Using Calculators for Students in Grades 9-12: Algebra
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Should high school students use calculators? Can they help students learn algebra? Following are examples of how some researchers think calculators can be incorporated into math lessons to help high school students learn these tasks.

Before describing these works, a quick caveat is needed. None of the studies presented here used a research design that shows unambiguous evidence that calculators lead to better student achievement. Indeed, many of the articles summarized below simply describe ideas that some teachers think were helpful (there are several of these, so we listed them as an annotated bibliography). Despite the limited evidence, it is important to let teachers know what types of calculator practices are available, and judge for themselves if any of these fit with their styles and specific classroom needs.

Curriculum studies
A study by Lagrange (1999) considered whether a teaching technique using the TI-92 (a graphing calculator) helped students understand pre-calculus. The goal was to assess the idea that there are links between technical offerings and conceptual understanding by designing an experiment to look at how and why Computer Algebra Systems (CAS) work. CAS is usually based on a separation between technical work and conceptual reflection in learning math. To look at the joint development of techniques and understanding, Lagrange worked with a nationally established curriculum in pre-calculus. The study entailed a two-year experiment where, in year one, teachers submitted lessons and researchers observed students. In year two, researchers worked with the teachers to implement the CAS curriculum. Outcome measures were observations of students, student knowledge of the calculator, and their attitudes toward it. More specifically, the researchers questioned the students three times per year about views of the TI-92 and a subset of students was interviewed three times per year about use of the calculator and abilities to use it to perform a function. All participants (20 girls and 34 boys of mixed ability) were in the
11th grade. The results indicate that students varied in their satisfaction with using the calculator for conceptual understanding. Using the TI-92 was not easy for the average student, and it seemed that calculators could not replace other teaching techniques.

Goos & colleagues (2003) consider the impact of technology-infused curricula in advanced mathematics courses. Most of the pedagogical approaches focused on conceptual (not functional) applications. Graphing calculators were used, along with other technologies to teach concepts such as chaos theory. The study used a mixed method approach, meaning that ethnographic observational approaches were used to study curriculum effects. Meanwhile, students completed surveys that assessed attitudes towards technology and its role in learning. Students came from a large city in Australia and were in grades 11-12. The sampling pool encompassed five mathematics classrooms (three focused on calculus and statistics, two provided more advanced topics for students endeavoring to study math at the college level). The study’s conclusions support technology use and note that some activities in math are not conducive to paper-pencil applications. The authors did, however, note that technology sometimes drives what concepts students might try to learn. Overall, calculator use was supported, at least implicitly so.

Hubbard (1998) analyzed the effects of increased use of the graphing calculator in Algebra II classrooms. Students were given pre- and post-tests on graphing calculator use. Grades for each chapter were also analyzed, and students were given two alternate assessments during the study. The study concluded the intervention was effective, as indicated by student grades and post-test performance.

Cedillo (2001) suggests that principles of language development can be applied to algebra instruction by using graphing calculators to depict numerical relationships. The study applies Bruner’s concept of format (a way of thinking about language acquisition) to provide a basis for using graphing calculators to teach algebraic concepts. Bruner’s work focuses on issues of syntax, semantics, and pragmatics, so Cedillo considered a way to teach the language of algebra. Cedillo used a case study approach to investigate how eight Mexican students learned algebra. Over 1,000 student worksheets were studied to capture growth in algebraic understanding. The results of the study suggest that students will be better able to learn mathematics concepts—and math achievement by proxy—if they develop operational nature of the syntax, pragmatics, and so on, that are part of calculator use.
Mok (1999) found that mathematics instruction in Hong Kong is largely expository, so he considered if technology could "elevate learning." The purpose of the study was to introduce a cognitive model while introducing graphing calculators to explore asymptotes. The cognitive model is from a constructivist view of learning, and includes concrete preparation, cognitive conflict, construction, metacognition, and bridging. The author used a class of 30 12th graders of average mathematical ability. The students went through four sessions of 70 minutes each, where they worked with their graphing calculators to understand asymptotes. There were two different tasks: a group-based activity for students with little experience in calculus, and an individual one for those with more experience. At the end of the study, all students were able to calculate asymptotes for simple functions. According to the author, the students "made their own predictions, verified and checked their own work with their graphing calculators, found their own mistakes, and resolved the conflict by creating a new definition" (p. 9).

Further reading
The short articles listed below, taken from three or four journals, provide ideas that may be of some use in the classroom. Following is a very brief, annotated bibliography; full references are available below:

Abramovich & Norton (2000) describe an activity designed for teachers to help students to reflect on what they are learning: "activities designed for computer-enhanced in-service training of high school mathematics teachers…using jointly a computer-based graphing calculator, a dynamic geometry program, and a spreadsheet program in exploring linear algebraic equations to bridge finite and infinite mathematics structures" (p. 36).

Arnold & Taylor (1996) describe some applications of the Cabri-Geometry II calculator. The article describes how to develop some functions that combine geometry and algebra.

Austin (1996) illustrates ways secondary students can explore the mathematical basis (basic algebra) of string art with graphing calculators. The author does not describe the students' characteristics, but he does mention that this activity can be used with students who are beginning to explore algebra.
Barker & Mahoney (2005) discuss how a graphing calculator can be used in conjunction with applets to explore the derivation of the central limit theorem and bell curve convergence.

Choate & Picciotto, (1997) describe a method of introducing the concept of dynamical systems through iterative calculations of linear functions.

Child (2001) describes ways teachers can use the Symbolic Math Guide (SMG) for the TI-89 and TI-92. In addition, a program that can be used to help students understand algebra skills used in calculus is made available (free download of partial program at www.education.ti.com).

Cuoco, A. & Manes, M. (2001) describes two examples from an emerging intervention being developed at the time of publication. One example shows how the TI-89 calculator can be used to develop a recursive model from a simple algebraic calculation, and the second example is designed to justify the need for mathematical proofs because of calculator limitations.

Embse, & Yoder, (1998) provide sample problems to use with a graphing calculator that highlight the utility of dynamic pictures as a support to problem-solving. Helfgott & Simonsen (1998) offer an approach that uses graphing calculators (instead of calculus) to derive laws of reflection for parabolic mirrors.

Kissane (2001) discusses how a graphing calculator can be used to explore concepts such as functions and equations. The author describes a tutorial that can be used to teach a lesson on parabolas. Graphing calculators can help students explore different algebraic equations and functions by showing them the results of their different inquiries on the screen.

Oldknow, A. (1996) describes the author’s attendance at a T-cubed conference (Teachers Teaching with Technology) which focused on using CBL (which encourages cross-curricula work between math, science, technology, and geography) and a TI-92 to teach calculus. The article describes the author’s use of these tools in experiments (e.g., discharge of a capacitor, teacups and cooling, and eliminating drips from a sprinkler) that graphically display models of exponential decay.
Swingle & Pachnowski (2003) discuss how a graphing calculator with a motion detector can be used to graph the movement of a bouncing ball. Using a graphing calculator can make the abstract representation of a parabola more meaningful when it is associated with the physical event it represents.

Torres-Skooumal (2001) describes a mathematics (algebra) curriculum, including cooperative learning and alternative assessments with graphing calculators, which teachers developed at the Vienna International School. The author does not provide specifics about the students other than that they are between ages 11 and 18 and that class size at the school ranges from 15 to 25.

References


