MEI Insights 2:

The Use of Technology in Mathematics Education

by **Tom Button, Stephen Lee** and **Charlie Stripp**

Introduction

Mathematics in Education and Industry (MEI) is an independent charity, committed to improving mathematics education. We work to support curriculum development and professional development for teachers, and to have a positive influence on national mathematics education policy. Throughout its history, MEI has demonstrated a firm belief in the importance of technology in mathematics education, both for increasing students' understanding of mathematics and to prepare them for a world in which technology is used extensively for mathematical processing. This, our second article in a series entitled 'MEI Insights', discusses the use of technology in teaching and learning mathematics.

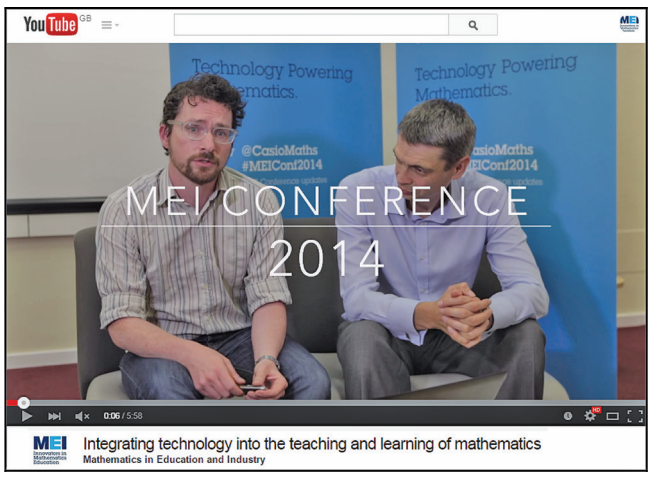
The Importance of Technology in Mathematics Education

There are many electronic tools that can be used for mathematics: four-function scientific and graphical calculators, spreadsheets, graphing software, dynamic geometry, programming languages, Computer Algebra Systems, and other tools that are combinations of these. In addition, there are mechanical tools such as abacuses and slide rules. This article focuses on the use of electronic tools to support the teaching and learning of mathematics. What all these tools have in common is that they can perform algorithmic processes and/or represent graphical/geometrical objects quickly and accurately.

MEI believes technology has an important role to play in mathematics education because the quick and accurate processing available through using technology, combined with its ability to display mathematical images, have the potential to develop students' understanding of mathematical concepts. Being able to perform many accurate calculations quickly can help students understand underlying mathematical structures, and multiple representations of mathematical objects can help students make important links between them, for example by observing the effect of altering a function algebraically on the graph of the function. This is further enhanced when these links are dynamic, so students can observe changes in mathematical objects directly.

In the modern world, the majority of mathematical processing is outsourced to technology. Indeed, it is already difficult to think of a future area of study or employment in which this processing is not carried out using technology (one clear exception being mathematics teaching). In preparing students for this world it is important that their mathematical education should include developing their skills in using technology for mathematics. This does not imply that we advocate training students to use technology to 'get the answer', rather than developing their understanding of mathematics. On the contrary, we believe technology should be embedded within the teaching and learning of mathematics in a way that enhances students' mathematical learning by helping them to develop their understanding of mathematical concepts and by allowing them to access more mathematical ideas and applications, particularly in the use of algorithms.

These guiding principles have driven MEI's work on developing the use of technology in mathematics education. Much of our focus has been on ways to support teachers in integrating technology into their teaching and their students' learning, and in developing innovative ways to embed students' use of technology in assessment.



You can view Tom and Charlie, MEI's Learning Technologies Specialist and Chief Executive, discussing how technology might be integrated into the teaching and learning of mathematics; how using technology in the classroom enables the use of large data sets, and why teaching students to use technology in maths is important for their future careers, in a video recorded at the 2014 MEI Conference: **http://bit.ly/TBCSMEI.**

Supporting Teachers in Integrating Technology in their Teaching and Learning

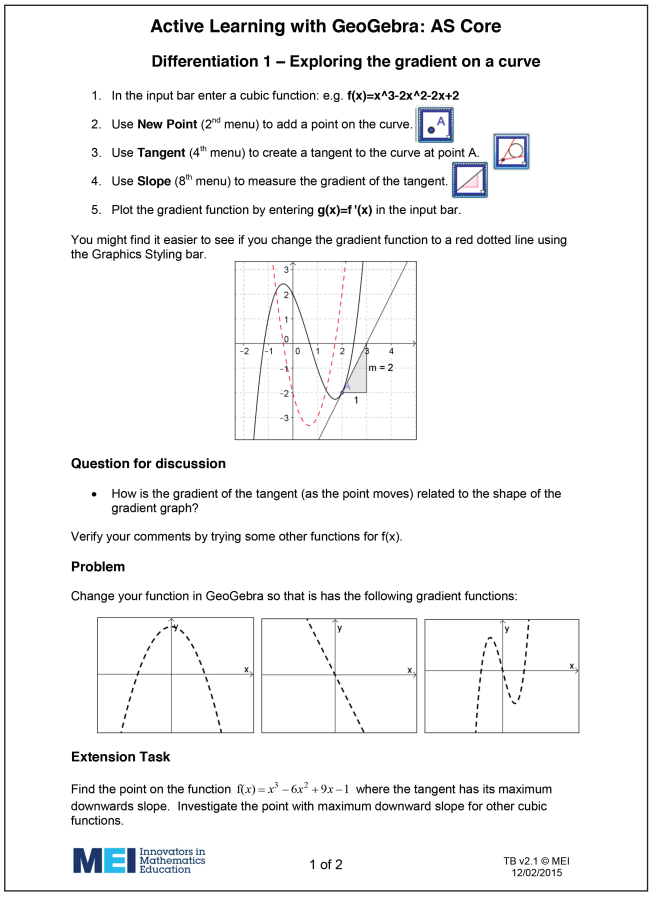
MEI has an extensive range of contacts with teachers through textbooks, online resources, the MEI website, professional development courses, an annual conference and links through the Further Mathematics Support Programme. All of these are used to encourage the effective use of technology in teaching and learning mathematics. The textbooks and online resources feature examples and tasks involving the use of technology to enhance the development of deeper mathematical understanding, and the professional development courses and conference allow for elements focusing on this. These courses and conference sessions have focused on the use of graphing tools, such as graphical calculators or software such as *Autograph*, as well as the use of spreadsheets, dynamic geometry software and other tools.

MEI is currently investing in developing more resources that exploit the use of technology to enhance the teaching and learning of mathematics to support teachers and students of GCSE, A level and Core Maths. This work will include interactive resources specifically designed for use on hand-held devices.

In recent years MEI has established itself as a GeoGebra Institute. *GeoGebra* is free software that integrates graphing, geometry, a spreadsheet and a Computer Algebra System (CAS) within the same software tool. We support teachers and students through various means, including:

- face-to-face and online workshops for teachers;
- the design of free teaching and professional development materials for A level and GCSE Maths teachers;
- online support for *GeoGebra* users;
- presentations at conferences.

You can visit our *GeoGebra* page on the MEI website at **www.mei.org.uk/geogebra** to access the free materials highlighted above, which include 'how to' guides and task documents, as well as exemplar *GeoGebra* files. These are suitable for anyone from absolute beginners to more experienced users looking for some new ideas. From this page you can also get in touch with us about any requirements you may have for using *GeoGebra* in teaching and learning mathematics that we may be able to help you with.



Active Learning with GeoGebra: AS Core

Differentiation 1 – Exploring the gradient on a curve

1. In the input bar enter a cubic function: e.g. **f(x)=x^3-2x^2-2x+2**
2. Use **New Point** (2nd menu) to add a point on the curve.
3. Use **Tangent** (4th menu) to create a tangent to the curve at point A.
4. Use **Slope** (8th menu) to measure the gradient of the tangent.
5. Plot the gradient function by entering **g(x)=f '(x)** in the input bar.

You might find it easier to see if you change the gradient function to a red dotted line using the Graphics Styling bar.

m = 2

Question for discussion

- How is the gradient of the tangent (as the point moves) related to the shape of the gradient graph?

Verify your comments by trying some other functions for f(x).

Problem

Change your function in GeoGebra so that is has the following gradient functions:

Extension Task

Find the point on the function $f(x) = x^3 - 6x^2 + 9x - 1$ where the tangent has its maximum downwards slope. Investigate the point with maximum downward slope for other cubic functions.

MEI Innovators in Mathematics Education

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MEI also works directly with education technology companies, provided the working relationship supports the use of technology to enhance mathematics teaching, rather than promoting a particular commercial product. Currently, MEI and Casio are working with a group of 50 teachers across England and Wales to develop their use of technology in A level Mathematics, including the use of graphical calculators, spreadsheets, graphing software and dynamic geometry. The aim of this network is to develop a group of teachers who can contribute to the trialling of resources that realize the potential of technology in enhancing the teaching and learning of A level Mathematics, and can support teachers in wider networks to develop their skills in embedding the use of technology into their mathematics teaching.

The network will produce classroom activities for using technology that have been tried and tested by practising teachers and the teachers themselves will be delivering training from September 2015. Updates from the network and details of the materials produced are available at: **www.mei.org.uk/casio-networks** (definitely a page to bookmark!)

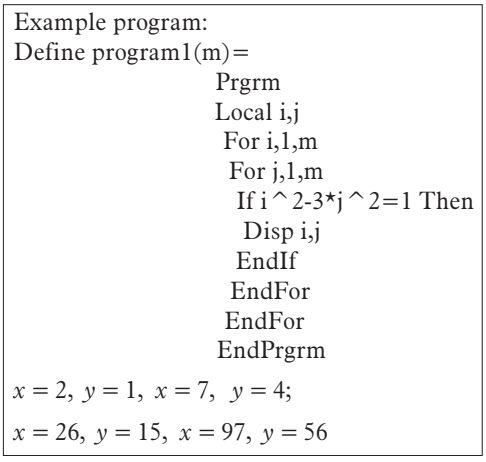
Innovative uses of Technology in Assessment

MEI is aware of the pressures on students and teachers to maximize their performance in assessment and the impact that this has on classroom practice. Consequently, we seek to innovate in the use of technology in assessment. We believe that having some elements of assessment that require the use of technology will have a positive impact

on how technology is used in the classroom, and so will contribute to improving students' understanding of mathematics, and their ability to apply it.

MEI's current A level specification (administered by OCR) includes a number of units where technology must be used within an element of the assessment. There are two units with coursework that require the use of spreadsheets for numerical methods; a topic in one of the Further Pure units that requires the use of a graphical calculator and two units, Decision Computation and Numerical Computation, where students must use spreadsheets and/or a linear programming package in the examination.

However, our most innovative use of technology in mathematics assessment is within MEI's 'Further Pure with Technology' (FPT) unit. This is an optional unit for study in A level Further Mathematics and the topic areas included are: Investigation of curves, Functions of complex variables and Number theory. The last two topics are not addressed by any of the other A level specifications but are quite suitable for study at this level, particularly when using technology to produce outputs that are then interpreted (see image for an example program that could be expected to be written).



A succinct paper summarizing the rationale and construction of the unit was given at the 2013 International Conference on Technology in Mathematics Teaching (Button and Lee, 2013). A more extensive overview, including useful documents such as the specification and specimen/exam papers can be found at: **www.mei.org.uk/FPT**

The Future of Technology in Enhancing the Teaching and Learning of Mathematics

The content document for the new mathematics A levels, for first teaching from September 2017, states: "The use of technology, in particular mathematical and statistical graphing tools and spreadsheets, must permeate the study of AS/A level Mathematics."

This content was developed through the university-led A level Content Advisory Board (ALCAB) and provides clear encouragement from higher education for the use of technology in the A level Mathematics classroom.

For A level Mathematics, the use of Computer Algebra Systems (CAS) is explicitly excluded from the assessment, because fluency with basic algebraic and calculus skills is deemed essential to developing an understanding of mathematics that can be built upon at a higher level. However, the new A level Further Mathematics does permit use of CAS in the assessment of optional elements and MEI is currently engaged in curriculum development work in this area, building from our experience of developing the current 'Further Pure with Technology' unit.

The new mathematics A levels are also quite bold in their intentions for the use of technology in the statistical aspects of the syllabus content, requiring that students 'become familiar with one or more large data set(s)' and *'are able to use calculator technology in the examinations that will enable them to compute summary statistics and access probabilities from standard statistical distributions.'*

This should put an end to boring and often meaningless statistics questions based upon plugging numbers into formulae to calculate summary statistics, or mechanically looking up numbers in statistical tables in formulae books. Instead, this explicit requirement for access to a large data set and the technology to explore it should mean students will develop a more meaningful understanding of statistical investigation and inference.

MEI is currently engaged in curriculum development work that aims to ensure that effective use of technology will enhance the new mathematics A levels, so improving students' understanding of mathematical concepts and statistical analysis.

Further into the future, access to computer technology during assessments/examinations is likely to become routine (this does not necessarily mean that all assessment/examinations should allow the use of computers). MEI intends to embrace the opportunities this can offer, enhancing students' understanding of mathematics and helping them to see more clearly the enormous impact the application of mathematics has on our world.

Reference

Button, T. and Lee, S. 2013 'Further Pure Mathematics with Technology: A Post-16 Unit of Study that uses Technology in the Teaching, Learning and Assessment', *Proceedings of the International Conference on Technology in Mathematics Teaching*, Bari, Italy, July 2013.

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