were filmed in Hampshire schools. Similarly a number of Hampshire schools' mathematics departments were selected by the DfES for video case studies to illustrate good practice in ICT as part of their support materials to help teachers embed ICT in teaching and learning [2]. There is now a thriving TV channel, called Teachers' TV, devoted to teachers' professional development (http://www.teachers.tv/node) which has used Hampshire schools as models for innovation in mathematics teaching, with and without ICT.

2. The collaborative ICT project

The project is based in five secondary schools in the Fareham & Gosport region of Hampshire. One is for pupils aged 11-18, the others cover the 11-16 age range. Each of the schools has achieved designation as a Specialist School. Two are Mathematics & Computing colleges, one is a Science college, one is a Performing Arts college and the fifth is a Sports College. The schools are well equipped with ICT tools including portable and wireless technologies, tablet PCs, Interactive whiteboards (IWB), digital cameras, video recorders, data capture hardware and software. The schools all teach to the English National Curriculum in which subjects such as mathematics, science and Design & Technology (D&T) are described, taught and assessed separately. The aim of the project is for teachers from these, and other, subject areas to work together to plan activities using ICT which relate the subjects through common themes and activities, e.g. using video clips of pupils' sporting activities to support collaborative work between physical education (PE), science and mathematics departments to facilitate data collection, analysis and mathematical modelling.

The project is increasing and extending the use of these and other ICT tools, especially the use of software to create and manipulate 3D images in mathematics, science, D&T, Art&Design and ICT. Visualisation and modelling in 3D is fundamental to a wide variety of disciplines - and to science, technology, engineering and mathematics (STEM) in particular. More work in 3D and better use of ICT were two of the key recommendations in the Royal Society geometry report [8]. The project's work is feeding into new developments in D&T, science and mathematics being undertaken by the Design and Technology Association (DATA), the Association for Science Education (ASE) and the Mathematical Association (MA) as part of the extension of the DfES' `CAD/CAM in Schools' project: www.cadinschools.org .

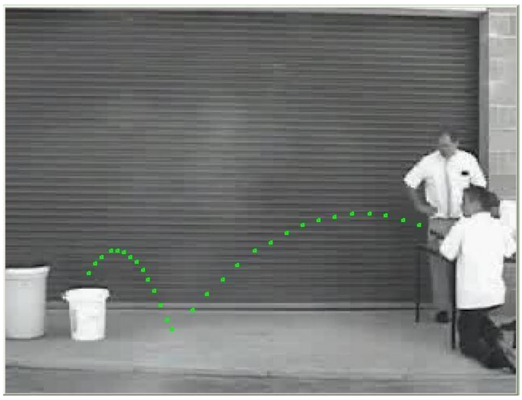


Figure 1: *a table tennis ball launcher*

The project is designed to support, evaluate and disseminate the practical classroom implementation of leading edge work on the use of such ICT tools by practitioners in different classroom subjects working together. The project funding allows teachers to be released to work together with the project support team for eight days in 2006/7, as well as to support in-school professional development activities. There is an external evaluation from Manchester Metropolitan University, and an extensive dissemination strategy. Hampshire already has a good structure in place to provide dissemination to other schools across the county. Through the Microsoft and TDA `Partners in Learning' support, the project is also ensured national and international dissemination.

3. Example 1 – video analysis

Several of the schools were already using professional video analysis software for sports – the main products being *Dartfish*, from Switzerland (http://www.dartfish.com/en/index.htm) and *Swinger*, from Australia (http://www.webbsoft.biz/). Others had come across [4] and were using the free video analysis software *Vidshell* for Physics from Doyle V. Davis (http://www.webphysics.nhctc.edu/vidshell/vidshell.html). In fact there is a wealth of open source software from the US to support physics teaching, including a powerful Java program from Douglas Brown for video analysis called *Tracker 2* (http://www.cabrillo.edu/~dbrown/tracker/). The main feature common to these video analysis tools is the ability to mark the trace of a point of interest over a series of video clips. If the video clip was made with the camera in a fixed position and with fixed focus then the trace will be the trajectory of the object in space. In the simplest case a screen shot can be made of a still frame showing the collected trace, and this visual scattergram can be imported as the background for a *Geometer's Sketchpad*, *Cabri II Plus* or *Geogebra* file over which geometric constructions can be made, or coordinate axes superimposed and graphs drawn [3]. The video analysis software also provides the means to calibrate the image using a known distance, and to superimpose coordinate axes. Since the time gap between frames is constant (typically 0.04s. for a 25 frame per second clip), each time a point is traced its (t,x,y) coordinates are logged. So a table of data collected in this way can also be exported e.g. to *Excel*, *TI InterActive!* or graphical calculators for display and analysis. Some of the software, such as *Tracker*, also enables the display and analysis (e.g. linear or quadratic regression) to be performed within itself. Thus students can use digital video cameras to record activities such as throwing, running, jumping etc. during physical education lessons or sports activities.

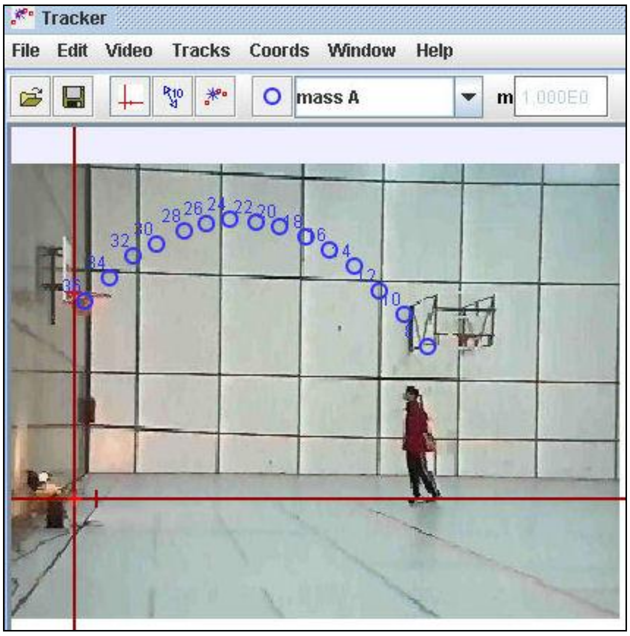


Figure 2: *Tracker used to annotate a video clip*

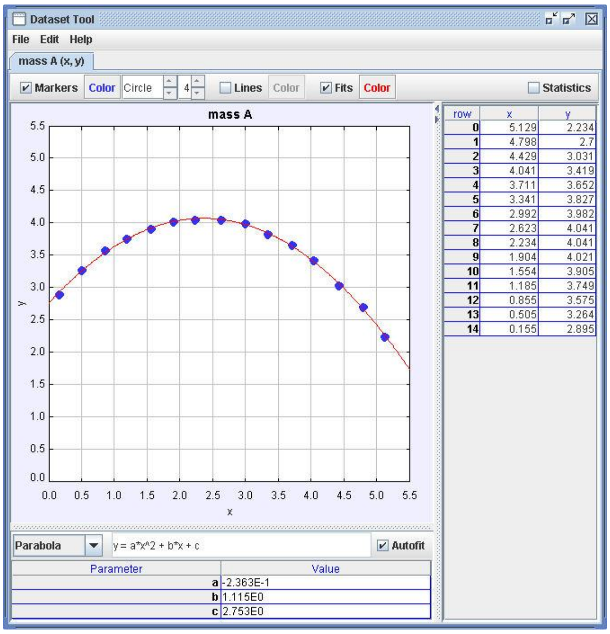


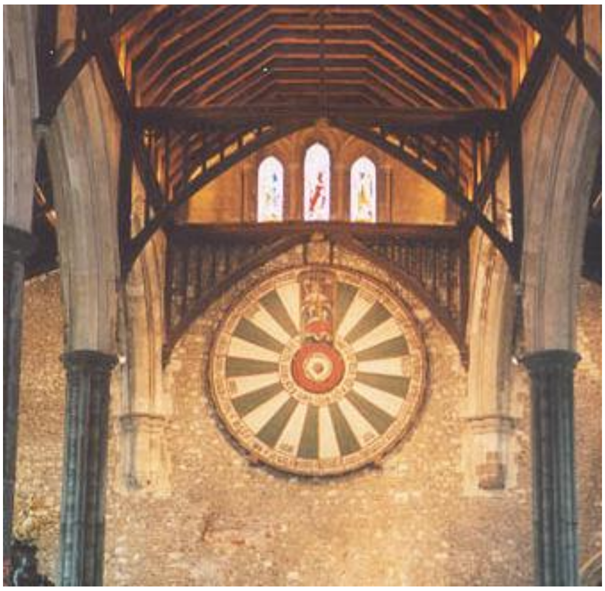
Figure 3: *Tracker's own analytic tools*

The video software enables teachers of Physical Education (PE) to help pupils improve their physical techniques – such as the angle to putt a shot in athletics. It also enables pupils to study the biomechanics of the activity. In science lessons, students can study the velocity, acceleration and forces acting on a body, explain the major features of the dynamics of the motion and make predictions about possible physical limits to performance. In mathematics lessons, students can discuss features of the scattergram or locus, fit graphs of mathematical functions `by eye' using trial and improvement, and determine `best fit' models using statistical techniques. They can find out estimates for velocities, accelerations, angles etc. and make predictions. In D&T they can design and make launching devices for projectiles with desired characteristics, such as to fire a table tennis ball into a bin – see Fig 1.! The UK 'Teachers' TV' service has a 15 minute video of one of the project schools using video analysis from sports as a means of motivating the transformation of quadratic functions in algebra: www.teachers.tv/video/19119. Overseas visitors can watch this on-line, while UK residents can register with the site to download the clips.

4. Example 2 – data-logging

Data-logging is an aspect both of the 11-16 science and D&T curricula. New programmes in science are putting a greater emphasis on experimental work, and some PE/sports departments also use data-logging e.g. for performance monitoring. Thus an activity using heart-rate monitors before, during and after exercise in PE will produce data which can be explained in a science lesson and analysed in a mathematics lesson. The Texas Instrument Calculator Based Ranger (CBR) provides a powerful and relatively cheap method of tracking motion for producing distance-time graphs for analysis both in mathematics and science. Software such as Vernier's *Logger Pro 3* allows videos of a scientific experiment to be synchronised with displays taken from sensors and probes such as CBR so that the video and data-logging approaches can be synthesised. The new range of simple USB probes, such as Vernier's *Go Temp!*, allows data-collection directly from the TI-84 graphing calculator or any PC.

The use of temperature probes for cooling liquids and of voltage probes for decay of charge from a capacitor provide direct and quick examples of decay curves – which can be explored well before exponential functions would normally be encountered in mathematics. Using a spreadsheet or graphical calculator model of a sequence in which each term is a multiple k of its predecessor, with $1>k>0$, students can gain an understanding of decay curves. Many students watch television series such as *CSI* and *Numb3rs* in which forensic science is used to solve crimes. Forensics provides an excellent vehicle for motivating the study of scientific principles which can easily be exported to the mathematics classroom as well. In fact for relatively short time periods (up to 12 hours, say) the cooling of blood temperature is closely approximated by a linear function. The same is true for radioactive decay, such as that of Carbon 14, with half-life of 5730 years used for dating historical/archaeological artefacts. Hampshire provides a very good source of the use of the latter in dating the wood used in the huge round table in Winchester which was by legend supposed to be the round table of the Arthurian legend. Arthur was believed to have reigned around 500AD, but the carbon dating of the table showed it to be made of wood cut down around 1234AD.



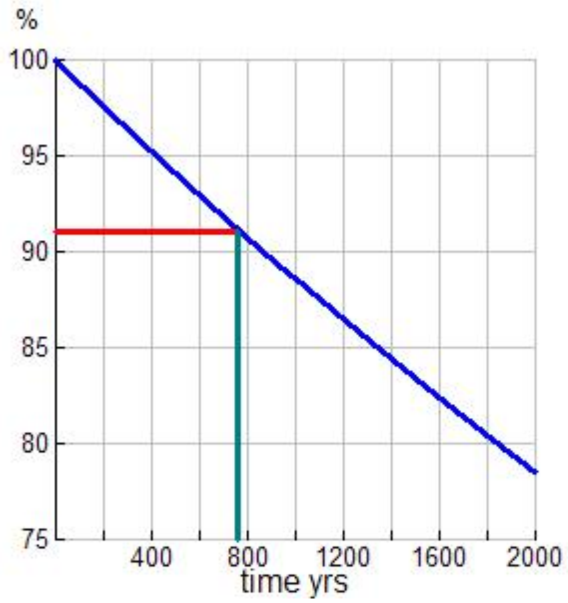


Figure 4: *the Winchester round table* Figure 5: *Inverse interpolation from a graph*

The UK 'Teachers' TV' service has a 15 minute video of a school introducing a variety of ICT tools into its mathematics teaching, including the use of the CBR for distance-time graphs: www.teachers.tv/video/154.

5. Example 3 – work in 3D

The subject called Design & Technology has a variety of modules all concerned with designing, making and testing. These include topics such as resistive media (wood, metal, plastic..), textiles, food technology, electronics, robotics, hydraulics etc. Thus a typical D&T workshop has a variety of machinery including drills, lathes and cutters. Through a major government initiative called `CADCAM in Schools' nearly all English secondary schools have multiple station licences for the *Pro/Desktop* CADCAM software (http://www.cadinschools.org/) as well as teachers trained in its use. Many schools are also buying 3D computer controlled equipment such as laser cutters, routers and 3D printers. Work in three dimensions is also part of the Art&Design curriculum, but it is very much under-emphasised both in science and mathematics.

The launch of the *Cabri 3D* software in 2004 has the potential to redress this [5], and is the subject of a separate paper submitted for this conference [7]. Schools are working on projects to design 3D models of built environments such as portable shelters, furniture and landscaped gardens linking work in D&T (CADCAM software, textiles, materials ..) with 3D geometry in maths (using pencil & paper, practical model making and *Cabri 3D* software). There is great opportunity to link mathematics in science, for instance in modelling molecular structures, atomic models and planetary models – particularly with *Cabri 3D*'s animation features. Another source of good models comes from optics, including models of vision by the retina, and of images formed by instruments such as telescopes, microscopes and cameras. Linking both with D&T and biomechanics, there are many examples of simple mechanisms which can be modelled in *Cabri 3D*, see e.g. [1].

Young people are surrounded by computer generated images of objects whose realistic effects depend upon an accurate representation in perspective. So the whole area of the historical development of perspective, and other forms of geometric, drawing is a rich source of collaborative work between mathematics, Art&Design, D&T, history and ICT. It also provides opportunity for the synthesis of mental imagery, rough sketching, accurate drawing, physical model-making, and for computer modelling in the context of artefacts which interest students.

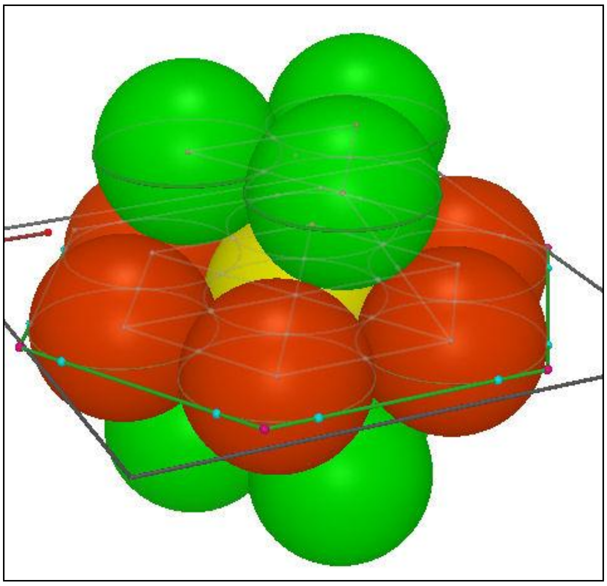


Figure 6: *one way to stack tennis balls*

Figure 7: *stacking modelled in Cabri 3D*

Support materials for the use of *Cabri 3D* can be found at:
http://www.counton.org/cabri/index.htm and http://educ.queensu.ca/~mackrelk/motion3D/
An mpg video file showing the use of *Cabri 3D* in a UK secondary school can be downloaded from: www.xube.co.uk/bettawards2007/cabri3d.mpg.

6. Conclusions

This paper was first prepared during the development phase of the project (January 2007) which came to its close soon after the time of the ICTMT-8 conference (July 2007) – so it would have been premature to try to draw too many conclusions at this juncture. What is most encouraging is that this is a completely teacher-driven and very innovative (as well as risky) project. The schools have access to a wide range of support from the project team, including the authors, and from helpful agencies such as Microsoft, the TDA and Texas Instruments – but it is entirely up to the schools and the teachers how much of this is used, and when. The current organisation of secondary schools makes it very difficult for staff from different subject areas to get together to plan, execute and evaluate integrated cross-curricular work – but the project teachers are determined and motivated people who are developing strategies which we hope will form workable models for many schools. Feedback from the schools is that the students are responding very well indeed to the planned subject integration, and ICT use, within the activities trialled to date. Also the other teaching colleagues are showing interest in wanting to be involved. The project coincides with a new government initiative to develop open-ended cross-curricular, ICT-supported, problem-solving work in the 11-14 mathematics curriculum to which we hope to make a major contribution based on examples such as those presented her.

7. References

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