National Centre for Excellence in the Teaching of Mathematics (NCETM)

Mathematics and Digital Technologies

New Beginnings

A report

Date: September 2010

Content

Executive Summary

This report was commissioned by the National Centre for Excellence in the Teaching of Mathematics (NCETM) as a consequence of OfSTED's report of 2008 (Mathematics: Understanding the score) and the NCETM-funded research report of Miller et al., 2008 (Enabling enhanced mathematics teaching with interactive whiteboards). These two publications highlight difficulties in access to ICT equipment for learners in mathematics lessons and suggest that there is a need for Continuing Professional Development (CPD) for mathematics teachers in the interactive use of ICT in mathematics and in supporting the use of ICT by learners.

As a result the NCETM established an ICT group and commissioned Keele University to work with the group with the aim of providing the NCETM with actions and key points in response to the issues raised in these two documents. The terms of reference of this report are concerned firstly with CPD to develop and improve the use of ICT in mathematics classrooms and secondly with the frequency of use of ICT by teachers and learners in mathematics lessons. In parallel with this work the Joint Mathematical Council (JMC) of the UK commissioned a group to consider the use of ICT in mathematics and this report is expected towards the end of 2010.

At the outset the group was concerned with the use of ICT in mathematics but now , following discussions with those involved in producing the JMC report, we believe that it is a time for 'curriculum renewal' and to exploit the potential of digital technologies in mathematics. For much of the report we have retained the use of the term 'ICT' as it was our starting point and reflects the literature base but our actions and key points embrace digital technologies.

Recommendations

It was agreed with the NCETM that the following recommendations would be implemented at the earliest possible opportunity. These are as follows:

Recommendation 1: Creation of a digital technologies microsite on the NCETM portal

It was agreed with the NCETM that a digital technologies microsite should be created on the NCETM portal as soon as possible.

Recommendation 2: Digital technologies self-evaluation tool on the NCETM portal

It was agreed with the NCETM that as a matter of priority a digital technologies self-evaluation tool should be developed on the NCETM portal.

Recommendation 3: NCETM online magazines

It was agreed with the NCETM that in each issue of the online magazine there should be a clearly identified section that looks at the use of digital technologies in mathematics and that this should happen as soon as possible.

Recommendation 4: Leading and supporting the development of digital technologies in mathematics

It was agreed with the NCETM that they should work with the appropriate subject associations to provide professional development in the use of digital technologies in mathematics for those involved in initial teacher education of mathematics teachers and for those, such as local authority mathematics advisors and equivalent, who have the potential and opportunity to impact on a large number of teachers. The four day course would run in autumn 2010 and spring 2011.

Recommendation 5: Digital technologies – a skills list

It was agreed with the NCETM that a skills list of seven zones should be produced to form a convenient home against which digital technologies activities could be referenced. The zones are: classroom hardware; interactive whiteboards; strategies for lessons on laptops and netbooks, and lessons in the computer room; word-processing for mathematics; spreadsheets for mathematics; internet resources and related issues; and specialist software.

Recommendation 6: Directory of digital technologies professional development trainers

It was agreed with the NCETM that they should produce a directory of trainers who can provide CPD in the use of digital technologies for mathematics teachers. Potential trainers will be asked to reference their own competences to the zones in the skills list. The NCETM will responsible for inviting applications for the Directory, ensuring quality through requiring trainers to be signed up for the NCETM CPD standard and advertising courses provided by members of the Directory through its CPD section and its digital technologies microsite.

Key points

The following are the key points from the report.

Key point 1: The interactive use of digital technologies in mathematics (a definition)

We broadly define the interactive use of digital technologies by teachers of mathematics as being typified by a classroom where there are certain pre-requisites in which particular features of the interactive use of digital technologies will be seen (adapted from Miller et al, 2008: p.8-9 and from Roschelle, 2009: p 1).

Pre-requisites

- regular and frequent use of a computer that is connected to a data projector (and IWB)
- all electronic resources are managed routinely (usually by storage in a single file)
- ideally - free access by the learners to appropriate digital technologies during all lessons (but we recognise that at present this is an aspirational aim rather than an actuality for most classrooms where mathematics is taught)

The approach used is typified by examples of one or more of these:

- 'at the board, in the head, at the desk' (Miller et al, 2008)
- 'do, talk, record' (Floyd et al, 1981)
- 'interactivity' as outlined by Roschelle (2009)
- 'rich mathematical activities' (Ahmed 1987)
- a digital technologies variation of the Improving Learning in Mathematics (Standards Box) materials and the approach of Swan (2006)

Features of interactive use of digital technologies in mathematics classrooms

- a collaborative classroom where learners work together and discuss their mathematical experiences using digital technologies as appropriate to support their work and where teachers and learners share a sense of responsibility for learning mathematics
- a wide variety of teacher and learner interactions are in evidence to explore and expand learners' understanding around the mathematical concepts and ideas stimulated by the digital technologies generated problems
- learners are engaged and actively involved in the exploration and making sense of mathematics (using digital technologies) through meaningful activities that make connections across all areas of mathematics
- computer projection displays are used to provide instant feedback to increase learners' cognitive engagement, not only for purposes of demonstration and assessment

Key point 2: Teacher development of digital technologies and pedagogic 'skills'

Evidence suggests that developing teachers' digital technologies and pedagogic skills together can develop teachers of mathematics who make interactive use of digital technologies. In doing this problems highlighted by OfSTED could be solved.

Key point 3: Overcoming barriers to access to digital technologies

School-related barriers to teacher use of digital technologies in mathematics will remain. These may arise from limited access to resources or existence within a culture of limited use of digital technologies. Here are two places for mathematics subject leaders to find support in addressing these barriers.

The Excellence in Mathematics Leadership (EiML) pages of the NCETM portal:

https://www.ncetm.org.uk/resources/21289 and

Chapter 11, Using ICT to enhance professional practice in Johnston-Wilder, S.J. and Lee, C. 2010 Leading Practice and Managing Change in the Mathematics Department, Tarquin, St Albans.

Key point 4: The importance of collaborative support

Where it is available the informal support from colleagues is the most popular form of training for digital technologies. Although such training will have made significant changes on individual teachers and departments it has not yet had a major impact on a national scale. However the use of external 'experts' or catalysts may be necessary to support such professional development.

Key point 5: Raising the digital technologies related skills and pedagogy of mathematics trainees

The NCETM should work with immediate effect with relevant stakeholders to help raise the digital technologies related skills and pedagogy of the tens of thousands of ITE students/trainees who are on primary, KS2/3 or secondary mathematics ITE courses.

Key point 6: The digital technologies microsite – its role in raising awareness

The digital technologies microsite on the NCETM portal should provide a starting point for those teachers of mathematics who wish to find digital technologies resources and professional development materials. It is suggested that these could be separated according to phase.

Key point 7: Large scale solutions and the JMC report

All actions and recommendations are intended as large scale solutions that might help bring about significant small 'cultural' changes at all levels and all phases of mathematics teaching. The JMC report is expected to provide the rationale for the use of digital technologies for all learners and teachers of mathematics. Learners need to use digital technologies in mathematics from their early days in school; teachers need to use digital technologies in their teaching and learning from the very first day of their ITE course so that all might recognise the pivotal role that digital technologies have in modern mathematics: it is not something that should be ignored or just considered as an add-on undertaken by those teachers with the relevant skills and pedagogical awareness.

Key point 8: New beginnings

There is considerable evidence to show that learners' enhanced mathematical understanding and attainment cannot be fostered by didactic teaching. Approaches which are interactive, challenging and cognitively productive need to become the everyday armoury of teachers of mathematics. To this end the NCETM should do everything they can to bring both this report and that of the JMC to the attention of all those involved in developing policies and, most importantly, in teaching mathematics.

Some of the appendices of this report provide ideas of equipment and software that should be made available to support the use of digital technologies by learners of mathematics. We hope that soon all mathematics classrooms will contain a wide variety of digital technologies for use by all, but recognise that where this is not possible all learners still have a right and an entitlement to make considerable use of digital technologies in mathematics.

Background and Context

This report was commissioned by the National Centre for Excellence in the Teaching of Mathematics (NCETM) as a consequence of the OfSTED report of 2008, Mathematics: Understanding the score, and the research report Enabling enhanced mathematics teaching with interactive whiteboards (Miller et al., 2008) arising from research funded by the NCETM and undertaken by the Keele University interactive whiteboard team. These two publications highlight difficulties in access to ICT equipment for learners in mathematics lessons and suggest that there is a need for Continuing Professional Development (CPD) for mathematics teachers in the interactive use of ICT in mathematics and in supporting the use of ICT by learners.

As a result the NCETM established an ICT group and commissioned Keele University to work with the group with the aim of providing the NCETM with actions in response to the issues raised in these two documents. These actions were to be followed through during and after the end of the meetings. The group met eight times between July 2009 and April 2010 and have worked since then to produce this report for September 2010.

The terms of reference of this report are concerned firstly with CPD to develop and improve the use of ICT in mathematics classrooms and secondly with the frequency of use of ICT by teachers and learners in mathematics lessons. In parallel with this work the Joint Mathematical Council (JMC) of the UK has commission a group to consider the use of ICT in mathematics from the perspective of the rationale for why we need to use ICT in mathematics and why it is an essential part of mathematics education. This report is expected towards the end of 2010.

At the outset the group was concerned with the use of ICT in mathematics but now , following discussions with those involved in producing the JMC report, we believe that it is a time for 'curriculum renewal' and to exploit the potential of digital technologies in mathematics. For much of the report we have retained the use of the term 'ICT' as it was our starting point and reflects the literature base but our actions and key points embrace digital technologies.

Ease of reading: 'abbreviations'

To make this document easier to read we are using 'abbreviations'. So throughout the document we only refer to England; the term learners is used for those learning mathematics (in schools, colleges etc.) in the 5 – 19 age range; the phrase teacher of mathematics applies to anyone teaching mathematics (including numeracy) to these learners; and the term school means the places of learning as appropriate for these learners. The term Initial Teacher Education (ITE) refers to that of teachers of mathematics (and in the case of primary and early years courses this will mean all students and trainee teachers on these courses).

The ICT group

The group comprised representatives from the major groups concerned with mathematics teaching and learning in schools. In almost all cases the representative was a person with a mathematics responsibility. The following groups were represented (some people belonged to more than one of these):

Becta, Initial Teacher Education, Joint Mathematical Council, National Centre for Excellence in the Teaching of Mathematics, National Stem Centre, National Strategies, OfSTED, Primary Headteacher, Qualifications and Curriculum Development Agency, Secondary Head of Mathematics, Specialist Schools and Academies Trust, Subject Associations, Training and Development Agency.

Additional expertise has been called on whenever any gaps have been identified.

Evidence Base

Evidence collected came from the following sources:

- discussion at the meetings and follow up of relevant items
- e-questionnaire to initial teacher education tutors
- e-questionnaire to primary headteachers
- individual semi-structured interviews with almost all of the ICT group

- literature review
- search for materials considered to be useful to support the use of ICT in mathematics
- specific ICT and/or mathematics reports: including the OfSTED report, the IWB report and sources used by Becta to compile their annual Harnessing Technology reports
- two-day focus group meeting of secondary mathematics teachers

The methods used, time and staffing available means that the evidence, although substantial, is not complete or based on objective data. However given the nature and experience of the ICT group we believe that the evidence presents a reasonably accurate picture of the current situation in England.

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The Literature Review: a brief summary

In undertaking the literature review over one hundred sources were examined (see Appendix 7). The full review has been organised under the headings used in this brief overview. The intention in this overview is to give a broad flavour of the full review – and this will be made available in due course. Much of the research is general rather than about mathematics but we have only used that, which in our judgement, might also be applicable to mathematics. For ease of reading that we have not referenced any sources here since they are all fully referenced later in the report.

The context of ICT use

Across all subjects much is written about barriers and enhancers to ICT use but even with the wider availability of equipment in schools there is still debate about whether there are pedagogical advantages connected with ICT use. In recent years ICT use by learners in mathematics lessons seems to have decreased.

Drawing from other evidence - The list

Initially emphasis on ICT use was placed on teacher professional development concerned with hardware and software but researchers then start to comment on barriers and enhancers that appear to impact on ICT use. We have drawn on this literature to collect factors classified according to technologic or pedagogic emphasis and the impact on teacher or learner.

Creating the culture to maximise ICT use

It appears that a number of factors impact on the ICT culture of a school or department including: leadership (school or department); teachers' skills and their curriculum understanding from an ICT point of view; available technology; and the level of appropriate CPD to support ICT integration.

Pedagogic change to encourage ICT use

Learner attainment is influenced by teacher's individual pedagogies and ICT use can bring about increased motivation, but the use of ICT does not in itself change underlying pedagogical practice. In mathematics the constraint of three part lessons and the option to use PowerPoint can lead to a stifled pedagogy.

The learner view of ICT use in mathematics lessons

Research seems mostly positive on what learners can gain from ICT use in mathematics but evidence, as one might expect, suggests that it the determining factor is how the teacher structures the learning environment and allows elements of learner control.

Changing teacher attitudes to ICT use

A consistent theme of the research over time is teacher attitude to ICT use. Chief concerns are related to confidence, fears about technology problems and knowing less than learners; access; inappropriate training; time for preparation; not being aware of the benefits and not having ICT use clearly embedded into schemes of work. The subject leader has an important role in supporting teacher development.

Initial teacher education and ICT use

General ICT skills are required by all Newly Qualified Teachers (NQTs). Recent evidence suggests that 'key issues in developing very good use of ICT are access, support for, and modelling of, ICT' as well as 'the belief that ICT could make a positive difference to teaching and learning and a willingness to 'learn by doing'.' Use of ICT during the ITE period is a strong influence on use as a teacher, 'in particular past modelling of ICT use by mentors and tutors'.

Continuing professional development for enhanced ICT use

Evidence suggests that in mathematics CPD needs to address attitudes and perceptions as well as technological skill development and that there are gains from collaborative and continued involvement with a group of peers.

Supporting non-users and limited users to become interactive – beyond CPD

It is likely that agents of change are necessary to impact on this group to provide motivation through a supportive social environment. It may help that there is evidence that technology can play a key role in improving achievement, that a large majority of teachers agree that technology has an impact on engagement in learning and that it is not necessary to know a lot of ICT to use it effectively.

Living with developing technology

Although learners and teachers use technology widely outside school the classroom use of ICT in mathematics ranges from virtually no use by some to innovative use with hand-held devices. Infrastructure is increasing to widen learner contact with the school from home.

Conclusion

Barriers and enhancers to ICT use in mathematics may be both technical and pedagogic. So much depends upon the attitude of the teacher and the culture of the school and department within which the teacher works. The literature suggests that although the key to ICT use appears to lie in ITE it also needs the individual teacher to believe that ICT can provide support for active, challenging and effective teaching.

The Use of Digital Technologies in Mathematics: Results and Findings

The report is an on-going document and at each stage all members of the ICT group have been invited to make comments. Subsequent versions take these comments into account.

The use of digital technologies in mathematics

At an early stage the ICT group realised that 'the use of ICT in mathematics' may mean completely different things to different readers. Here are four examples of the spectrum of ICT use:

- ICT is rarely used by anyone, teacher or learner in any format
- virtually all the use of ICT is by the teacher using either PowerPoint or interactive whiteboard (IWB) presentations – there may be elements of learner interaction with these presentations
- as the case above with teacher use of mathematical software (e.g. a graphing or geometry program), virtual manipulatives (usually web-based specific short programs with a particular purpose, often referred to as (java) applets or flash programs); there may also be occasional use of these programs by learners when the class can get access to computers (either laptops or in a computer room)
- learners have free access to ICT to support their learning of mathematics and at times have to make choices about whether to use ICT and if so what programs to use

Key point 1: The interactive use of digital technologies in mathematics (a definition)

We broadly define the interactive use of digital technologies by teachers of mathematics as being typified by a classroom where there are certain pre-requisites in which particular features of the interactive use of digital technologies will be seen (adapted from Miller et al, 2008: p.8-9 and from Roschelle, 2009: p 1).

Pre-requisites

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Features of interactive use of digital technologies in mathematics classrooms

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Implications

The use of digital technologies provide feedback so provided learners develop the motivation to 'read' the feedback (this does not always happen) and can interpret it (and this too does not always happen) - it means they are not so dependent on the teacher to support their problem solving and validate their solutions. In essence digital technologies are more than 'just tools' there is a potentially transformational use of digital technologies where the pedagogical approach is transformed through a high level of teacher and learner use of digital technologies.

The interactive use of digital technologies requires, for many teachers, an adapted pedagogy as well as skills in the use of digital technologies and access to appropriate digital technologies. Given some development with these skills and an appropriate pedagogy, and an opportunity to try things out (ideally working with colleagues) time is then needed to reflect on progress made in order that teaching might evolve.

Current Practice

Having looked at the wider literature we focus here on the data coming out of schools as reported through the work of Becta (Becta, 2008a, 2009a; Keating, 2009; Smith et al, 2008a, 2008b) and OfSTED (2008) and the reports of Hammond et al (2009a, 2009b). The OfSTED report (2008), p. 6, states

"The content of the mathematics curriculum in most of the schools surveyed was age-appropriate. However, the majority of pupils had too few opportunities to use and apply mathematics, to make connections across different areas of the subject, to extend their reasoning or to use information and communication technology (ICT). Higher-attaining pupils were not always challenged enough in lessons. Links with other subjects were insufficient."

Key point 2: Teacher development of digital technologies and pedagogic 'skills'

Evidence suggests that developing teachers' digital technologies and pedagogic skills together can develop teachers of mathematics who make interactive use of digital technologies. In doing this problems highlighted by OfSTED could be solved.

Barriers to ICT use

These are widely dealt with in the literature and appear to come down to these three broad areas of:

- school-related
- teacher-related and
- professional development issues

School-related issues

These are concerned with:

- access
- assessment
- school ethos and leadership

Access

Although primary schools have a ratio of 6.6 learners per computer, secondary schools 4.2 and special school 2.6 the use of ICT facilities in mathematics lessons declines significantly in secondary schools (Keating et al, 2009) - see figure 1 (though this may not be related wholly to issues of access). In secondary schools 41% of all subject teachers said that they found ICT difficult to access in their school (Smith et al, 2008a).

Figure one (Keating et al, 2009) shows the differing level of access to technology in mathematics lessons, as reported by learners, between primary and secondary, where in the latter 59% of learners use ICT less often than once a month (or never) and only 7% appear to have relatively consistent access (at least once a week).

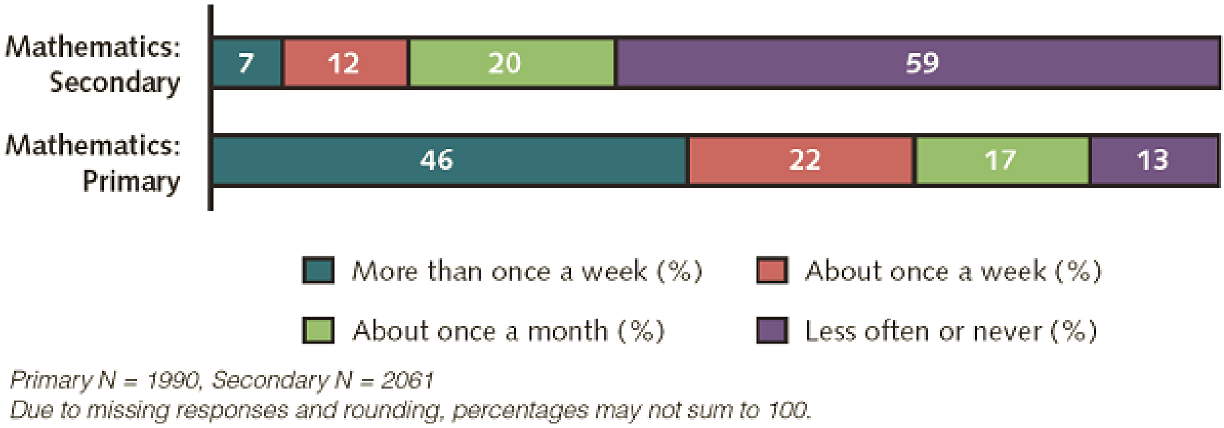

Figure 1: Technology use in mathematics (Keating et al, 2009)

As Ruthven (2008), drawing on the literature, comments using a computer room is not without its own problems: the change of teaching space; getting there; its physical layout; the new classroom procedures and routines needed for this environment; the need to share computers; the reliability of equipment and that it is likely that learners already have established routines in this room that may be entirely different from (and unknown to) those of the teacher of mathematics. We think that this is less of a problem in primary where only two thirds of primary schools report having an ICT suite compared to almost all secondary schools (Smith et al, 2008b).

Assessment

OfSTED (2008) comment on how 'the rising trends in attainment are not generally being matched by identifiable improvements in learners' understanding of mathematics or in the quality of teaching' noting that improvements come from 'teaching that focuses on the skills required by examination questions and extensive use of revision'. This trend is noted 'albeit to a lesser extent' in primary schools.

The pressure put on teachers of mathematics by school managers looking to maximise the level 4 and 5 scores in a primary school and the '5 A*-C including mathematics and English' in a secondary school has not helped – as OfSTED (2008) note "Too much teaching concentrates on the acquisition of sets of disparate skills needed to pass examinations."

Where this is the case we think that such a focus on external results can, when combined with other factors, result in an ICT deficient mathematics curriculum.

School ethos and leadership

In general ICT terms a statistically significant positive association was found between teachers' reported enthusiasm in using ICT to deliver the curriculum and the level of technical support available in a school (Smith et al, 2008a), though since 2007 it appears that having an ICT technician on site is decreasing (2008 figures report 80% of secondary schools and 15% of primary schools have such a technician).

According to Becta "Schools holding the Becta ICT Mark have demonstrated that they are committed to using technology to improve their overall effectiveness and efficiency. They are more likely to be regarded as good or outstanding by OfSTED, and are able to demonstrate the impact of their investment in technology. They are also better qualified to share their strengths with other schools." The ICT Mark is part of the Next Generation Learning Charter. With the closing of Becta it is not clear how this might change and whether the ICT mark might remain.

Teacher-related issues

These are concerned with:

- attitudes and belief

- confidence in ICT skills
- hardware
- learners
- pedagogical awareness or understanding
- software, both subject specific and generic
- subject knowledge
- workload

Attitudes and belief and confidence in ICT skills

Although a slight majority of all teachers agree that learners enjoy lessons more if they use ICT than if they do not and that 'ICT in primary, secondary and special school plays a positive role in engaging learners in learning, having an impact on attainment, and in personalising learning' slightly under one third of secondary teachers do not always think ICT is 'time-effective a lot or some of the time' (Smith et al, 2008a).

There is recent evidence that attitude and belief make a difference to frequency of ICT use by teachers. Hammond et al (2009a) in their paper on student teachers who make very good use of ICT comment on the importance of the 'belief that ICT could make a positive difference to teaching and learning'. In a follow up paper on new teachers Hammond et al (2009b) comment that the two key factors (from a larger list) that determine ICT use by new teachers are access and 'the belief that ICT can provide support for good teaching'.

There is an interesting comparison in Smith et al (2008a) in responses with a statistically significant association with teachers' level of professional experience; firstly that ICT makes learning more effective and secondly with teachers' reported effectiveness in using ICT. In the first case 'teachers with five or fewer years of teaching experience were more likely to strongly agree with the statement that ICT makes learning more effective (31 per cent) – the proportion of teachers who strongly agreed decreased with their experience (thus only 16 per cent of teachers with more than 20 years' experience strongly agreed).' In the second case 'the highest proportion of teachers who thought they were very effective using ICT were in the most experienced group (28 per cent), namely those who have taught for more than 20 years and the lowest proportion (20 per cent) was in the group of teachers with up to five years' experience.' They also note a significant association that those teachers who thought that they were not very or not at all effective with ICT were much less like to use software or the Internet in their teaching. This has implications for ITE.

Hardware

The fitness for purpose of interactive whiteboards is rated very positively by all teachers in all sectors and they rarely create technical problems (Smith et al, 2008b). Though this does not guarantee appropriateness of use as Smith et al (2008) state 'interactive whiteboards are the dominant technology in schools, and that this technology continues to be used primarily for presentational purposes.' They report that a similar thing has been found by Golden et al (2008) in FE. This backed up the OfSTED (2008) findings 'too often teachers used them simply for PowerPoint presentations with no interaction by the pupils. '

According to Becta (2009a) 'some 86 per cent of all primary teachers use an IWB and other display technologies at least once a day, compared to 73 per cent of all secondary teachers', though in secondary we would suggest that figures are likely to be higher for mathematics teachers.

When learners were asked about their use of equipment their responses are shown in Table 1 – however, as the authors (Keating et al, 2009) point out, this does not clarify what is meant by use. We have added a bottom row to this table which is taken from Figure 1 earlier in our report.

Learners

ICT can be used in many ways and one of the ways noted in the two Becta entitlement documents (Becta, 2008b and Becta, 2009b) involves learners using ICT to explore mathematics. However if learners are not used to exploring ideas in mathematics (in any situation) then asking them to explore an aspect of mathematics using ICT may initially create problems for the teacher (with learners not knowing how to use ICT to do this). This can cause inexperienced or trainee teachers to give up trying to let learners use ICT. This has implications for ITE and the induction of newly qualified teachers. According to Keating et al (2009) ‘many learners felt there is scope for more technology to be used in lessons to support learning’ and they recommend that schools ‘build upon and make greater use of the ICT skills and experience that learners have acquired at home and outside of school’.

	More than once a week		About once a week or more (more than once a week and about once a week combined)	
Technology	Primary (%)	Secondary (%)	Primary (%)	Secondary (%)
Computers	38	62	93	83
IWBs	79	63	85	76
Computers (Mathematics)	46	7	68	19

Primary N = 1990 Secondary N = 2061 (for all data)

Table 1 Frequency of use of computers and IWBs by learners (adapted from Keating et al, 2009)

Pedagogical awareness or understanding

OfSTED (2008) and Smith et al (2008a) comment on how IWBs are often used only for presentational purposes. Although the use of any materials can be transformed (both positively and negatively) by the teacher using it some commercial presentation programmes, for example MyMaths in secondary schools, tend to reinforce this pedagogical approach by basically providing presentation screens, that usually contain some structured ‘interaction’, that are then followed by opportunities for practice.

There are many other pedagogical approaches and examples include those mentioned earlier related to interactivity but further examples include the NRich materials for primary and secondary and, at secondary level, the ideas of Prestage & Perks (2001) and the materials from Bowland and Cre8ate. Ruthven (2008) discusses examples for ICT lessons and identifies the difficulties associated with establishing a new pedagogy and the need to create detailed lesson plans and new materials. The challenge in all this is in providing teachers of mathematics with professional development, support and guidance so that they might develop their own pedagogy for allowing learners to make interactive use of ICT.

Looking generally at the use of ICT in schools Keating et al (2009) state “There is a continuing need for further encouragement of the use of particular (and new) technology skills and tasks in lessons, homework and coursework. While there are some signs that new technologies are becoming increasingly embedded across the curriculum there are still too many variations in the use of ICT across different school subjects.’

Looking specifically at the IWB Miller et al, (2008) describe their ‘at the board, on the desk, in the head’ which involves ‘working with the IWB so that all lesson activities are integrated into an interactive (rather than a didactic or presentational) whole and orchestrated/facilitated using the IWB software as the means of storing and organising all the electronic resources for the lesson’.

If pedagogical change is to come about in the mathematics classroom then there is a need for appropriate CPD to support and enhance this development.

Software, both subject-specific and generic

Mathematics and history teachers were most likely to rate curriculum-related software highly and all teachers are reasonably satisfied with the software available for school curriculum use (Smith et al, 2008a). Primary teachers, in particular, reported that curriculum-related software is easy to find and that fitness for purpose is either ‘very good’ or ‘quite good’, however around a quarter said that they didn’t know where to find or how to use ICT resources.

Subject knowledge

Although the information does not appear to be in the literature it is thought that non-subject specialist teachers of mathematics in secondary schools, who number about 25% of those teaching mathematics (Moor et al, 2006), are less likely to use ICT in mathematics lessons. With expertise in other departments these teachers are much less likely to be involved in mathematics professional development of any type (until the recent creation of the Mathematics Development Programme for Teachers aimed at 200 non-specialists a year for two years, though it is not clear how these courses are looking at ICT for mathematics teaching). There are implications here for such courses and the NCETM.

At primary level Williams (2008) recommended that all primary schools should have a mathematics specialist with 'deep mathematical and pedagogical knowledge'. It is not yet clear how this will impact on teacher and learner use of ICT in mathematics lessons in primary schools. There are implications here for such courses and the NCETM.

Workload

Most aspects of using ICT take extra time initially due to hardware, software and planning issues especially if one wants learners to use ICT regularly. Pierce and Ball (2009) in an investigation of inhibitors for teachers show how perceptions of possible workload, materials use and technical problems lead to resistance to the use of ICT and the need for professional development. However, professional development time to work on ICT-related lessons then has to 'compete' with other demands such as passing examinations; Assessing Pupil Progress; the changing demands of the new curriculum; and, for secondary teachers, adapting courses in line with the Functional Skills agenda.

Key point 3: Overcoming barriers to access to digital technologies

School-related barriers to teacher use of digital technologies in mathematics will remain. These may arise from limited access to resources or existence within a culture of limited use of digital technologies. Here are two places for mathematics subject leaders to find support in addressing these barriers.

The Excellence in Mathematics Leadership (EiML) pages of the NCETM portal:

https://www.ncetm.org.uk/resources/21289 and

Chapter 11, Using ICT to enhance professional practice in Johnston-Wilder, S.J. and Lee, C. 2010 Leading Practice and Managing Change in the Mathematics Department, Tarquin, St Albans.

Professional development-related issues

These, in alphabetical order, are concerned with:

- access to, the nature and quality of professional development
- factors that influence the ICT skills of NQTs
- ICT professional development resources
- ICT resources

Access to, the nature and quality of professional development

Two factors that limit access to CPD are school policies on covering colleagues and funding available for CPD (and these apply wherever CPD takes place). However despite this Smith et al (2008b) report on high percentage (60%+ secondary and 75% primary and special) of staff reported to have received ICT training. They also provide data on the perceived quality of ICT training and/or ICT support (see Table 2). This has implications for CPD and the NCETM.

Although in-school training provision for ICT is the most positively received, in itself it may not be sufficient since in some schools teachers do not recognise the need for additional support for ICT by 'not knowing what they do not know' – i.e. in terms of the Consciousness ladder (Dubin, 1962), they are 'unconsciously incompetent'.

	'Very good' and 'Good' responses to ICT training and/or ICT support		
	Primary	**Secondary**	**Special**
Informal support (e.g. discussions with other teaching staff)	95	91	92
Formal training courses delivered in person	88	75	84
Finding information online	70	58	69
DVDs or CD-ROMs (e.g. demonstrations of how to use a software package)	72	60	64
Reading books or manuals	32	31	36
Formal training courses delivered online	43	33	31

Table 2: Combined percentage 'Very good' and 'Good' responses to ICT training and/or ICT support accessed by all teachers (from Smith et al, 2008b)

ICT training for mathematics staff comes from a variety of places including the TSM conferences (specifically ICT-related) in the summer holiday, and the Easter subject association conferences (usually have some ICT-related sessions) but for both these teachers have to decide to use their own time and are likely to have to fund the conference costs themselves. Otherwise out of school ICT-related CPD is limited, is often targeted at what CPD professionals decide to offer and frequently only lasts a day with a limited amount of time to consider both ICT and pedagogic issues.

The NCETM also provide opportunities for groups of teachers to work on ICT professional development through their funded projects scheme, but presently this involves small numbers of teachers working with colleagues and often with a wider group, including 'experts'.

Key point 4: The importance of collaborative support

Where it is available the informal support from colleagues is the most popular form of training for digital technologies. Although such training will have made significant changes on individual teachers and departments it has not yet had a major impact on a national scale. However the use of external 'experts' or catalysts may be necessary to support such professional development.

Factors that influence the ICT skills of NQTs

All ITE institutions will vary in what they offer to their trainees in ICT skills and pedagogy at both the generic and at the subject-specific levels. Primary and secondary courses will focus on different things but as a minimum all NQTs will have satisfied the following three (out of 33) ICT-related Q standards:

- Q16 Passed the literacy, numeracy and ICT Skills tests
- Q17 Know how to use skills in literacy, numeracy and ICT to support their teaching and wider professional activities
- Q23 Design opportunities for learners to develop their literacy, numeracy and ICT skills

However this will be influenced by factors including course philosophy and delivery, the background of the tutors and mentors and opportunities available on teaching practices. So at one extreme some NQTs will have been required to follow, for example, an IWB skills and pedagogical component on their ITE course, been provided with a variety of resources that illustrate use of ICT in mathematics lessons, used an IWB on a daily basis with all their classes and have easy access to an ICT suite, or equivalent, so that their learners have used ICT on a regular basis for mathematics throughout their course. At the other extreme an NQT might have seen ICT as an add-on activity, and only seen an IWB used occasionally on their ITE course, have the minimal skills and pedagogical awareness to pass the standards above and little classroom experience of seeing ICT being used by learners in mathematics lessons.

In reality there is a wide variation of what is offered in training institutions and schools and this will have an impact on the teaching of the trainee and the NQT. Two recent studies offer insight: the first (Hammond et al 2009) into why some student teachers make very good use of ICT and the second (Hammond et al 2009b) then follows some of them through as NQTs. In the first Hammond et al, 2009a, state:

> "Findings indicate that access, support for, and modelling of, ICT use in the classroom were key issues in developing this very good use of ICT. Equally important, however, seemed to be the belief that ICT could make a positive difference to teaching and learning and a willingness to 'learn by doing'. "

In the follow up Hammond et al, 2009b, state:

> "… they continue to see ICT as supporting both their whole-class teaching and pupils' independent working. The impact ICT has in the classroom provides the underlying rationale for its use by new teachers. Environmental factors, including access and expectations in school, further influence ICT use. Pre-service training remains a strong influence, in particular past modelling of ICT use by mentors and tutors."

Key point 5: Raising the digital technologies related skills and pedagogy of mathematics trainees

The NCETM should work with immediate effect with relevant stakeholders to help raise the digital technologies related skills and pedagogy of the tens of thousands of ITE students/trainees who are on primary, KS2/3 or secondary mathematics ITE courses.

ICT professional development resources for mathematics teaching

There is a wealth of materials available that offer development in a number of different formats including:

- books on mathematics teaching that provide examples of ICT use throughout
- Bowland professional development materials
- IWB beginners on-line course (for a specific manufacturers' IWB software)
- guides or handbooks (sometimes with videos) for particular pieces of mathematics software
- journal articles, or collections of such, that discuss ICT applications and pedagogy
- national strategy guides
- NCETM materials that support teachers or departments to adapt their ICT practice
- learner worksheet and teacher materials associated with the use of particular mathematical ideas and programs
- 'screen-videos' of how to do particular things with mathematics software
- specific books that focus on the use of ICT in mathematics
- subject-leader materials that support subject leaders to lead practice and develop their department's ICT capabilities
- teacher guides to ICT use related to particular texts
- Teachers' TV videos on innovative use of technology
- Teachers' TV videos on pedagogical issues concerned with 'Hard to teach' topics
- Vital – the new ICT CPD programme funded by the DfE and managed by the Open University

Although the ICT group were collectively aware of all of these few knew of all of them, since at present a central 'index' of ICT-related resources is not yet available.

Key point 6: The digital technologies microsite – its role in raising awareness

The digital technologies microsite on the NCETM portal should provide a starting point for those teachers of mathematics who wish to find digital technologies resources and professional development materials. It is suggested that these could be separated according to phase.

ICT resources

IWBs were introduced into England for use in mathematics over a relatively short time and now they are to be found in a large majority of classrooms used for teaching mathematics (OfSTED, 2008; Becta, 2009). They had an early positive impact by producing presentational and motivational gains as well as bringing mathematics software, for teacher use, into the mathematics classroom. The impossibility of creating new materials for every single lesson brought about a vacuum that was filled, by secondary schools, buying in well-thought out, cleverly designed, ready-made presentations (like MyMaths) that mostly conform to the format of exposition, example and exercise. These took into account the presentation advantages of the IWB, allowed for some interaction around this format, providing homework and revision opportunities (later), but did not engage with the potential of IWB use by offering a new pedagogical approach.

To date there are different pedagogical approaches but these appear to be confined to individual teachers, departments or schools, are not generally widely used and so have not moved the standard mathematics lesson into the 21st century.

The introduction of IWBs, and all that comes with it, in secondary schools may also be partially responsible for the decline in use of ICT by secondary school learners with possibly two underlying causes: firstly budgetary/equality and secondly the changed nature of teaching with an IWB. The first of these might account for some of the access problems (of learners to ICT in mathematics lessons), now so evident, since IWBs were often placed first in mathematics classrooms resulting in a belief (that might still be present) that this was their share of the ICT budget and ICT resourcing. The second of these arises from the improved presentations, increased motivation and interest by learners and also brought a computer into the mathematics classroom, allowing teachers to use, for example 'virtual manipulatives', and graphing and geometry programs – in effect the ICT component was considered fulfilled by the teacher making use of ICT on the IWB. At one level these programs can be used to demonstrate mathematics (through exposition) while at another level they could be used interactively by both learners and teachers. At present the evidence of OfSTED (2008) and others suggests that the latter of these is not the norm.

In primary schools, things were different as generally the increase in use of IWBs followed behind that in secondary schools, giving more time for developers to think and plan a wider variety of uses for IWBs in classrooms. In addition there may have been advantages with teachers usually teaching more than just mathematics, having easier access to computers and a greater variety of software to use in their teaching.

Conclusion and recommendations

This report has addressed some of the issues of ICT for all involved in mathematics teaching. As we now move forward we should look for use of digital technologies in the mathematics curriculum and leave behind the problems associated with mathematics and ICT. Most, but not all, learners and teachers now make considerable, but different, uses of digital technologies in all aspects of their non-school lives. For most digital technologies are now a feature of everyday life: they are embedded in the culture and fabric of society.

Yet the culture of the mathematics classroom today has not yet caught up with the everyday experience of either the learners or the teachers. The recommendations and actions within this report all look to extend the digital technologies enculturation of society into the mathematics classroom.

Key point 7: Large scale solutions and the JMC report

All actions and recommendations are intended as large scale solutions that might help bring about significant small 'cultural' changes at all levels and all phases of mathematics teaching. The JMC report is expected to provide the rationale for the use of digital technologies for all learners and teachers of mathematics. Learners need to use digital technologies in mathematics from their early days in school; teachers need to use digital technologies in their teaching and learning from the very first day of their ITE course so that all might recognise the pivotal role that digital technologies have in modern mathematics: it is not something that should be ignored or just considered as an add-on undertaken by those teachers with the relevant skills and pedagogical awareness.

To help us do this we are providing a number of appendices that should be seen as a means to moving forward. To support development we offer a simple snapshot of what digitally proficient mathematics teachers might be expected to do, how their classroom might look and how they

And finally: new beginnings with digital technologies

The mathematics curriculum has suffered as a result of access to equipment, ICT often being seen as an add-on, the 'concern' with high-stakes assessment and a pedagogy which is limited and often presentational rather than integrative and interactive. This has had an impact on many ITE courses where access to ICT in schools is limited often resulting in students/trainees achieving the standards but with a limited technical competence and awareness of how digital technologies might serve learning and provide a new pedagogical impetus to the mathematics curriculum.

CPD has often offered some competence and pedagogic awareness of ICT use and experience but the 'league table' mentality has not allowed digital technologies to be seen at forefront of mathematics in schools. As we move into the second decade of the twenty-first century it is time for new beginnings.

Key point 8: New beginnings

There is considerable evidence to show that learners' enhanced mathematical understanding and attainment cannot be fostered by didactic teaching. Approaches which are interactive, challenging and cognitively productive need to become the everyday armoury of teachers of mathematics. To this end the NCETM should do everything they can to bring both this report and that of the JMC to the attention of all those involved in developing policies and, most importantly, in teaching mathematics.

Some of the appendices of this report provide ideas of equipment and software that should be made available to support the use of digital technologies by learners of mathematics. We hope that soon all mathematics classrooms will contain a wide variety of digital technologies for use by all, but recognise that where this is not possible all learners still have a right and an entitlement to make considerable use of digital technologies in mathematics.

References and bibliography

Ahmed A (1987) *Better Mathematics* HMSO: London.

Becta, 2008a. Harnessing Technology Review 2008: The role of technology and its impact on education, Coventry: Becta

Becta, 2008b, Secondary Mathematics with ICT: A pupil's entitlement at Key Stages 3 and 4, Coventry: Becta

Becta, 2008c. ICT Mark: A Guide for School Leaders, Coventry: Becta

Becta, 2009a. Harnessing Technology Review 2009: The role of technology in education and skills, Coventry: Becta

Becta, 2009b, Primary Mathematics with ICT: A pupil's entitlement in primary mathematics, Coventry: Becta

Becta, 2010. 21st century teacher: Are you ready to meet the challenge? Coventry: Becta

Dubin, P. 1962. Human Relations in Administration. Englewood Cliffs, NJ, Prentice Hall

Floyd, A., Burton, L., James, N., & Mason, J. (1981), EM235: Developing Mathematical Thinking. Milton Keynes: Open University.

Golden, S., McCrone, T., Walker, M. and Rudd, P. (2006), *Impact of e-learning in further education: Survey of scale and breadth*, DfES Research Report 745. London: DfES. Available at: http://www.dfes.gov.uk/research/data/uploadfiles/RR745.pdf (10 August 2010)

Hammond, M., Crosson, S., Fragkouli, E., Ingram, J., Johnston-Wilder, P., Johnston-Wilder, S., Kingston, Y., Pope, M. and Wray, D. 2009a Why do some student teachers make very good use of ICT? An exploratory case study, Technology, Pedagogy and Education, 18: 1, 59 — 73

Hammond, M., Fragkouli, E., Suandi, I., Crosson, S., Ingram, J., Johnston-Wilder, P., Johnston-Wilder, S., Kingston, Y., Pope, M. and Wray, D. 2009b What happens as student teachers who made very good use of ICT during pre-service training enter their first year of teaching?', Teacher Development, 13: 2, 93 — 106

Johnston-Wilder, S.J. and Lee, C. 2010 Leading Practice and Managing Change in the Mathematics Department, Tarquin, St Albans, UK

Keating, A., Gardiner, C. and Rudd, P., (2009) E-access, e-maturity, e-safety: a learner survey, Coventry

Miller, D., Glover, D. & Averis, D. 2008. Enabling enhanced mathematics teaching with interactive whiteboards: Final Report for the National Centre for Excellence in the Teaching of Mathematics, Keele: Keele University

Moor, H., Jones, M., Johnson, F., Martin, K., Cowell, E. & Bojke, C. 2006. Mathematics and Science in Secondary Schools: The Deployment of Teachers and Support Staff to Deliver the Curriculum. London. NFER

OfSTED. (2008) Mathematics: Understanding the score. HMSO

Pierce, R., Ball, L. (2009) Perceptions that may affect teachers' intention to use technology in secondary mathematics classes Educational Studies in Mathematics, 71, 299-317

Prestage, S. & Perks, P. (2001). Adapting and Extending Secondary Mathematics Activities: New Tasks for Old. London. David Fulton Publishers

Ruthven, K. (2008). The didactical challenge of technology integration in school mathematics. Proceedings of the 17th Annual Meeting of the Mathematics Education Section of the Portuguese Society for Educational Sciences [EIEM XVII]

Smith, P., Rudd, P. and Coghlan, M. 2008a. Harnessing Technology Schools Survey 2008: Report 1 – Analysis. Coventry: Becta.

Smith, P., Rudd, P. and Coghlan, M. 2008b. Harnessing Technology Schools Survey 2008: Report 2 – Data. Coventry: Becta.

Swan, M. 2006. Collaborative Learning in Mathematics: A Challenge to Our Beliefs and Practices. Leicester. National Institute of Adult Continuing Education

Williams, P. 2008. Independent Review of Mathematics Teaching in Early Years Settings and Primary Schools. London. DCSF

Appendix 1: Digital technologies and the primary mathematics teacher

This appendix is only concerned with the use of digital technologies as part of teaching and learning however it recognises that the primary mathematics teacher will use digital technologies for themselves as part of their professional practice for administration; monitoring, assessment and recording; planning; and teaching. In addition they will allow learners to make use of digital technologies on a frequent and regular basis knowing that digital technologies is an integral part of the mathematics curriculum for all learners. They will keep up-to-date with digital technologies developments by regular visits to the digital technologies microsite on the NCETM portal by using, for example, Really Simple Syndication (RSS) feeds and other Web 2.0 technologies.

It is recognised that primary teachers of mathematics will be at different points on the 'digital technologies spectrum' so this appendix offers an example of what ought to be possible for most primary teachers of mathematics – given time and professional development. Central to this is the ability and willingness of class teachers to make clear, well informed decisions about when to use and when not to use digital technologies, as well as what to use. This includes taking into account the needs of the children and the effectiveness of the teacher (Wild et al, 2005).

Digital technologies in the role of teaching

Data projectors and visualisers

Skills

Digital technologies will be used to enhance the presentation of mathematics to learners and provide access to appropriate resources from the Internet. The visualiser will be used to show examples of learners' work and other appropriate objects. The computer attached to the data projector will allow use by the teacher of mathematics and other relevant software.

Pedagogy

Use of an interactive pedagogy that may include exposition, extended discussion of learner's work, example and exercise-type lessons but will also include a variety of interactive lessons some of which have groups/classes of learners using digital technologies.

Interactive whiteboards

A minimum 'passport' of skills that exploit the IWB software to:

- support lesson management (i.e. knowing how to store electronic materials for lessons in a single file: including web links as well)
- build IWB pages from the resources available in the library/gallery that comes with the software
- create lesson content with templates using tools such as the camera, grids creator, recorder, tracing paper) and by importing text, graphics, magic boxes, magic windows, resources, animations, sounds, videos and virtual manipulatives
- develop resources that make use of the manipulations such as 'drag and drop' and 'hide and reveal' to help aid discussion
- give teachers confidence so that they might let learners use the IWB, for example, when working on a mathematical project in a lesson
- make 'recorded' materials using the IWB software recorder
- present mathematics in a colourful and interactive way using a range of subject-specific software to create appropriate starting points for learners (using e.g. geometry, graph and statistics programs)
- teach lessons using tools such as the general tools (drawing, writing, clock, shape and movement) and the mathematical tools (compass, protractor, ruler, dice and the transformation library)
- use Virtual Manipulatives from the Internet (such as geoboards, 3-D models, isometric paper, net-folding pages) in lessons

Pedagogy: At the board, on the desk, in the head

For more see: https://www.ncetm.org.uk/mathemapedia/BoardDeskHead

This is an interactive way of working with the IWB so that all lesson activities are integrated into an interactive (rather than a didactic or presentational) whole and orchestrated/facilitated using the IWB software as the means of storing and organising all the electronic resources for the lesson. The lesson consists of a cycle of learning opportunities, integrating the learning process so that activities might start from work on the IWB (i.e. at the board) or from a desk-based activity (on the desk) or from a concept, idea or learning objective (in the head). The essential feature is that these activities are carefully integrated into an interactive whole.

There is an assumption that

- the mathematics classroom is a collaborative classroom where learners regularly work in groups (not just pairs) and discuss their mathematical experiences
- lessons are interesting and motivational (more than just colourful) and involve learners in mathematical thought and discussion rather than consisting of exposition, example and exercise – it is not enough just to do well in examinations and tests
- the ‘at the board, in the head, at the desk’ activities are fully integrated
- all electronic resources and links are stored with the IWB software file
- questioning begins at Bloom's analysis level (using for example “What can you see?”) rather than at the knowledge level
- wherever possible work is targeted at Bloom’s higher levels
- activities at the board will often involve the use of ‘virtual manipulatives’ used in an exploratory way - a virtual manipulative is, for example, an onscreen version of a graphic calculator, geoboard, protractor, fraction wall (there are many of these available from the Internet)
- the use of the ‘virtual manipulative’ by the teacher does not replace the use of real manipulatives by learners, but complements their use
- teaching will involve a variety of approaches that will cater for all learning styles (although we do not necessarily accept theories about such learning styles we recognise that the IWB allows a variety of approaches including visual, oral and kinaesthetic)
- the IWB software allows for a variety of means of interaction (e.g. drag and drop, hide and reveal etc.) that can (and should) be used in innovative and imaginative ways
- linear presentations (as often seen in PowerPoints) are not the best way to prepare for such lessons as they constrain the teacher to demonstrate and display rather than use other means
- mathematics lessons are much more than exposition, example and exercise

Digital technologies and its use in primary mathematics teaching

Many schools now look at what happens to a learner during a school day. Here we consider how the teacher’s use of digital technologies should impact on learners. Digital technologies use should be related to the primary curriculum. There is an assumption within this that the teacher has developed an appropriate pedagogy so fully in line with this curriculum.

The primary mathematics teacher should be able to use digital technologies to:

- adapt the materials of others by using generic programs such as word processors, spreadsheets, IWB software, sound, video and drawing programs etc.
- allow learners to see appropriate software when working in both two and three dimensions helping with learners’ visualisation and understanding of all aspects of geometry
- build up resources for use on, for example, an IWB, so that topics can be taught efficiently and interactively
- create, collect and use mathematical photographs and videos by storing them in IWB files for efficient use in lessons
- demonstrate ideas and principles, working interactively with virtual manipulatives (applets)
- find and manipulate relevant data for use in lessons on data handling knowing where to find national and world data

- help teach topics, for example, fractions, area, time and temperature
- keep and maintain (or know where to find) a catalogue of resources, for example, that might be made available to learners and colleagues
- log simple data using appropriate data-logging equipment
- keep-up-date with, for example, Teachers.TV programmes so that the ideas from these can be used to help develop ITE students' teaching
- make short on-screen animations using, for example, the recorder features of IWB software
- prepare learners so that they might use mathematical and generic software to help them learn mathematics
- search the Internet to find items, structures, data or images that can be used as stimulus material for learners
- support learners use of calculators and IWB calculator 'kits' – and for some use of graphic calculators
- take learners outside to investigate contexts outside the classroom in which mathematical learning can take place, as well as collect evidence that can be used back in the classroom to help solve a particular problem or to create a mathematics trail for parents or other learners
- work with colleagues from other subject areas to develop relevant, timely and interesting projects that involve applications of digital technologies and mathematics
- write short computer programs, for example for movements of 'roamers' on the floor

Examples

Examples of all these things will be found on the digital technologies microsite on the NCETM portal.

Digital technologies in the hands of learners

Examples will found on the digital technologies microsite on the NCETM portal.

Appendix 2: Digital technologies and the secondary mathematics teacher

This appendix is only concerned with the use of digital technologies as part of teaching and learning however it recognises that the secondary mathematics teacher (in this interpretation we mean teachers of pupils of age 11 - 19) will use digital technologies for themselves as part of their professional practice for administration; monitoring, assessment and recording; planning; and teaching. In addition they will allow learners to make use of digital technologies on a frequent and regular basis knowing that digital technologies is an integral part of the mathematics curriculum for all learners. They will keep up-to-date with digital technologies developments by regular visits to the digital technologies microsite on the NCETM portal by using, for example, Really Simple Syndication (RSS) feeds and other Web 2.0 technologies.

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- develop resources that make use of the manipulations such as 'drag and drop' and 'hide and reveal' to help aid discussion
- give teachers confidence so that they might let learners use the IWB, for example, when working on a mathematical problem in a lesson
- make 'recorded' materials using the IWB software recorder
- present mathematics in a colourful and interactive way using a range of subject-specific software to create appropriate starting points for learners (using e.g. geometry, graph and statistics programs)
- teach lessons using tools such as the general tools (drawing, writing, clock, shape and movement) and the mathematical tools (compass, protractor, ruler, dice and the transformation library)
- use Virtual Manipulatives from the Internet (such as geoboards, 3-D models, isometric paper, net-folding pages) in lessons

Pedagogy: At the board, on the desk, in the head

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- the 'at the board, in the head, at the desk' activities are fully integrated
- all electronic resources and links are stored with the IWB software file
- questioning begins at Bloom's analysis level (using for example "What can you see?") rather than at the knowledge level
- wherever possible work is targeted at Bloom's higher levels
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- the IWB software allows for a variety of means of interaction (e.g. drag and drop, hide and reveal etc.) that can (and should) be used in innovative and imaginative ways
- linear presentations (as often seen in PowerPoints) are not the best way to prepare for such lessons as they constrain the teacher to demonstrate and display rather than use other means
- mathematics lessons are much more than exposition, example and exercise

A typical lesson will have learners interacting with the teacher, the IWB and with each other and would involve some of the similar features found in lessons that are typified by the approach of Swan (2005) and by the Improving Learning in Mathematics materials found at http://www.ncetm.org.uk/Default.aspx?page=13&module=res&mode=100&resid=1442.

IWB versions of these can be found by following the Improving Learning in Mathematics link at: http://www.iwbmathstraining.co.uk/.

Digital technologies and its use in secondary mathematics teaching

Many schools now look at what happens to a learner during a school day. Here we consider how the teacher's use of digital technologies should impact on learners. Digital technologies use should be related to the Key concepts, Key processes, Range and content and Curriculum opportunities of the Mathematics Curriculum: 2008. There is an assumption within this that the teacher has developed an appropriate pedagogy so fully in line with this curriculum.

The secondary mathematics teacher should be able to use digital technologies to:

- adapt the materials of others by using generic programs such as word processors, spreadsheets, IWB software, sound, video and drawing programs etc.
- allow learners to see geometry software when working in both two and three dimensions helping with learners' visualisation and understanding of all aspects of geometry

- build up resources for use on, for example, an IWB, so that topics can be taught efficiently and interactively
- create, collect and use mathematical photographs and videos by storing them in IWB files for efficient use in lessons
- demonstrate ideas and principles, working interactively with virtual manipulatives (applets)
- find and manipulate relevant data for use in lessons on statistics knowing where to find national and world data including, for example, population pyramids and local data
- help teach topics, for example, graphs, quadratics, calculus
- keep and maintain (or know where to find) a catalogue of resources, for example, that might be made available to learners and colleagues
- keep-up-date with, for example, Teachers.TV programmes so that the ideas from these can be used to help develop ITE students' teaching
- log data making use of data-loggers or equivalent that record movement, temperature, speed etc. in order to use the data for some appropriate purpose (learning of mathematics or solution of a problem)
- make short on-screen animations using, for example, the recorder features of IWB software, and show learners how to do this so that they might provide interest material for other (younger) learners or revision materials for peers
- plan for the use of the Bowland materials that require digital technologies use
- prepare learners so that they might use mathematical and generic software to help them learn mathematics
- search the Internet to find items, structures, data or images that can be used as stimulus material for learners
- support learners use of calculators making use of emulators (available for many graphic and scientific calculators) and IWB calculator 'kits'
- take learners outside to collect evidence that can be used back in the classroom to help solve a particular problem or to create a mathematics trail for parents or other learners
- work with colleagues from other subject areas to develop relevant, timely and interesting projects that involve applications of digital technologies and mathematics
- write short computer programs or applets

Examples

Examples of all these things will be found on the digital technologies microsite on the NCETM portal.

Digital technologies in the hands of learners

Examples will found on the Digital technologies microsite on the NCETM portal.

Appendix 3: The primary mathematics classroom

This list is adapted from the original list for the secondary mathematics classroom produced by the Keele University Interactive Whiteboard team is part of their NCETM research.

Essential equipment and features of the mathematics classroom

Every mathematics classroom is different and we all have our own ideas of essential kit but recognise that we may have to work to build up this kit. We know that teachers can use digital technologies effectively without the full set of “Essential” kit and so any lack of provision should not prevent any mathematics teacher from using digital technologies and having learners use digital technologies in lessons. However we provide this list to help make interactive digital technologies an everyday affair without undue anxiety or effort that is disproportionate to the outcomes.

It should also be noted that in a primary school some of these items might be available in the school for all learners but not be available in all classrooms.

It is surprising how many mathematics classrooms with an IWB in it have problems in relation to the first two bullet points below:

- at least one non-mobile interactive whiteboard (with a suitably bright data projector) arranged in a position so there is easy access to it (either side) with a suitably fast Internet connected computer/laptop (with speed to play DVDs properly), a quick simple printer and speakers, with appropriate blinds/curtains so that the display can be seen all day and all year
- software that can be easily added/updated on the IWB and all school computers
- subject-specific and generic software, including IWB software (for use on IWB, teacher’s and learners’ computers, including home use) – see Appendix 5
- all learners having their own calculator (e.g. bought for them and loaned to them, in year 4) – (a graphic calculator has the advantage that it has a screen that can show calculations)
- wireless laptop computers or netbooks for at least one between two with some technical support so that use of these is not difficult (that have been tried and tested with applications before purchase)
- classroom set of mini-whiteboards; and assorted practical equipment of a suitable size such as number cards, geoboards; multilink or cubes, (e.g. 1000); ATM mats; normal dice (e.g. 200); assorted other dice; pairs of compasses; protractors etc.
- paper to include tracing paper, variety of squared, dotted, isometric, 100 square, coloured, display, A3 and larger blank etc.
- access to local maps
- ‘historical’ items (modern versions) such as abaci, Napier's bones, old calculators
- subject association materials that you consider useful
- mathematical books, games, posters, for learners and staff to use
- practical equipment (e.g. assorted measuring devices etc.)
- at least one digital camera with a large memory card (e.g. 2GB which is very cheap)
- set of personal response systems (though these are, at present, expensive)
- intranet system so that learners might use lesson materials about the school or from home (with a simple means of arranging this e.g. through a virtual learning environment, VLE) - though the effective use of this will depend on the expertise or willingness to employ a technician to set this up and perform the necessary maintenance

Other items for some teachers

These are items that would seem to be things that might make mathematics lessons more interesting and allow for more creativity in the classroom. They perhaps should be essential features of a classroom but we have not completely assumed unlimited costs:

- a second IWB
- at least one video camera to create animations and videos, these are now very cheap
- data-loggers and equivalent

- digital cameras, classroom set for one between two (in the school) – though mobile phones can be used in this way
- voice recorders (to create podcasts) – in the school with an expert on how to use them
- web-camera or visualiser to show learners' work on the interactive whiteboard

Future developments

We are already aware of mathematics classrooms where these things are beginning to happen

- an interactive table
- animation and video creation
- augmented reality
- computer and other games available on hand-held technology
- e-readers or equivalent tablet devices
- mathematics Apps on 3G phones
- mobile phone use within mathematics lessons (most have a calculator, camera and many a sound recorder and video recorder)
- podcasts and software appropriate for teachers and learners to make them

Appendix 4: The secondary mathematics classroom

This list is adapted from the original list produced by the Keele University Interactive Whiteboard team as part of their NCETM research.

Essential equipment and features of the mathematics classroom

Every mathematics classroom is different and we all have our own ideas of essential kit but recognise that we may have to work to build up this kit. We know that teachers can use digital technologies effectively without the full set of "Essential" kit and so any lack of provision should not prevent any mathematics teacher from using digital technologies and having learners use digital technologies in lessons. However we provide this list to help make interactive digital technologies an everyday affair without undue anxiety or effort that is disproportionate to the outcomes.

It is surprising how many mathematics classrooms with an IWB in it have problems in relation to the first two bullet points below:

- at least one non-mobile interactive whiteboard (with a suitably bright data projector) arranged in a position so there is easy access to it (either side) with a suitably fast Internet connected computer/laptop (with speed to play DVDs properly), a quick simple printer and speakers, with appropriate blinds/curtains so that the display can be seen all day and all year
- software that can be easily added/updated on the IWB and all school computers
- subject-specific and generic software, including IWB software (for use on IWB, teacher's and learners' computers, including home use) – see Appendix 6
- all learners having their own graphic calculator (e.g. bought for them and loaned to them, in year 7) – one of the makes that can be used in external calculator papers
- wireless laptop computers or netbooks for at least one between two with some technical support so that use of these is not difficult (that have been tried and tested with applications before purchase
- classroom set of mini-whiteboards; and assorted practical equipment such as geoboards; reaction timers; multilink or cubes, (e.g. 1000); ATM mats; normal dice (e.g. 200); assorted other dice; pairs of compasses; protractors etc.
- paper to include tracing paper, variety of squared, dotted, isometric, 100 square, coloured, display, A3 and larger blank etc.
- access to local maps thorough your geography department (the Ordnance Survey has given sets of these to most schools)
- 'historical' items (modern versions) such as abaci, log tables, Napier's bones, old calculators, slide rules
- subject association materials that you consider useful
- mathematical books, games, posters, for learners and staff to use
- practical equipment (e.g. assorted measuring devices etc.)
- at least one digital camera with a large memory card (e.g. 2GB which is very cheap)
- set of personal response systems (though these are, at present, expensive)
- intranet system so that learners might use lesson materials about the school or from home (with a simple means of arranging this e.g. through a virtual learning environment, VLE)

Other items for some teachers

These are items that would seem to be things that might make mathematics lessons more interesting and allow for more creativity in the classroom. They perhaps should be essential features of a classroom but we have not completely assumed unlimited costs:

- a second IWB
- at least one video camera to create animations and videos, these are now very cheap
- data-loggers and equivalent, classroom sets, possibly shared with science colleagues
- digital cameras, classroom set for one between two (in the department) – though mobile phones can be used in this way
- voice recorders (to create podcasts) – set in the department with the expertise to use them
- web-camera or visualiser to show learners' work on the interactive whiteboard

Future developments

We are already aware of mathematics classrooms where these things are beginning to happen

- an interactive table
- animation and video creation
- augmented reality
- computer and other games available on hand-held technology
- e-readers or equivalent tablet devices
- mathematics Apps on 3G phones
- mobile phone use within mathematics lessons (most have a calculator, camera and many a sound recorder and video recorder)
- podcasts and software appropriate for teachers and learners to make them
- web2.0 applications such as Facebook and Twitter used systematically

Appendix 5: Essential software for primary teachers

In considering how the mathematics classroom functions we also put together our list of essential software, much of which is free (indicated by *), all of which can be found by an internet search.

This is based on a PC but most have equivalents available for a MAC.

- acrobat reader* to read pdf files
- adobe (or another) SVG viewer* to view population pyramids
- adventure game, simulation software to support problem solving, application in realistic contexts, such as for example Zoombini island mountain rescue
- animation creation software such as Scratch, though some IWB programs have their own such software
- data branching programme such as Decision tree
- data handling programmes leading to use of spreadsheets (these should be able to cater for the wide range of understanding found within the primary school from those just starting to develop an understanding of representation to those capable of using Excel; programs could include things like RM Starting graph, Number Magic – which has a customisable interface to load a suitable set of options depending on pupil understanding – Excel, Open Office)
- Flash*, java*, shockwave* that allow applets and internet-based programs to be used on the computer (free, but need to be installed and regularly up-dated)
- interactive teaching programs (ITPs), such as Data Handling, Measuring cylinder, Place value etc – (available at time of writing from the National Strategies website)
- interactive whiteboard software (free with interactive whiteboard)
- Internet browser (plus anti-virus, firewall, anti-spy-ware software)
- logo type programme (such as Super Logo, MSW Logo*, Microworlds, Roamer world or "Turtle" type programmes within a suite of applications such as Textease)
- media player such as Real player*, windows media player* to play video clips from Teachers.TV or YouTube
- photograph and music compilation software to create resources or stimuli for mathematical contexts, such as Movie Maker* as part of Windows
- robots that become precursors to using Logo type programmes (such as Roamers, Beebots, Probots and Pixies – sometimes these link naturally to computer based software as in the case of Roamers leading to Roamer world)
- sound and audio editor such as audacity*
- spreadsheet such as Excel, or Open Office*
- Teacher tube* access
- Teachers.TV access
- Testbase for assessment examples at key Stage 2
- video conversion software such as Dvdvideosoft downloader* to convert video into a format which can be useable
- virtual manipulatives (these are usually Flash programs and java applets that can be accessed from the internet, with the reference to the program or applet stored in the IWB file)
- word processor such as Word or Open Office*
- YouTube* access (along with a YouTube downloader such as Dvdvideosoft downloader* to enable content to be used creatively) – you will need to check out copyright law here

Note that video retrieval websites such as Teacher tube and YouTube are not allowed routinely in many schools, however we are aware that a number of schools allow (some) staff access to these websites so that they can use worthwhile material (though it is possible to download relevant files and play them through a media player).

It is also possible that some mathematics departments might want learners to make use of programming software such as Flash (which is not free if you want to have learners use it), Logo (there are a variety of variations some of which are free) and others – one of the research team had learners using Flash in this way.

Appendix 6: Essential software for secondary teachers of mathematics

In considering how the mathematics classroom functions we also put together our list of essential software, much of which is free (indicated by *), all of which can be found by an internet search.

This is based on a PC but most have equivalents available for a MAC.

- acrobat reader* to read pdf files
- adobe (or another) SVG viewer* to view population pyramids
- animation creation software such as Scratch, though some IWB programs have their own such software
- Bowland mathematics materials (from DVD or Internet, but latter will take much longer to install)
- data logging software
- digital image manipulator such as picasa*
- drawing program for mathematical diagrams, equation-editor for writing equations in a word processor such as FX-maths pack
- EXP Maths 7, 8 and 9 (short programs that cover most of KS3 material)
- Flash*, java*, shockwave* that allow applets and internet-based programs to be used on the computer (free, but need to be installed and regularly up-dated)
- Formulator Tarsia* to create and use your own 'jigsaws'
- geometry program such as Geometer's SketchPad, Cabri-Géomètre or Geogebra*
- Google earth*
- graph drawing package such as Omnigraph, Autograph, Geogebra*
- graphic calculator emulator to match graphic calculators in use
- interactive whiteboard software (free with interactive whiteboard)
- Internet browser (plus anti-virus, firewall, anti-spy-ware software)
- Mathematica player* to run Wolfram demonstration project files
- media player such as Real player*, windows media player* to play video clips from Teachers.TV or YouTube
- photograph and music compilation software to create resources or stimuli for mathematical contexts, such as Movie Maker* as part of Windows
- sound and audio editor such as audacity*
- spreadsheet such as Excel, Geogebra* (available 2009) or Open Office*
- statistics software such as Autograph, Fathom, Tinkerplots
- Testbase equivalent for GCSE and A level assessment
- Teacher tube* access
- Teachers.TV access
- video conversion software such as Dvdvideosoft downloader* to convert video into a format which can be useable
- virtual manipulatives (these are usually Flash programs and java applets that can be accessed from the internet, with the reference to the program or applet stored in the IWB file)
- word processor such as Word or Open Office*
- YouTube* access

Note that video retrieval websites such as Teacher tube and YouTube are not allowed routinely in many schools, however we are aware that a number of schools allow (some) staff access to these websites so that they can use worthwhile material (though it is possible to download relevant files and play them through a media player).

It is also possible that some mathematics departments might want learners to make use of programming software such as Flash (which is not free if you want to have learners use it), Logo (there are a variety of variations some of which are free) and others – one of the research team had learners using Flash in this way.

Appendix 7: Sources used in the literature survey

Allen, K. (2009) *Learning Objects* Futurelab Learning_Objects_discpaper.pdf

Al-Senaidi, S, Lin, L., Poirot, J. (2009) Barriers to adopting technology for teaching and learning in Oman. *Computers in Education* 53 (575-590

Andersson, S.B. (2006) Newly qualified teachers' learning related to their use of information and communication technology: a Swedish perspective. *British Journal of educational technology* 37 (5) 665-682

Balanksat, A., Blamire, R., Kefala, S. *(2006) A review of studies of ICT impact on schools in Europe European* Schoolnet

Barton, R., Haydn, T. (2007) Trainee teachers' views on what helps them to use information and communication technology effectively in their subject teaching. *Journal of Computer Assisted Learning* 24 (2) 128-143

Becta (2003). Handheld computers: PDAS

Becta (2004) *Using ICT to share tools of the teaching trade: Open source teaching* Coventry, Becta

Becta (2005) *Evidence on the progress of ICT in education* Coventry, Becta

Becta (2006) *Evidence on the progress of ICT in education* Coventry, Becta

Becta (2007) *Harnessing Technology Review 2007: Progress and impact of technology in education* Coventry, Becta

Becta (2008) *Harnessing Technology review 2008: The role of technology and its impact on education* Coventry, Becta

Becta (2009a) *Enabling next generation learning: enhancing learning through technology* Coventry, Becta

Becta (2009b) *Secondary Mathematics with ICT: A pupil's entitlement to ICT in*

secondary mathematics. Coventry: Becta.

Bell M.A. (2002) Why use an interactive whiteboard? A baker's dozen reasons!: Available at: http://teachers.net/gazette/JAN02

Bingimlas, K., (2009) Barriers to the Successful Integration of ICT in Teaching and Learning Environments: A Review of the Literature. *Eurasia Journal of Maths, Technology and Science Education* 3 (5) 235-245

Burden, K., Keuchel, T. (2004) *Evaluation report of the Teaching and Learning with Digital Video Assets Pilot 2003-4* Coventry, Becta

Butt S., Cebulla, A. (2006) *E-maturity and school performance* Coventry, Becta

Clark-Wilson, A. (2010) Developing ICT for teaching and learning in the mathematics classroom: Learning from the past... and moving forwards...

NAMA 36 Presentation March 2010

Cline, K. (2006). Classroom voting in mathematics. *Mathematics Teacher* 100 (2) 100-104

Condie, R., Munro, B., Muir, D., Collins, R. (2005) *The Impact of ICT initiatives in Scottish Schools* Edinburgh, SEED

Condie, R., Munro, B. (2006) *The Impact of ICT in Schools – a landscape review.* Coventry, Becta

Condie, R., Munro, B. (2007) *The Impact of ICT in Schools – a landscape review* Coventry, Becta

Conole, G., Dyke, M(2004). What are the affordances of information and communication technologies? *Research in Learning Technology* 12 (2) 113-124

Cox, M.J. (1999) Motivating pupils through the use of ICT. in Leask, M. & Pachler, N. (Eds.) *Learning to Teach using ICT in the Secondary School*. London: Routledge

Cox, M., Abbott, C., Webb, M (2003) *ICT and Pedagogy: A review of the research literature* Coventry/ London, Becta / DfES

Crisan, C. , Lerman, S.,Winbourne, P. (2007) 'Mathematics and ICT: a framework for conceptualising secondary school mathematics teachers' classroom practices', Technology, Pedagogy and Education, 16:1, 21 — 39

Cunningham, M., Harris, S., Kerr, K. McEune, R. (2003). *New Technologies Supporting Teaching and Learning* (LGA Research Report 49). Slough: NFER

Davis, F. D. (1986). A technology acceptance model for empirically testing new end-user information systems: Theory and results. (*Doctoral dissertation*, Sloan School of Management, Massachusetts Institute of Technology). Retrieved 22 March 2010 from http://dspace.mit.edu/handle/1721.1/15192

Davies, C., Hayward, G., Lukman, L. (2005) *14-19 Digital Technologies: A review of research and projects* NESTA Futurelab

Dawes, L (1999) First connections: teachers and the National Grid for Learning. *Computers and Education* 33 235-52

Edwards, J. A., Wright, D. (Eds.). (2005). *Integrating ICT into the mathematics curriculum: 21 years of Micromath*. Derby: Association of Teachers of Mathematics

Ertmer, P.E.A. (1999)). Examining teachers' beliefs about the role of technology in the elementary classroom. *Journal of Research on Computing in Education* 32 (1) 54-72

Fisher, T., Higgins, C., Loveless, A. (2006) *Teachers Learning with Digital Technologies: A review of research and projects* Bristol; Futurelab

Galanouli, D., Murphy, C., Gardner, J. (2004) Teachers perceptions of the effectiveness of ICT-competence training. *Computers and Education* 43 63-79

Glover, D., Miller, D., Averis, D., Door, V. (2005) The interactive whiteboard: a literature survey. *Technology, Pedagogy and Education* 14 (2) 155-170

Gobbo, C., Girardi M., (2001) Teachers' beliefs and integration of information and communications technology in Italian schools. *Technology, Pedagogy and Education*, Vol. 10 Issues 1 and 2.

Goulding, M., Kyriacou, C. (2008) *A Systematic Review of the Use of ICTs in Developing Pupils' Understanding of Algebraic Ideas*. In: Research Evidence in Education Library. London: EPPI-Centre,

Social Science Research Unit, Institute of Education

Grandgenett, N., Grandgenett, D., Topp, N, Fluckiger, J., Ostler, E., Mortenson, R. (1997) Integrating technology into teaching and learning: the three keys to the kingdom. *Innovations in Education and Training International* 34 (4) 252-256

Harrison, C., Comber, C., Fisher, T., Hawe, K., Scrimshaw, P., Somekh, B., Watling, R.(2002) *The Impact of ICT on Pupils' Learning and Attainment* Coventry / London; Becta / DfES

Haslam, J. (2009) Putting evidence into practice. *Better* 2 (1) 18-19

Hooper, S., Rieber, L. P. (1995). Teaching with technology. In A. Ornstein (Ed.), *Teaching: Theory into practices*. Boston: Allyn and Bacon

Hoyles C., Noss, R (2009) The Technological Mediation of Mathematics and Its Learning In Nunes, T (ed) Special Issue, 'Giving Meaning to Mathematical Signs: Psychological, Pedagogical and Cultural Processes' *Human Development*, Vol 52, No 2, April, pp. 129-147

Hwang, W.-Y., Su, J.-H., Huang, Y.-M., & Dong, J.-J. (2009). A Study of Multi-Representation of Geometry Problem Solving with Virtual Manipulatives and Whiteboard System. *Educational Technology & Society*, *12* (3), 229–247.

Hyde, R. (2004) What do mathematics teachers say about the impact of *ICT* on pupils learning mathematics***?***. *Micro Math*, Summer2004 20 (2) 11-13

d'Inverno, R., Davis, H., White, S. (2003). Using a personal response system for promoting student interaction. *Teaching Mathematics and Its Applications*, 22(4), 163-169.

Johnston-Wilder, **S.,** Lee C, (2010) *Leading Practice and Managing Change in the Mathematics Department* Editors: Johnston-Wilder, S. Lee, C., St Albans: Tarquin Publications

Kastberg, S., Leatham, K. (2005). Research on graphing calculators at the secondary level: Implications for mathematics teacher education. *Contemporary Issues in Technology and Teacher Education* [Online serial], *5*(1). Available: http://www.citejournal.org/vol5/iss1/mathematics/article1.cfm

Kennewell S., Tanner H., Jones, S., Beauchamp, G. (2008) Analysing the use of interactive technology to implement interactive teaching. *Journal of Computer Assisted Learning* 24 61-73

King, S. O., Robinson, C. L. (2009). "Pretty Lights" and maths! Increasing student engagement and enhancing learning through the use of electronic voting systems. *Computers & Education* 53 189-199.

Kirkland, K., Sutch, D. (2009) *Overcoming the barriers to educational innovation: a literature review* Bristol: Futurelab

Kyriacou, C. (2009) The development of pupils' skills *Better* 2 (1) 8-9 York: York University

Law, N. (2009) Mathematics and science teachers' pedagogical orientations and their use of ICT in teaching, *Educational Information Technology* 14:309–323

Lee, J., Ng Lai Hong., Ng Lai Ling. (2002) An analysis of students' preparation for the virtual learning environment *Internet and Higher Education* 4 232-242

Littlejohn, A., Campbell, L. M., Tizard, J., Smith, A. (2003) From Pilot Project to Strategic Development: scaling up staff support in the use of ICT for teaching and learning. *Journal of Further and Higher Education* 27 (1) 47-52

Lopez, O. (2006) Lighting the Flame of Learning for English Language Learners paper Su-2006-01

N. Carolina, North Central Regional Educational Laboratory

Marzano , R.J., (2009) Teaching with interactive whiteboards *Educational Leadership* 20: 80-82

Mayer R.E. (2003) The promise of multimedia learning: using the same instructional design methods across different media. *Learning and Instruction* 13 125–139

Miller, D.J., Glover, D. (2006). Interactive whiteboard evaluation for the secondary national strategy: Developing the use of interactive whiteboards in mathematics, Final Report for the Secondary National Strategy. Available at:

http://www.standards.dfes.gov.uk/keystage3/downloads/ma_iaw_eval_rpt.pdf

Miller, D.J., Glover, D., Averis, D. (2008). Enabling enhanced mathematics teaching: Final Report for the National Centre for Excellence in the Teaching of Mathematics. Retrieved March 22, 2009, from http://www.keele.ac.uk/media/keeleuniversity/fachumsocsci/sclpppp/education/interactivewhiteboard/ncetmreport-1.pdf

Miller D. (2010) Using ICT to enhance professional practice in *Leading Practice and Managing Change in the Mathematics Department* Editors: Johnston-Wilder, S. Lee, C., St Albans: Tarquin Publications

Mumtaz, S. (2000) Factors affecting teachers' use of ICT: a review of the literature *Journal of Information Technology for Teacher Education* 9 319- 341

Murphy, C., Greenwood, L. (1998) Effective integration of ICT in teacher education *Technology, Pedagogy and Education* 7 (3) 413-429

Naismith, L., Lonsdale, P., Vavoula, G., Sharples, M.(2005) *Literature Review in Mobile Technologies and Learning* Bristol; Futurelab

Norton, S., McRobbie, C.J., Cooper, T. (2000) Exploring secondary mathematics teachers' reasons for not using computers in their teaching: five case studies. *Journal of Research on Computing in Education* 33 (1) 87-110

OfSTED (2005) Embedding ICT in Schools – a dual evaluation exercise

Passey, D., Rogers, C., Machell, J., McHugh, G. (2004) *The Motivational Effect of ICT on Pupils* DfES Research Series RR523, London, DfES

Pierce, R., Ball, L. (2009) Perceptions that may affect teachers' intention to use technology in secondary mathematics classes *Educational Studies in Mathematics* 71: 299-317

Piggott , J. (2006). *An investigation into the nature of mathematical enrichment: a case study of implementation*. Thesis submitted for Doctor in Education, Institute of Education, University of London.

Preston, C., Cox, M. , Cox, K. (1999). *Teachers as Innovators: An evaluation of the Motivation of Teachers to use Information and Communications Technologies*. South Croydon: MirandaNet.

Presinger. T. (2009) *Graph Based Algorithms for Pareto Preference Query Evaluation* Norderstet, Germany: Herstellung und Verlag

Quashie, V. (2009) How interactive is the interactive whiteboard? Mathematics Teaching 214; 33-38

Rodd, M., Monaghan, J. (2002). Graphic calculator use in Leeds schools: Fragments of practice. Journal of Information Technology for Teacher Education 11 (1) 93-108

Roschelle, J., Rafanan, K., Bhanot, R., Estrella, G., Penuel, b., Nussbaum, M., Claro, S. ((2010) Scaffolding group explanation and feedback with handheld technology: impact on students' mathematics learning, *Education Tech Research Dev,* 58: 399-419

Ruthven, K. (2002) 'Instrumenting mathematical activity: Reflections on key

studies of the educational use of computer algebra systems'. *International*

Journal of Computers for Mathematical Learning 7 (3) 275-291

Ruthven, K., Hennessey, S. (2003) Successful ICT use in secondary mathematics--a teacher perspective. *Micro Math* 19 (92) 20

Ruthven, K. (2008) Towards a naturalistic conceptualisation of technology integration in classroom practice: the example of school mathematics *Education & Didactique* 2 (3) 1-15

Ruthven, K., Deaney, R., Hennessey, S. (2009) Using graphing software to teach about algebraic forms: a study of technology supported practice in secondary school mathematics. *Educational Studies in Mathematics* 71 (3) 279-293

Shulman, L.S., Shulman, J.H. (2004). How and what teachers learn: a shifting perspective. *Journal of Curriculum Studies* 36 (2) 257-271

Simpson, M., Payne, F., Munro, R., Lynch, E. (1998) Using Information and Communications

Technology as a Pedagogical Tool: a survey of initial teacher education in Scotland. *Journal of Information Technology for Teacher Education* 7 (3) 431-446

Smarkola, C. (2007). Technology acceptance predictors among student teachers and experienced classroom teachers. *Journal of Educational Computing Research* 37 (1) 65-82

Smith, H.J., Higgins, S., Wall, K., Miller, J. (2005) Interactive whiteboards: boon or bandwagon, a critical review of the literature. *Journal of Computer Assisted Learning* 91–101

Smith, P., Rudd, P., Coghlan, M. (NFER) (2008), *Harnessing Technology: Schools Survey 2008 Report 1: Analysis*, Coventry, Becta. www.becta.org.uk/research/reports/htschools2008

Somekh, B., (2004) Taking the sociological imagination to school: an analysis of the (lack of) impact of ICT on education systems *Technology, Pedagogy and Education* 13 (2) 163-179

Sutherland, R., Armstrong, V., Barnes, S., Brawn, R., Breeze, N., Gall, M., Matthewman, S., Olivero, F., Taylor, A., Triggs, P., Wishart, J., John, P. (2004) Transforming teaching and learning: embedding ICT into everyday classroom practices. *Journal of Computer Assisted Learning* 20 (6) 413

Tanner, R. (2009) Hard to teach topics : using ICT Part 1 *Mathematics Teaching*, May2009 (214) 30-32

Teo, T., Lee, C.B., Chai. C.S. (2007) Understanding pre-service teachers' computer attitudes: applying and extending the technology acceptance model. *Journal of Computer Assisted Learning* 24 (2) 128-143

Timotheus, J. From mathematics to mathematics with ICT, *Mathematics Teaching* 212: 4-6

Tolley, R.J. Report Completed July 2008, "The current state of affairs with regard to virtual and managed learning environments in UK schools" presented to Becta

Virtual Learning (2003c) How do interactive whiteboards enhance learning? Available at: http://www.virtuallear ning.org.uk/whiteboards/Learning_theories.pdf.

Walker-Tileston D. (2004) What every teacher should know about media and technology. Corwin Press, Thousand Oaks, CA

Appendix 8: Digital technologies – a skills list

This skill list has been structured so that it could form a convenient home against which digital technologies activities could be referenced. Potential trainers could also be asked to reference their own competences against these zones.

Zone 1: Classroom hardware

It is not commonly realised that mathematics teachers need to have their digital technologies equipment to be set up in an appropriate manner. This list is provided so that mathematics teachers understand about the best way to set up the mathematics environment and to provide technical support staff with appropriate information.

a. Connecting desktop and/or laptop to a projector and interactive whiteboard.

b. Projector controls: use of 'blank' and 'freeze'; setting the contrast correctly (default setting invariably loses graph grid lines); adequate speaker system.

c. The vital importance of getting aspect ratio right (circles and ellipses!); problems associated with mixed systems (4:3, 16:9, 16:10), and checking that the graphics card can cope.

d. Screen resolution: lower the better to achieve a clear image for the pupils in the back row. Need to know about the wide-screen equivalents of 800x600.

e. Use of a tablet PC (with associated wireless projector link, and bandwidth problems).

f. Use of wireless graphics tablet. These devises generally connect seamlessly to laptops, but need a Bluetooth dongle for a desktop connection.

g. Classroom lighting: control of lights vis-à-vis the whiteboard; control of sunlight.

h. Lo-tech classroom requirements: plastic ruler and protractor (though not to be used with a Smartboard); mini white-boards, etc.

i. The provision of a lectern so that keyboard and mouse can be used standing up (especially important if there is not an interactive whiteboard.

j. PC-Mac issues (for some).

Mathematics staff involved in IWB purchase would need to consider:

k. Installation and usage issues.

l. Pen or finger, how the software varies on the different IWBs and pros and cons of the different makes; conversion between different file types; future proofing and peripherals available.

Zone 2: Interactive whiteboards

A large proportion of mathematics classrooms in England have been equipped with IWBs, some pen-based, some finger-based, and more recently some are a bit of both! It is important that this investment is not wasted, and that the teachers know how to put this equipment to good use.

a. At the board, on the desk, in the head: maximising the effective use of the IWB for mathematics teaching (see also Key point 1).

b. IWB software as the management tool for all electronic resources in a lesson.

c. Full consideration should be given to the pedagogy of the IWB.

d. Converting from one IWB software type to another (when this is possible and when it is not possible) – essential to know what is possible when staff start at a school or move from one school to another (i.e. portability of resources across different makes of IWB).

e. Using the IWB software tools specific to the board including: mathematical tools e.g. (compass, protractor ruler); grid creation; camera; hyperlinks; video recorder etc.

f. Use of virtual manipulatives, Teachers' TV, and other resources within IWB files.

g. Creation of animations (i.e. video resources) using IWB software.

h. IWB software for mathematics - ActivStudio, ActivInspire; Smart Notebook, other makes.

i. Learner response systems and the variety of uses – games; revision; AfL; text responses.

Zone 3: Strategies for lessons on laptops and netbooks, and lessons in the computer room

It is highly desirable that students get to experience the power of digital technologies for themselves, and increasingly they will be able to do so at home. At school, the choice of hardware is changing fast, but for now is still likely to be classroom laptops or a room of desktops. The teaching strategies for these different situations need careful planning.

a. A changed pedagogical practice and the dynamics of the classroom.

b. Planning and problems of implementation. The 'culture' of the computer room (see earlier).

c. Alternative technologies: smart phones and e-readers, smart 'pad' and e-readers.

d. Issues with the widespread use of wireless internet connection; contention ratio problems.

Zone 4: Word-processing for mathematics

Teachers need to be able to produce high quality worksheets, on paper and on screen. As well as general word processing skills, teachers need to create high quality mathematical diagrams and mathematical expressions. Pupils also need to know how to create reports on mathematical activities.

There are now many word-processing options now, falling into two categories:

a. traditional word processors (e.g. MS Office, Open Office). MS Office is still evolving and there are significant interface differences between versions. Office 2003 has toolbars and menus, whereas Office 2007 (and now Office 2010) has threads and ribbons.

b. in the 'clouds' (e.g. Google Docs) – where documents can be easily shared and co-authored online, but some features are lost.

The following techniques need to be mastered for any system in use:

c. How to create one-line mathematical expressions as text, without using an equation editor. These make use of the large number of font independent Unicode symbols that are available. Either use "Insert Symbol" or use the Autograph on-screen keyboard.

   e.g. $y = |x| \pm \sqrt{(4 - x^2)}$

d. How to create multi-layered mathematics expressions. These are created as a graphic object (i.e. not text). An 'Equation Editor' can be used for this, or many WP systems have a sophisticated equation tool; there are alternatives such as FX-maths pack, and MathType.

e. Creating mathematical diagrams; use of shift (to make figures regular); Ctrl (centres figures); Ctrl-D (duplicates in a controlled way). FX-maths pack for mathematical diagrams.

f. Creating hyperlinks to other files and URLs.

g. Pasting images from the web.

h. Knowing how to use the right-click and what it does.

i. Creation of portable, document files (pdf) – smaller, 'portable', loss of edit facility

j. Putting mail-merge to use to create multiple documents based on spreadsheet data.

Zone 5: Spreadsheets for mathematics

Although designed for use in commerce, spreadsheets can be used in a wide variety of ways to support mathematics teachers. They can be as useful in teaching situations, where mathematical concepts can be modelled, as in day-to-day administration. They can be used to mathematical models. They can also be used to create 'self-marking' random exercises.

a. Managing cells, formulae, series, charts; statistical operations (including filters, pivot tables, frequency counts, histograms and tables).

b. Making a spreadsheet interactive with slider bars, conditional statements and self-checking methods.

c. Knowing when Excel goes wrong, or does not quite get it right!

d. Handling large datasets; selecting (and hiding) columns of data.

e. Converting data pasted from websites when necessary using “Text to Columns”.

f. Sorting data; filtering data.

g. Creating and using comma, separated variable (csv) files.

Zone 6: Internet resources and related issues

The availability of a fast internet connection in the classroom is becoming something most teachers in this country are fortunate to expect. This ability to ‘bring the world into the classroom’ can leave many teachers overwhelmed by the quantity and the very variable quality of what can be accessed.

a. Awareness of web resources, from NCETM portal and other mathematics sites.

b. Java and Flash applets (virtual manipulatives), and how to embed in other digital resources.

c. Ability to retrieve data (into Excel) and images (into Paint or Autograph) and everything (into IWB software) from websites.

d. Using Teachers’ TV, YouTube, etc.; converting to FLV or other formats for showing offline.

e. Software to create and edit podcasts, videos and animations.

f. Use of video resources (e.g. ‘Jing’ for on-screen recording, or files from digital cameras).

g. Understanding the vulnerability and reliability of information on the web, e.g. Wikis.

h. Email lists; forums; social networks.

i. Virtual Learning Environments: contributing material and accessing resources.

j. Creative use of games and smart phone apps.

k. Ensuring that sites with mathematical input (e.g. NRICH, Mathletics) are used creatively.

Zone 7: Specialist software

There will be a need for specialist software trainers to train the trainers in the effective use of primary software. Some of the secondary packages have junior versions (e.g. Cabri).

There will also be a need for specialist trainers in these secondary software packages:

a. Computer Algebra Systems (CAS): TI-Nspire.

b. Geometry packages: 2D like Geometer’s Sketchpad; Cabri II; Geogebra. 3D like Cabri 3.

c. Dynamic Coordinate Geometry: 2D and 3D Autograph.

d. Statistics: Autograph; Excel; Tinkerplots; Fathom.

e. Graphic calculators: Casio and Texas (i.e. non-CAS) require expertise to use well.

f. Programming languages: Scratch; Logo.

Trainers need to be aware of the basic principles of ensuring that dynamic software is used effectively:

g. The judicial use of parameters.

h. The use of student prediction before the computer does anything.

i. Awareness that learners do not have a lifetime of ‘traditional’ mathematical study on which to ‘prop’ visual images. A visualisation that excites a teacher may well not excite a learner.