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TECH RESEARCH BRIEF

Using Virtual Manipulatives to Teach Math

Center for Technology Implementation

Overview

The use of manipulatives in math instruction can help you in addressing the Common Core State Standards for Mathematical Practice.

Abstract concepts are essential to understanding and doing math. They are also a source of difficulty for students who struggle with math, many of whom find even basic math concepts hard to understand. A popular approach to help students understand abstract concepts is the use of concrete materials, often referred to as manipulatives. Manipulatives help students and teachers concretely represent abstract math concepts. Also, they enable students to link these concepts to prior knowledge. The use of manipulatives in math instruction can help you in addressing the Common Core State Standards for Mathematical Practice—particularly the standards related to making sense of problems and reasoning abstractly.

In the past, most classrooms only had physical manipulatives. Today, more classrooms have improved access to computers and the Internet. As a result, virtual manipulatives are becoming more common. These can be useful tools for students and can help support them in learning to use appropriate technology tools for mathematics.

Using In Your Classroom

Virtual manipulatives are digital “objects” that resemble physical objects.

You can manipulate them, often with a mouse, in the same ways you would real objects. Many virtual manipulatives typically used in math education are available for free online. These include Base-10 Blocks, Cuisenaire Rods, and tangrams. Most virtual manipulatives come with structured activities or suggestions to help teachers use them in the classroom.

Virtual manipulatives can benefit your students in several ways. Using these tools in your classroom can:

- Help students understand abstract math concepts.
- Lead to richer and more complex understandings of concepts.
- Help clarify student misconceptions and build connections between concepts and representations.

These tools can be especially helpful for students with disabilities. Virtual manipulatives can improve their understanding of the abstract symbolic language of math. Students who struggle in math often find it hard to connect visual and symbolic representations. Virtual manipulatives can help make these connections clear.

In addition, virtual objects can be altered in ways that concrete ones cannot. For example, the size, shape, and color of a block can be changed. This means that, in many cases, students can create more examples using virtual versus physical objects. An added benefit of virtual manipulatives is that many of them give students hints and feedback, which allows them to practice on their own, without teacher assistance.

Due to these features, virtual manipulatives may be especially helpful to students with language difficulties, including English language learners. These students often have trouble explaining what they are learning in math. Virtual manipulatives may help them clarify their thinking and share it with others.

When choosing from one of the many options available for virtual manipulatives, there are several key factors to keep in mind:

- Ensure that manipulatives are linked to specific math content and evidence-based strategies, not used as a separate activity.
- Ensure that manipulatives are used as part of a progression from concrete to pictorial to abstract (see *What the Research Says*).
- Evaluate embedded options and supports:
    - Can you adjust the level of difficulty for different students?
    - Is feedback provided? What type?
    - Will you need to be on hand to provide additional feedback and support?
    - How clear are the instructions for use? Will you need to provide additional guidance?

Used wisely, virtual manipulatives can be an excellent addition to your teaching toolkit. They can provide students with opportunities for guided exploration, helping them build a solid understanding of math concepts. They can also help students demonstrate and share their learning.

What the Research Says

Studies have evaluated the effectiveness of manipulatives as a tool in math instruction. One line of research has studied the Concrete-Representational-Abstract (CRA) sequence. This form of explicit instruction moves students from concrete manipulatives to pictorial representations of those manipulatives, and finally to abstract concepts. Butler, Miller, Crehan, Babbitt, and Pierce (2003) compared the effectiveness of teaching fraction concepts to students with learning disabilities using a CRA approach versus a Representational-Abstract (RA) approach (starting with pictorial representations and moving to abstract concepts, with no concrete manipulatives). Although both groups improved their understanding of fractions, the CRA group had overall higher scores than the RA group.

A study by Witzel, Mercer, and Miller (2003) also supports the effectiveness of a CRA approach for developing the basic math skills of students with learning disabilities. Students were taught to solve algebraic equations using either a CRA approach or a traditional approach. The study involved 34 matched pairs of students in Grades 6 and 7 who either had been diagnosed with learning disabilities or were categorized as at risk for learning problems. After a four-week intervention, both groups showed improvement, but the CRA group significantly outperformed those who had received traditional instruction.

In another CRA study (Maccini & Hughes, 2000), six adolescents with learning disabilities used algebra tiles to represent algebra word problems during the concrete phase of instruction. The students were able to transition successfully to pictorial and ultimately symbolic representations of the problems.

Reimer and Moyer (2005) investigated the performance of 19 Grade 3 students during a two-week unit on fractions that used virtual manipulatives. More than half of the students improved their conceptual understanding of fractions on a teacher-designed measure. In another study of 19 Grade 2 students, Moyer, Niezgoda, and Stanley (2005) observed that virtual Base-10 Blocks enabled students to demonstrate more sophisticated strategies and explanations of place value. Bolyard and Moyer-Packenham (2006) studied the use of virtual manipulatives with 99 Grade 6 students learning addition and subtraction of integers. The students showed significant gains in achievement, and the researchers concluded that virtual manipulatives can support learning these concepts.

Suh and Moyer (2007) compared the use of concrete and virtual manipulatives in Grade 3 students studying algebraic thinking. Both types of manipulatives were associated with higher achievement and increased flexibility in representing algebraic concepts. Steen, Brooks, and Lyon (2006) compared the academic achievement of a group of Grade 1 students who used virtual manipulatives for practice in geometry instruction (treatment group) with another group who did not (control group). A total of 31 students were randomly assigned to either the treatment or control group. Achievement was measured by the Grade 1 and Grade 2 assessments provided by the classroom textbook's publisher. The treatment group improved significantly on both the Grade 1 and Grade 2 tests, while the control group showed significant improvement only on the Grade 1 test. The teacher of the treatment group also noted that her students showed increased motivation and time on task.

Teachers play an important role in helping students understand the concepts that manipulatives represent. This was highlighted in a one-year study of 10 middle school math teachers and their use of manipulatives (Moyer, 2001). Teachers who were unable to represent math concepts were more likely to use manipulatives as a diversionary rather than an instructional activity.

The CRA studies described above also demonstrate the importance of structure and guidance in linking concrete materials to abstract concepts. For example, students in Maccini and Hughes' study (2000) were taught not only to use algebra tiles to represent word problems but also to use a structured strategy in solving them. In the Reimer and Moyer study (2005), students benefited from another important aspect of guidance: feedback. When students were interviewed regarding their impressions of the virtual manipulatives, an emergent theme was their appreciation for the immediate feedback possible with the computer-based manipulatives.

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SUGGESTED CITATION: Center for Technology Implementation. (2011). *Using virtual manipulatives to teach math.* Washington, DC: American Institutes for Research.