

# How can teachers translate students' positive attitudes towards ICTs into better mathematics learning?

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## Powerful Tools Can Improve Student Attitudes

Technology in general and graphing calculators in particular have great potential in improving students' affective responses to math learning tasks (Kaput, 1989). A recent meta-analysis of 18 classroom experiments with student attitudinal outcomes revealed that students using calculators during instruction reported significantly better attitudes toward math than those who did not (Ellington, 2003). Researchers look at the size of an effect in determining whether a positive intervention is worth spreading. The size of the effect of calculators on attitudes falls in the same range as other instructional practices that researchers recommend strongly.

*Most of today's students like technology. Yet liking technology does not automatically translate into better learning. To make the link, teachers can give students more responsibility for their own learning and challenge students with substantive mathematical problems. Benefits include increased persistence in solving problems, and greater willingness to take on challenging problems requiring deep understanding.*

However, better attitudes do not automatically translate into more learning. Expert teachers take advantage of positive attitudes to raise expectations for their students. Of course, there are many ways in which teachers may attempt to raise expectations, not all of which work. After discussing the relation of positive attitudes to persistence in math, we highlight two research-based, effective approaches to raising expectations and increasing learning.

## Positive Attitudes Lead to Persistence in Math

Generating positive attitudes towards math among students is an important goal of math education. Research conducted over the last two decades has shown that positive attitudes can impact on students' inclination for further studies and careers in math-related fields (Haladyna et al., 1983; Maple and Stage, 1991; Trusty, 2002). For example, a recent study using the Third International Math and Science Study (TIMSS) data from Canada, Norway and the United States found attitudes toward math as the strongest predictor of student participation in advanced math courses (Ercikan, et al., 2005).

Addressing student mathematical disposition, including students' confidence, interest, perseverance, and curiosity in learning math, is particularly important in the middle years of school and above (ages 12 to high school graduation). Researchers have reported that it is in the middle years of school that students' level of enjoyment with math tends to decline considerably and the gender difference in math confidence widens, favoring boys over girls (Dossey et al., 1988; Strutchens et al., 2004; Seegers & Boekaerts, 1996). For students to persist in advanced mathematics, teachers need to develop students' positive attitudes, not just their concepts and skills. Developing positive attitudes creates fertile ground in which teachers can plant the seeds of deeper mathematics learning and cultivate independent, advanced math learners.

## Give Students More Responsibility for Their Own Learning

In giving students a graphing calculator, teachers can also give students more responsibility for their own learning. Students can examine multiple representations interactively and examine meanings of representations and their relationships. They can work on interactive explorations, real-world data collection, and investigations. Furthermore, they can assess their work and discover errors on their own.

One strong theory of student responsibility for learning is called "self-regulation." Self-regulating learners show more ability to control their thoughts, feelings, and actions in support of learning (Zimmerman, 1998; 2000). Self-regulated learners believe that learning depends on their own emotional, cognitive, and reflective processes (and are more able to learn without a teacher by their side) (Zimmerman, 1998). In the context of mathematical problem solving, self-regulated learners carefully analyze a given problem, select from a repertoire of strategies, and monitor the problem-solving process, thereby generating internal feedback to assess the success of their efforts (Page & Smith, 2002). Additionally, self-directed learners know how to deal with frustration and keep themselves on task in the face of difficulty (Corno, 1993). In short, self-regulated learners have both the "will" and "skill" to learn (Pintrich & DeGroot, 1990),

and their problem-solving behaviors are similar to those of experts (Schoenfeld, 1989). The more students take responsibility for their own learning, the more likely they are to attribute success to their own efforts, which in turn is likely to increase levels of effort and persistence (Hagen & Weinstein, 1995; Pintrich, 1994).

Evidence from classroom research shows that self-regulation can be explicitly taught and that students benefit from it (De Corte et al., 2000; Pape, Bell, & Yetkin, 2003). For example, a classroom experiment in Israel investigated effects of self-regulated learning (SRL) combined with the use of Computerized Algebra Systems (CAS), a feature available on graphing calculators (Kramarski & Hirsch, 2003). Students were randomly assigned to either a CAS-only condition or to a CAS-plus-SRL condition. The CAS-plus-SRL group received explicit training on self-questioning (e.g., questions to comprehend a problem, to develop connections between what is known and unknown, to assess strategies, and to reflect on the processes or solution). While the number of students involved in the study was small (43 students), the study found significant effectiveness of the CAS-plus-SRL condition: the CAS-plus-SRL students significantly outperformed the CAS-only students on algebraic thinking. Additionally, the CAS-plus-SRL students were able to use self-regulated skills more effectively than the CAS-only students for solving a novel problem.

### Challenge Students with Problems, Dilemmas, and Deep Questions

When students are strongly motivated (as is often the case when they use technology in math), they are likely to be more willing to take on deeper mathematical challenges. Problem-based learning (PBL) is a pedagogical strategy that organizes learning around a driving question and provides students with opportunities to design problem-solving, decision making, and investigative activities, which often results in products or presentations (Thomas, 2000). Researchers have identified key factors that facilitate successful PBL (Erickson, 1999; Roh, 2003; Thomas, 2000). One PBL approach proposed specifically for mathematical pedagogy is “making math problematic” — beginning the lesson with problems, dilemmas, or questions for which no readily known routines or procedures exist, thereby requiring students to explore problems, generate hypotheses, search for solutions, and resolve incongruities through mathematical thinking and reasoning (Hiebert et al., 1996).

Strong evidence comes from a longitudinal study that used pre- and post-tests as well as the case study approach with approximately 300 British students (ages 11-13) at two closely matched schools (Boaler, 1998, 1999). The study investigated student learning resulting from two contrasting instructional approaches at two schools — one school using PBL focused on application of mathematical knowledge and skills, and the other using traditional textbook-based instruction with a series of short, closed exercises. The study results show that students at the PBL school significantly outperformed students at the traditional school on the national examination, particularly on conceptual questions. The study also revealed that PBL students developed more flexible knowledge that enabled them to successfully solve novel tasks. Moreover, a majority of PBL students interviewed did not see boundaries between school math and real-world math, while no students who received traditional instruction held such a view. Furthermore, research has shown that diverse populations of students — girls, English-as-a-second-language students, and students at varying achievement levels — benefit from the PBL approach, attaining higher results on average than in traditional math classrooms (Boaler 1998; Mevarech & Kramarski, 1997; NCES 1996).

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