Exploring the Quantitative and Qualitative Gap Between Expectation and Implementation: A Survey of English Mathematics Teachers' Uses of ICT

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Abstract This chapter reports the results of a survey of English secondary school mathematics teachers' technology use ($n=188$). Set within the context of a broader study aiming to develop a deeper understanding of how and why mathematics teachers use technology in their classroom practice, the survey findings are used to explore the widely perceived quantitative gap and qualitative gap between the reality of teachers' use of ICT and the potential for ICT suggested by research and policy. Teachers were asked about their access to hardware and software; their perception of the impact of hardware on students' learning; the frequency of their use of ICT resources; their pedagogic practices in relation to ICT; and school and individual-level factors which may influence their use of ICT. This survey suggests that given the right conditions, at least those currently existing in England, ICT might contribute as a lever for change; however, the direction of this change might be construed as an incremental shift towards more teacher-centred practices rather than encouraging more student-centred practices.

Keywords Technology integration • Mathematics education • Teachers' ICT practices • Hardware and software use

Introduction

This chapter reports the findings of a survey of English mathematics teachers' use of Information and Communication Technologies (ICT) in secondary schools. The survey forms part of a broader research study aiming to develop a deeper understanding of how and why mathematics teachers use technology in their classroom practice.

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Lagrange and Erdogan (2008) record both a quantitative and a qualitative gap between institutional expectations and teachers' use of digital technologies in classroom practice. The apparent gulf between institutional expectations and classroom reality is particularly significant in the context of unprecedented spending by governments around the world on initiatives to develop educational technology (Selwyn 2000), the emphasis placed on using ICT in the UK National Curriculum for mathematics and the inclusion of technology in mathematics curricula more globally (Wong 2003).

The survey findings are used to explore the widely perceived quantitative gap and more subtle qualitative gap between the reality of teachers' use of ICT in the classroom compared with the legacy of the UK Labour government's vision (1997–2010) and the potential of ICT use highlighted by educational research. Teachers were asked about their access to hardware and software; their perception of the impact of hardware on students' learning; the frequency of their use of ICT resources; their pedagogic practices in relation to ICT; and school and individual-level factors which may influence their use of ICT. Previous surveys have tended to be confused by a lack of differentiation between hardware and software use. In contrast, this survey aims to provide insight into the types of software mathematics teachers choose to use in conjunction with particular types of hardware. More specifically, questions were posed separately regarding teachers' use of software with interactive whiteboards (IWBs) or data projectors in a whole class context and teachers' use of software in the context of a computer suite or using laptops, where students work individually, in pairs or in small groups. In addition, the reasons underlying the gap between expectations and classroom implementation are probed using the data collected in relation to school and individual-level factors.

The Quantitative and Qualitative Gap in Mathematics Teachers' ICT Use

The evidence for a quantitative gap seems fairly unequivocal. The TIMSS 2007 study (Mullis et al. 2008) reports that it was rare for computers to be used for any activity as often as in half the mathematics lessons, even in countries with relatively high availability. In the UK, the ImpaCT2 report (2003) stated that 67 % of pupils at Key Stage 3 never or hardly ever used ICT in their mathematics lessons. In addition, Ofsted (2008) reported that opportunities for pupils to use ICT to solve or explore mathematical problems had markedly decreased, despite the previous years of unprecedented investment by the then Labour government, directing over £5 billion of funding towards educational ICT during the 1997–2007 period (Selwyn 2008). On the other hand, Moss et al.'s (2007) survey on the introduction of IWBs in London schools reports that many teachers are using IWBs in most or every lesson, especially in mathematics and science, and that mathematics teachers made the most use of externally produced subject-specific software.

Citing Ruthven and Hennessy's (2002) study of mathematics teachers in England as evidence, Lagrange and Erdogan (2008, p. 66) define a qualitative gap between the expectation and implementation of ICT as the tendency of teachers to view the benefits of technology in terms of enabling "general 'pedagogical' aspirations rather than for its 'didactical' contribution to mathematics learning". That is, mathematics teachers articulated the benefits of technology as indirectly enhancing students' learning through increased *pace and productivity* and improved engagement (Ruthven and Hennessy 2002) rather than providing a direct means of enhancing mathematics pedagogy. Evidence for a qualitative gap may also be inferred from survey reports of mathematics teachers' typical software use. For example in the US, Becker, Ravitz and Wong (1999) found that drill and practice software was most often used by mathematics teachers. Although this inference is problematic, the use of presentation-oriented software might suggest an additional obstacle to more student-centred practices. Despite this, *The Geometer's Sketchpad* (Key Curriculum Press 2003) was the most favoured mathematical software amongst teachers in Becker et al.'s (1999) study. However, as will be discussed in the paragraph below, surveys tend to give an overview of technology use and are not detailed enough to provide a picture of the different types of software teachers use in conjunction with particular types of hardware. Investigating the choices teachers make about the software and hardware they use in their classrooms is therefore important in order to understand the apparent failure of ICT to make an impression on school mathematics.

Mathematics Teachers' Choices: Hardware and Software

The type of hardware and its deployment appears to be an important factor in structuring teachers' choices about technology use in their classroom practice. In particular, the hardware available affects the types of classroom organisation possible and the nature of pupil interactions with any software used in conjunction with the hardware. It seems reasonable then that the available hardware might also affect teachers' choice of software and how they choose to integrate the use of such software into their classroom practice. For example, investigating teachers' use of technology in the US, Becker et al. (1999) found that teachers with computers in their classrooms were three times more likely to use them compared to teachers who have access to larger numbers of computers but only available in shared computer rooms. One of five key factors in structuring teachers' classroom practice that Ruthven (2009) describes is the *working environment*, which is the physical location and layout of the classroom, the classroom organisation and procedures of a lesson. Indeed, the reported popularity of IWBs amongst teachers in the UK appears due to their ease of use in a whole class context, making this hardware seem a more teacher-oriented form of technology (Moss et al. 2007).

Currently, little is known about what types of software teachers choose to use in conjunction with particular types of hardware (Clark-Wilson 2008). International comparisons of educational technology use such as the TIMSS (Mullis et al. 2008), PISA (OECD 2005) or SITES (Law et al. 2008) surveys can only give a broad overview of technology use and are not fine-grained enough to consider usage of different types of software or hardware at the school level. In terms of hardware, the UK represents a special case since it became the first school-level system to invest heavily in IWBs (Moss et al. 2007). However, large-scale surveys of technology use within the UK tend not to report in detail on technology use within subject areas, such as mathematics, nor to differentiate sufficiently between hardware and software use. Thus whilst large-scale surveys can provide a broad picture of technology use, they cannot provide much insight into the nature of the specific uses by teachers in general or by mathematics teachers in particular. For example, the annual Becta schools survey *Harnessing Technology* reported that 53 % of mathematics teachers use subject-specific software in half or more lessons (Kitchen et al. 2007). However, no further detail is given on what type of subject-specific software is used, nor any indication of the hardware involved. Surveys focusing on mathematics teachers' use of technology, such as the survey conducted by the Fischer Family Trust (2003) or Hyde's (2004) small-scale survey, give a more detailed picture of the types of software used by mathematics teachers; however, this picture is again confused by the lack of distinction between hardware and software use. Similarly, Forgasz's (2002) survey of mathematics teachers' use of technology in Victoria, Australia, gives a detailed picture of the types of software used by mathematics teachers with computers. However, it is not clear whether other types of hardware were available or used by teachers, nor how frequently specific software was used. Miller and Glover's (2006) study of UK mathematics teachers' use of IWBs reports that fewer than 5 % of lessons observed used 'Other ICT' such as geometry packages, spreadsheet or graphing programs; however, they note their lack of use may simply be a consequence of the topics being taught at the time of observation.

The survey reported in this chapter builds on previous surveys by providing an insight into the types of software mathematics teachers choose to use in conjunction with particular types of hardware. In particular, teachers were asked to report their frequency of use of a list of software types in a whole-class context with IWBs or data projectors and their use of the software in the context of a computer suite or when using laptops, where students work individually or in pairs. Teachers were also asked to give an indication of their pedagogic practices using ICT in each of these contexts. Responding to more teacher-centred statements like "I use ICT for presentation purposes" (IWB context) and "Students use ICT to practice mathematical skills" (computer suite context) alongside more student-centred statements like "I use ICT to follow up and explore students' ideas" (IWB context) and "I let students 'get a feel' for the software" (computer suite context), teachers indicated how often these practices occurred in their classroom teaching using ICT. Thus the data from this survey provides a basis for an exploration of the nature of both the quantitative and qualitative gap between expectation and implementation of ICT in English mathematics classrooms.

Factors Influencing Mathematics Teachers' Use of ICT

Summarising previous surveys, Assude et al. (2010) note the similarity of factors encouraging or discouraging mathematics teachers' use of ICT across a range of national and international settings spanning more than a decade. At school level in particular, they raise as issues: access to hardware and software; professional development needs; and technical support and resources as factors which appear to outweigh individual-level factors such as confidence, in preventing teachers from integrating technology into their mathematics teaching (Assude et al. 2010, p. 416). Based on the findings of previous surveys, the survey reported in this chapter also asked teachers about school and individual-level factors which may influence their use of ICT. In the school context, teachers were asked for the level of their agreement with statements addressing factors such as access to hardware, software issues, collegial and technical support, provision of professional development and ICT integration in schemes of work. Again in contrast to previous surveys, questions regarding individual-level factors were posed separately in relation to teachers' use of IWBs or data projectors in a whole class context and teachers' use of computer suites or a class set of laptops, where students work individually or in pairs. This data should provide for a more nuanced discussion of the factors underlying classroom use of ICT, in particular the apparent popularity of IWBs in comparison to other forms of hardware, beyond a common-sense statement that IWBs are a more teacher-oriented form of technology.

Understanding Teachers' Use of Technology from a Socio-Cultural Perspective

The broader aim of this study is to develop a deeper understanding of both how and why mathematics teachers use technology in their classroom practice. As with any curriculum resource, how and why teachers make use of the resource in their teaching is a central research question. In this sense, I view digital technologies simply as a particular type of resource amongst a wider range of curriculum resources and not as something special or unique. This approach is similar to that adopted by Ruthven (2009) and Gueudet and Trouche (2009), and contrasts to some extent with Zbiek et al.'s (2007) approach of singling out and focusing on certain digital technologies as *cognitive tools*. Addressing the broader aim of this study, I assume a socio-cultural perspective on teachers' use of resources in accordance with that described by Remillard (2005) as "*curriculum use as participation with the text*". Remillard's (2005) perspective was developed in relation to 'curriculum materials', specifically referring to printed, often published resources designed for use by teachers and students during instruction. Nevertheless, this perspective is appropriate in the light of my stance towards technology as simply one amongst a range of resources, essentially as a particular type of 'text'. In addition, similar perspectives have been applied to a much wider range of resources and in particular to digital technologies (Gueudet and Trouche 2009; Ruthven et al. 2008; Ruthven 2009).

Applying Remillard's Perspective to Teachers' Use of Technology

Remillard's (2005) perspective of "*curriculum use as participation with the text*" views teachers as sense-makers (Spillane 2006), actively interpreting curriculum materials through a process of dynamic interaction. Underlying this perspective are Vygotskian notions of tool use, wherein tools both shape and are shaped by human action through their constraints and affordances (Remillard 2005, p. 221). Applying Remillard's perspective to technology implies that, although the constraints and affordances inherent in digital technologies may help to shape its end use in the classroom, inevitably, the end user, in this case individual teachers, will also work to shape the technology. Thus the design and nature of hardware or software is an ingredient in, but does not determine, the way individual teachers interpret and make use of particular technologies in their classroom practice. For example, Ruthven's (2008, 2009) research on mathematics teachers' use of technology, in his notion of *interpretative flexibility* and claims of interaction between teachers' *curriculum scripts* and *resource systems* coincide with the perspective described by Remillard. Similarly, Gueudet and Trouche's (2009) outline of the documentational approach, extending the widely influential instrumental approach to teachers' appropriation of technology, shares the same Vygotskian roots as Remillard's perspective. Put more simply, there is no guarantee that teachers will use mathematical software designated *cognitive tools* (Zbiek et al. 2007), such as dynamic geometry, graphing or spreadsheet software, if they use them at all, in ways approaching those envisaged by their designers or advocated in policy literature or mathematics education research. Significantly, Ruthven and Hennessy (2002) provide empirical evidence of teachers using such technology to indirectly enhance students' learning through increased *pace and productivity* and improved engagement rather than providing a direct means of enhancing mathematics pedagogy.

Remillard's (2005) perspective also recognises the impact of contextual features in enabling or constraining teachers' interpretations of technology. Stein et al. (2007) identify *context* as one of the factors influencing the participatory relationship between teachers and curriculum materials. In particular, they highlight contextual features, such as *time* available for planning and instruction, *locale* (school and departmental) *cultures* and *teacher support* through professional development, that can constrain or enable teachers' interpretations of curriculum materials. Similarly, Ruthven (2009) describes *working environment* and *time economy* as two of five structuring factors of classroom practice in relation to technology and Gueudet and Trouche (2009) include institutional influences as part of their model of the documentational approach.

Theoretical Issues in Using Self-Report Data to Understand Technology Use

This sub-section outlines a theoretical approach to understanding the possibilities and limitation in using self-report data to gain insight into teachers' use of technology. To capture elements of the ways mathematics teachers in England interpret and use digital technologies in their classrooms, items relating to teachers' pedagogic practices using ICT in a whole-class context with interactive whiteboards or data projectors and their use of ICT in the context of a computer suite or using laptops, were included in the survey instrument. These self-report pedagogic practice items attempt to access the ways teachers interpret and use these types of hardware, to explore the qualitative gap in technology use, however they cannot provide an indication of how teachers interpret specific software packages within these contexts. Further, a distinction must be acknowledged between what we say we do and what we do, relating to Argyris and Schon's (1974, pp. 6–10) definition of 'espoused theory' (theory to which we give our allegiance) and 'theory-in-use' (theory which governs actions). Thus, teachers' self-reports must be considered "as being their account for us of what they do, refracting their espoused theory of teaching practice, through the items in the instrument that refer them to their concrete, practical actions" (Pampaka et al. 2012). In this sense, teachers' self-reports of pedagogic practice cannot be assumed to correspond exactly with what they do in the actuality of the classroom. Nevertheless, Adler (2001) argues there is some relation or overlap between espoused theories and theories-in-use, although one cannot be reduced to the other. Hence, in the absence of direct observation data, teachers' self-reports may be taken to give some insight into their use of hardware in classroom practice, whilst acknowledging the imperfections of the measure. Viewed as espoused theories, these self-reports of pedagogic practice may also provide insight into teachers' conceptions (Thompson 1992; Zbiek et al. 2007) of mathematics teaching with regard to technology, mediated by the items in the instrument.

Consequently, my broader study is directed not simply at documenting the extent of teachers' use of technology and the degree to which the quantitative and qualitative gap exists, but also at highlighting ways in which teachers, as sense-makers, interpret and shape the technology within the constraining or enabling features of their local school and departmental contexts. This chapter focuses primarily on detailing the types of hardware and software teachers use in their classroom practice, together with indications of how technology is being used, thus any conclusions with regard to why teachers use technology in their classroom practice are necessarily tentative.

The Survey: Instrument, Sample and Data Analyses

The survey instrument has been progressively developed over the course of various phases of piloting. The initial questionnaire design was informed by previous surveys of mathematics teachers' use of ICT, primarily Hyde's (2004) survey of mathematics teachers in Southampton and Forgasz's (2002) survey of mathematics teachers in Victoria, Australia. This questionnaire was trialled with students on the Post-Graduate Certificate of Education[1] (PGCE) mathematics course at King's College London, before being piloted with 27 schools working in partnership with King's College London to offer initial teacher education in secondary mathematics. The results of the pilot survey are reported in Bretscher (2011). As a result of this piloting, the questionnaire was re-developed to include items relating to teachers' pedagogic practices with ICT and to highlight more clearly the division of questions between using ICT in a whole-class context and using ICT in the context of a computer suite or using laptops. Items relating to school and individual factors affecting teachers' use of ICT were also re-written to aid clarity. The re-designed questionnaire was trialled in two further think-alouds[2] with PGCE students and with three experienced in-service teachers, who completed the questionnaire and then gave verbal feedback. The theoretical perspective outlined above implies that survey respondents engage in a participatory relationship with the text of the questionnaire, actively interpreting questionnaire items in the light of their own circumstances, whilst the questionnaire items may also shape respondents' perception of these circumstances. Indeed, one of the three experienced in-service teachers, with whom the questionnaire was trialled, commented with surprise on how she perceived shifts in her own conception of what 'ICT use' meant as she progressed through different sections of the questionnaire.

The final survey instrument contained mainly closed Likert-type response formats grouped under the following sections:

A. *ICT in your school* – items on access to hardware/software and school/departmental level factors effecting ICT use;
B. *ICT use in your own mathematics teaching*
    i. *Your use of hardware* – perceived impact and frequency of use of hardware;
    ii. *Using an interactive whiteboard or data projector in maths lessons* – items on frequency of software use, individual factors effecting ICT use and pedagogic practices with an IWB or data projector in a whole-class context;
    iii. *Maths lessons in a computer suite or using laptops* – similarly, items on frequency of software use, individual factors effecting ICT use and pedagogic practices with ICT in the context of a computer suite or using laptops;
C. *Your own mathematics teaching in general* – Pampaka et al.'s (2012) items relating to pedagogic practices in general (not specific to ICT use); and
D. *About You* – personal background details.

[1] The Post-Graduate Certificate of Education is a 1-year initial teacher-training course.

[2] A think-aloud is an interview where the survey respondent offers a verbal explanation of their responses as they progress through the questionnaire.

In addition, two open-ended response questions were included so that teachers could comment more widely on issues relating to access to hardware or software and on using ICT in general in maths lessons. The list of software was derived mainly from Hyde's (2004) list, checked against a survey of software use by the Fischer Family Trust (2003), with the notable inclusion of IWB software and the MyMaths.co.uk website (Oxford University Press 2012). IWB software refers to presentation-type software that is designed specifically for use with IWB hardware, for example SMART Notebook or Promethean ActivInspire. The growing presence of IWBs in mathematics lessons in England, indicated by the pilot study and other reports (e.g. Moss et al. 2007), suggests that IWB software may be used regularly by mathematics teachers and it was therefore included in the list of software for this survey. The *MyMaths* website was included since this site was known anecdotally to be widely used in UK schools (see for example, the school case studies reported in Clark-Wilson 2008, pp. 103–104). It is a subscription site offering teachers pre-planned lessons, on-line homework and many other resources. The lessons and homework are linked to an 'Assessment Management system', allowing teachers to track individual student's progress.

Questionnaires were sent to 87 secondary schools selected through contacts with mathematics educators in three English universities. The schools were thus situated mainly within three rough geographic areas: Greater London, West Yorkshire and the South of England (taken as comprising the counties of Hampshire, West Sussex and Dorset). Nine questionnaires were sent to each school and 50 schools agreed to take part. A total of 188 completed individual teacher questionnaires returned, an average of 3.8 questionnaires per school. Twelve schools returned only one completed questionnaire, whilst one returned all nine. The sample cannot be said to be statistically representative, nevertheless, the participating schools cover a range of characteristics including a wide range of attainment in national tests; most were state schools but some were private schools; some have speciality status and some do not; some are single sex and some are selective. The participating teachers (101 F; 86 M; 1 unspecified) had an average age of 38.5 years and an average length of service of 10.5 years. The majority of respondents (96) described their main responsibility as classroom teacher. The sample also included 24 heads of department, 18 deputy heads of department and 24 Key Stage[3] coordinators. There may be a potential bias in the sample towards teachers who are relatively well-disposed towards ICT or those wishing to be seen as frequent users of ICT. Comparing themselves to their colleagues in the maths department, only 9.0 % of survey respondents thought they use ICT less or much less frequently whereas 33.5 % thought they use ICT more or much more frequently.

Data that could be analysed statistically were manually entered into PASW Statistics 18.0. This package was used to generate descriptive statistics (i.e. frequency

[3] A Key Stage coordinator is a teacher with responsibility for overseeing the delivery of the mathematics curriculum to certain year groups. For example, Key Stage 3 refers to the first three years of secondary school, whilst Key Stage 4 refers to the remaining two years of compulsory secondary schooling.

distributions and means) and inferential statistics (t-tests and χ^2 tests) were calculated as appropriate. An independent data coding check, based on a 10 % sample of questionnaires, gave a coding accuracy of greater than 99.9 %.

In order to investigate the influence of contextual factors relating to teachers' local school and departmental contexts on their technology use, a crude measure of school level support for ICT use was also calculated for each school, as follows. A school score for each of the 'school level' factors relating to ICT use was calculated i.e. the mean of the responses given by the teachers in that school. An overall support score for each school was then calculated as the mean of its scores for the 'school level' factors (negatively worded items were reverse-coded). Schools were labeled 1 if their overall support score was higher than the school sample mean and 0 if their mean support score was lower than or equal to the school sample mean.

Results

Access to Hardware and Software

All schools in the sample equipped their teachers with either IWBs or data projectors. The near ubiquity of IWBs in English mathematics classrooms can be ascribed in large part to funding initiatives put in place by the previous Labour government, allowing the purchase of this technology by schools on a large scale. Indeed, in only two schools did all the responding teachers say they had no access to IWBs: in school 90, one teacher responded, reporting access to data projectors (but not IWBs). Similarly in school 42, eight teachers responded, seven of these reporting access to data projectors. The eighth teacher in school 42 was the only respondent in the survey to report having access neither to an IWB nor to a data projector, specifically commenting on the questionnaire that s/he never used this hardware in classroom teaching – despite his/her colleagues' access to and frequent use of this technology.

In contrast only 71.8 % of teachers reported having access to a computer suite shared with other departments. This seems surprisingly low, especially when compared with the coverage of IWBs (93.1 % – see Table 1). Although 53 teachers report having no access to a shared computer suite, 21 of these teachers report having access instead to a computer suite dedicated to the maths department. This leaves 32 teachers (17.0 %) saying they have no access to a computer suite at all (either shared or dedicated to the maths department). Looking across schools however, there are only three schools in which none of the teachers report having access to a computer suite of either type. In each of these three schools only one or two teachers completed questionnaires. Furthermore, 55 % of the 53 teachers who report having no access to a shared computer suite, conflictingly report using a shared computer suite with some frequency during their teaching. Based on this measure, the apparent unreliability of reporting access to shared computer suites was far higher than for other types of hardware. 32 % of teachers who reported no access to

Table 1 Number of teachers with access to hardware, $n = 188$

	With access	(%)
Interactive whiteboard	175	(93.1)
Data projector	36	(19.1)
Computer suite (shared)	135	(71.8)
Computer suite (maths only)	39	(20.7)
Laptops	41	(21.8)
Graphic calculators	65	(34.6)

a data projector claimed to use them in their teaching, possibly reflecting confusion between the IWB and data projector categories.[4] For all other types of hardware included in the survey this figure was below 10 %. The lack of consistency in teachers' responses, both across schools and individually, suggests that while some teachers are reporting access to shared computer suites on the basis of their awareness of the existence of hardware, others are responding according to their perception of availability of the hardware for use (and there may be other interpretations too). Difficulties in booking computer rooms mean that, although shared computer suites exist, their availability for actual use is often restricted. 23.1 % of teachers' responses to an open-ended question regarding issues with access to hardware and software commented on difficulties relating to gaining access to computer suites. The quote below gives a sense of these teachers' comments on hardware access and neatly summarises the contrast in accessibility between IWBs and computer rooms:

> It is easy for us to use ICT with the software from the front but difficult to gain access to the computers for an ICT lesson where students use the computers.

In addition, 25.6 % of teachers' responses commented on the unreliability or slowness of ICT facilities: thus even where access was not an impediment, technical issues could make lessons involving ICT highly problematic as illustrated by the following comment:

> Main issue is unreliability of ICT – so that you cannot guarantee that a planned lesson using ICT will run to plan.

A computer suite dedicated to the maths department or class sets of laptops might be a potential solution to difficulties in gaining access. However, these facilities are still fairly rare and increased access does not overcome technical issues – indeed, in the case of laptops at least, they may carry additional technical difficulties, as one frustrated teacher commented:

> I have access to a class set of laptops (one between two) but [I] never use [them] as the batteries do not last a full lesson. There is very limited access to computer rooms as an alternative.

Access to generic software tools such as word-processing, spreadsheet and presentation software is almost universal (above 90 %). The majority of teachers appear

[4] In the survey, the IWB category was referred to as 'Interactive whiteboard with a data projector' whereas the data projector category was defined as 'Data projector only, linked to a computer'.

Table 2 Number of teachers with access to software, $n = 188$

	With access (%)	
Spreadsheet	176	(93.6)
PowerPoint	171	(91.0)
Word	171	(91.0)
MyMaths.co.uk website	168	(89.4)
Interactive whiteboard software	166	(88.3)
Email	160	(85.1)
Graphing software	148	(78.7)
Other websites	141	(75.0)
Interactive geometry software	124	(66.0)
CD Roms	117	(62.2)
Database	81	(43.1)
Logo	54	(28.7)
SMILE	39	(20.7)

to have access to graphing software (e.g. *Autograph* and *Omnigraph*) and dynamic geometry software (e.g. *Cabri*, *The Geometer's Sketchpad* and *GeoGebra*), however a significant minority report no access to these resources (21.3 % and 34.0 % respectively). Of course, this may reflect teachers' lack of awareness of the existence of the software at their school or, as with hardware, teachers may be responding based on their perception of the ease of accessing software rather than its existence. Nevertheless, the number of teachers reporting no access to these types of software is surprising perhaps, given recommendations in national curricula that pupils be given opportunities to use such software in mathematics, although there is no compulsion to do so through national examinations, for example (Table 2).

Perhaps more surprising is the near ubiquity of the *MyMaths* website, with 89.4 % of teachers reporting access, costing secondary schools around £540 in annual subscription fees. Indeed, in only two schools did all the teachers consistently report not having access to the *MyMaths* website. Using databases in work on data-handling was a statutory requirement of the original National Curriculum in 1989 (DES 1989) and Logo appeared more frequently than any other form of software in algebra and geometry contexts, although references to these software disappeared in later revisions (Andrews 1997). Despite this only 43.1 % of teachers report access to database software and 28.7 % of teachers responded positively for access to Logo. Some teachers complained about restrictions on downloading and installing software, such as *GeoGebra*, and access to some websites being unnecessarily blocked. Although software might exist in a school, teachers expressed uncertainties over whether it had been installed on all computers or whether it was available at any given time, thereby adding complexity to conducting lessons in a computer suite, as the following comments illustrate:

> Migration of software to new network has caused several items of software to be inaccessible.
>
> The school system is sometimes slow which makes accessing the software time-consuming at times. Changes in our school status mean we have lost some software. Updates in SMARTboard have caused squared paper options to disappear.

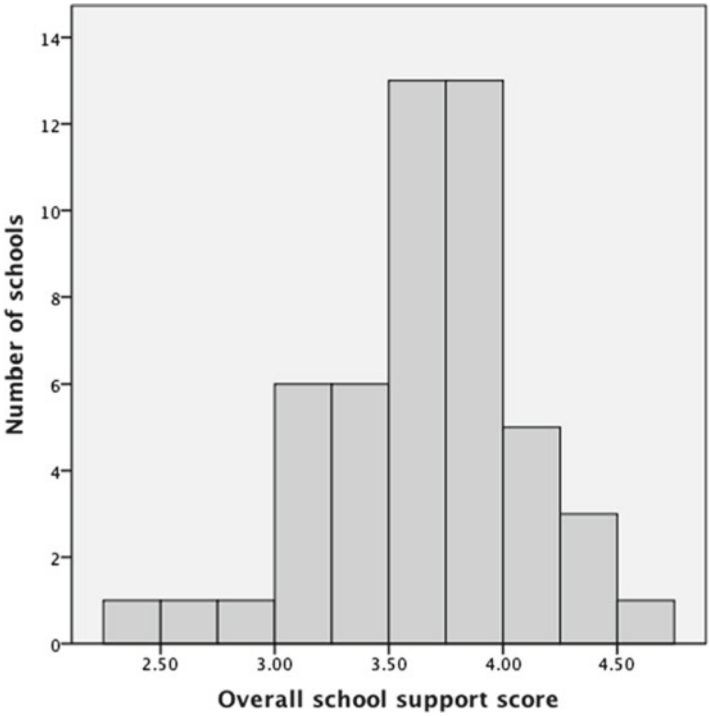

Fig. 1 Distribution of overall school support scores, $n = 50$, mean = 3.64, s.d. = .44

School Level Factors Relating to ICT Use

Overall, teachers' responses were positive about the factors affecting ICT use, casting their departments and schools in general as supportive communities in which to develop their mathematics teaching using ICT. Indeed Fig. 1 shows that the overall support score for the sample of schools was skewed towards the positive agreement end of the response scale. This could be interpreted as resulting from sample bias – that schools in the sample were more likely to be supportive of ICT use than is the norm – or that teachers simply tend to represent their schools and departments in a positive light. The overall school support score for the three lowest-scoring schools were based upon only one or two respondents from each school; this was not necessarily the case for high scoring schools.

Table 3 shows the mean school score for the school level factors included in the survey instrument. In particular, teachers highlighted their departmental colleagues as supporting their use of ICT. Surprisingly perhaps, given the comments in the previous section, in general teachers tended to disagree that they often had problems accessing hardware. It is important to note here that this question didn't discriminate between access to IWB hardware or computer hardware: thus the positive

Table 3 Mean school support scores for school level factors, $n = 50$. Scored on a 5-point Likert-scale where 5 = strongly agree to 1 = strongly disagree

	Mean	(SD)
ICT use is a high priority in my department	3.64	(.72)
I get support on using ICT from colleagues in my department	4.01	(.53)
ICT resources are poorly integrated into schemes of work	2.60	(.78)
I often have problems accessing hardware	2.62	(.77)
Access to software is easy and reliable	3.50	(.76)
The available software lacks relevance to the curriculum	2.03	(.56)
The level of technical support is poor	2.15	(.88)
I have had relevant professional development in using ICT	3.37	(.76)

response might reflect the relative ease of accessing IWB hardware, masking difficulties teachers have in booking computer suites. For example, teachers from two of the highest scoring schools for overall support (school 60 scored 4.18; school 80 scored 4.25) raised difficulties with giving their students direct access to ICT due to problems booking computer suites and the unreliability of laptops via the open-ended response questions. In addition, there was no statistically significant difference in access to any type of hardware or software listed in the survey between schools identified as providing high and low support for using ICT in teaching mathematics (based on χ^2 tests at the 5 % level).

Frequency and Perceived Impact of Hardware Use

The majority of teachers use IWBs and data projectors in almost every lesson, with 85 % of teachers using IWBs in almost every lesson, see Table 4. The ready availability of IWBs and data projectors in normal classrooms makes it unsurprising that they are the most frequently used hardware. IWBs stand out from the other types of hardware as having the highest perceived impact (see Table 5) – this is likely to be linked to their high frequency of use. Interestingly, the perceived impact of data projectors is little different from and actually slightly lower than that of computer suites and laptops in general. Of the 139 teachers reporting impact on student learning for data projectors, only 12 did not have access to IWBs. The relatively low mean impact score for data projectors compared to that of IWBs may reflect a perception that the additional 'interactivity' of IWBs makes them superior for teaching purposes.

Computer rooms shared with other departments have a much lower frequency of use, with 77 % of teachers using them once or twice a term or less. As with IWBs, the frequency of use is to some extent reflected by difficulties in access and in turn reflects the lower impact score of shared computer rooms. Computer suites dedicated to the mathematics department appear to be used slightly more frequently, with a smaller percentage of teachers claiming they never use the resource and a

Table 4 Frequency of hardware use, in %. Note the 'Never' column excludes those who reported having no access to the hardware

		Never	Annually	Once or twice a term	Once a week	Almost every lesson
Interactive whiteboard	$n=175$	4	1	2	8	**85**
Data projector	$n=35$	3	0	9	26	**63**
Computer suite (shared)	$n=131$	6	11	**60**	21	1
Computer suite (maths)	$n=37$	3	16	**51**	**30**	0
Laptops	$n=41$	**32**	7	**37**	20	5
Graphic calculators	$n=63$	**30**	**29**	**40**	2	0

Table 5 Mean perceived impact score. Scored on a 4-point Likert scale where 4 = substantial; 3 = significant; 2 = some; 1 = very little

		Mean impact	(SD)
Interactive whiteboard	$n=182$	3.16	(.84)
Data projector	$n=139$	2.43	(.89)
Computer suite (shared)	$n=168$	2.53	(.80)
Computer suite (maths only)	$n=131$	2.53	(.99)
Laptops	$n=133$	2.47	(.97)
Graphic calculators	$n=140$	2.21	(.90)

somewhat larger percentage saying they use the resource once a week. Nevertheless, the increased frequency of use is marginal since 70 % of teachers still only use a computer suite dedicated to the maths department once or twice a term or less. Similarly there is no apparent difference in teachers' perception of the impact on students' learning of a computer suite dedicated to the maths department compared to one shared by other departments.

The portability of laptops might make it easier to give students direct access to ICT within a 'normal' classroom context; however, this survey suggests that they do not lead to an increase in usage compared to a shared computer suite. Indeed, a greater proportion of teachers with access to laptops report never using them, perhaps due to the kinds of technical difficulties alluded to in previous sections. Whilst the mean impact score of computer suites, laptops and data projectors are fairly similar, the perceived impact of graphic calculators is appreciably lower than this cluster. Likewise, graphic calculators have the lowest profile of frequency of use with 99 % of teachers reporting usage of once or twice a term or less.

Differences in the frequency of use of IWBs between schools with higher and lower support for ICT use were statistically significant ($\chi^2=16.67$, df = 2, p = .0002). Specifically, teachers in schools with higher support reported higher frequency of use for IWBs in almost every lesson than those in schools with lower support. The difference in the frequency of data projector usage between schools with higher and lower support for ICT was also statistically significant ($\chi^2=17.04$, df = 3, p = .001). In higher support schools, more teachers claim never to use data projectors than was expected compared to those in lower support schools. Thus teachers in higher support schools used data projectors less frequently than those in lower support schools. There were no statistically significant differences in frequency of use for any of the other hardware listed in the survey, tested at the 5 % level. The differences between higher and lower support schools in terms of teachers' perceptions of the impact of using hardware on students' learning followed a similar pattern. Those in higher support schools were significantly more likely to perceive IWBs as having a substantial impact on students' learning, whereas those in lower support schools thought IWBs only had some impact ($\chi^2 = 22.38$, df = 2, $p < .0001$). There were also significant differences in the perception of impact of data projectors between teachers in higher and lower support schools ($\chi^2 = 8.61$, df = 3, $p = .035$). In higher support schools, more teachers than expected thought that data projectors had either very little impact or substantial impact. Although it is not so easy to interpret this result, it could be taken to suggest that teachers in higher support schools have more extreme views about the impact of data projectors. Again there were no statistically significant differences in teachers' perception of impact for any of the other hardware listed in the survey, tested at the 5 % level. These results can be interpreted in at least two ways: when considering school or departmental factors relating to ICT use, teachers appear to equate ICT use with IWB use. An alternative interpretation is that whilst supportive departments can apparently facilitate teachers' use of IWBs, they do little to ameliorate obstacles to giving students direct access to ICT via computer suites or laptops. These results also tend to support the finding noted above that teachers appear to prefer IWBs to data projectors.

Frequency of Software Use

Table 6 compares the mean frequency of software use in lessons with an IWB or data projector to lessons where students are given direct access to the software, i.e. those that take place in a computer room or with laptops. A score of above 2 indicates the software is used more than once or twice a term. Databases, SMILE and Logo scored very low in both contexts, with a score of below 1 indicating less than annual use, so no satisfactory comparison can be made for these software packages. IWB software was the most frequently used piece of software (3.19) in a whole-class context with an IWB. This was followed by PowerPoint, other (unspecified) websites and the *MyMaths* website which also scored above 2. All other types of software including graphing, geometry and spreadsheet software were used on average less than once or twice a term in a whole-class context with an IWB. Thus in general, presentation-oriented software dominates IWB use. Whilst the theoretical stance adopted in this study suggests that making any inferences regarding teachers' actual use of such software is problematic, it is reasonable to note that the design of such presentation-oriented software tends to be more teacher-centred and may therefore present an additional obstacle to the development of more student-centred practices.

Table 6 Mean frequency of software use (a) with IWB or data projector and (b) giving students' direct access via a computer suite or with laptops. Scored on a 5-point Likert-scale where 0 = never, 1 = annually, 2 = once or twice a term, 3 = once a week, 4 = almost every lesson

(a)			(b)		
For IWB/data projectors, *n* = 147	Mean freq.	(SD)	For direct student access, *n* = 158	Mean freq.	(SD)
IWB software	**3.19**	**(1.39)**	IWB software	1.24	(1.54)
PowerPoint	**2.57**	**(1.24)**	PowerPoint	1.46	(.98)
Other websites	**2.56**	**(.95)**	Other websites	1.85	(1.13)
MyMaths.co.uk	**2.41**	**(1.22)**	**MyMaths.co.uk**	**2.03**	**(1.25)**
Word	1.95	(1.23)	Word	1.34	(1.11)
Graphing software	1.89	(1.09)	Graphing software	1.39	(1.01)
Spreadsheet	1.82	(1.04)	Spreadsheet	1.39	(1.30)
Geometry software	1.53	(1.11)	Geometry software	1.20	(.99)
Email	1.37	(1.60)	Email	.66	(1.09)
CD Roms	1.46	(1.29)	CD Roms	.55	(.92)
Database	.84	(1.19)	Database	.58	(.94)
SMILE	.50	(.95)	SMILE	.25	(.62)
Logo	.35	(.67)	Logo	.37	(.72)

The frequency of use in lessons where students were given direct access to the software was low in comparison to lessons with an IWB: only *MyMaths* had a mean frequency score above 2 – a finding supported by the pilot study. This is unsurprising given the frequency of hardware use in mathematics lessons reported above: computer rooms are used much less frequently than IWBs. However the decrease in use is not uniform across all types of software. The mean frequency score of IWB software (−1.95) and PowerPoint (−1.11) dropped the most. Since the main purpose of IWB software and PowerPoint is for presentation, it appears well suited to teacher exposition in lessons with an IWB but not so relevant in lessons where students have direct access to the software. *MyMaths* (−0.38) and geometry software (−0.33) had the smallest drops in frequency use between contexts. Although the *MyMaths* website can be used for teacher presentation, one of its main features are textbook-like exercises and on-line homework, linked to an 'Assessment Management system', allowing teachers to track individual student's progress. Hence it can also be used in lessons where students are given direct access to computers. Similar to geometry software, graphing (−0.50) and spreadsheet (−0.43) software also have relatively low drops in use between contexts, maintaining a mean frequency of use between once or twice a term and annual usage.

In a whole-class context with an IWB, teachers in higher support schools tended to use IWB software ($\chi^2 = 28.93$, df = 3, $p < .0001$) and email ($\chi^2 = 8.89$, df = 3, $p = .031$) statistically significantly more than those in lower support schools. Although teachers in higher support schools also used Logo significantly more often than those in lower support schools ($\chi^2 = 7.27$, df = 2, $p = .026$), this still corresponds to very low levels of use overall. There were no statistically significant differences in frequency of use with an IWB for any of the other software listed in the survey tested at the 5 % level, in particular graphing, geometry and spreadsheet software, PowerPoint and *MyMaths* showed no significant difference in use between higher and lower support schools. Higher support school teachers' more frequent use of IWB software is likely to be a reflection of their more frequent use of IWBs in general, although perhaps of more interest is that they do not use other software significantly more or less often than those in lower support schools. Nevertheless this result might be seen to offer support to the suggestion that when considering school or departmental factors relating to ICT use, teachers appear to equate ICT use with IWB use.

In the context of giving students direct access to ICT in a computer suite, the only software with a significant difference in frequency of use between teachers in higher and lower support schools was Logo ($\chi^2 = 12.15$, df = 2, p = .002). Teachers in higher support schools used Logo more frequently, however again this still corresponds to very low levels of use overall. Again there were no statistically significant differences in frequency of use with a computer suite for any of the other software listed in the survey tested at the 5 % level, in particular graphing, geometry and spreadsheet software and *MyMaths* showed no significant difference in use between higher and lower support schools.

Individual Level Factors Relating to ICT Use

In general, teachers agreed that ICT makes an important contribution to students' learning and helps them to understand mathematics, irrespective of whether students are given direct access to ICT or they experience ICT indirectly through whole-class teaching using an IWB (see Tables 7 and 8). The pattern of response differed little between using IWBs in a whole-class context and giving students direct access to ICT via a computer suite: there were no statistically significant differences between the two contexts, according to a paired *t*-test at the 5 % level. Similarly, teachers agreed that using ICT improves students' engagement in lessons, with no significant difference between the two classroom contexts. These results suggest mathematics teachers in England generally have a favourable outlook towards using ICT in their teaching and to a similar extent whether students are given direct access to ICT or they experience ICT indirectly through whole-class teaching using an IWB.

Time is highlighted by Stein et al. (2007) as one of many contextual factors impacting on the participatory relationship between curriculum materials and teachers. In terms of time needed for lesson preparation, overall, teachers tended to agree slightly that lessons involving ICT in both classroom contexts took more time to prepare (see Tables 7 and 8); there were no statistically significant differences between the two contexts. However, in both contexts there was a relatively large variation in the perceived time costs across the sample, with 29.0 % ($n = 183$) disagreeing or strongly disagreeing that lessons with an IWB took more time to prepare and similarly 30.1 % ($n = 176$) for lessons in a computer suite. The large variation in perceived time costs for ICT use may reflect that while start-up costs can be high in terms of designing lesson materials, once made, the materials can be

Table 7 Mean score for individual level factors using ICT with an IWB or data projector. Scored on a 5-point Likert-scale where 5 = strongly agree to 1 = strongly disagree

For lessons using an IWB or data projector in a whole-class context		Mean	(SD)
I am confident using ICT in lessons	$n = 181$	4.24	(.90)
Lessons using an IWB/data projector take more time to prepare	$n = 183$	3.18	(1.14)
ICT makes an important contribution to students' learning of mathematics	$n = 184$	3.87	(.82)
Using ICT improves student engagement in lessons	$n = 185$	3.97	(.75)
Students' lack of familiarity with software make lessons with ICT difficult	$n = 186$	2.68	(1.01)
ICT resources help students to understand mathematics	$n = 184$	3.85	(.80)
Classroom management is more difficult when using an IWB/data projector	$n = 185$	1.86	(.88)
We cover more ground in lessons with an IWB/data projector	$n = 184$	3.57	(.90)

Table 8 Mean score for individual level factors using ICT in a computer suite or with laptops. Scored on a 5-point Likert-scale where 5 = strongly agree to 1 = strongly disagree

Giving students direct access in a computer suite or with laptops		Mean	(SD)
I am confident using ICT in lessons	$n = 175$	4.09	(.98)
ICT lessons take more time to prepare	$n = 176$	3.18	(1.14)
ICT makes an important contribution to students' learning of mathematics	$n = 176$	3.85	(.83)
Using ICT improves student engagement in lessons	$n = 176$	3.89	(.81)
Students' lack of familiarity with software make lessons with ICT difficult	$n = 175$	2.78	(1.02)
ICT resources help students to understand mathematics	$n = 175$	3.75	(.82)
Classroom management is more difficult in ICT lessons	$n = 176$	2.64	(1.03)
We cover more ground in ICT lessons	$n = 174$	2.92	(.87)

stored electronically, ready to be used in perpetuity. Thus teachers who are new to using a piece of hardware or software or teaching a topic for the first time might agree that preparation time is increased, whereas those who have already accumulated a bank of lesson materials may disagree. Preparation time also depends on how the hardware is used. For example, if an IWB is essentially used as a normal whiteboard then additional time costs may be minimal; however if a PowerPoint presentation is specially prepared for the lesson, the additional time costs could be considerable. Similarly, for lessons in a computer suite, if pupils work through a pre-prepared *MyMaths* lesson and exercises, the teachers' time spent in preparation may be minimal, whereas preparing graphing or dynamic geometry software files for the pupils to interact with could be very time-consuming.

Overall, teachers tended to disagree slightly that students' lack of familiarity with software make ICT lessons more difficult. Still, there was a sizeable minority who either agreed or strongly agreed that students' lack of familiarity with software caused difficulties in ICT lessons: 24.2 % of responding teachers ($n = 186$) in

Table 9 Statistically significant results of paired t-tests at the 5 % level, comparing means for individual level factors between using IWBs in a whole-class context and giving students direct access to ICT in a computer suite

		Mean difference (IWB – CS)	SE	t-score	p-value
Confidence	$n=169$	.154	.054	2.83	.005
Class management	$n=173$	−.786	.085	−9.29	$p<.001$
Ground covered	$n=170$	.665	.080	8.35	$p<.001$

the context of using an IWB and 26.3 % of responding teachers ($n=175$) where students were given direct access to ICT via a computer suite. Surprisingly there were no statistically significant differences in this regard between using IWBs in a whole-class context and giving students direct access to ICT in a computer suite – despite the dominance of teacher control over software when using IWBs, see the following section.

Three individual level factors stood out as showing statistically significant differences between using IWBs in a whole-class context and giving students direct access to ICT in a computer suite: teachers' confidence in using ICT; teachers' perception of the difficulty of classroom management; and the amount of ground (i.e. the amount of curriculum material) covered in ICT lessons – see Table 9 above. Teachers do appear to feel confident in using ICT in lessons both with an IWB and in a computer suite. Although mathematics teachers' confidence has appeared as an obstacle towards using ICT in previous surveys (e.g. Hadley and Sheingold 1993), a more recent survey of mathematics teachers (Forgasz 2006) suggested that teachers' personal confidence and relevant skills were consistently one of the factors most encouraging their use of ICT. However, according to the results shown in Table 9, teachers do appear less confident using ICT in lessons in a computer suite than in lessons with an IWB.

Classroom management is perceived by teachers as being significantly more difficult in ICT lessons taking place in a computer suite than in lessons involving ICT using an IWB. Around 83 % of responding teachers ($n=185$) disagree or strongly disagree that classroom management is more difficult when using an IWB or data projector, suggesting that, in the main, teachers believe that using an IWB facilitates classroom management. Although overall it appears that teachers also slightly disagree that classroom management is more difficult in a computer suite, by comparison this figure is much lower with nearly 50 % of teachers disagreeing or strongly disagreeing that classroom is more difficult when giving students direct access to ICT in a computer suite.

Overall, teachers have the perception that they cover slightly more ground in lessons when using an IWB, with over half agreeing or strongly agreeing with the statement ($n=184$). However, for lessons where students are given direct access to ICT in a computer suite, 50 % of responding teachers ($n=174$) thought it made little difference to the amount of ground covered, whilst slightly over 25 % disagreed or strongly disagreed – presumably suggesting they think less ground is covered in lessons taking place in a computer suite. Thus in general, teachers believe that they

Table 10 Chi-squared tests for differences in individual level factors using an IWB in a whole-class context between high and low support schools

For IWB lessons	χ^2-value	df	p-value
Confidence	21.03	4	p < .001[a]
Preparation time	10.57	4	.032[a]
Contribution to learning	25.47	4	p < .001[a]
Student engagement	8.71	3	.033[a]
Students' lack of familiarity	11.60	4	.021[a]
Help understanding	22.95	4	p < .001[a]
Classroom management	17.30	3	p < .001[a]
Ground covered	15.31	3	.002[a]

[a]Indicates a statistically significant result at the 5 % level

Table 11 Chi-squared tests for differences in individual level factors using ICT in a computer suite between high and low support schools

For computer suite lessons	χ^2-value	df	p-value
Confidence	12.33	4	.015[a]
Preparation time	3.08	4	.545
Contribution to learning	16.09	4	.003[a]
Student engagement	4.79	4	.309
Students' lack of familiarity	2.52	4	.641
Help understanding	12.19	4	.016[a]
Classroom management	6.78	4	.148
Ground covered	10.18	4	.038[a]

[a]Indicates a statistically significant result at the 5 % level

cover significantly less ground in lessons where students are given direct access to ICT compared to those conducted in a whole-class context using an IWB. This result is particularly interesting given the pace and productivity rationale for using ICT identified by Ruthven and Hennessy (2002).

Comparing individual level factors in high and low support schools, all showed significant differences with regard to using an IWB in a whole-class context (Table 10).

Overall, teachers in high support schools were more positive in the perceptions of using ICT in a whole-class context with an IWB than those in low support schools. More teachers in high support schools strongly agreed to being confident using IWBs compared to those in low support schools. Similarly, teachers in high support schools agreed more strongly that ICT makes an important contribution to students' learning; that using ICT improves student engagement and helps students to understand mathematics when using an IWB in a whole-class context compared to teachers in low support schools. However, teachers in high support schools disagreed more strongly that ICT lessons take more time to prepare; that classroom management is more difficult and that students' lack of familiarity with software causes difficulties when using an IWB in a whole-class context compared to teachers in low support schools (Table 11).

Table 12 Mean frequency of self-reported pedagogic practices using an IWB in a whole-class context. Scored on a 5-point Likert-scale where 5 = almost always to 1 = almost never

		Mean	(SD)
I use ICT for presentation purposes	$n = 182$	4.12	(1.07)
I use ICT to generate student discussion	$n = 184$	3.28	(1.09)
I control the software on the interactive whiteboard or data projector	$n = 183$	4.03	(.97)
I use ICT to follow up and explore students' ideas	$n = 184$	2.79	(1.12)
I manage software carefully to prevent mathematical discrepancies arising	$n = 173$	3.06	(1.32)
Students control the software on the interactive whiteboard or data projector	$n = 184$	2.03	(.86)
I draw attention to mathematical discrepancies in the software	$n = 176$	2.66	(1.40)
Using ICT, I avoid students making mistakes by explaining things carefully first	$n = 181$	3.15	(1.16)

Comparing individual level factors using ICT in a computer suite between high and low support schools offers a different picture. Teachers in high support schools agreed significantly more strongly that they are confident using ICT in computer suite and that ICT makes an important contribution to students' learning and helps their understanding when students are given direct access to it than those in low support schools. Although there was a significant difference between high and low support schools with regard to teachers' perception of the amount of ground covered in ICT lessons, this result was less easy to interpret. None of the other factors showed statistically significant differences between high and low support schools at the 5 % level.

Teachers' Pedagogic Practices Using ICT with an IWB and in a Computer Suite

Perhaps unsurprisingly given the apparent teacher-centred nature of IWBs, teacher-centred practices such as using ICT for presentation purposes and maintaining teacher-control of the software are the dominant pedagogic practices reported by teachers when using an IWB (see Table 12). Conversely, allowing students to take control of the software on an IWB is reported as the least frequent pedagogic practice. Using ICT to generate student discussion is reported as fairly frequent, though substantially less often than using ICT for presentation purposes. In particular, teachers relatively rarely report using ICT to follow up and explore student ideas, suggesting perhaps that the discussion might be rather one-sided. Interpreting this data, it is important to recall that teachers' self-reports may not accurately reflect classroom practice, since they represent espoused-theories rather than theories-in-action, and that direct observation data is required to validate any assertions made on the basis of the survey data. The lower number of responses for the statements regarding mathematical discrepancies (such as rounding errors) in the software is

Table 13 Mean frequency of self-reported pedagogic practices using giving students direct access to ICT in a computer suite. Scored on a 5-point Likert-scale where 5 = almost always to 1 = almost never

		Mean	(SD)
Students use ICT to practice mathematical skills	$n = 170$	3.41	(1.16)
I encourage students to work collaboratively	$n = 175$	3.35	(1.03)
I let students 'get a feel' for the software	$n = 175$	3.19	(1.15)
Students explore mathematical discrepancies in the software	$n = 167$	2.07	(1.13)
Students work on their own, consulting a neighbour from time to time	$n = 172$	3.15	(1.06)
Students use ICT to investigate mathematical problems and concepts	$n = 175$	2.90	(1.14)
I provide precise instructions for software use	$n = 170$	3.42	(1.10)
I prepare software files in advance to avoid student difficulties using the software	$n = 170$	2.55	(1.36)

due to teachers' confusion over the meaning of 'discrepancies'. It is difficult to offer any interpretation of the data as a result, beyond noting perhaps that it may indicate that teachers are generally not aware of discrepancies between mathematics as modeled by the software and standard mathematics.

Using ICT in a computer suite where students have direct access, the most common pedagogic practices were getting students to use ICT to practice mathematical skills and providing precise instructions for software use. Using ICT for students to investigate mathematical problems and concepts was one of the least frequent self-reported pedagogic practices. Surprisingly, preparing software files in advance was also one of the least frequent reported practices. Due to the dominant use of *MyMaths* in lessons taking place in a computer suite, perhaps it is unnecessary for teachers to prepare software files in advance, alternatively they may download materials from the Internet or from their own pool of resources rather than having to create new resources on a frequent basis. Again teachers found it difficult to understand what was indicated by 'mathematical discrepancies'. The reduced number of responses in comparison to IWB practices is partly due to a number of teachers omitting this question as they felt unable to give reliable responses because they use computer suites so infrequently (Table 13).

Conclusion and Discussion

This study underlines the quantitative gap between institutional expectations and classroom reality in maths teachers' use of both hardware and software. Allowing students direct access to digital technology remains at the margins of teaching practice, with over 75 % of responding teachers ($n = 131$) using computer suites shared with other departments – the most commonly available resource for students' direct access – one or twice a term or less. In contrast, IWBs are used almost every lesson by 85 % of responding teachers ($n = 175$), where control of the technology is rarely devolved to students. The quantitative gap is further emphasised by software use in both classroom contexts. Use of mathematical analysis software (Pierce and Stacey 2010), most commonly associated with theoretical notion of *cognitive tools* (Zbiek et al. 2007) and thus advocated by mathematics education research and government policy, is relatively rare in either classroom context. Presentation-oriented software dominates IWB use, whilst surprisingly the *MyMaths* web-site offering pre-prepared lessons dominates teachers' use of computer suites as well as featuring prominently amongst software used with IWBs. Coming to understand the ways in which software such as the *MyMaths* web-site and IWB software may be viewed as cognitive tools, might help provide insights into why teachers rely on these resources as well as reducing the impression of a deficit in teachers' use of technology.

Difficulty in gaining access to computer suites clearly remains an obstacle to use. Yet even in schools more supportive of ICT use, where conceivably access might be ameliorated by other supporting factors, use of shared computer suites is not significantly higher, although IWB use *is* higher. An alternative interpretation is that teachers judge the support for ICT given by their school based mainly on the ease of use of IWBs, essentially equating ICT use with IWBs. Neither interpretation offers a particularly positive outlook on closing the quantitative gap in ICT use. Similarly, a supportive school context does not improve the use of mathematical analysis software neither does it decrease the reliance on more presentation-oriented software like *MyMaths* and PowerPoint. These findings serve to illustrate how aspects of the *working environment* (Ruthven 2009), such as classroom 'ownership' and organisation, interacting with features of local departmental culture (Stein et al. 2007), both enable and constrain teachers' use of technology and thus curriculum resources more generally.

It has been suggested that the success of IWBs lies in their teacher-centred design, since they allow teachers to incorporate ICT without disturbing well-established teaching practices. This study does nothing to disrupt this viewpoint, however it does offer a slightly more nuanced account. In general, teachers believe that giving students direct access to ICT through computer suites and using IWBs in a whole-class context support students' learning and understanding of mathematics to a similar extent (although the perceived impact of IWBs is higher perhaps due to the increased frequency of use). Likewise, teachers appear to see both classroom contexts as similarly engaging to students. However, teachers are more confident using IWBs than conducting a lesson in a computer suite, perhaps due in part to their teacher-centred design and to their high frequency of use. Again this reflects the influence of the working environment enabling teachers' use of IWBs, whilst limiting their use of computer suites, despite favourable orientations towards both types of hardware. More tellingly, perhaps, teachers perceive IWBs to make general pedagogic aspirations easier to attain: classroom management was seen to be significantly easier with IWBs than a lesson in a computer suite and teachers felt able to cover significantly more ground in lessons with an IWB than those in a computer suite. This finding supports the pace and productivity rationale for using ICT identified by Ruthven and Hennessy (2002) and also suggests the influence of *time economy* (Ruthven 2009) on teachers' use of technology. The positive effect of a supportive departmental culture (Stein et al. 2007) also appears to encourage more favourable individual orientations towards both IWB and computer suites. However in the case of computer suites, this positive effect is limited to enhancing enabling factors and does relatively little to effect what might be regarded as hindering factors to teachers' technology use (Zammit 1992).

This study uses survey data to extend the evidence for a qualitative gap in ICT use amongst mathematics teachers in England beyond that provided by case studies or intermediate studies such as Ruthven and Hennessey (2002). In particular, the survey offers some insight into teachers' pedagogic practices using ICT, although as it is based on self-report data, any inferences must be treated with caution. In the first instance, the dominance of presentation-oriented software in an IWB context and *MyMaths* in computer suite lessons may be taken as evidence for a qualitative gap in ICT use. This inference is, of course, problematic. Just as *interpretative flexibility* (Ruthven et al. 2008) implies that cognitive tools may be used in ways that deviate from those envisaged by their designers or advocated in mathematics education research, digital technologies often associated with replicating 'traditional' or teacher-centred practices, such as IWBs or presentational software like PowerPoint and *MyMaths*, may be interpreted and used by teachers in ways that run counter to this association, to support student-centred practices. Nevertheless, the frequent use of this type of software might suggest an additional obstacle to more student-centred practices. Whilst a strength of the theoretical perspective adopted in this study is the acknowledgement of teachers' sense-making of software, it is also important to temper this with an awareness that the software design is an important factor influencing the participatory relationship between teacher and software, as Stein et al. (2007) point out. Further evidence for a qualitative gap may be inferred from the data on teachers' self-reported pedagogic practices. Of the practices reported in both contexts, the most frequently occurring tended to be more teacher-centred and those with lowest frequency tended to be more student-centred. For example, using ICT for presentation purposes and maintaining teacher-control of the software were highest for using IWBs in a whole-class context, whereas using ICT to follow up and explore students' ideas and allowing students control of the software was lowest. For ICT lessons in computer suites, providing precise instructions for software use and using ICT to practice skills were the practices with the highest reported frequency, whilst using ICT to investigate mathematical problems and concepts was among the lowest. Drawing firm conclusions regarding teachers' pedagogic practices using ICT based on this data is problematic due to the reliance on self-report data, thus these findings should be investigated and validated through further research.

The Second Information Technology in Education Survey (SITES) concluded that, whilst ICT cannot be considered as a catalyst that will necessarily bring about change, given the right conditions, ICT might contribute as a lever for such changes (Law et al. 2008). The direction of this change is implied as a shift in teaching towards a focus on 'twenty-first century skills' associated with more student-centred practices. Roughly half the educational systems included in SITES maintained a similar pattern practices whether or not the teachers used ICT (Law et al. 2008, p. 146). The majority of systems where the pattern of practice was dissimilar showed a stronger 'twenty-first century' orientation in their teacher practices involving ICT. One exception was Hong Kong, which showed a slight increase in the tendency towards teacher-centred practices when using ICT. Cuban (1993) argues that reforms intent on shifting teaching towards student-centred practices tend at best to achieve incremental changes and only marginally reshape existing practices. In particular, Cuban (2001) argues that even if computing technology is taken up on a large-scale it is unlikely to fundamentally change teaching practice. Somewhere between these two viewpoints, Ruthven and Hennessy (2002, p. 85) suggest that as well as providing a 'lever' to make established practices more effective, technology also appears to act as a 'fulcrum' for some degree of reorientation of teachers' practice. The evidence from this survey pointing to a quantitative gap in ICT use, broadly concurs with Cuban's argument: computer use remains low in frequency and therefore at the margins of practice. In the case of IWBs, where technology has been adopted on a large-scale, its use appears to cohere with existing structures of whole-class teaching especially through the predominant use of presentation-oriented software. Coupling the dominance of the IWB in whole-class teaching and presentation-oriented software in both classroom contexts with the evidence of a qualitative gap in teaching practices with technology, this survey suggests that given the right conditions, at least those currently existing in England, ICT might indeed contribute as a lever for change. England did not participate in the SITES study, however in common with Hong Kong and in opposition to the majority of systems in the SITES study, the direction of this change might be construed as an incremental shift towards more teacher-centred practices.

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