Using Calculators for Teaching and Learning Mathematics

This research brief is based on a synthesis of nearly 200 research studies, dating from 1976 to 2009, on calculator use in the classroom. Our goal here is to provide advice to practitioners and researchers on how the existing research base can be used to guide classroom practice and support future research. (See Rakes et al., 2011 for a full description of the literature review.) We address the common question of practice: Are there consistent findings in mathematics education technology research about the use of calculators? In general, we found that the body of research consistently shows that the use of calculators in the teaching and learning of mathematics does not contribute to any negative outcomes for skill development or procedural proficiency, but instead enhances the understanding of mathematics concepts and student orientation toward mathematics.

We divided the studies by types of calculator features (four-function, scientific, graphing, and advanced features such as CAS, dynamic geometry, and classroom connectivity) and by the year of the study in order to provide a sense of how calculator research has progressed over time (see figure 1). Earlier studies in the period were conducted on hand-held, four-function, and electronic calculators, and focused on student basic skills and/or orientation measures (e.g., mathematics anxiety) as outcomes (e.g., Hutton, 1976; Jamski, 1976; Jones, 1976; Lunder, 1978). With the advent of the graphing calculator, an overwhelming proportion of studies focused on the new features offered (e.g., dynamic geometry, statistics, CAS).

Examining such a large body of work makes the task of synthesizing difficult, but structured reviews of research make patterns, themes, and consistent effects much simpler to recognize. As a starting point, we reviewed three existing research syntheses to identify important trends and effects observed over time. Hembree and Dessart (1986) conducted one of the first calculator meta-analyses, considering 79 studies to assess the effects of calculators on student achievement and attitude. This study showed that using a calculator with traditional instruction improves students’ basic skills with paper and pencil, both in working exercises and in problem solving (with an exception for Grade 4) and that students at all grade levels and ability levels improved in self-concept and attitude. Hembree and Dessart analyzed more than a simple measure of student achievement. They captured categories of basic operations and problem solving across various conditions (e.g., skills acquisition with and without calculators and skills retention and transfer).

Ellington (2003) conducted a subsequent meta-analysis of 54 studies reported after the sample from Hembree and Dessart (1986) to determine if the effects of calculators noted by Hembree and Dessart on student achievement and attitude were consistent over time. She found that students’ operational skills and problem-solving skills improved when calculators were an integral part of testing and instruction. She also found that calculator use did not hinder the development of basic mathematical skills and additionally improved student attitudes toward mathematics.

In 2006, Ellington presented a meta-analysis that specifically targeted studies examining graphing calculators in middle, secondary, and post-secondary mathematics classes. Her meta-analysis of 42 studies showed that, regardless of the mode of testing, graphing calculators helped students understand mathematical concepts. Most strikingly, Ellington found, “There were no circumstances under which the students taught without calculators performed better than the students with access to calculators” (p. 24).

Collectively, these three meta-analyses provide a striking level of consistent findings across more than 150 studies.
spanning several decades. Our current study incorporates the studies from each meta-analysis along with almost 50 additional studies, which included a wide range of research quality, methodologies, and contexts. The result: we found no evidence to contradict the previous analyses’ findings (Rakes, et al., 2011).

Few areas in mathematics education technology have had such focused attention with such consistent results, yet the issue of whether the use of calculators is a positive addition to the mathematics classroom is still questioned in many areas of the mathematics community, as evidenced by continually repeated studies of the same topic. As a result, we concluded that future practitioner questions about calculator use for mathematics teaching and learning should advance from questions of whether or not they are effective to questions of what effective practices with calculators entail. Another question to explore is how their capabilities can be combined with other technologies to produce learning experiences not possible without the technology (e.g., probeware, classroom response systems). Researchers, on the other hand, should build on the existing base by pursuing questions about such effective practices and the structures needed at the classroom and school level to support calculator use in the classroom.

One particular line of research illustrates this point clearly. A four-year longitudinal study involving teacher professional development included both student and teacher outcomes, measured both quantitatively and qualitatively (Irving, Sanalan, & Shirley, 2009; Irving et al., 2010; Owens et al., 2008; Pape, Bell, Owens, & Sert, 2011; Pape, et al., 2010; Pape, Irving, Owens, et al., 2011; Shirley, Irving, Sanalan, Pape, & Owens, 2011). This line of research went beyond merely measuring effect sizes quantitatively or describing patterns of teacher behavior through classroom observation. These studies also examined the components of professional development that increased teacher knowledge about technology (such as TPACK: see Mishra & Koehler, 2006; Niess, 2005; Niess et al., 2009) and how that knowledge translated into practices that were more or less effective for enhancing student achievement, learning, orientation, and learning behaviors in mathematics (Pape, Irving, Bell, et al., 2011).

Authors of practitioner journal articles should also begin to take advantage of the solid research base for calculator usage in the mathematics classroom. For example, more explicit links to research should be included in articles and book chapters for practitioners presenting teaching strategies and in resource books for teachers on how to use technology in the classroom. Such a practice is not currently held as a standard: Only 18 of the 100 such papers in our sample made any connections to research. The dearth of such connections in practitioner articles points to a need for the field to begin concentrating on enhancing the use of the existing research base for informing practice and disseminating ideas to others.

In summary, a wide array of evidence of nearly four decades points to the usefulness of calculators for enhancing student achievement, learning concepts, orientation towards mathematics, and learning behaviors in mathematics. This evidence could propel practitioners to begin to produce robust, dynamic learning environments in which students learn mathematics with understanding and emerge ready to apply mathematics to issues unique to the 21st century. Meanwhile, new lines of research should investigate phenomena beyond whether or not calculators are effective; instead, we can begin to explore the conditions, resources, and contexts needed to maximize the degree to which calculator use can enhance the teaching and learning of mathematics.

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