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Celebrating 20 Years of Computers in Mathematics Education: a research bibliography

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The aim of this *research bibliography* is to celebrate some of the key publications on the use of computers in the teaching and learning of mathematics over the past twenty years (or so). Inevitably this has to be rather selective (and, unfortunately, restricted to publications in English). The aim has been to cover most areas of mathematics and most major applications of technology.

The first section, immediately below, is a chronology of selected key research texts and articles on the use of computers in the teaching and learning of mathematics since 1980:

Papert, S. (1980), *Mindstorms: children, computers, and powerful ideas*. New York: Basic Books.
A mindstorm of a book. Demonstrates how a strong philosophical underpinning can put learners in control of technology. Still a good read and still able to storm minds.

Hoyles, C., & Sutherland, R. (1989), *Logo Mathematics in the Classroom*, London, Routledge.
Pioneering classroom study. Full of amazing pupil achievements showing what is possible when learners have some say in what they learn, and have the tools at hand to put their ideas into practice.

Laborde, J.-M. and Straesser, R. (1990), Cabri-géomètre, a microworld of geometry for guided discovery learning, *Zentralblatt für Didaktik der Mathematik*, **22**(5), 171–177.
A new decade and a new revolution in software - software that allows interaction with mathematical theorems by manipulation with the computer mouse. Read the originators.

Shuard, H. (1991), *Calculators, Children and Mathematics*. London: Simon & Schuster.
Not so much a research study, more a revolutionary approach to designing a "calculator-aware" number curriculum. Those involved will never forget the experience.

Tall, D. and Thomas, M. (1991), Encouraging versatile thinking in algebra using the computer, *Educational Studies in Mathematics*, **22**(2), 125-147.
Shows what is possible with fairly simple computer tools but a good understanding of what is involved in learning algebra.

Biehler, R. (1993), Software tools and mathematics education: the case of statistics. In C. Keitel & K. Ruthven (Eds.), *Learning from computers: mathematics education and technology* (pp. 68-80). NY: Springer-Verlag (NATO ASI Series F, vol. 121).
Illustrates a range of computer uses in teaching statistics (made possible by a series of studies sponsored by NATO – if only they'd do that again! – not swords to ploughshares, but near enough).

Laborde, C. (1993), The Computer as part of the Learning Environment: the case of geometry. *In*: C. Keitel and K. Ruthven (Eds), *Learning from Computers: mathematics education and technology*. Berlin: Springer-Verlag (NATO ASI Series F, vol. 121).
What to do when you have software that allows interaction with mathematical theorems by manipulation with the computer mouse. Advice from the expert!

Sutherland, R., and Rojano, T. (1993), A Spreadsheet Approach to Solving Algebra Problems, *Journal of Mathematical Behaviour*, **12**(4), 351-383.
Classic study demonstrating how judicious use of spreadsheets can lead to algebraic understanding.

Hölzl, R. (1996), How does 'Dragging' affect the Learning of Geometry, *International Journal of Computers for Mathematical Learning*, **1**(2), 169–187.
The research study that captures a central issue in learning with dynamic geometry software.

Noss, R. and Hoyles, C. (1996), *Windows on Mathematical Meanings: learning cultures and computers*, Dordrecht: Kluwer.
Brings together a wealth of research and classroom experience to explain how children develop mathematical meaning through interaction with technological tools,

Guin, D. and Trouche, L. (1999), The Complex Process of Converting Tools into Mathematical Instruments: the case of calculators, *International Journal of Computers for Mathematical Learning*, **3**(3), 195-227.
The 1990s saw the refinement of algebra software and the development of sophisticated hand-held calculators that combine graphic and symbolic capability. This paper develops a sophisticated theoretical model to explain what happens when learners have this form of technology.

Lagrange, J-B (1999), Complex Calculators in the Classroom: theoretical and practical reflections on teaching pre-calculus. *International Journal of Computers for Mathematical Learning*, **4**(1), 51-81.

Research on the tasks and techniques that help students make the best use of sophisticated hand-held calculators in learning algebra and functions in preparation for calculus.

Cuban, L. (2001), *Oversold and Underused: Computers in the Classroom*. Cambridge, MA: Harvard University Press.
Not specifically about the teaching and learning of mathematics, more a sobering account of the continuing barriers to widespread use of computers in teaching. Argues "It is premature to call the investment in computers in schools a failure because of lack of evidence for increased productivity and transformed teaching and learning. As the infrastructure matures and teachers' beliefs about teaching and learning evolve, more and more teachers will change their practices and become serious users of computers in their classrooms". Read the full text of the book (it's very readable) online at:
http://www.hup.harvard.edu/catalog/CUBOVE.html

Artigue, M. (2002), Learning Mathematics in a CAS environment: the genesis of a reflection about instrumentation and the dialectics between technical and conceptual work, *International Journal of Computers for Mathematical Learning*, **7**(3), 245-274.
An analysis of the style of work that develops when students use computer algebra software in an analytic context.

Godwin, S. and Sutherland, R. (2004), Whole-class Technology for Learning Mathematics: the case of Functions and Graphs. *Education, Communication and Information Journal (ECi)*, **4**(1), 131-152.
Another decade and another new technology in the classroom, this time one that might facilitate whole-class interactive learning.

The second section, again immediately below, is a chronology of useful review articles that capture the developments over the past twenty years (or so):

Hembree, R. & Dessart, D. J. (1986), Effects of Hand-held Calculators in Pre-college Mathematics Education: A meta-analysis. *Journal for Research in Mathematics Education*, **17**(2), 83-99.
Classic review of research on four-function calculators (updated in 1992).

Fey, J. T. (1989), Technology and Mathematics Education: a survey of recent developments and important problems, *Educational Studies in Mathematics*, **20**, 237-272.

Kaput, J. (1992), Technology and Mathematics Education. *In*: D. Grouws (Ed.) A Handbook of Research on Mathematics Teaching and Learning. NY: MacMillan (pp515-556).
Records that "Anyone who presumes to describe the roles of technology in mathematics education faces challenges akin to describing a newly active volcano – the mathematical mountain is changing before our eyes, with myriad forces operating on it and within it simultaneously."

Kaput, J. J. & Thompson, P. W. (1994), Technology in mathematics education research: The first 25 years in the JRME, *Journal for Research in Mathematics Education*, **25**(6), 676-684.

Yelland, N. (1995), Mindstorms or storm in a teacup? A review of research with Logo, *International Journal of Mathematics Education, Science and Technology*, **26**(6), 853-869.

Balacheff, N. and Kaput, J. (1996), Computer-Based Learning Environments in Mathematics. *In*: A. Bishop (Ed), *International Handbook in Mathematics Education*. Dordrecht: Kluwer. (pp.469-501)

Burrill, G., Allison, J., Breaux, G., Kastberg, S., Leatham, K., & Sanchez, W. (2002), *Handheld Graphing Technology in Secondary Mathematics: research findings and implications for classroom practice*. Austin, Txs: Texas Instruments.

Clements, D. H. (2002), Computers in Early Childhood Mathematics, *Contemporary Issues in Early Childhood*, **3**(2), 160-181.

Hoyles, C. & Noss, R. (2003), What can digital technologies take from and bring to research in mathematics education? *In*: A. Bishop (Ed), *Second International*
Handbook of Research in Mathematics Education. Dordrecht: Kluwer.
Hoyles and Noss observe, "Research in the use of digital technologies has proliferated, using a wide range of theories and methodologies. Whereas it might have been possible a decade or so ago to write a comprehensive review, in just one chapter, of research on the effects of digital technologies on the whole of mathematics teaching and learning, the vast corpus of study that exists now makes this no longer feasible."

Heid, M. K. and Blume, G. (Eds) (in press), *Research on Technology in the Learning and Teaching of Mathematics (2 volumes)*. Greenwich, CT: Information Age Publishing.
Illustrates how the wealth of research in the use of computers in mathematics education has blossomed so much that it takes two volumes to cover it all!

***MicroMath* Research Bibliographies**

Every year hundreds of teachers engage in classroom-based research for a variety of purposes. As more and more opportunities arise for teachers to get support for engaging with research, *MicroMath* is devoting a section to a series of *research bibliographies* designed to provide details of the most pertinent research on using particular ICT applications in the teaching and learning of mathematics.

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