How can teachers use technology to help students with special needs improve learning in mathematics?

Research Note 17

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Addressing students' special needs must start with getting the foundations of mathematics teaching right. Within good teaching practice, technology can support special needs students by offering multiple ways to represent mathematics, support action and expression, and engage students' interest, consonant with the principles of Universal Design for Learning.

Most Classrooms Have Special Needs Students

Today, most classrooms have at least some students with special needs. Kroesbergan and Luit (2003) estimate that 5% to 10% of the students in typical classrooms are designated as having difficulties in learning mathematics.

There are two classes of students in classrooms that have special needs: students with general learning disabilities (LD) and students who have emotional or behavior disorders (ED). Of these, most have learning difficulties across subject matters, not only in mathematics. A much smaller group has mathematics-specific learning difficulties. Another large group that can be considered to need special attention is English Language Learners (ELL).

Legal Rights for Students with Special Needs

In the United States, the Individuals with Disabilities Education Act (1997, 2004) requires that students with special needs have access to the general education curriculum, including rigorous mathematical standards and higher order problem-solving.

English language learners, those students whose native language is not English, also have a right, by law, to learn mathematics at the same academic level expected of all other students (NCLB, 2001).

Teachers have the challenge of providing their students with appropriate instruction that will allow all of their students to meet the high expectations for learning mathematics.

In addition, expectations for what it means to learn mathematics have been increasing.
For example, the National Council of Teachers of Mathematics (NCTM, 2000) emphasizes developing a child's ability to think about mathematical ideas and how to use these ideas to solve meaningful problems.

Mathematics learning today not only addresses procedures, but also concepts, strategies, communication and students' productive disposition to mathematics.

Issues for Special Needs Students

There are a wide variety of specific learning issues amongst LD, ED, and ELL students in terms of severity and type. However, these groups also face a large set of common issues (see box below).

Other researchers in the area of special education and math disabilities (Miller, 1997) describe a variety of student weakness in the area of processing information that may affect math performance. Many students lack awareness of the skills, strategies and resources that are needed to perform a task.

Common Issues for Special Needs Students

- Difficulty processing information that results in problems learning to read and solve problems.
- Difficulty with distinguishing the relevant information in story problems.
- Low motivation, self-esteem, or self-efficacy to learn due to repeated academic failure.
- Problems with higher-level mathematics that requires reasoning and problem-solving skills.
- Passive learners reluctant to try new academic tasks or to sustain attention to task.
- Difficulty with self-monitoring and self-regulation during problem-solving.
- Difficult with arithmetic, computational deficits.

ELL learners have some overlapping issues and some unique ones. Researchers of ELL learners and for students with language disabilities share a consensus that there is a complex relationship between language and mathematics learning (Diaz-Rico, 2006; Hawkins, 2005; Carr, 2009).

There exists a common misunderstanding that math is a universal symbolic language, independent of words. To the contrary, speaking mathematics in a natural language is an important component of learning to use the "universal" symbols.

Full participation in a solid mathematics education in American classrooms requires an ability to understand how mathematics is spoken in English, in order to participate in classroom discourse and engage in the symbolic language. (Miller, 1997).

Talking about mathematics, using appropriately descriptive words and symbols can be daunting for ELL's (Carr, 2009). For example, we recently observed a group of ELL students doing an activity by a teacher that involved manipulating coins to solve a problem.

The students could not make progress on the problem because they didn't know the common names of U.S. coins. Language difficulties can create barriers for ELL students to follow the teachers' instructions and engage in doing mathematics in the classroom.

Teaching Special Needs and ELL Students

The necessary foundations for teaching special need and ELL students are the same as the foundations for teaching mathematics to all students. One state-of-the-art approach has been termed "Universal Design for Learning" and features the idea that good instruction benefits everyone (see http://www.udlcenter.org/aboutudl/udlguidelines). The three principles of Universal Design for Learning (UDL) are:

1. Provide multiple means of representation.
2. Provide multiple means of action and expression.
3. Provide multiple means of affective engagement.

UDL principles are often applied within a framework of formative assessment and differentiated instruction. Formative assessment helps a teacher to track students' progress in learning the mathematics. Differentiated instruction enables a teacher to provide additional means of representation, expression and engagement to suit the needs of particular students.

With a variety of types of students with LD and HD problems, as well as ELL students, differentiating instruction, though challenging, is critical to support all students in learning complex mathematical concepts and problem-solving strategies (Carr, 2009).

There is a tendency for teachers to focus on rote memorization goals for special needs and ELL students, which does not meet their needs or address the legal requirements for these students to have an opportunity to learn. It is particularly important, therefore, to use formative assessment and differentiated instruction to enable special needs students to meet high expectations.

Meeting Special Needs Through Technology

Technologies such as TI-Nspire™ learning technology and the TI-Navigator™ classroom learning system can provide capabilities that enable teachers to apply each of the three UDL principles.

First, TI-Nspire technology features multiple representations, including algebraic symbols, graphs, tables, diagrams, and words. Researchers of mathematics learning by special education and ELL students agree that the teacher must promote the understanding of mathematical concepts before a formalized presentation of problem-solving techniques are addressed (Diaz-Rico, 2006; Hawkins, 2005; Carr, 2009). Multiple representations are particularly important for building conceptual understanding.

One of the key findings in an analysis of studies using a variety of math interventions is that using visual graphical and other representation techniques are effective instruction strategies to help students with special needs (Gersten, 2009). While a very traditional teacher might define a "linear function" as a function where the power of the independent variable is 1," a teacher using TI-Nspire technology can involve students in graphing two sets of equations, some which are linear and some that are not.

Students may be able to recognize the pattern that lines appear in the graph when the function does not have an x^2, x^3, or higher term. Many special needs students may be able to recognize the pattern long before they can make sense of the phrase "a function where the power of the independent variable is 1."

Likewise, for ELL students, it is important to build bridges between mathematical symbols and ways of speaking about those symbols using English (Diaz-Rico, 2006). Prepositions such as "by" and "per" are often problematic in phrases such as "this is a linear function, because y goes up by 2 every time x goes up by 1." Making a table with TI-Nspire technology for the function y=2*x may be an effective way to connect the phrase "goes up by" to its intended meaning in reading a table of x and y values.

Second, TI-Nspire technology and the TI-Navigator system can provide new modes of action and expression. For example, a common mistake in plotting points is to reverse the x and y coordinates. Special needs students may have a hard time remembering the convention that the ordered pair is written (x,y).

In a classic TI-Navigator activity, instead of "plotting" a point, students in a classroom each move a point that they control; the group of points controlled by all students is projected on a common display. Students first "go" to their x coordinate on the x-axis, then move up to the y-coordinate. Special needs students may have an easier time remembering how to plot when expressed as first going left or right to an x-axis location and then moving up.

In addition, because the TI-Navigator system shows their classmates doing this routine, students get re-enforcement for the correct procedure (and a teacher can rather easily see when one of the students is moving on the y-axis first). In another example, it may be difficult for special needs students to understand the key idea of "similar triangles" by looking at only two triangles on a printed page.

Using TI-Nspire geometry capabilities, students can express a family of similar triangles by dragging a vertex. Consider giving such students two kinds of triangles that can be dragged: one that is constrained so that all drags result in similar triangles and another that does not observe this constraint. Students may have an easier time intuiting the meaning of similar triangles when they observe how the constrained triangles behave in contrast to the unconstrained triangles.

An addition basic point is that when the focus is on higher-level reasoning, giving students a calculator may reduce their cognitive load sufficiently so that they can pay attention to the big idea and not just the effort of doing calculations.

Another common recommendation is that the teacher should provide more live demonstrations of concepts when teaching ELL students (e.g. Carr, 2009). TI-Nspire technology makes it possible to present a wide variety of live demonstrations of key algebra, geometry and data analysis concepts.

Third, TI-Nspire technology and the TI-Navigator system can promote new ways to engage students with positive results. The TI-Navigator system, for instance, supports an anonymous "Quick Poll" capability that a teacher can use to see the various ideas students have in a classroom.

A well-chosen question that draws a range of opinions can engage students in learning. Consider making the bridge from linear to quadratic functions in an Algebra class. A conventional teaching technique might be to simply introduce a quadratic function.

With the TI-Navigator system, the teacher might take a quick poll on the question, "are there any two functions we can graph that will intersect at two points instead of only intersecting at one point?" Some students might say "yes" and engage the interest of the class in learning what kinds of functions generate more than one intersection point.

Likewise, the many collaborative activities possible with the TI-Navigator system can use social activity to recruit student interest. Being able to discuss mathematical ideas and understanding are considered critical for all students learning mathematics (NCTM, 2007), but especially so for ELL students (Diaz-Rico, 2006; Hawkins, 2005; Carr, 2009).

In the same way, a classic approach with TI-Nspire technology is to recruit interest by engaging students in an exploratory activity centered on a surprising phenomenon. A simple example would be to ask students to play with the parameter “m” in the function “f(x) = mx + 2” with the question: “Can you describe what changing m from positive to negative (e.g., from 2 to -2) does to the line?”

In addition, the interactivity of TI-Nspire technology and the TI-Navigator system gives students continuous feedback and may enhance their ability to self-regulate their learning. A student whose task is to make two different lines that cross the y-axis at (0,2) can get immediate feedback when one of their lines does not go through that point, and may be able to motivated to try again without asking for the teacher’s help.

Another major strategy recommended and used by teachers to enhance mathematics achievement (and performance in other content areas) is to provide feedback to students about their effort or performance (Schunk & Cox, 1986). In a recent analysis of studies that provided feedback on their performance or effort to special education students found this method to be effective (Gersten, 2009).

Quick polls can also be used to implement the recommendation that a teacher frequently check for students’ understanding of key vocabulary in the ELL classroom (Carr, 2009).

In addition to these specific issues, technology can support teachers in spending more time with individual students who need the attention. This becomes possible because technology-rich activities may sustain the independent or collaborative work of many students for longer periods of time, freeing the teacher to circulate among students who need help with reading,

Conclusion

Overall, the trend in research with special needs and ELL students is for teachers to avoid taking only one specific, narrow approach, but rather to acquire skills in differentiating instruction so that alternative approaches are routinely used to better meet the learning needs of all of their students.

To respond to students’ difficulties in processing information and distinguishing relevant information, teachers may engage additional modes of representation and expression made available through technology. To address students’ low esteem in response to their difficulties in traditional classroom formats, teachers may use technology to give students new modes of expression and new means of engagement.

To help students move on to higher order mathematics reasoning, without getting bogged down in mechanical computations or procedures, some of the cognitive load may be offloaded to technological capabilities to compute and visualize.

Students who are reluctant or passive learners may become more active when exploratory or collaborative modes of engagement are available as part of the classroom repertoire.

Overall, self-regulation is strongly encouraged in a more interactive mathematics classroom, because students have more opportunities to try mathematical actions and see the resulting mathematical consequences, as well as the potential for more support from their peers through social and collaborative activities.

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