Cite as: Jones, K. (2005), Graphing Calculators in the Teaching and Learning of Mathematics: a research bibliography, *MicroMath*, 21(2), 31-33.

Graphing Calculators

in the Teaching and Learning of Mathematics:

a research bibliography

Keith Jones

The aim of this research bibliography is to capture the main themes and findings of research into the use and impact of a form of hand-held technology often called a graphing (or graphic or graphics or graphical) calculator.

While graphing calculators have been around for more than 20 years (the first one appeared in 1985), their capabilities continue to expand. The more sophisticated models now come complete with versions of software previously found only on computers (such as computer algebra and dynamic geometry). For the purposes of this bibliography, the focus is on the more standard model of graphing calculator, the capability of which encompasses numerical calculations, the graphing of functions, the manipulation of lists of data, and the calculation and display of statistical graphs.

Since their introduction, the use of graphing calculators has spawned much research and debate. Almost all the research studies have examined topics in algebra, and mostly with upper secondary school/senior high school pupils. Very few studies appear to have focused on the teaching and learning of statistics (although relevant teaching resources, and teaching advice, abound).

Overall, the available research suggests that using graphing calculators in mathematics education can enable students to approach situations graphically, numerically and symbolically, and can support students' visualisation, allowing them to explore situations which they may not otherwise be able to tackle (and thus perhaps enable them to take their mathematics to a more advanced level). In this way, using graphing calculators can lead to higher achievement among students, perhaps through increased student use of graphical solution strategies, improved understanding of functions, and increased teacher time spent on presentation and explanation of graphs, tables and problem solving activities (compared with students not using such calculators). The impact of the availability of this form of calculator on teaching methods and curricula appears to have been more limited, with teachers reportedly tending to use graphing calculators as an extension of the way they have always taught, rather than provoking any radical change in style of teaching or design of the curriculum.

The publications listed below are in chronological order of publication.

Shuman, R. J. (1988), Graphic Calculators: skills versus concepts. *In*: J. de Lange & M. Doorman (Eds), *Senior Secondary School Mathematics Education*. Utrecht, Holland: OW & OC.
Early exploration of a key issue in research in using graphing calculators.

Ruthven, K. (1990), The Influence of Graphic Calculator use on Translation from Graphic to Symbolic Forms, *Educational Studies in Mathematics*, **21**(5), 431-450.
Classic pioneering study showing that students using a graphing calculator on a regular basis make more use of graphical approaches in solving problems and are thereby able to rehearse relationships amongst symbolic and graphic representations of functions.

Demana, F., Schoen, H. L., & Waits, B. (1993), Graphing in the K-12 Curriculum: the impact of the graphing calculator. *In*: E. F. T. A. Romberg, & T. P. Carpenter (Eds.) *Integrating Research on the Graphical Representation of Functions* (pp. 11-39). Hillsdale, NJ: Lawrence Erlbaum.
A useful analysis of the graphing curriculum and how the advent of the graphing calculator might impact on this.

Lauten, A. D. (1994). Student Understanding of Basic Calculus Concepts: interaction with the Graphics Calculator, *Journal of Mathematical Behavior*, **13**(2), 225-237.
Early graphing calculator study of college students illustrating the power of multiple representations in deepening mathematical understanding but that students can display confusion over the roles of x and y in equations.

Wilson, M. R., & Krapfl, C. M. (1994), The Impact of Graphics Calculators on Students' Understanding of Function, *Journal of Computers in Mathematics and Science Teaching*, **13**(3), 252-264.
A timely paper pointing both to the benefits to student learning of using graphing calculators, and to the problems and pitfalls (such as difficulties with scaling and with domain and range concepts) that need to be faced if students are to gain maximum benefit from the technology.

Drijvers, P., & Doorman, M. (1996), The Graphics Calculator in Mathematics Education, *Journal of Mathematical Behavior*, **15**(4), 425-440.
Results of a study from Holland suggesting that the use of graphing calculators can stimulate both the use of realistic contexts in mathematics and more exploratory learning approaches for students, leading to students having a more integrated view of mathematics and being more flexible in their use of problem solving strategies.

Penglase, M., & Arnold, S. (1996), *The Graphics Calculator in Mathematics Education: a critical review of recent research*, Mathematics Education Research Journal, **8**(1), 58-90.
Extensive review of the literature that observes that many research studies fail to clarify carefully between the impact of the graphing calculator and the context in which it is being used, leading to inconsistent findings regarding the effectiveness of graphing calculators in mathematics education. Recommends that future research attempts to address graphing calculator use within particular learning contexts and environments.

Oldknow, A. (1997) International Study on Graphing Calculators in Secondary Education. *IFIP (International Federation for Information Processing) WG 3.1 (Informatics and ICT in Secondary Education) Working Group Conference*, Grenoble.
Online at: http://www.education.leeds.ac.uk
Useful survey (from 1997) of the prevalence of graphing calculator use across 20 countries around the world. Found a mixture of practice, from passive encouragement of graphing calculator use, through to almost making such use mandatory.

Doerr, H. M., & Zangor, R. (2000), Creating Meaning for and with the Graphing Calculator, *Educational Studies in Mathematics*, **41**(2), 143-163.
Suggests that the nature of the mathematical tasks, and the role, knowledge and beliefs of the teacher, influence the form of student use of the graphing calculator. Also found that the use of the calculator as a personal device can sometimes inhibit communication in small groups, while its use as a shared device can support learning in a whole class setting.

Graham, A. T., & Thomas, M. O. J. (2000), Building a Versatile Understanding of Algebraic Variables with a Graphic Calculator, *Educational Studies in Mathematics*, **41**(3), 265-282.
Found that 13-14 year old students taught using a graphing calculator improved their understanding of variables in algebraic expressions more than a matched control group. The graphing calculator group performed as well as the control group on a test of procedural skill with algebraic expressions.

Harskamp, E. G., Suhre, C. J. M., & van Struen, A. (2000), The Graphics Calculator and Students' Solution Strategies, *Mathematics Education Research Journal*, **12**(1), 37-52.
van Streun, A., Harskamp, E. G., & Suhre, C. J. M. (2000), The Effect of the Graphic Calculator on Students' Solution Approaches: a secondary analysis, *Hiroshima Journal of Mathematics Education*, **8**, 27-39.
Two reports that suggest that students using graphing calculators tend to attempt more mathematical problems, and tend to obtain higher scores, than students not taught using graphing calculators, primarily because the former are able to use graphical approaches as well as other approaches.

Mitchelmore, M., & Cavanagh, M. (2000), Students' Difficulties in Operating a Graphics Calculator, *Mathematics Education Research Journal*, **12**(3), 254-268.
Found that students can make errors when using graphing calculators and that such errors relate to the students accepting the graphical image on the calculator uncritically, having a poor understanding of scale, and an inadequate grasp of accuracy and approximation.

Burrill, G. et al (2002), *Handheld Graphing Technology in Secondary Mathematics: research findings and implications for classroom practice*. Austin, Txs: Texas Instruments.
Available online at: http://education.ti.com
Starting with over 180 research reports, this review selected 43 studies to evaluate. Concludes that students using graphing calculators (alongside curriculum materials that support such use) improve their understanding of functions, variables, solving algebra problems in applied contexts, and interpreting graphs. Also suggests that teachers generally tend to use graphing calculators as an extension to the way in which they have always taught, rather than the availability of the technology necessarily encouraging any major change in curricula design.

Rodd, M. & Monaghan, J. (2002), Graphic Calculator Use in Leeds Schools: fragments of practice, *Journal of Information Technology in Teacher Education*, **11**(1), 93-108.
Based on research in a major UK city, found that the key factors which contributed to use of calculators include the expertise within mathematics departments in schools and positive regard for such calculators as learning aides. Factors which inhibited use included teachers' lack of time to learn how to use such calculators and how to teach with them, concerns over examination restrictions, and perceptions of computers being a resource priority.

Interactive Educational Systems Design (2003), *Using Handheld Graphing Technology in Secondary Mathematics: what scientifically-based research has to say*. Austin, Txs: Texas Instruments. Online at: http://education.ti.com
Starting with the same database of research reports as Burrill *et al* (above), this review selected studies that used an experimental or quasi-experimental design to evaluate the impact of including graphing calculators in teaching. All the five selected studies were with upper secondary/senior high school students and focused on the teaching of algebra topics. The evaluation of this research concludes that using graphing calculators can lead to higher achievement among students, perhaps through increased student use of graphical solution strategies, improved understanding of functions, and increased teacher time spent on presentation and explanation of graphs and tables, and on problem solving activities (compared with students not using such calculators).

Kastberg, S., & Leatham, K. (2005). Research on Graphing Calculators at the Secondary Level: implications for mathematics teacher education, *Contemporary Issues in Technology and Teacher Education* [Online serial], **5**(1). Available online at: http://www.citejournal.org
This review suggests that access to graphing calculators is associated with student achievement gains and that students' achievement is improved when they use curricula designed with a graphing calculator as a major tool. The report suggests how teacher education programmes might take account of such findings.

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. Previous bibliographies are:
Using Spreadsheets in the Teaching and Learning of Mathematics: a research bibliography, *MicroMath*, **21**(1), 30-31.
Using Interactive Whiteboards in the Teaching and Learning of Mathematics: a research bibliography, *MicroMath*, **20**(2), 5-6.
Celebrating 20 Years of Computers in Mathematics Education: a research bibliography, *MicroMath*, **20**(1), 29-30.
Using the Internet in the Teaching and Learning of Mathematics: a research bibliography, *MicroMath*, **19**(2), 43-44.
Research Bibliography: Four-function Calculators, *MicroMath*, **19**(1), 33-34.
Research Bibliography: Dynamic Geometry Software, *MicroMath*, **18**(3), 44-45.

Keith Jones is a member of the Collaborative Group for Research in Mathematics Education at the University of Southampton, UK. From 2001-2003, he led the thematic group on *Tools and Technologies in Mathematical Didactics* for the European Society for Research in Mathematics Education (ERME). See:
http://www.crme.soton.ac.uk