Digital technology and secondary mathematics in England: Have we really moved on from Cockcroft's vision in 1982?

Alison Parish

University of Warwick

What happened to the 1980s vision where computers would be an integral part of teaching of secondary mathematics? The Cockcroft Committee referred to computers providing opportunities for enhancement of teachers' existing practice and to work in new ways that had not been possible before (1982, p.117) while pointing out that there was under-use of technology in schools and lack of good quality mathematics software. Her Majesty's Inspectors (HMI's) investigated the use of calculators as a replacement for mathematical tables suggesting that their use in examination courses was not widespread, which some interpreted as no calculators to be used during the course. Comments about under-use are still highlighted in numerous reports, including the National Centre for Excellence in Teaching Mathematics (NCETM) 37 years later. What is restricting digital technology use in secondary school mathematics? This article considers some of the reasons for lack of progress towards the vision of the 1980s.

Keywords: digital technology; constraints; teachers; secondary schools; innovative diffusion model; technology acceptance model

Early 1980s visions of the future

The Cockcroft Report (1982) was commissioned by the government on the teaching of mathematics in which chapter 7 (pp.109-207) was devoted to computers and calculators, believing that: '... their increasing availability at low cost is of the greatest significance for the teaching of mathematics' (Paragraph 327 p.95).

> We are therefore in a situation in which increasing numbers of children will grow up in homes in which calculators and microcomputers are readily available, in which there is access to a variety of information services displayed on domestic television sets and in which the playing of 'interactive' games, either on microcomputers or by means of special attachments to television sets, is commonplace.

In the early days of classroom computers, there was an expectation that teachers would change their pedagogy to a more constructivist approach (Shulman, 1987). Cornu (1995) suggested a more integrated pedagogy and by making IT inclusive, teacher direction and exposition would decrease, and students would be allowed more control over their learning, with teacher support when necessary.

Pre-national curriculum

From the 1960s mainframe computers appeared in centres such as universities and colleges with much of the emphasis on understanding how to work the equipment rather than for curriculum use. Before schools were provided with terminals (late 60s to early 70s) which could connect directly to the mainframe computers, teacher's and student's programs were written by onto tape or card which were then sent to colleges for processing (Millwood, 2009). In the 1970s smaller, more portable technology including scientific calculators appeared (Pimm & Johnston-Wilder, 2005). From 1979 there was major investment in computer access, computers were given to schools via Local Education Authorities (LEAs) through government initiatives, coinciding with the government's desire to boost the United Kingdom (UK) computer industry (Hammond, Younie, Woollard, Cartwright & Benzie, 2009).

Pre-national curriculum, teachers were able to try new ideas and be creative as they were less constrained by government requirements. The enthusiasts and IT-motivated began to develop skills, materials and ideas for their own use in classrooms and to share with colleagues and beyond including publishing in the Association of Teachers of Mathematics (ATM) journal MicroMath and writing books on topics such as Logo (Noss, 1983; Papert, 1980). The Secondary Mathematics Individualised Learning Experiment (SMILE) and Newman College produced learning resources, mostly written by practising teachers, including software for the British Broadcasting Company (BBC) and Research Machines (RM), (Gazzard, 2016; Govier, 2004).

Innovative diffusion model (IDM)

Rogers (1983) sought to explain how innovations were disseminated in a social group, describing those who quickly embraced the new idea as innovators and venturesome (2.5%) in that they "desire the hazardous, the rash, the daring, and the risky" and willing to accept setbacks (p.248). The early adopters (13.5%) followed who, in the early stages, also tackled particular pedagogical issues as opposed to the early (34%) and late (34%) majorities who focussed on the technology itself rather than a pedagogical purpose. His final group, laggards (16%) were not engaged with the use of technology. Hodgson (1995), described the early core of enthusiastic teachers as 'multiplicative agents' as they were expected to pass on their knowledge to colleagues, however where people did not see value-added or benefits to their teaching, they were less likely to implement change.

National Curriculum

From 1988 government initiatives began to impact on teachers' agency in their classroom including an inspection regime namely Ofsted, in 1992 followed by a National Curriculum in 1988 and, in 1997, the National Grid for Learning (NGfL) and National Strategies. The National Strategies provided a detailed scheme of work including activities and teaching approaches diminishing teachers' freedom to organise teaching and learning in their classroom. Technology opportunities in mathematics existed in curriculum documents (Department for Education and Employment (DfEE), 1997; 2001). In 2003 the Department for Education and Science (DfES) produced Integrating ICT into Mathematics in Key Stage 3 to provide more advice including pedagogy, the advantages of using Information and Communications Technology (ICT) (pp. 2-3), areas where ICT could be used (p. 9) and the ICT resource to use with teaching objectives (pp. 17-19). Commercial mathematics software was now marketed, including graphing packages to support pencil and paper methods (Ruthven, Hennessey & Deaney, 2008) and dynamic geometry programs with the release of Cabri ll in 1994 (Pimm & Johnston-Wilder, 2005).

All was not positive in moving towards the 1980s vision

Even prior to the introduction of the National Strategies, Ofsted's review of IT inspections carried out in 1993 and 1994 (Ofsted, 1995) indicated that hardware was ageing badly; desktop machines were often used ineffectively (often in computer rooms) with too many students working together at one screen presenting potential barriers when teaching through unreliability and access. In 1995-6, only 7% of secondary schools had access to portable technology (DfEE, 1997). There were also issues of training teachers, the McKinsey Report (1997 p.27) stated "There is evidence that many teachers lack the training, support, communications and therefore proficiency to be fully effective in the use of IT". Their recommendation was that teachers needed 60 hours of professional development to become proficient users. Through the British Educational Communications and Technology Agency (Becta) the government set up two schemes, the Laptops for Teachers scheme 1996 -1998 whereby some teachers could purchase laptops from approved suppliers at a discount and the National Opportunities Fund (NOF) from 1999-2003 training to equip teachers with skills to be confident and competent using ICT for teaching (Hammond, Younie, Woollard, Cartwright, & Benzie, 2009). Unfortunately, the training did not take into account teachers' actual needs or pre-existing skills with no funding to release teachers for study or formal recognition on completion (Preston, 2004). The curriculum became more prescriptive and outcomes-based than processes-based with each government initiative (Nuffield, 2009) while professional development focussed on curriculum delivery, meeting targets and assessment, i.e. top-down central control.

What is the present-day situation?

Reports such as those written by NCETM (2010) and Office for Standards in Education (Ofsted) (2008) have highlighted the lack of use of digital technology in mathematics classrooms. This can be related to a number of factors from funding (resources and teacher training), curriculum expectations, school and departmental ethos, engagement and competence of individual teachers, initial teacher training experiences and in-service professional development.

Government control of the curriculum and examinations has been increasing and currently (2019) there is little specific mention of using digital technology in secondary mathematics curriculum or examination syllabi. With public examinations including non-calculator papers this may be interpreted as a signal that digital technology is not an essential part of school mathematics. The report by the Organisation for Economic Co-operation and Development (OECD) (2015) said there was no evidence that digital technology improves examination grades per se thus giving no impetus for the government to include it as a curriculum requirement.

Teacher knowledge of subject specific software is underdeveloped in training (NCETM, 2010) and there is often little personal school experience to build on. Once qualified, access to training is restricted by the availability of funding by the school for course fees and release from teaching. The cascade model and in-house training are used but the effectiveness of these depends on the capability of those charged with delivering the knowledge and skills especially if the people leading the training have limited knowledge themselves as suggested by the conscious competence ladder (Dubin, 1982). Constrained school budgets have limited ability to provide new resources resulting in access and reliability issues while the availability of technical support has decreased. Jones (2004) suggested that teachers' fear of things going wrong, such as equipment breaking down in a lesson or that they will inadvertently cause damage to the system deters teachers, especially the less confident. Cuban, Kirkpatrick & Peck (2001) pointed out that if this were a regular occurrence this has a negative impact on the teacher. Preston, Cox & Cox (2000) also reported on the breakdown of equipment acting as a disincentive to using ICT.

Why use digital technology?

As it plays such an important role in modern life it is important to give the message that mathematics does use digital technology. While exam grade enhancement is not proven (OECD, 2015), there are benefits to using digital technology by facilitating the ability to access more complex concepts (DfES, 2003; National Council for Educational Technology (NCET) 1995; NCETM, 2010), Mann & Tall (1992) pointed out that ICT can be used for teaching most mathematical topics, providing an additional tool for the teacher to impart information through demonstration and exploration. such as more efficient working practices by students; eliminating repetitive calculations (Selinger, 2001), releasing time for activities including deeper analysis of data and applying mathematical ideas to the ‘real’ world with internet access giving the possibility of seeing ‘maths-in-action’ such as engineering and real data situations to enhance knowledge of statistics (NCETM, 2010; Oldknow & Taylor, 2003; Ruthven, Hennessey & Brindley, 2004; Webb & Cox, 2004).

The ability to carry out tasks more quickly, including using spreadsheets and dynamic geometry software (Clements, 2000; Sutherland et al., 2004), enables the trail and improvement of techniques in a shorter space of time, developing problem solving strategies, acting as a stimulus and motivator and giving opportunities for researching topics. Other advantages include support for those with fine motor control difficulties and an expectation that pupils produce work of a high-standard, including reports and presentations, as editing can be carried out without full re-writes.

Technology acceptance model (TAM)

Influences of peers and superiors affects attitudes to perceived usefulness of technology and ease of use will be affected through the provision of support and resources illustrating the importance of others when deciding whether to use technology. The Technology Acceptance Model (TAM) as suggested by Davis (1989) explains the influence of external variables on the use of technology, predicting user acceptance of technology as determined by three factors: (a) perceived usefulness, (b) perceived ease of use, and (c) behavioural intentions. It investigated perceived usefulness, perceived ease of use and behavioural intentions with a high degree of convergent and discriminant validity found for perceived usefulness and perceived ease of use (Davis, 1989). This was built on the theory of reasoned action in describing the influence of others in the decision of whether technology is useful or not. This idea was further developed by Venkatesh & Davis (2000) as TAM2 to include voluntary and involuntary environments such as ethos of the workplace and colleagues, the training received and its accessibility and resource provision in terms of technical support, hardware and software.

Have we actually moved forward?

Technology is more powerful, used for research and presentation, giving an improved display, often interactive by using projectors and whiteboards and personal use is widespread. However subject specific digital technology resources, while freely available, are not integrated into the mathematics curriculum as an entitlement, or expectation, and examinations still have non-calculator papers. Pedagogical progress has not been made in the way envisaged by the early writers. Without support, training and raising of digital technology's profile in curriculum and examinations as a teaching aid progress will continue to remain constrained.

References

Clements, D. (2000). From exercises and tasks to problems and projects – unique contributions of computers to innovative mathematics education. *The Journal of Mathematical Behavior, 19*(1), 9-47.

Cockcroft, W. (1982). *Mathematics counts: Report of the Committee of Inquiry into the Teaching of Mathematics in Schools.* London: Her Majesty's Stationery Office.

Cornu, B. (1995). New technologies: Integration into education. In D. Watson, & D. Tinsley (Eds.), *Integrating information technology into education* (pp.3-11). London: Chapman and Hall.

Cuban, L., Kirkpatrick, H., & Peck, C. (2001). High access and low use of technologies in high school classrooms: Explaining an apparent paradox. *American Educational Research Journal*, *38*(4), 813-834.

Davis, F. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319-340.

Department for Education and Employment. (1997). *Connecting to the learning society: National grid for learning. The Government's consultation paper.* London: Her Majesty's Stationery Office (HMSO).

Department for Education and Employment. (2001). *Key stage 3 national strategy: Framework for teaching mathematics: Years 7, 8 and 9.* London: HMSO.

Department for Education and Skills. (2003). *Integrating ICT into mathematics in key stage 3*. (DfES 0332/2003) London: DfES.

Dubin, P. (1982). *Human relations in administration*. Englewood Cliffs, N.J: Prentice Hall.

Gazzard, A. (2016). *Now the chips are down: The BBC micro.* MIT Press: London.

Govier, H. (2004). *Micros and primary education (MAPE)* NAACE.

Hammond, M., Younie, S. Woollard, J., Cartwright, V., & Benzie, D. (2009). *What does our past involvement with computers in education tell us? A view from the research community.* The Association for Information Technology in Teacher Education. Coventry: Centre for new technologies research in education, University of Warwick

Hodgson, B. (1995). The roles and needs of mathematics teachers using IT. In D. Watson, & D. Tinsley (Eds.), *Integrating information technology into education* (pp.27-37). Springer: Boston, MA.

Jones, A. (2004). *A review of the research literature on barriers to the uptake of ICT by teachers.* Coventry: Becta.

Mann, W., & Tall, D. (Eds.). (1992). *Computers in the mathematics curriculum. A report of the Mathematical Association*. Leicester: Phelan.

McKinsey and Company. (1997). *The future of information technology in UK schools*. London: McKinsey & Company.

Millwood, R. (2009). *A short history off-line*. Coventry: Becta.

National Centre for Excellence in Teaching Mathematics. (2010). *Mathematics and digital technologies: New beginnings. Report.* Retrieved from https://www.ncetm.org.uk/files/3399662/NCETMDigitTechReport2010.pdf

Noss, R. (1983). Doing maths while learning Logo. *Mathematics Teaching, 104,* 5-10.

Nuffield Foundation. (2009). *Review of 14-19 education and training*. Retrieved from http://www.nuffieldfoundation.org/14-19review.

Organisation for Economic Co-operation and Development. (2015). *Students, computers and learning: Making the connection. Report.* PISA, OECD Publishing. Retrieved from http://dx.doi.org/10.1787/9789264239555-en.

Office for Standards in Education. (1995). *Information technology: A review of inspection findings 1993/94*. London: HMSO.

Office for Standards in Education. (2008). *Understanding the score: The contribution of information and communication technology to the mathematics curriculum*. London: HMSO.

Oldknow, A., & Taylor, R. (2003). *Teaching mathematics* (2nd ed.). London: Continuum.

Papert, S. (1980). *Mindstorms: Children, computers and powerful ideas*. New York: Basic Books.

Pimm, D., & Johnston-Wilder, S. (Eds). (2005). *Teaching secondary mathematics with ICT*. Maidenhead: Open University Press.

Preston, C., Cox M., & Cox K. (2000). *Teachers as innovators in learning: What motivates teachers to use ICT*? London: Teacher Training Agency / MirandaNet / Oracle / Compaq.

Preston, C. (2004). *Learning to use ICT in classrooms: teachers' and trainers' perspectives. The full evaluation of the NoF teacher training programme 1999-2003.* Oxford: MirandaNet.

Rogers, E. (1983). *Diffusions of Innovations* (3rd ed.). The Free Press: New York.

Ruthven, K., Hennessy, S., & Brindley, S. (2004). Teacher representations of the successful use of computer-based tools and resources in secondary-school English, mathematics and science. *Teaching and Teacher Education, 20*(*3*), 259-275.

Ruthven, K., Hennessy, S., & Deaney, R. (2008). Constructions of dynamic geometry: A study of the interpretative flexibility of educational software in classroom practice. *Computers and Education, 51,* 297-317.

Selinger, M. (2001). Learning information and communications technology skills and the subject context of learning. *Journal of Information Technology for Teacher Education, 10*(1-2), 143-156.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-22.

Sutherland, R., Armstrong, V., Barnes, S., Brawn, R., Breeze, N., Gall, M., Matthewman, S., Olivero, F., Taylor, A., Triggs, P., Wishart, J., & John, P. (2004). Transforming teaching and learning: embedding ICT into everyday classroom practices. *Journal of Computer Assisted Learning, 20*, 413–425.

Venkatesh, V., & Davis, F. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*(2), 186-204

Webb, M., & Cox, M. (2004). A review of pedagogy related to information technology related to information and communications technology. *Technology, Pedagogy and Education, 13*(3), 235-86.