Centres for Excellence in Mathematics

Technology and data

Introduction and background

Outlining the terrain and definitions

This theme refers to digital technologies and the use of data in teaching and learning. Digital technology usually means computing devices, such as laptops, iPads and smartphones but also, and importantly in the context of mathematics education, includes calculators. However, digital technology comprises more than hardware such as computers and smartphones; the software behind its operation also needs to be taken into account and it should be recognised that it is the combination of the hardware and the software that should be considered when the term 'digital technology' is used (Joubert, 2007). For example, we might discuss how students use spreadsheets in their mathematics learning, and in a sense it is irrelevant whether the hardware used is a computer, a graphical calculator or a smartphone. In this document, we refer to 'technology' as shorthand for hardware and software.

Data, in the context here, which aims to inform approaches to intervention and trials in the Centres for Excellence in mathematics, refers to the data collected to monitor and inform activity in colleges and in this context, is generated and/or collected by computers.

GCSE resits

The Centres for Excellence in mathematics are concerned with students who are re-taking GCSE mathematics. The time for teaching is limited to about seven months, the students tend to have negative attitudes to mathematics and education in general (Anderson & Peart, 2016; Hough, Solomon, Dickinson, & Gough, 2017) and frequently drop out of the course, and the teachers are not always well-qualified in mathematics teaching (Bellamy, 2017).

Technology in the mathematics classroom

Technology and data can be, and are, used by teachers and students in schools and colleges in multiple different ways. In this document, we focus on four aspects of the use of computers and data. We focus on how technology can be used by students to:

- automate mathematical processes and speed them up thus experiencing mathematics in new (to them) ways
- practise answering mathematics questions and get immediate feedback.

We also focus on how technology and data can be used by teachers to:

- engage students and sustain their engagement in mathematics
- diagnose student misconceptions and monitor their engagement.

Technology can be used by students to automate mathematical processes and speed them up, allowing them to experience mathematics in new (to them) ways

Some forms of technology have an 'intrinsically cognitive character' (Balacheff & Kaput, 1996, p. 469) which means that, for some software used in the teaching and learning of mathematics, the implication is that, to a greater or lesser extent, the software can perform mathematical processes (or 'do the mathematics') (Drijvers et al., 2016; Hoyles, 2018; Hoyles & Noss, 2003; Sutherland, 2007; Young, 2017) for the user. For example, calculators are of this type, and are a commonly used technology in mathematics teaching and learning. They can be used to perform calculations and more sophisticated mathematical operations such as plotting graphs. As a further example, in traditional mathematics classrooms producing a bar chart from a set of data is seen as doing the mathematics, but a data handling package is able to 'do' this mathematics (as described by Ruthven Hennessey and Deaney (2009). Similarly solving equations can be seen as doing mathematics, but computer algebra systems can also do this mathematics (Gravemeijer, Stephan, Julie, Lin, & Ohtani, 2017; Weigand, 2017).

These technologies are used to a different degree in mathematics teaching towards level 2 qualifications. Whereas students routinely use calculators in their mathematics (Close, Oldham, Shiel, Dooley, & O'Leary, 2012), there is not always an effective use of other technologies such as spreadsheets and computer algebra systems (Young, 2017). The ability of technology to 'do the mathematics' could be harnessed and used in more imaginative and creative ways, to enhance the learning experiences of students, not merely restricted to calculator use. For example, students could quickly and easily create a range of graphical representations using, for example, graphing packages, and then focus on the shape and features of different graphs in order to draw out common features and patterns (Bokhove & Drijvers, 2012; Condie & Munro, 2007; Godwin & Sutherland, 2004; Sutherland, 2007).

Technology can be used by students to practise answering mathematical questions and get immediate feedback

There are multiple examples of technology that provide students with the opportunity to practise answering mathematical questions (Slavin & Lake, 2008; Snow, 2011). In some cases, the software is pre-programmed with 'correct' answers, with the role of the computer as a 'knowledge holder' (Sutherland & Balacheff, 1999, p. 6) and in other cases random questions are generated and the technology is programmed to calculate the correct answer. More sophisticated versions provide adaptive questions, in which if a student provides a correct answer they are given a more difficult question, but if their answer is incorrect they are given another question at the same level of difficulty (Purohit et al., 2012). These technology-based practise applications, sometimes termed 'drill and practice' exercises, can be used to build confidence and fluency which in turn can improve engagement and increase motivation.

This use of technology is sometimes frowned upon (Doering & Veletsianos, 2009), because, for example, theoretical notions of good learning are often underpinned by social constructivism which posits that learning is a social activity and knowledge is developed through interactions with peers and the teacher (Vygotsky, Cole, John-Steiner, Scribner, & Souberman, 1978). Further, this approach is not aligned with the dominant pedagogical aspiration of teaching for understanding (Darling-Hammond et al., 2015; Huang, Gong, & Han, 2016) which relates to teaching for Mastery. However, for many GCSE resit students, building confidence and fluency may be important and the non-judgemental feedback provided to them by the technology (Roschelle, Feng, Murphy, & Mason, 2016) could provide an ideal environment for some (but not all) for their mathematical activity.

Technology and data can be used by teachers to engage students and sustain their engagement in mathematics

In terms of teachers' use of technology, perhaps the most common, and not mathematics-specific, use of digital technology is the use of data projectors and presentation software, such as PowerPoint (Ruggiero & Mong, 2015). For some teachers, particularly those who are not confident with the mathematical content they are teaching, the use of PowerPoint presentations put together by expert teachers can be reassuring. Examples of such 'expert' presentations are readily available on the Internet, but generally they do not come with any guarantee of quality. Ensuring that key concept areas for GCSE resit students have a resource bank of high quality presentations is something that might be achieved as part of the Centres for Excellence programme.

Another use of technology is to create or find video recordings of classroom (mathematics) teaching, and provide these for students to watch at home. Research suggests that, if students watch the videos and take notes, more class time is available for activities such as developing deeper understanding through activities that help students make connections or practising examination questions (E Silva, 2014; Jungic, Kaur, Mulholland, & Xin, 2105; Oakes, Davies, Joubert, & Lyakhova, 2018). This is known as the 'flipped classroom' approach (Straw, Quinlan, Harland, & Walker, 2015) and has recently been trialled, successfully, in North Wales with A-level mathematics students (Oakes et al., 2018). Once again, for teachers lacking in confidence, use of video-recorded teaching either inside or out of the classroom might be helpful.

For some students, mathematics in seen to be remote and abstract and they find it difficult to engage with the mathematical content. This may be particularly true for GCSE resit students who tend to have had negative experiences of mathematics at school. Technology is sometimes used to pique and sustain their interest. For example:

- Video recordings of real-life situations are shown to the students to set a context, or to get them wondering, before mathematics questions related to the situation are addressed (Chao, Chen, Star, & Dede, 2016; Stohlmann, 2012).
- Simulations are used to demonstrate how variables change over time, for example, with accompanying graphs constructed simultaneously (Bush, Webb, Kress, Yang, & Perkins, 2018; Hoyles & Noss, 2016)
- A situation is modelled (Lowe, Cooper, & Carter, 2018; Oliveira & Nápoles, 2017) (e.g. money growing with compound interest) using a spreadsheet to introduce a topic about interest rates. Students can be shown how a seemingly small change in interest rate results in a surprising difference in the growth of the money.

Technology and data can be used by teachers to diagnose student misconceptions and monitor their engagement.

Technology can be used by teachers to gather and analyse data about their students' performance (Wayman, Shaw, & Cho, 2017). For example, in some software packages students answer mathematics questions, and teachers are able to see how many questions they answered correctly, which questions they appeared to find difficult and how quickly they answered the questions (Hoyles, 2018; Roschelle et al., 2016). Such approaches can be operationalised in different ways which include students working at a distance through to being used within teacher-led whole-class work including involving discussion about misconceptions different methods used and so on. Clearly, the quality of the data, and of the students' learning experience, depends on the nature and quality of the questions they are asked. Well-designed questions have the potential to provide teachers with diagnostic assessments, which can be used to pin-point students' mathematical misconceptions (Roschelle et al., 2016). Teachers can use these assessments in formative ways to provide follow up activities to address the misconceptions, and some software provides suggested activities which are bespoke to each individual student (Hoyles, Noss, Vahey, & Roschelle, 2013; Roschelle et al., 2016).

Within schools and colleges, computer mediated learning management systems, which allow the electronic distribution of assignments, marking and keeping track of students' progress, are attracting considerable research interest (for example, see Dalby & Swan, 2019). There are many such products, including *Nearpod, Showbie*, and *iTunes U* for example, and research suggests that, in appropriately designed teaching and learning situations, their use can facilitate and enhance the processes of formative assessment in mathematics and other subject areas (Abdulaziz Al-Saleh, 2018; Dalby & Swan, 2019)

More generally, some teachers, particularly in FE colleges where attendance and participation are sometimes problematic, may use software to monitor their students' attendance and their use of online materials and activities (which may or may not be linked to maths specific diagnostics as above). The data they gather can be analysed to identify students who are at risk of dropping out, for example, and pastoral measures can be put in place. Students who miss lessons can be sent the day's work so that this can be completed at home and in this way students do not miss out or get left behind. (For example, Leeds College does this). (Cross-reference to Motivation and engagement Briefing)

Summary

Use of technology

There is a wide range of uses to which technology might be used in the GCSE resit context. We propose to undertake three strands of activity each of which directly relates to classroom teaching and learning and with one also having a particular focus on providing data that can inform our wider work.

The first focus makes use of technologies which allow students to have direct experience of mathematics in ways that are new to them. There are both generic and bespoke mathematics apps they might use that can provide dynamic access to mathematical ideas and structures. It is proposed to develop opportunities for students to experience this in a limited number of carefully targeted key areas.

Further to this, it is possible to take a ‘flipped classroom’ approach to learning where students can use technology, particularly videos but also other technologies, in ways that allows class time to be used differently, and potentially providing opportunities to gain deeper insight to potentially achieve mastery.

Finally, technology can provide initial and diagnostic data for teachers in classroom settings to inform formative assessment. For example, some software packages, when used with well-crafted diagnostic questions, allow teachers to identify students’ misconceptions and adapt their teaching in-the-moment to address these misconceptions. Alternatively, the technology can provide the same data but in a less immediate way providing more time for teacher reflection and preparation. There are, of course, possibilities of involving students individually with diagnoses of their own work and taking a more individual approach. The use of technology in this way provides a challenge as to how the data might best be used as it is easy for teachers and students to become overwhelmed because of the quantity of data that can be generated very quickly. This is an issue that we will consider carefully.

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