

Should primary school children be 'calculator aware' or 'calculator beware'?

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Abstract

This literature review examines calculators in the primary school classroom in light of their recent prohibition for younger children in England.¹ Contrary to political fears about calculators being harmful, the existing literature indicates that calculators have many benefits: they can develop conceptual understanding, support and improve mental and written methods, be a stimulus for dialogic talk, provide instant feedback and help to develop key mathematical ideas such as 'number sense'. The ingrained nature of teacher attitudes, in particular relation to what skills they believe an effective mathematician requires, is explored and a link made between such attitudes and the potential use of calculators. Greater clarity is needed regarding what fundamental mathematical understanding actually entails and a long-term strategy needs to be in place in order for pre-service teachers' underlying beliefs to change.

Key Words

Calculators; beliefs; fundamentals; primary; number sense; mental; written; dialogic talk.

Introduction

The role of calculators has been the source of much debate since their introduction to classrooms in the 1970s. This debate is not confined to the UK; there is a wealth of international research regarding their use (Stacey and Groves, 1994; Banks, 2011; Bouck *et al.*, 2013). This literature review will highlight an apparently increasing dichotomy between empirical research and the status of calculators in the National Curriculum (Richardson, 2014).

In 1987, a working group was formed by the Government in order to make recommendations regarding the content of the new curriculum. One recommendation was to exclude attainment targets for written methods for division and multiplication (National Curriculum Mathematics Working Group, cited in Ruthven, 1998). However, Spooner (1996:42) notes that the Secretary of State made 'significant departures from the curriculum envisaged by the working group'. These included alerting teachers to the 'risks' posed by calculators and giving greater emphasis to written methods of calculations. A year later, the Secretary of State for the new Labour government explained that children should be encouraged to calculate mentally *as opposed to* via a calculator.

According to research in the classroom, calculators have been found to actually help develop conceptual understanding (Forrester, 2003; Ruthven, 2009). However, a common perception is that the use of calculators is actually at odds with the acquisition of "key" mathematical skills (Norton, *et al.*, 2000; Sweeney, 2004). Bright, *et al.* (1992) suggest that the manner in which calculators are used

¹ 'Calculator aware' is in reference to the Calculator Aware Number project (Shuard, *et al.*, 1991): 'Calculator beware' references Ruthven (1998:23).

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in everyday situations is different to how they are used in the classroom and that this might contribute to these perceptions.

This blurring of the boundaries between rhetoric and research has been brought more sharply into focus with the introduction of the new National Curriculum in England (2013:3-4), which contains significant implications for the use of calculators in primary schools.

Calculators should not be used as a substitute for good written and mental arithmetic. They should therefore only be introduced near the end of key stage 2 to support pupils' conceptual understanding and exploration of more complex number problems, if written and mental arithmetic are secure.

In December 2012, perhaps reflecting these changes, the UK coalition government banned the use of calculators in maths tests for 11-year-olds (DfE, 2012). Via a Department of Education and Skills (DfE) press release, Elizabeth Truss (former Education and Childcare Minister) warned that children were using calculators 'too much, too soon' (DfE, 2012:1) and thus they were, 'not getting the rigorous grounding in mental and written arithmetic they needed to progress' (*ibid.*), indicating that the 'wariness of calculators' highlighted by Ruthven (1998:23) is still prevalent in the English education system.

Massachusetts and Hong Kong were cited as examples of successful curricula that do not over-rely on calculators (DfE, 2012:1). However, according to the TIMMS 2007 (no comparative data from the 2011 study is available), the use of calculators by fourth grade students from Hong Kong is actually *increasing*. The Massachusetts Curriculum (Massachusetts Department of Elementary and Secondary Education, 2011:10) states that calculators *can* contribute to a, 'rich learning environment'.

The Review Process

A literature search was undertaken using a University's electronic catalogue using the search terms 'calculators' and 'mathematics'. Though the focus was on primary schools, the reason that 'primary' was not included in the literature search was that this might have excluded a number of US studies.

Further criteria for filtering documents included:

1. Studies written in English.
2. Studies undertaken after 1986.
3. Studies from the discipline of "education" and "mathematics".

Criterion two was created so that the literature could be reviewed in the light of the creation of the National Curriculum in England. Criterion three was to help narrow the search and ensure that irrelevant publications were ignored. Using the above criteria, 511 articles were identified. These abstracts were then scrutinised with the most relevant to ITE included in the final review.

An initial review of the research indicated that there were a number of documents that had been cited across multiple texts that were not identified by the initial search. Thus a snowballing method of research was employed to ensure that these texts formed part of the final review. The objective was to conduct a descriptive review in order to ascertain the key themes with regard to calculators and the associated implications for ITE.

Findings of the Review

Teacher Education

The role of Teacher Education for pre-service and in-service teachers is an ongoing topic of discussion. Existing philosophies of teaching have a significant impact on whether calculators are used and there is much debate over how and to what extent training can alter such beliefs.

Many studies have been undertaken into whether training can have an impact on the use of calculators in the classroom. In Laumakis and Herman's (2007) study, 17 Florida teachers were given in-service training regarding graphing calculators. The researchers found significant increases in the Florida Comprehensive Assessment Test (FCAT) scores amongst the 360 students who were taught by teachers who had received the training, compared to the 209 who were not. Interestingly, the graphing calculator is not permitted on the FCAT (though a basic calculator is), yet gains were still made, perhaps due to the improvements in conceptual understanding initiated by the use of graphing calculators (Ellington, 2003). Bitter and Hatfield (1992) and Burke (2001) also point to teacher training as being key. Sweeney (2004:205) advocates teacher workshops as being the, 'best way to learn', though does not refer to primary research evidence that supports this claim.

When reviewing the Calculators in Primary Maths (CPM) project, an Australian longitudinal study involving over 1000 Kindergarten and Year 1 children, Stacey and Groves (1994) found that teachers' attitudes towards calculators were broadly positive yet they were rarely used in practice. Walen, *et al.* (2003) found that pre-service teachers would readily engage with calculators in order to solve a problem presented to them; however, they were reticent to use it as a *teaching* tool, seeing it more as a *doing* tool. The authors explain this dichotomy by suggesting that teachers saw their own task as different to the pupils' task, thus the calculator was useful in one context but not so in another.

The existence of a teacher's underlying beliefs is thought to have an impact on their propensity to use calculators to teach (Stigler and Hiebert, 1999; Johnson, 2008). In a study of 210 American pre-service teachers, Johnson (2008) found that 49% linked their current views about calculators to their own mathematics education. In a two-year study, Struyk and Cangelosi (1993) found that three one-day workshops had no impact on teachers' propensity to use calculators, perhaps as a result of their underlying beliefs.

Tharp, *et al.* (1997) found that five monthly, three-hour training sessions, coupled with teachers keeping reflective journals, had some impact on teachers' views on calculators. However, this impact was mainly on teachers who viewed mathematics as an opportunity to solve problems and make generalisations; those who conceived mathematics as a rule-based subject were much less likely to incorporate calculators into their practice. Tharp, *et al.* (*ibid*: 559) speculated that 'it was easier for these teachers to try a new teaching tool than it was for them to change their conceptualization of the nature of mathematics.'

Shuard, *et al.* (1991) found that, initially, the teachers involved in the Calculator Aware Number Project (CAN), a project that ran from 1986 to 1992 and involved 15 primary schools based in England and Wales, found it difficult to "invent" a new curriculum (Shuard, *et al.*, 1991). However, as the project progressed, both researchers and teachers recognised that teachers were listening more carefully to children's conversations and using this information to help them not only develop new activities but to develop new philosophies of mathematics teaching (Ruthven, *et al.*, 1997). Similarly, in a case study, Hodgen and Askew (2007) identified shifts in a teacher's mathematical thinking as a result of 20 days of professional development over a three-year period. In common is the longevity of these two schemes, which could explain why the findings were different to those of Tharp, *et al.* (1997).

However, many believe the relationship between teacher training and improved teacher performance to be less than straightforward. Zhao and Frank (2003:832) are more sceptical about the impact of in-service teacher training. Their view is that teachers are 'socialised' by other colleagues into using new technology but that such a process is a 'double-edged sword' in respect of the fact that colleagues can be supportive of the implementation of new technologies; however, equally, they could be obstructive of it. It has been felt that teachers' underlying philosophies (Simmt, 1997; Tharp, *et al.* 1997) have a far more profound impact on teaching than teacher training. Stigler and Hiebert (1999) suggested that philosophies are particularly rigid in teaching due to the complexity of the teaching system and there are suggestions that these issues are amplified in the subject of mathematics (Hodgen and Askew, 1997).

Kagan (1992) recognised that teacher beliefs are, in the main, tacit, and that teachers rely on their own accumulated experience, rather than consulting empirical research. Kagan (*ibid*: 76) also notes that, even during teacher training, 'personal beliefs are resistant to change.' Johnson (2008) found that opportunities for discussion were of great importance in altering participants' beliefs, even for those who were part of a control group and therefore not involved in the teacher-led intervention. The belief that teachers are more greatly influenced by their teaching practice colleagues than University tutors (Kagan, 1992) could have implications for ITE training, although this does contrast with the findings of Laumakis and Herman (2007).

After interviewing 8 Australian education graduates, Frid and Sparrow (2009:50) claimed that it was possible to 'break the cycle of tradition', stating that the construction of University portfolios was key to this end. The graduates cited the importance of their lecturers (which included Frid and Sparrow themselves) in developing effective mathematics pedagogy, which contrasts with the views of Kagan (1992).

Given the above, it seems that a longer-term view is required if teachers' philosophies are to be changed (though Laumakis and Herman (2007) found that there were gains for trainees after in-service training, it is not known whether these gains were experienced by subsequent cohorts). There might be a greater possibility of such beliefs being altered during ITE before teaching experience is accumulated (Kagan, 1992), although because such beliefs are already in place, this is unlikely to be a straightforward process (Johnson, 2008).

Such a process would most likely involve discussion and collaboration, which has been a feature of successful studies (Shuard, *et al.*, 1991; Johnson, 2008). Trainee teachers must be given opportunities over an extended period of time to discuss and reflect on calculator activities that can be used to increase pupils' mathematical understanding. However, there is evidence to suggest that both teachers' existing mathematical beliefs (Tharp, *et al.*, 1997) and the relationships between participants will have an impact on what is gleaned from the discussions, although there are contrasting views regarding who shapes trainee teachers' beliefs and to what extent (Kagan, 1992; Frid and Sparrow, 2009).

Conceptual Understanding

According to international studies, English pupils' ability to apply and reason is declining (Askew, *et al.*, 2010). This is highly significant because conceptual understanding is identified in the three overarching aims of the National Curriculum (2013) and many studies have recognised that calculators can help to develop it. However, the way in which calculators are used in practice often prohibits their effectiveness.

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Smith (1997, cited in Polly, 2008) recognised that calculators improved conceptual understanding, similar to Borba and Selva (2005, cited in Borba and Selva, 2013) who theorised that different representations were helpful, the calculator being one such example. Sparrow and Swan (2005) draw an analogy with the use of Base-ten materials in schools to explain that calculators help pupils understand mathematics in the same way as a resource or manipulative might. The importance of mathematical resources in developing understanding has been noted by many (Bottle, 2005; Drews, 2007; National Curriculum, 2013).

These theories are underpinned by Bruner's (1961) notion of 'discovery learning', which advocates the use of concrete and iconic representations to aid abstract understanding. Importantly, Bruner (*ibid.*) theorised that children "translated" between different stages of cognitive development, which is in opposition to the fears that calculators might be introduced "too early" as mentioned above. Heid (1997) suggests that calculators can actually be used to create initial conceptual understanding and that this can later benefit pupils' abstract understanding. For example, with regard to word problems, pupils need to explicitly understand which operation is required in order to program a calculator accurately; in contrast to mental calculation where answers can be calculated without such explicit knowledge (Ruthven, 1992; Stacey and Groves, 1994). Duffin (1997) noted that it would be very difficult to solve a complex word problem without knowing which key to press.

The potential use of calculators across multiple areas of the curriculum is significant because they can therefore be used more frequently; this is seen as an important consideration because pupils will increase their understanding of their underlying structures (Forrester, 2003; Wittman, cited in Delaney, 2001a). In addition, this will support children in making connections between different curriculum areas; connections such as this are believed to be highly significant in terms of successful mathematics teaching (Delaney, 2001b; Askew, 2010).

Another reason given for calculators improving conceptual understanding is that they reduce time spent on computation, thus freeing up more time to develop knowledge of deeper mathematical concepts (Forrester 2003; Polly, 2008; Har, 2010). For example, algebraic functions can be displayed on graphing calculators and, critically, the outcome of changing a variable is quickly known (Forrester, 2003; Margaritis, 2003). This means that more time can be spent on developing higher-order thinking skills as less time will be devoted to copying out such graphs by hand (Polly, 2008).

Despite this, researchers have often found that calculators are mainly used for computation and the checking of calculations (Burke, 2001, Adabor, 2008). Ofsted (1993:11) remarked that calculators were 'neglected', this in reference to a previous curriculum that was more encouraging towards calculators. Initially, Shuard, *et al.* (1991) found that calculators were predominantly used for checking; however, as the project continued, teachers were increasingly seeing them as a tool that could be used to investigate mathematical concepts and ideas.

There is strong evidence to suggest that calculators can play a role in developing conceptual understanding and making connections (Duffin, 1997; Heid, 1997; Polly, 2008) but the prohibition of calculators for children of Year 4 and younger may make it harder for trainee teachers to see the benefits of them, particularly, as discussed earlier, if *they* see the calculator as a doing tool rather than as a teaching tool (Walen, *et al.*, 2003) and thus mainly use them for computation and checking (Burke, 2001; Adabor, 2008).

Mental and Written Calculation

Within the DfE press release referred to earlier, it was stated that: 'a clear signal is being given to increase the focus on ensuring every child can perform the relevant written methods for the core

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number operations' (DfE, 2012:1). Part of the rationale for delaying the introduction of calculators was to ensure that pupils were, 'secure in written and mental arithmetic' before using them (DfE, 2012:1). However, contrary to this belief, much evidence exists to suggest that calculators are actually quite supportive of children's mental and written strategies.

When written methods have been taught alongside calculators, calculators have been found to not adversely affect their acquisition. Close, *et al.* (2012) found there was no correlation between calculator usage and performance in either the PISA or TIMSS tests during the 21st century. In a meta-analysis of 58 studies, Ellington (2003) found that written calculation skills were actually enhanced when calculators were used for testing purposes, although this could potentially be an example of teachers teaching to the test. Other authors have found that testing can have a significant impact on teaching content (Willoughby and Weinberg, 1991; Li and Ma, 2011). Ruthven (1998) found that there were significant changes in teaching approaches in CAN-schools after the introduction of SATs.

Shuard, *et al.* (1991) found that the CAN project children were actually *more* likely to use mental methods to solve problems, seeing it as a challenge. Ruthven (1998:40) suggested that this might occur because they had explicitly been taught mental methods whereas non-CAN children saw 'mental calculation as something to be done quickly or abandoned'; this also led to an improved attitude (Ruthven, *et al.*, 1997). The researchers involved in the CPM project made similar findings; children familiar with calculators were better at mental computation (Stacey and Groves, 1994). The implications of this are to emphasise to trainees that when calculators are used the intention is not to replace mental and written methods, something that tends to be a concern (DfE, 2012). To do so it is essential that trainees undertake activities involving calculators, perhaps similar to those that were used successfully on the CAN project which highlight how calculators can be used to develop key mathematical skills.

The 'fundamentals' of mathematics

Another key theme in the literature is the impact that calculators have on the fundamentals of mathematics. Again, there appears to be a contrast between the views of the government and research. However, arguably of greater importance is what knowledge is actually "fundamental" to mathematical understanding. A longitudinal study conducted by Nunes, *et al.* (2009) suggests that the ability to reason mathematically has the greatest impact on mathematical achievement. According to the first aim of the National Curriculum (2013:3), the rationale for children becoming, 'fluent in the fundamentals of mathematics,' is to, 'develop conceptual understanding and the ability to recall and apply knowledge rapidly and accurately.' However, the DfE (2012:1) states that 'we must get the order right'. These views seem almost Piagetian in that a child must "complete" one stage before moving onto another.

Indeed, a common theme amongst teachers is that calculators should only be used *after* understanding of concepts and skills have been established. In his study of 160 Ghanaian teachers, Adabor (2008) found that 80% of them held this view. Groves and Stacey (1998:123) recognised that the teachers who were less comfortable with calculators were concerned about pupils encountering certain concepts 'before they are ready.' In their interviews with Australian High-School teachers, Norton, *et al.* (2000:104) recognised that some believed the use of technology could inhibit the acquisition of 'basic skills and procedures.'

However, it is open to interpretation what the 'fundamentals' actually are. Sweeney (2004) found that the overriding negative concern about calculators amongst parents (32 of the 34 questioned) was that children would not learn 'the basics'. Some parents referred to the four operations, though

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many others were non-specific about what constituted “the basics”. The DfE (2012) refer to times tables and written methods for the four operations as constituting ‘the basics’. However, many theorists view ‘number sense’ as being key to mathematical understanding (Groves, 1994; Hedren, 1999; Forrester, 2003); indeed, Groves and Stacey (1998:120) feel there is, ‘no need to debate’ its importance; all of the authors cited above feel that calculators can help foster it. Similar to ‘the basics’ there does not appear to be a universal definition of ‘number sense’. Sengul (2013), based on a review of number sense literature, explains that it incorporates: an understanding of the size of numbers, an understanding of the meaning of operations, an understanding of equivalence, flexible calculation strategies and measurement benchmarks.

With reference to the ‘size of numbers’ mentioned above, one of the most significant gains from using calculators could be children’s access to large numbers. Shuard, *et al.* (1991) provide examples of nine-year-old pupils confidently discussing numbers beyond one million and explain that access to such numbers using alternative resources, e.g. cubes, would be impractical, if not impossible. Both Shuard, *et al.* (*ibid.*) and Duffin (1997) explain how the constant function can be used to investigate larger numbers and that this can lead to conjecture and generalisations about the number system, an aim explicitly outlined within the new National Curriculum (2013). Groves and Stacey (1998) made similar findings, adding that Kindergarten children could gain an understanding of negative and decimal numbers too.

Trainees should be given opportunities to engage with activities that help them to appreciate the contribution that calculators can make to developing number sense. Comparisons with other mathematical resources are important to help reposition the calculator as a tool to support learning, rather than a tool to replace it. However, there are disagreements regarding what “the fundamentals” of mathematics actually are. Without a consensus, it is harder for ITE (Initial Teacher Education) providers to crystallise to trainees what is at the core of mathematical understanding and thus the potential role of the calculator in facilitating it.

Talk and Feedback

Mathematical resources are known to be a stimulus for talk (Bottle, 2005) and research suggests that calculators are no different; indeed, their unique ability to issue feedback may have additional benefits in terms of talk. Their potential role in formalising informal thinking may enable mathematical connections to be made, the importance of which has been noted earlier. Calculators issue immediate feedback, which is helpful in allowing children to explore mathematical ideas independently, which, in turn, may help to build resilience (Margaritis, 2003). Familiarity with calculators has been found to lead to improved attitudes towards them (Close, *et al.*, 2012) but also towards mathematics as a whole (Brown, *et al.*, 2007). Forrester (2003:9) makes the link explicit: ‘There is no need to wait for the teacher to come along with a red pen ... This type of activity helps to build confidence as mistakes can be made in private and corrected.’

McNamara (1995) researched the effectiveness of calculators in helping pupils to learn multiplication facts. She refers to the benefits of the immediate feedback that calculators can provide but remarks that this may lead to children failing to undertake self-correction. However, many would argue that children are actually *more* likely to correct their work independently if the feedback from the calculator indicates that they need to (Shuard, *et al.*, 1991; Forrester, 2003; Margaritis, 2003).

Heid (1997) suggests that technology can help externalise representations that had previously been internalised, enabling dialogic talk (Harre, cited in Ernest, 1998). This can help pupils to overcome the ‘mismatch between the informal concepts of students and the formal ‘language of the

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calculator.' (Ruthven, 1992:94). Ernest (1998) adds that writing and recording can extend what has been orally communicated, supporting the view that recording calculations is important when using a calculator (Ruthven, 1998). Duffin (1997:137) views the calculator as a 'bridge' that can link mental calculation to written recording.

Graphing calculators are able to record multi-step calculations which may make them an even better stimulus for discussion and dialogic talk than simple calculators (Harre, cited in Ernest, 1998). This might also help to allay the fear that calculators could inhibit self-correction (McNamara, 1995). The existence of dialogic talk can help to address what some term cognitive conflict (Sparrow and Swan, 2005). McNamara (1995:308) recognised that, 'If they [children] generate incorrect answers, these answers exist at some strength and compete with the correct answer.' This emphasises the importance of a teacher's role in guiding group discussion to help children develop reasoning skills (Thompson, 1997). As mentioned earlier, the ability to reason is thought to be a key indicator of mathematical success (Nunes, *et al.*, 2009).

Training teachers how to use graphing calculators is recommended as, if they can be used in areas such as Geometry and Statistics, this will increase pupils' familiarity with them; the benefits of which were discussed earlier. For example, LOGO could be used to help children reconceptualise geometric ideas, thereby helping them to improve their level of geometric thinking (van Hiele, 1986; Karakirik and Durmus, 2005). A calculator is by no means the only vehicle via which geometric thinking can be explored but the instant feedback, coupled with the ability to change variables quickly, make it a very efficient resource for doing so.

Conclusion

With regard to calculators in ITE, collaboration is seen to have a key role. It has been suggested that the complex nature of the teaching system (Stigler and Hiebert, 1999) makes fundamental change very difficult, which might explain why short-term training programmes have been found to have little impact (Struyk and Cangelosi, 1993; Simmt, 1997). However, as identified by Frid and Sparrow (2009), it does seem possible that the philosophies of pre-service teachers *can* be changed. Lesson Study could be one such vehicle because it involves collaboration and is known to engender changes in philosophical beliefs about how children learn (Lewis, 2002). There is a growing interest in Lesson Study in the UK for pre-service teachers (Cajkler, *et al.*, 2013; Cajkler, *et al.*, 2014) but findings indicate that although this has been successful in terms of changing pedagogy, there is less evidence that it has led to changes in teaching philosophy. This may be due to Lesson Study being implemented differently in the UK (Cajkler, *et al.*, 2013).

Underlying philosophies are critical for calculators because there is evidence to suggest that those who view mathematics as rule-based are less likely to integrate calculators into their classroom practice and, conversely, those who view mathematical enquiry as a key part of learning are more likely to advocate the use of calculators (Simmt, 1997; Sharp, *et al.*, 1997). It follows that the views of ITE tutors and lecturers will have a significant impact on whether calculators are integrated into teacher training or not and thus trainees are likely to have significantly differing experiences according to which institution they attend.

In addition, there seems to be a political fear that calculators may harm the acquisition of mathematical knowledge if they are introduced too soon (DfE, 2012). However, this view is at odds with long-term studies into calculators, which have indicated mainly positive relationships between both calculators and mental methods (Shuard, *et al.* 1991; Groves and Stacey, 1998) and calculators and written methods (Ellington, 2003). As discussed earlier, teachers' views of calculators changed over an extended period of time. This may be difficult for ITE providers to address because of the

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periods of time required, particularly when one considers that the PGCE route takes only one year to complete. The stipulation that calculators cannot be used by children younger than Year 5 may also add to the negativity regarding calculators. More research may need to be undertaken into what trainees' views on calculators actually are when they enter ITE so providers have a better understanding of how to address them.

Concerns regarding calculators often centre around "the basics". However, long-term studies have indicated that the reverse may be true; calculators can actually help to *promote* fundamental knowledge such as number sense (Shuard., *et al.* 1991; Groves and Stacey, 1998). In addition, calculators can help develop mathematical reasoning skills. Nevertheless, there is still ambiguity and confusion about what does constitute fundamental mathematical knowledge (Groves and Stacey, 1998; DfE, 2012). Here, ITE providers can play a leading role in establishing greater consensus, which will hopefully have an impact on future curriculum changes.

A common belief is that the calculator reduces time spent on computation; the payoff being that greater amounts of time can be spent on developing deeper understanding of mathematical ideas (Forrester, 2003; Polly, 2008). However, an obstacle to overcome is that the everyday use of a calculator is often for routine computations, making it difficult to convince people that calculators can stimulate mathematical thinking (Bright, *et al.*, 1992). In the short term, giving trainees opportunities to engage in calculator activities should help them to understand the benefits of them. Longer term, research should be undertaken into which activities may provide greatest benefits; again though, this will require greater agreement about what constitutes fundamental mathematical understanding.

Given the existing literature, and despite it pointing overwhelmingly in favour of calculators, it seems plausible that calculator use will diminish as a result of them being prohibited in the SATs (tests conducted at the end of a child's primary school education in England). There is a strong belief that standardised testing has a substantial bearing on lesson content (Willoughby and Weinberg, 1991; Ellington, 2003) and thus reinstating a calculator paper could be a short-term solution. However, greater evidence may be required in order to embed their presence in primary schools. The aims of the new curriculum may provide such an opportunity. If more evidence can be gathered that indicates calculators can be used to create conceptual understanding then, potentially, the prohibition of calculators for younger children could be reversed.

Of arguably even more fundamental importance is greater consensus with regard to what skills are fundamental for an effective mathematician; a consensus that should be based on robust research rather than political posturing. Then, it may be possible to reframe and clarify attitudes so calculators become known as a tool for problem solving and developing conceptual understanding; a resource that will *augment* rather than *replace* mental and written methods.

References

- Adabor, J.K. (2008) *An investigation into elementary school teachers' and high school mathematics teachers' attitudes towards the use of calculators in mathematics instruction and learning: A study of selected schools in Ghana*. Doctor of Philosophy: College of Education of Ohio University.
- Askew, M. (2010) 'It ain't (just) what you do: effective teachers of numeracy', in Thompson, I. (ed.) *Issues in Teaching Numeracy in Primary Schools* (2nd ed.). Maidenhead: Open University Press. pp. 31-44.
- Askew, M., Hodgen, J., Hossain, S. and Bretscher, N. (2010) *Values and Variables: Mathematics education in high-performing countries*. London: Nuffield Foundation.

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- Banks, S.A. (2011) *A Historical Analysis of Attitudes toward the Use of Calculators in Junior High and High School Math Classrooms in the United States since 1975*. Masters of Education. Cedarville University.
- Bitter, G. G. and Hatfield, M. M. (1992) 'Training Elementary Mathematics Using Interactive Multimedia', *Educational Studies in Mathematics*, 26, pp. 405-49.
- Borba, R. and Selva, A., (2013) 'Analysis of the role of the calculator in Brazilian textbooks', *ZDM*, 45(5), pp. 737-750.
- Bottle, G. (2005) *Teaching Mathematics in the Primary School*. London: Continuum.
- Bouck, E., Joshi, G. and Johnson, L. (2013) 'Examining calculator use among students with and without disabilities educated with different mathematical curricula', *Educational Studies in Mathematics*, 83(3), pp. 369-385.
- Brown, E. T., Karp, K., Petrosko, J. M., Jones, J., Beswick, G., Howe, C. & Zwagnig, K. (2007) 'Crutch or Catalyst: Teachers' Beliefs and Practices Regarding Calculator Use in Mathematics Instruction', *School Science and Mathematics*, 107(3), pp. 102-116.
- Bright, G., Lamphere, P. and Usnick, V. (1992) 'Statewide In-Service Programs on Calculators in Mathematics Teaching', in Fey, J. and Hirsch, C. (eds.) *Calculators in Mathematics Education*. NCTM: USA. pp. 217-226.
- Bruner, J.S. (1961) 'The Act of Discovery', *Harvard Educational Review*, 31, pp. 21-23.
- Burke, G. (2001) *Computers and Calculators in Schools: A Status Report*. Mississippi State University.
- Cajkler, W., Wood, P., Norton, J. and Pedder, D. (2013) 'Lesson Study: Towards a collaborative approach to learning in Initial Teacher Education', *Cambridge Journal of Education*, 43(4), pp. 537-554.
- Cajkler, W., Wood, P., Norton, J. and Pedder, D. (2014) 'Lesson Study as a vehicle for collaborative teaching in a secondary school', *Professional Development in Education*, 40(4), pp. 511-529.
- Close, S., Oldham, E., Shiel, G., Dooley, T. and O'Leary, M. (2012) 'Effects of Calculators on Mathematics Achievement and Attitudes of Ninth-Grade Students', *Journal of Educational Research*, 105(6), pp. 377-390.
- Delaney, K. (2001a) 'Teaching mathematics resourcefully', in Gates, P. (ed.) *Issues in mathematics teaching*. London: Routledge Falmer. pp. 123-145.
- Delaney, K. (2001b) 'Making Connections', in Thompson, I. (ed.) *Issues in Teaching Numeracy in Primary Schools*. 2nd ed. Open University Press, Maidenhead. pp. 72-83.
- DfE (2012) 'Government bans calculators in tests for 11 year olds' *Department for Education*. Available at: <https://www.gov.uk/government/news/government-bans-calculators-in-tests-for-11-year-olds> (Accessed: 8 July 2014).
- Drews, D. (2007) 'Do resources matter in primary mathematics teaching and learning?', in Drews, D. and Hansen, A. (eds.) *Using resources to support mathematical thinking*. Exeter, Devon: Learning Matters Ltd.
- Duffin, J. (1997) 'The role of calculators', in Thompson, I. (ed.) *Teaching and learning early number*, Buckingham: Open University Press. pp. 133-141.
- Ellington, A. (2003) 'A meta-analysis on the effects of calculators on students' achievement', *Journal for Research in Mathematics Education*, 34(5), pp. 433-463.
- Ernest, P. (1998) *Social Constructivism as a Philosophy of Mathematics*. State University of New York Press: Albany.
- Forrester, R. (2003) 'It's Not Calculators But How They Are Used', in Way, J. and Beardon, T. (eds.) *ICT and Primary Mathematics*. Buckingham: Open University Press. pp. 7-28.
- Frid, S. and Sparrow, L. (2009) "'You just have to take a bit of a risk sometimes": Breaking the 'Cycle of Tradition' in Primary Mathematics', *Mathematics Teacher Education & Development*, 11, pp. 36-53.
- Groves, S. (1994) 'Calculators: A Learning Environment To Promote Number Sense' *Annual Meeting of the American Educational Research Association*. New Orleans, LA, April 5-8 1994.

BOORMAN: SHOULD PRIMARY SCHOOL CHILDREN BE 'CALCULATOR AWARE' OR 'CALCULATOR BEWARE'?

- Groves, S. and Stacey, K. (1998) 'Calculators in Primary Mathematics: Exploring Number before Teaching Algorithms', in Morrow, L and Kenny, M. (eds.) *The teaching and learning of algorithms in school mathematics*. Reston, VA: National Council of Teachers of Mathematics, pp. 120-129.
- Har, Y. B. (2010) 'Improving Mathematical Understanding Through Assessment', *Journal of Science and Mathematics Education in Southeast Asia*, 33(2), pp. 187-197.
- Hedren, R. (1999) 'The teaching of traditional standard algorithms for the four arithmetic operations versus the use of pupils' own methods', in Schwank, I. (ed.) *European Research in Mathematics Education 1*. Osnabruck: Forschungsinstitut fur Mathematikdidaktik. pp. 233-244.
- Heid, K. (1997) 'The Technological Revolution and the Reform of High School Mathematics', *American Journal of Education*, 106, pp. 5-61.
- Hodgen, J. and Askew, M. (2007) 'Emotion, identity and teacher learning: becoming a primary mathematics teacher', *Oxford Review of Education*, 33(4), pp. 469-487.
<http://dx.doi.org/10.1080/03054980701451090> (Accessed 22 June 2015).
- Johnson (2008) 'Preservice Elementary School Teachers' Beliefs Related to Technology Use in Mathematics Classes', *2008 International conference of the Society for Information Technology and Teacher Education*. Available at: <http://files.eric.ed.gov/fulltext/ED501223.pdf> (Accessed 13 May 2015).
- Kagan, D. M. (1992) 'Implications of research on teacher belief', *Educational Psychologist*, 27(1), pp. 65-90.
- Karakirik, E. and Durmus, S. (2005) 'An alternative approach to Logo-based geometry', *The Turkish Online Journal of Educational Technology*, 4(1), pp. 3-16.
- Laumakis, P and Herman, M. (2007) 'The Effect of a Calculator Training Workshop for High School Teachers on their Students' Performance', *International Journal for Technology in Mathematics Education*, 15(3), pp. 87-93.
- Lewis, D. (2002) 'Does lesson study have a future in the United States?', *Nagoya Journal of Education and Human Development*, 1, pp. 1-23.
- Li, Q. and Ma, X. (2011) 'A Meta-Analysis of the Effects of Computer Technology on School Students' Mathematics Learning', *Educational Psychology Review*, 22, pp. 215-243.
- Margaritis, A. (2003) 'Using Calculators in the Montessori Middle School Classroom', *Montessori Life*, Spring 2003, pp. 42-43.
- Massachusetts Department of Elementary and Secondary Education (2011) 'Massachusetts Curriculum Framework for Mathematics', Available at: <http://www.doe.mass.edu/frameworks/math/0311.pdf> (Accessed: 9 July 2014).
- McNamara, D. (1995) 'Effects of Prior Knowledge on the Generation Advantage: Calculators Versus Calculation to Learn Simple Multiplication', *Journal of Educational Psychology*, 87(2), pp. 307-318.
- National Curriculum (2013) 'National Curriculum in England: Mathematics Programme of Study', *The National Curriculum for England: Key Stages 1-4*. Department for Education. Available at: <https://www.gov.uk/government/collections/national-curriculum> (Accessed: 9 July 2014).
- Norton, S., McRobbie, C. J. and Cooper, T. J. (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), pp. 87-109.
- Nunes, T., Bryant, P., Sylva, K. and Barros, R. (2009) *Development of Maths Capabilities and Confidence in Primary School*. London: Department for Children, Schools and Families.
- Ofsted (1993) *The Teaching and Learning of Number in Primary School*. London: Ofsted.
- Polly, D. (2008) 'Modeling the Influence of Calculator Use and Teacher Effects on First Grade Students' Mathematics Achievement', *Journal of Computers in Mathematics and Science Teaching*, 27(3), pp. 245-263.

BOORMAN: SHOULD PRIMARY SCHOOL CHILDREN BE 'CALCULATOR AWARE' OR 'CALCULATOR BEWARE'?

- Richardson, G. (2014) 'Calculators – Challenging the rhetoric', *Association of Teachers of Mathematics*, 238, pp. 6-8.
- Ruthven, K. (2009) 'Towards a calculator-aware number curriculum', *Mediterranean Journal for Research in Mathematics Education*, 8(1), pp. 1-14.
- Ruthven, K. (1998) 'The use of Mental, Written and Calculator Strategies of Numerical Computation by Upper Primary Pupils within a 'calculator-aware' Number Curriculum', *British Educational Research Journal*, 24(1), pp. 21-42.
- Ruthven, K. (1992) 'Personal Technology and Classroom change: A British Perspective', in Fey, J. and Hirsch, C. (eds.) *Calculators in Mathematics Education*. NCTM: USA. pp. 91-100.
- Ruthven, K., Rousham, L. and Chaplin, D. (1997) 'The Long-Term Influence of a "Calculator-Aware" Number Curriculum on Pupils' Mathematical Attainments and Attitudes in the Primary Phase', *Research Papers in Education: Policy and Practice*, 12(3), pp. 249-281.
- Sengul, S. (2013) 'Identification of Number Sense Strategies used by Pre-service Elementary Teachers', *Educational Sciences: Theory & Practice*, 13(3), pp. 1965-1974.
- Shuard, H., Walsh, A., Goodwin, J. & Worcester, V. (1991) *Calculators, Children and Mathematics*. London, UK: Simon & Schuster.
- Simmt, E. (1997) 'Graphing calculators in high school', *Journal of Computers in Mathematics and Science Teaching*, 16, pp. 269-289.
- Sparrow, L. and Swan, P. (2005) 'Decimals, Denominators, Demons, Calculators, and Connections', *Australian Primary Mathematics Classroom*, 10(3), pp. 21-26.
- Spooner, M. (1996) 'Mathematics in the National Curriculum', in Coulby, D. and Ward, S. (eds.) *The Primary core national curriculum: policy into practice* (2nd ed.). Cassell Education: London. pp. 38-52.
- Stacey, K. and Groves, S. (1994) 'Calculators in Primary Mathematics', *Annual Meeting of the National Council of Teachers of Mathematics*. 72nd, Indianapolis, IN, April 1994. Available at: <http://files.eric.ed.gov/fulltext/ED373963.pdf> (Accessed: 14 May 2015).
- Stigler, J. W. and Hiebert, J. (1999) *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom*. New York, NY: Simon and Schuster.
- Struyk, L. and Cangelosi, J. S. (1993) 'The Impact of a Calculator-Based Mathematics-Teaching In-Service Program for Elementary School Teachers', *Annual Meeting of the American Educational Research Association*. Atlanta, April 1993.
- Sweeney, S. (2004) *Attitudes and beliefs of parents of middle school children about calculators in school mathematics*. Doctor of Philosophy. The Ohio State University.
- Tharp, M. L., Fitzsimmons, J. A. and Ayers, R. A. B. (1997) 'Negotiating a technological shift: Teacher perception of the implementation of graphing calculators', *Journal of Computers in Mathematics and Science Teaching*, 16, pp. 551-575.
- Thompson, I. (1997) 'Mental and written algorithms: can the gap be bridged?', in Thompson, I. (ed.) *Teaching and learning early number*. Buckingham: Open University Press. pp. 97-110.
- Van Hiele, P. M. (1986) *Structure and Insight: A Theory of Mathematics Education*. Orlando: Academic Press.
- Walen, S.B., Williams, S.R. and Garner, B.E. (2003) 'Pre-service teachers learning mathematics using calculators: a failure to connect current and future practice', *Teaching and Teacher Education*, 19, pp. 445-462.
- Willoughby, S.S. and Weinberg, S.L. (1991) *K-6 Supplementary Mathematics Materials for a Technological Society: Final Project Report*.
- Zhao, Y. and Frank, K. (2003) 'Factors Affecting Technology Use: An Ecological Perspective', *American Educational Research Journal*, 40(4), pp. 807-840.