Does mathematical learning improve when teachers know more about student thinking in a TI-Navigator™ classroom?

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Research shows that students tend to achieve more in mathematics exams when the teacher knows, through a network-connected classroom, more about how students are thinking about mathematics.

Strong Evidence from Classroom Connectivity in Maths Classrooms: Results of a Randomised Control Trial

Experimental research funded by the Institute of Educational Sciences at the U.S. Department of Education has yielded the strongest form of evidence on this question. Investigators led by The Ohio State University compared the use of the TI-Navigator™ classroom learning system in teaching Algebra to ordinary teaching of Algebra (in some cases, with graphing calculators).

The TI-Navigator system was employed in order to create a "connected classroom" in which teachers had more information about how students were thinking about mathematics. The experiment involved a national sample of 68 algebra teachers and 1,128 students in a randomized, controlled trial to examine the impact of a connected classroom on student achievement and students' beliefs about mathematics.

Classrooms that used the TI-Navigator system scored significantly higher–approximately a 14% mean learning gain compared with students not using the TI-Navigator system–on an algebra test. The results were calculated after controlling for student pre-test scores, teacher's years of experience, teacher's gender, and percent of free/reduced lunch students (Owens, 2008).

Teacher interviews were conducted to further investigate the impact of classroom connectivity. The main finding of the interviews was that the technology and the professional development contributed to changing classroom teaching for the better. The level of teacher knowledge about how students were performing was positively associated with student performance on the total algebra post-test score (Owens, 2008).

All students also completed pre- and post-surveys on several aspects of their attitudes toward mathematics. Students in connected classrooms showed greater improvement in how effective they felt about their ability to learn math and about the expectations they have for their own potential for success when compared with the group without classroom connectivity.

In related research, Marat (2005) examined the relationship between students' self-confidence and achievement. By receiving feedback on their performance and the performances of others, students are given an opportunity to perceive their own achievement in science and mathematics (Bandura, 1997; Luzzo, Hasper, Albert, Bibby, & Martinelli, 1999).

High School Classroom Experiences in Canada

An additional study with the TI-Navigator system was conducted in 10th grade classrooms in three secondary schools in an urban setting in Ontario, Canada. The school district had purchased TI-Navigator systems for the entire district and wanted to know if the system was effective in supporting the teaching of mathematics in 9th and 10th grades.

In two of the schools, eight maths classes used the TI-Navigator system. In the other school, eight 10th grade math classes did not use the TI-Navigator system; they were used as the control or comparison group.

All students took a pre-test (scores used as a covariate to the post-test scores) and post-tests. In Canada, the type of mathematics class assignment depends on whether students pursue either an applied college apprenticeship or an academic university track.

The experimental *academic* track students performed significantly better on the post-test than the control group. There were no significant differences found between the *applied* experimental group and the control group.

Based on qualitative data from classroom observations, focus groups, and teacher interviews, the experimental *applied* students reported to enjoy working on activities with the connected technology and appreciated being able to share answers anonymously. Teachers and observers believed students benefited from their participation in the experimental group, though applied class achievement gains were not significant (Sinclair, 2008).

During teacher interviews, all of the teachers who used the TI-Navigator system said that they enjoyed using the system. While all of the teachers said that the LearningCheck™ and Quick Poll features of the system helped them to determine whether or not their students understood the material, most teachers said that they liked the way the instant feedback got the students involved.

One teacher commented "it's student-centered… [It] gets kids discussing the ideas." A department head stated that "incorporating technology into lessons requires a willingness to change one's pedagogy." A mentor teacher, assisting the teachers to incorporate the TI-Navigator system, reported that teachers used the customized materials for their classes and asked for more (Sinclair, 2008).

How Teachers Use and Integrate the TI-Navigator System

As shown by studies of teachers' use of the TI-Navigator system (Owens, 2008; Penuel, 2008; Irving, 2008), teachers use TI-Navigator technology in a variety of ways. Most teachers use the capability to display student responses as a method of orchestrating class discussion focused on math understanding (Penuel, 2008).

Most teachers also use the Quick Poll feature as a method for checking homework comprehension, to focus on a particular concept being taught, or to increase student engagement.

Although the LearningCheck feature required putting the questions into the system before class, it was also used by a majority of the teachers. They reported that the feature made it easy to assess students quickly and informally, so they could immediately know whether to move forward in the lesson or not.

In a low-achieving school, all algebra teachers used the TI-Navigator system to assess student competence on a practice state test. This aggregated data formed the basis for targeting specific content areas (Penuel, 2008).

A case study was conducted to find some of the ways the TI-Navigator system was implemented in physical science classes. One physical science teacher talked about having to initially set up new classroom routines to integrate the use of the TI-Navigator system, as well as adapt her lessons. She commented that the benefits of finding out what students understand outweighed the time to adapt her lessons.

Another teacher began the class with a "Bell Problem," the first problem to be done, using the TI-Navigator system. She then gathered and displayed results. These served as a basis for determining student understanding of the current topic and as a basis for class discussion (Irving, 2008).

Data collection sensors in science classes were used to collect, aggregate, and display data from motion detectors and pH meters. The use of the public screen to display these data led supported discussion on important aspects of scientific inquiry, such as accuracy, multiple measurements and averaging of class data (Owens, 2008).

How Technology is Implemented Matters

The TI MathForward™ program is a systemic reform initiative aimed at improving algebra achievement. The design of the program was informed by an earlier program in Hawaiian classrooms in which students using the TI-Navigator system overwhelmingly demonstrated higher maths achievement and responded faster to teacher directions or presentation of tasks than students who did not use the system (Dougherty, 2005).

In a TI MathForward class, students experience challenging algebra teaching supported by the TI-Navigator system. TI MathForward is a district-level program, and teachers are required to participate in intensive professional development activities to support their use of TI MathForward materials and TI-Navigator technology.

An evaluation of TI MathForward took place in 2007-2008 and included 140 teachers in 35 schools from 11 districts. Classrooms in Ohio, New York and Texas, where implementation was strong, had students that gained 3 and 10 percent more than controls in a single year in mathematics. Researchers found that all schools increased mathematics teaching time for students; teacher's professional development experiences were deep, extended and varied in format, although most schools did not provide common planning time for teachers.

Teachers and students found that TI-Navigator technology contributed positively to teaching and learning. When using the TI-Navigator system, teachers used the Quick Poll feature and other formative assessment functions most often to collect information about student learning and change the pace of lessons. The top benefits of TI-Navigator technology, from most teachers' point of view, were more immediate feedback about what students know and can do, and enhanced student conceptual understanding of mathematics.

Districts reported differences in achievement between experiment and control groups. In Brentwood, California, 8th grade students in the TI MathForward program significantly outgained comparison students (Penuel, 2008[a]). The findings were similar in Springfield, Ohio (Penuel, 2008[b]).

Canton, Ohio is a case of a district where differences in outcomes by grade level appeared to be correlated with levels of program implementation. Better student outcomes were linked to teachers who incorporated the TI MathForward interactive system more fully into their classrooms. Interactive teaching methods are an important ingredient in the program's success. In addition, Canton was an example of a district where TI MathForward had a positive, gap-closing effect for African American students (Penuel, 2008[c]).

In Richardson, Texas, the overall gains made in mathematics by TI MathForward students on the Texas Assessment of Knowledge and Skills (TAKS™) were significantly greater than for comparison students, who differed from the program students in that they were higher achieving and less likely to be minority students.

The gains of TI MathForward students in Richardson were greatest in 7th grade, relative to the other two grades that participated. Among the TI MathForward™ students, 55 percent of students scored proficient or higher in mathematics in spring 2008, compared to 48 percent the year before, (Penuel, 2008[d]).

Rigorous Research is Rare in Education

Randomized trials and other forms of rigorous evaluation are rarely conducted in education. Even when they are conducted, finding strong positive effects is rare. For example, a national study commissioned by the U.S. Department of Education to assess the effectiveness of educational technology in maths and reading, showed that test scores were not significantly higher in classrooms using selected technology products than classrooms that were not (Campuzano, L., 2009).

In each of the three studies above, the TI-Navigator system was used to create a "connected classroom" in which teachers were able to easily gain more information about students' mathematical thinking. Each of the studies employed a rigorous design and found clear benefits for student achievement, as well as other important variables such as students' self-efficacy and enjoyment of mathematics classrooms.

We emphasize that for these benefits to occur, teachers must leverage additional information about students' thinking in their practice–for example, by adapting teaching to better fit students' needs (Sanalan, 2008).

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