

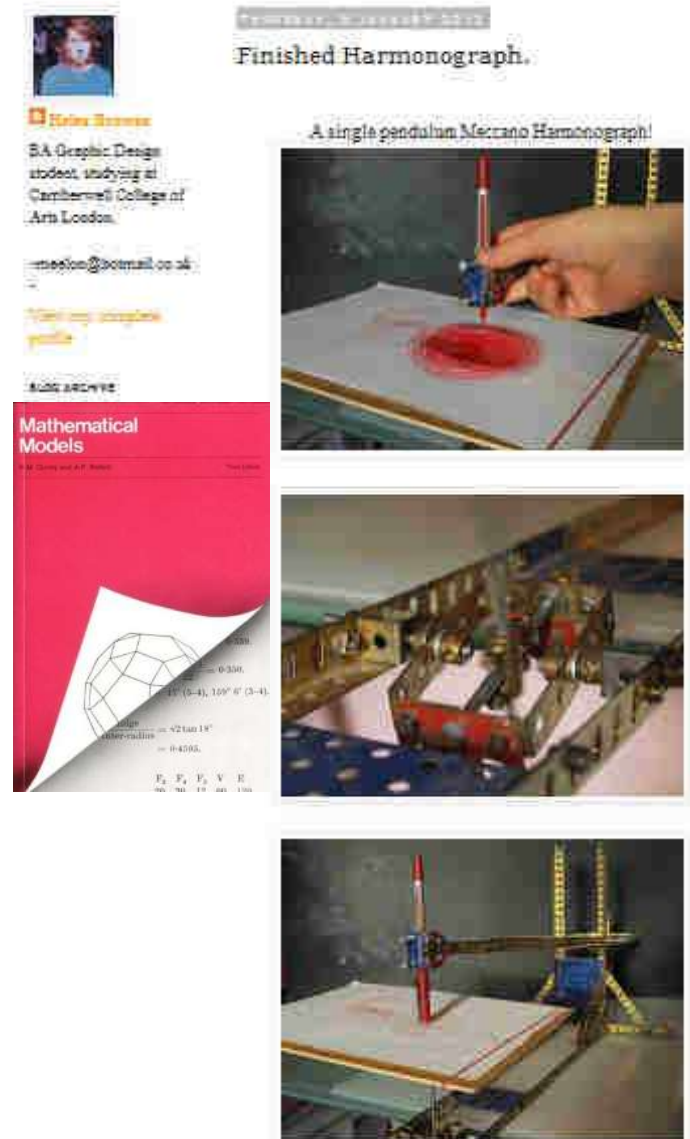
Software and activities to motivate and support learners in mathematics, science and technology

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Abstract: Very many countries have concerns over meeting the future skills needs of industry, commerce and research to support economic prosperity and social well-being. In the US and UK the phrase “STEM” is used, whereas in the European Union the term is “MST” – but in either case it is not just a matter of getting more students to take qualifications in mathematics, science and technology. Schools need to enthuse and motivate students to engage actively with technology, not just to be passive consumers. In my talk I will give some examples of how modern developments in hardware and software, as well as in electronic communications, can be used to make technological education more exciting, engaging and challenging for learners and teachers alike – inside and outside schools.

Thanks. This is not an academic address re research.
It is a personal reflection at the end of my own career.
The scope of this conference is broad for Math Ed with
focus on **Computer Algebra** and **Dynamic Geometry**. I
focus on the use of tools to stimulate and support
learning by younger students - using few words,
preferring pictures, videos, software. First hardware:
I grew up with books, construction toys, a bicycle and
the radio. Building **Meccano**, with clockwork motors, I
learned about triangles as well as turning circular
motion into linear motion. I learned to visualise in 3D.
I built a **harmonograph**. Helen Browne is a student of
graphic design in London. No doubt with **iPhone** etc!



Mike Ive was silversmith and teacher of DT, School Inspector, member of the Design & Technology Association, brought Computer Aided Design (CAD) systems into UK schools. Jony – Sir **Jonathan Ive** KBE - born 1967, studied Industrial Design at Newcastle Polytechnic. Mac launched in 1984, Jony used at end of his degree. 1992 joined **Apple** – in financial crisis, invested \$100m in Apple **Newton**. Why “Newton”? Apple needed a fast efficient processor for hand-held device with hand-writing. Met **Hermann Hauser**, set up **Acorn Computers** in Cambridge in 1978. My sabbatical in 1981 at CADC as Acorn built BBC micro for home Computer Literacy. Chris, born in 1971 – first home computer was BBC £500 with TV for output and cassette for input/output. Acorn developed very fast processor: **Advanced RISC Machine** based on an operating system designed by Roger, now Sophie, Wilson.



Do you have a mobile phone? Very small, powerful processor using very little electricity designed by UK company **ARM Holdings** in Cambridge. Uses encryption system designed by Prof. **Henry Beker**: read maths at Cambridge, PhD cryptography, Technical Director at Racal Research, founded Zergo and Baltimore Technologies, became very rich, President of IMA, established e-Learning Foundation to provide portable computers for every schoolchild, provided seed-corn funding to support Zsolt and me in setting up the **Centre for Innovation in Technological Education in Cambridge**.



One partner is **Raspberry Pi Foundation** developed a very low cost single board computer to re-kindle spirit of excitement which BBC micro sparked in 1982 (30 years ago). Raspberry Pi Model B has Ethernet connection, twin USB sockets, HDMI video output, size of credit card, costs c£25. C 300,000 orders for developers' version. Educational version soon to be launched with **Python, Scratch** and **Greenfoot**.



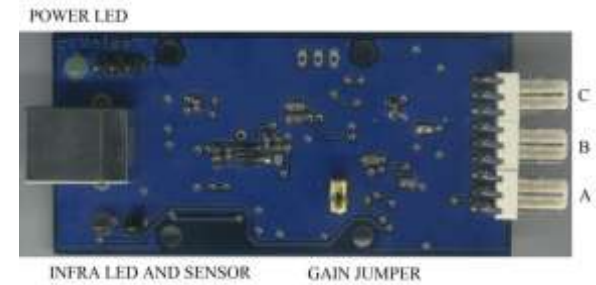
Processors, pocket computers and programming languages are only just one part of the picture which has changed so very rapidly and favourably for education. We are surrounded by **sensors** and systems which control all sorts of devices. I have the medical condition “sleep apnoea” where my windpipe collapses during sleep, cutting off oxygen supply. Diagnosed by finger tip sensor system detects pulse, by **sonar**, and dissolved oxygen, by **light** changes, records data on an SD card and can transmit wirelessly! Such a data-logging system retails at £180. The treatment for sleep apnoea is a device called **CPAP**, for Continuous Positive Air Pressure. Just a pump which delivers air under pressure through a flexible tube and nose mask, but which can detect back-pressure (exhalation) and hence log my sleep patterns on SD card which a nurse examines once a year. This unit costs £500 and has changed my life.



We can capture data from experiments and activities in a variety of ways – which are becoming cheaper and easier to set up and use. Here are two different versions of the **expEYES** 32-channel USB data-logging system developed for school use in India – for around \$25 – connected to a Raspberry Pi. Below is the **EDAQ530** 3-channel USB system being developed by Zoltán Gingl and colleagues at the

University of Szeged, which I saw for the first time on Tuesday.

Of course students now have access to many other forms of data-logging, such as **accelerometers** and **GPS** chips in their mobile devices.



The Nintendo **WiiMote+** controller c£20 has 3-accelerometers, a gyroscope and an infra-red positioning camera which send data wirelessly via Bluetooth. Microsoft has system called **Kinect** with mix of video and infra-red cameras as well as an array of microphones. The bar, which contains a motor, costs around £100.

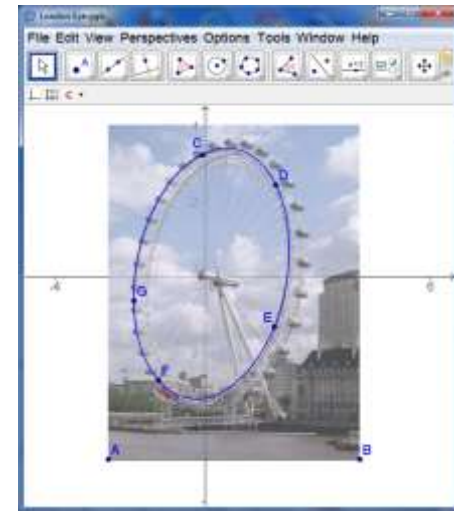
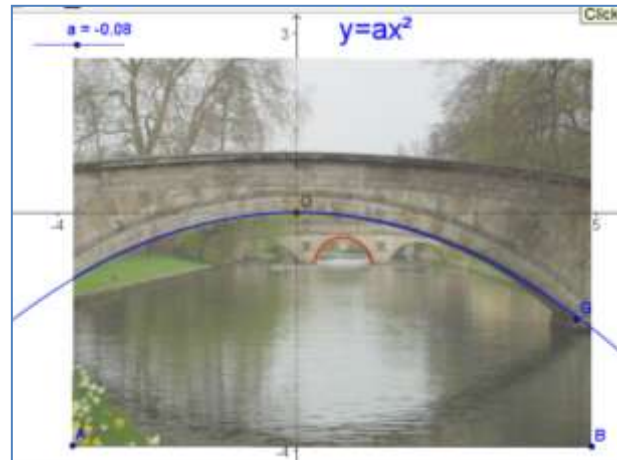
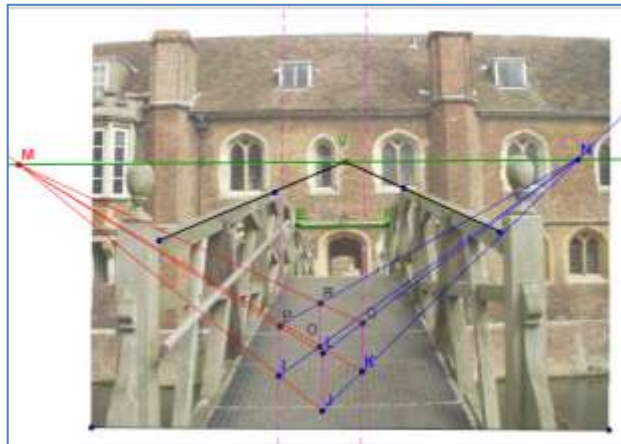


Which brings us to **GeoGebra**! The lead developer now is a UK high school mathematics teacher called **Mike Borchers**. We have now been working for over a year on interfacing a variety of data-logging systems with GeoGebra so that it can capture data streams directly into the SpreadSheet View. This summer we will have groups of 17 year-old students doing one month projects in Cambridge developing ideas for using GeoGebra in a variety of teaching and learning contexts within STEM/MST education – including a possible **Cambridge/Szeged Dynamics Kit** for use in school, at home or in the field.

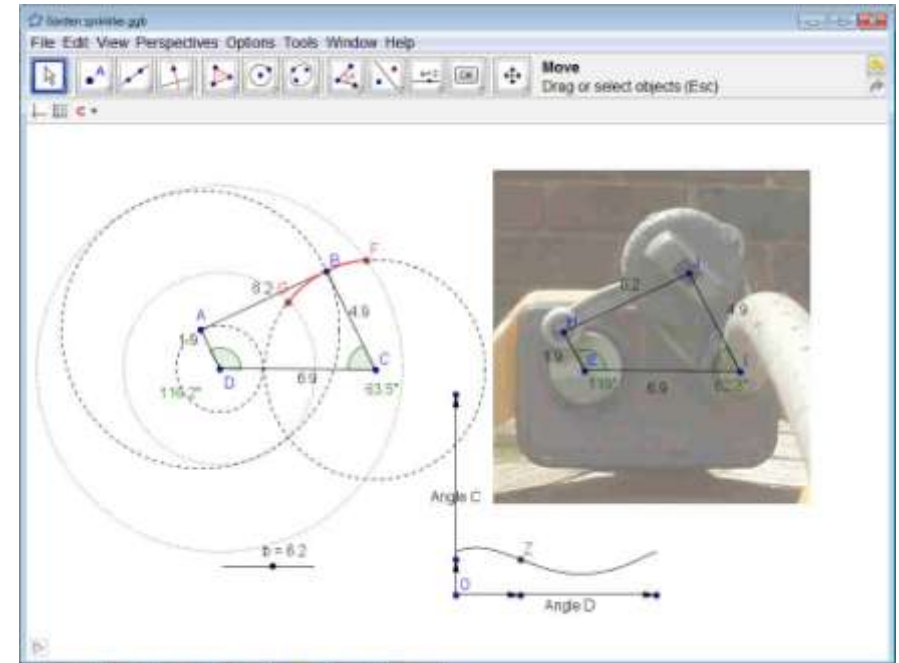


GeoGebra combines **Computer Algebra** (Reduce) and **Dynamic Geometry**. Not unique e.g. TI N-spire. It is **free** and **open-source** – available for all students at whatever age.

My role is to extend GeoGebra's facilities into science, technology and engineering. Raspberry Pi educational release includes GeoGebra pre-installed. Examples from Raspberry Filling: figures from section 2 of GeoGebra chapter. Where were they taken – comments on their mathematical potential? Modern kids all carry around digital cameras with them of their phones and pods – most of which take video clips as well.

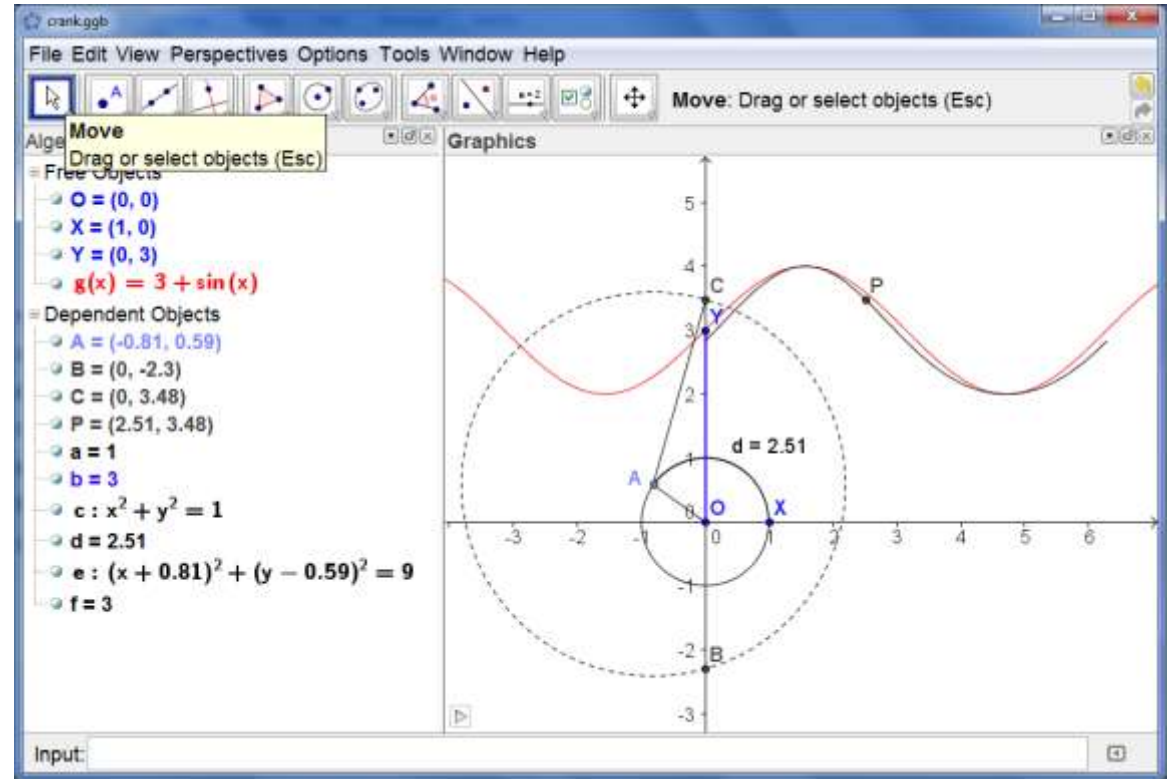


When the weather is hot and dry in England – a rare event – I use a mechanical device to sprinkle water on my grass. The pressure of water in the hose drives a turbine which uses a four-bar linkage to convert into oscillatory motion – moving the sprinkler bar from side to side. Could you model this linkage in your favourite Dynamic Geometry software? Does it allow animation?



Chapter 3 of the Raspberry Pi guide uses a simpler mechanism, the slider-crank, as an example.

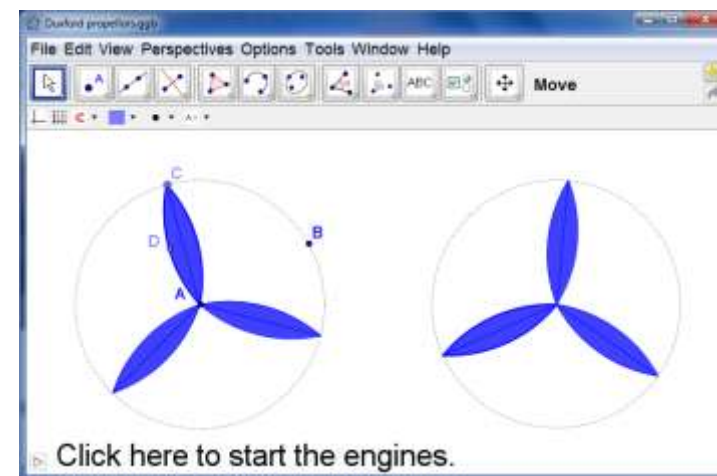
Of course you all know that the motion of C up and down the y -axis must be periodic – but is it a sine-wave? If not, what is the function describing the y -coordinate of C against time?



Sometimes I am allowed out – last week at an Air Museum near Cambridge.



13 year-olds underneath Concorde – the world's first commercial supersonic aeroplane!
Challenge to model a revolving propeller! Some decided on 3-bladed version. How would you do this? What mathematics might you need? How could you make two, or more? Once they had a result they tidied up their constructions, coloured it in and published it to the web via **GeoGebraTube**. In just over 1 hour – never having used GeoGebra before!



That was an example of DG software used to create animations and videos. The kids wanted to add sound – something I have only just learned from Mike is already there – but not yet with the capacity to add your own wav files for sound effects. That might take a week or so to fix!



My digital camera has high-speed video modes with good definition at 240 fps, and speeds up to 1000 fps! For most actions, frame rates of 25 or 30 fps are good enough.

Free US Open Source **Tracker** software from Doug Brown can capture data easily from video clips. You just need to calibrate one frame which has a known distance on it, and superimpose axes. Provided you don't pan or zoom the camera you should be able to collect data from successive frames of a video clip of a moving object like a ball dropped from rest. Here is data collected from a 30 fps video clip of a tennis ball dropped from rest.

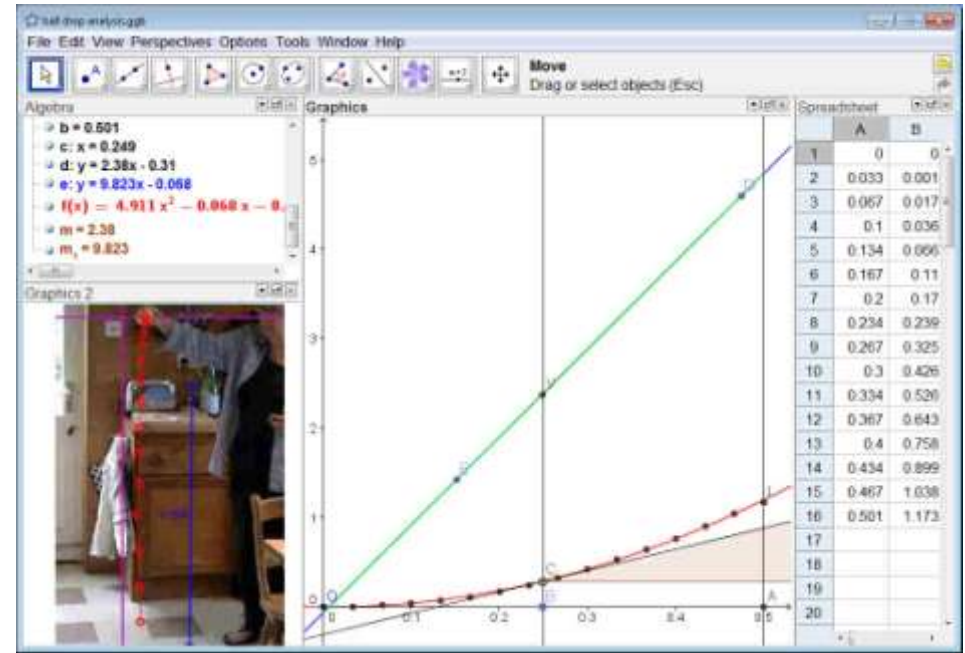


The data can be analysed in Tracker, or copied and pasted into a spreadsheet, e.g. the Spreadsheet View of GeoGebra. Yes, you've guessed it – there is a version in development to allow data capture from video within GeoGebra!

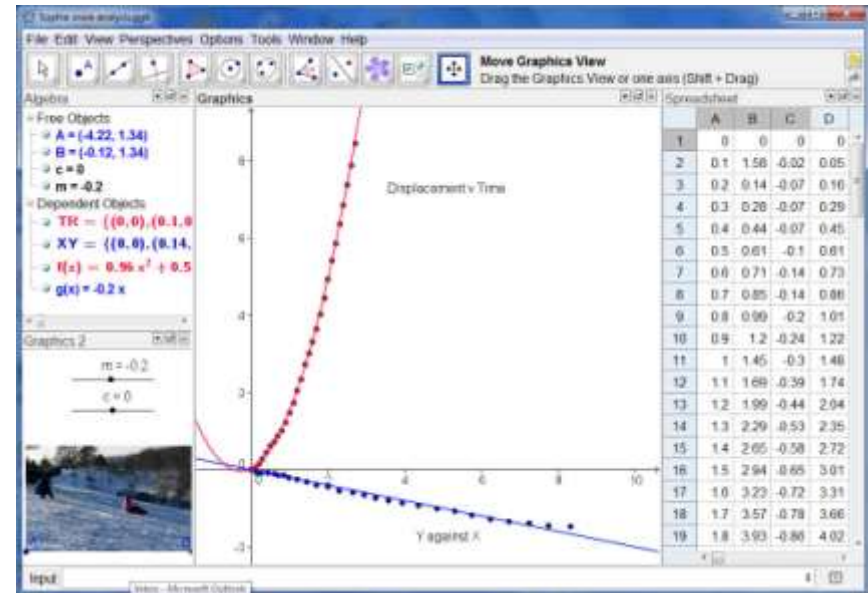
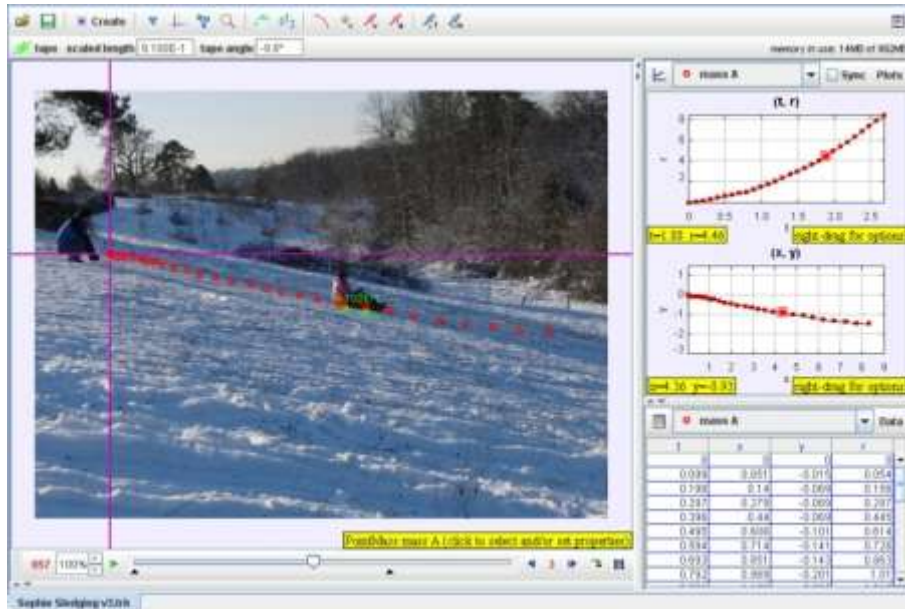
In GeoGebra we can easily measure the slopes at points on the displacement against time graph and see that they are well fitted

by a straight line graph. So we can check that displacement follows a quadratic model, while the velocity follows a linear one. Hence the acceleration model is a constant given by the slope of the velocity-time graph – which just seems to be more or less 9.8 ms^{-2} .

Newton strikes again!



More fun, though, is to put yourself in motion, rather than just dropping a ball!
 So here is my friend's daughter, Sophie having fun on her toboggan in the snow.
 Fortunately Sophie's sister had a camera with her at the time and was able to take a video clip. So not only were there enough data to calculate an estimate for g – from this outdoor version of the Galileo experiment, but also sufficient data to estimate the coefficient of friction between the snow and the runners of the toboggan.



Well the mathematics here is all pretty familiar stuff to this distinguished audience. But we can quite easily run into uncharted territory even in the back garden. Sophie also has a trampoline!

Perhaps you would like to discuss what form the displacement time graph takes in this case?

So what was the point of this talk? My abstract says that: “I will give some examples of how modern developments in hardware and software, as well as in electronic communications, can be used to make technological education more exciting, engaging and challenging for learners and teachers alike – inside and outside schools.”



As well as pointing to some of that hardware, such as the iPad, Raspberry Pi, Wii and digital cameras, I have used the case of GeoGebra to exemplify some extended features of CADG based software which are now coming on stream.

I have not discussed control technology with devices such as the low-cost Arduino **microcontroller** for robotics, nor the opportunities opened up by **stereo 3D geometry**, nor the **Python programming** interface - all of which are under development for GeoGebra, but I have mentioned GeoGebraTube as one example of how the modern communications used extensively by young people can also support mathematics (and STEM) education.

I have given some examples of the contributions which UK educated people like Sophie Wilson, Henry Beker, Mike Ive, Jony Ive and Mike Borchers have made, and are making, to the IT tools on which we depend – as well as valuable foreign imports such as Hermann Hauser from Austria and Zsolt Lavicza from Hungary.

Schools and educators need to **enthuse and motivate** students to **engage actively** with technology, not just to be passive consumers. By doing so, those students will also come to appreciate the pervasive role which science and mathematics play in controlling the world around us. That is the challenge which we are addressing with the development of our ambitious Centre for Innovation in Technological Education in Cambridge. Once that is under way I shall be retiring, not like Rousseau to spend more time tending my garden, but to have more fun playing with my grandkids Al and Gabriel. It is for you to carry on the good work. Good luck!

