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Improving Basic Mathematics Instruction

Promising Technology Resources for Students with Special Needs

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Technology can help teachers support student understanding of mathematical concepts and increase achievement. This *Technology in Action* describes how educators can use technology to help students with disabilities succeed in standards-based mathematics instruction.

Technology and Media Division

Many students with disabilities face mathematics with dread and trepidation. Higher expectations, compounded with more complex curricula, add to the challenge. As demonstrated by the most recent National Assessment of Educational Progress, students with disabilities continue to underachieve in mathematics (Perie, Grigg, & Dion, 2005). Students with high-incidence disabilities such as learning disabilities and mild cognitive impairments struggle with computation and problem-solving skills, reading and comprehension, and applying strategies. Research has shown that students with disabilities are falling farther behind their non-disabled peers in retention and recall of basic facts through the elementary years (Cawley et al., 1996; Hasselbring, Lott, & Zydney, 2005), jeopardizing their success with higher mathematics such as algebra that are required in middle and high school.

Few students have isolated math disabilities. Most also have concomitant issues related to language processing and reading challenges. For example, many children with dyslexia have the same difficulty recognizing a math basic problem as they do a written word. That these problems are presented left to right (3 + 1 = 4) as well as top to bottom only adds to the difficulty. Students with language disorders often have difficulty in math because they must process the language before they can process the math problem. The use of inconsistent language (sum, add, total, plus, etc.) to describe the same operation can present additional challenges.

Researchers have identified several practices that are effective in teaching mathematics to students with a range of learning needs (Hasselbring, Lott, & Zydney, 2005):

- Providing practice in basic skills for computational fluency.

- Providing manipulatives for conceptual understanding.
- Using enhanced anchored instruction and web-based activities for problem solving.

Each of these practices has the potential to enhance mathematics instruction. Evidence suggests that technology may, in turn, make it easier to implement these practices. For example, technology can represent mathematical concepts in different ways, helping students form mental representations of concepts in ways that are meaningful to them. Technology can provide support for students who have trouble remembering math facts and procedures or whose fine motor skills make writing problems and drawing diagrams difficult. The flexibility and interactivity that are inherent in technology can help students who otherwise avoid math become engaged in the subject.

Practice in Basic Skills to Support Fluency

Difficulty with computational fluency, or automatic retrieval of basic math facts, is a problem for many students with disabilities. Typically, young children use counting strategies to solve basic problems such as 2 + 3. Over time they develop more efficient strategies, such as counting on (saying "2" and counting up 3). Once they have learned a few facts and can retrieve them from memory, they begin to link new facts to ones they already know (e.g., they know 3 + 3 = 6, so 3 + 4 is one more than 6).

However, many students who struggle with math never move beyond counting strategies. Because using counting strategies requires conscious effort, their ability to learn higher-order problem-solving strategies may be compromised because their effort is directed toward counting rather than solving the problem.

Basic facts should not be practiced simply by rote. The learning sequence should be structured (Hasselbring, Lott, & Zydney, 2005). The challenge is to determine the facts with which students are not yet fluent (e.g., still using counting to find the answer) and help them make the link to what they already know. Teachers also need to help students build "number sense"–the awareness of the names, values, and relationships of numbers (Gersten & Chard, 1999; Hasselbring, Lott, & Zydney, 2005).

How Technology Can Help

The inability to retrieve information quickly creates fluency problems for many students (Geary, 2004). Several studies have found that daily practice can help students increase both their speed and their accuracy in recalling basic facts (Miller, Butler, & Lee, 1998).

Technology can provide students with different formats for practicing math skills. Practice activities and games found on various websites offer one such approach. Web-based activities offer teachers and parents options that are free, and teachers with limited budgets can find multiple sites to meet the needs of students with varied abilities.

Following are two examples:

- **Shodor Education Foundation** (**www.shodor.org/interactivate/**) is a website that includes interactive tools and curriculum materials for intermediate and middle school mathematics. Users can search the portal by grade level or subject. The site contains interactive lessons, discussions, and activities.
- **The Math Forum**, hosted by Drexel University (**http://mathforum.org/**), has a digital catalog of math activities and discussion forums. Users can search by math topic, grade level, technology type, and resource type. There also are free discussion forums.

Teachers should consider the following factors when using technology to help students with disabilities practice math skills:

- Can the ***level of difficulty*** be adjusted to match the needs of individual students?
- What ***type of feedback*** does it provide for correct and incorrect responses? Do students have a chance to correct errors? Can it track a student's correct and incorrect responses? (Many students like to know how they're doing, and teachers can use this information to adjust the level of difficulty.)
- Is the activity ***timed***? Can the timing be adjusted? Is there an untimed version? (Some students may enjoy the challenge of a timed activity, while others may need to work at their own pace.)

- Are the math problems presented ***frequently*** enough to build fluency, or are they given only periodically as a part of a game? (Some activities present problems so infrequently that they would not help a student learn to retrieve basic facts automatically.)
- What ***type of response*** is required? Do students select a correct answer, or do they enter it from the keyboard? If they select an answer, how many options must they choose from? (Some activities present so many choices that it may be difficult for students to scan them all efficiently.)
- Are the ***directions*** clear enough for students to use the activity without additional instructions? (Many activities have minimal directions, and while some students may enjoy figuring out what to do, others might need more help in getting started.)
- Are there ***distracting elements*** on the screen? Are there advertisements or other distracting pop-up materials?
- Does the site have ***accessible features*** that a student with disabilities might require (e.g., switch and screen reader compatibility, built-in text-to-speech, font size control, or voice recognition input options)?

Figure 1 presents a sample grid for reviewing web-based activities according to these components. *Note*: For some students with disabilities, a game format (e.g., shooting aliens) is less effective at increasing fluency than a more straightforward practice activity (Christensen & Gerber, 1990). This may be because the game itself draws attention away from the math. In addition, if the game is complex, students with disabilities may have trouble focusing on both the rules of the game and the math presented. Both formats have been found to engage students; the key is to select the format that best fits each student's needs, not simply the one that appears to be the most engaging.

Figure 1 : Sample Grid for Reviewing Web-based Activities

Game/Site	Description	Math Topic	Directions	Adjustable Difficulty	Feedback	Timed	Response Mode	Distracters	Comments
AAAMath **www.aaamath.com/**	many different practice activities for all grades has practice for basic facts (reviewed here)	addition, subtraction, multiplication, division	gives detailed lesson on how to solve the problems before the game format	yes can choose types of problems (e.g., adding 0 or 1, 2 or 3)	yes keeps track of errors, gives corrective feedback	yes three versions/ options	select (choice of numbers in order) direct entry	minimal advertising for their CD	problems presented horizontally
Sum Sense **http://www.oswego.org/ocsd-web/games/SumSense/sumadd.html**	student is given 3 or 4 number cards (e.g., 1, 1, 5, 6) that they move to create a basic fact (5+6=11)	addition–basic facts	yes clear directions on how to use	can select number of problems to solve and amount of time	tells if response is incorrect – student corrects	yes	drag and drop		fairly complex
Froggy Hops **http://atschool.eduweb.co.uk/toftwood/frog.html**	addition problem appears at top of screen frog is on the pad with the first addend, the sequence of numbers appears under the next 11 pads click the correct answer and the frog hops to that pad	addition–1 and 2 digit	no directions	no	no does not accept incorrect answer	no continues indefinitely	select (choice of 11 in order)		
Sums Stacker **http://www.carstensstudios.com/mathdoodles/sumsstacker.html**	move stacks of numbers until their sums match three given values	addition–basic facts	very basic directions	no you can choose whether to work with numbers, dice, or coins	indicates when all sums are correct and gives a new set	yes one version has time limit or keeps track of time (stops after 5 sets)	drag and drop		game format is fun but might be confusing

Teachers should establish guidelines and set performance expectations to ensure success when using web-based practice activities with students. They should consider creating a digital activity sheet that shows the various screens for the activity to assist students and helpers (e.g., parents, paraprofessionals, etc.).

Figure 2 provides an example. Students and their helpers can use an activity sheet to familiarize themselves with the framework of the program and set expectations before they begin. The activity sheet can include a link to the activity along with more detailed instructions about how to use it. For example:

- Give a specific assignment, such as the number of problems to do or a time limit for the activity.
- Explain how to set the level, if this can be done.
- Think about how to evaluate the activity. Should students record the number of correct and incorrect answers?

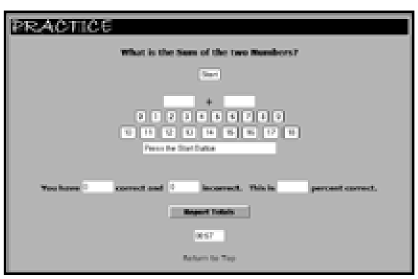
In addition to free websites, there are a number of commercial programs that provide practice activities. Although neither the authors nor TAM endorse these programs, users may wish to review them. The Math Matrix at **www.techmatrix.org** provides a review of products designed to build computational fluency.

Manipulatives to Support Conceptual Understanding

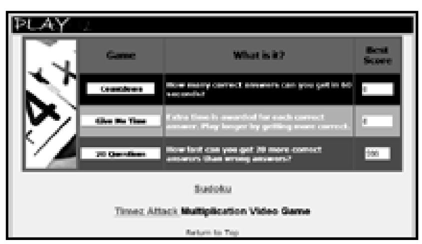
Many students struggle to understand even basic math concepts (Geary, 2004). The language of math is abstract and symbolic, and they may need help making sense of it. Providing students with manipulative materials designed to represent abstract concepts can help them to make connections between informal conceptual knowledge and formal mathematical symbols and procedures. An instructional approach that starts with concrete representations, then moves to

Figure 2: Sample Activity Sheet — Fluency

Addition Facts for 3 and 4 from AAAMath

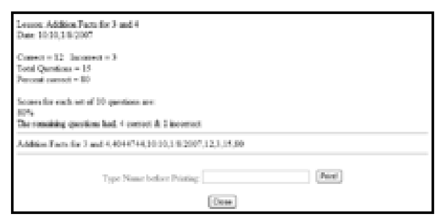


CLICK HERE to take you to the addition activity. You will see a page that looks like this. Click on the **Give Me Time** button.



Now the screen will look like this.

- Click on the **Start** button.
- A number will appear in each of the two boxes below the Start button.
- Below the boxes are the numbers from 0 to 18. Click on the number that is the sum of the two numbers.
- When your time is up, click the **Report Totals** button.



You will see a page that looks like this. It tells how many answers were correct.

- Type in your name.
- Click Print to print your results.
- Bring the printed results to me so we can talk about how well you are doing.

representations that use images, and finally connects these to the abstract, symbolic representations of mathematics has been shown to be effective. See Anstrom (2006) for a review of the research.

The concrete stage may be particularly important for students with math difficulties, who often find even pictorial representations hard to understand. For concrete manipulatives to be effective, however, they must make sense to students. The objects in and of themselves have no mathematical meaning. It is the role of the teacher to help students understand how these materials can represent what they are learning in math. Research has shown that teachers who thoroughly understand the underlying concept represented by the manipulatives are able to help their students make the connections between these concrete materials and the abstract concepts (Moyer, 2001).

How Technology Can Help

Virtual manipulatives—sometimes called computer-based manipulatives—are an alternative to concrete materials. Virtual manipulatives can make the research-based sequence of concrete-representational-abstract instruction available to all teachers and learners with an Internet connection. Even teachers with only one computer can use virtual manipulatives to illustrate concepts to a group or class in an engaging and comprehensible manner.

Students may find virtual manipulatives helpful, engaging, and generally easy to use (Reimer & Moyer, 2005). For example, when a student copies a Tangram design, a block that is positioned correctly might snap into place. The computer can make it easier for students who are not physically able to handle traditional manipulatives due to fine motor difficulties to move virtual objects, allowing them to focus on the concepts being represented.

Students can explore virtual manipulatives on their own. However, as with physical manipulatives, students will benefit from teacher guidance. Teachers will want to plan how virtual manipulatives will be used, determine how to provide guidance, and decide how to evaluate their effectiveness in conveying concepts.

In some cases it may be helpful to have students explore with the physical manipulatives before moving to the screen-based versions. For example, Zorfass and associates (2006) have developed an Instructional Planning Matrix that is designed to help teachers use web-based applets, including virtual manipulatives. They suggest three ways that applets might be incorporated into the math curriculum:

- To introduce a skill or concept.
- To provide practice or assessment.
- To provide remediation.

They include suggestions for the supports that teachers may need to provide before, during, and after the activity. They also include an example of a worksheet that teachers can develop to structure a virtual manipulative activity for individual students. The worksheet includes a link to the applet along with a series of questions for students to answer by using the manipulatives.

While virtual manipulatives are available on several websites, two sites focus on virtual versions of several different concrete manipulatives that are commonly used in math classes:

- **Arcytech (www.arcytech.org/java)** is a free site that includes interactive tools for several manipulatives commonly used in the elementary grades–Cuisenaire rods, base 10 blocks, pattern blocks, and fraction bars. Each tool provides instructions and suggested lessons on separate web pages. Many of the activities give students hints and feedback, something that the more traditional physical manipulatives cannot do.
- **The National Library of Virtual Manipulatives (http://nlvm.usu.edu/en/nav/vlibrary.html)** developed at Utah State University and funded by the National Science Foundation is a library of web-based interactive virtual manipulatives and concept tutorials. The manipulatives include some that are commonly used in teaching, such as base 10 blocks, pattern blocks, and algebra blocks. Manipulatives are cataloged by grade level and National Council of Teachers of Mathematics (NCTM) content standard area (number and operations, algebra, geometry, measurement,

and data analysis and probability). Each manipulative includes instructions, suggested activities, lesson plans, and a connection to relevant NCTM standards. Teachers also can submit lesson plans that they develop using the manipulatives available on this site.

Enhanced Anchored Instruction and Web-based Activities for Problem Solving

Many students who struggle with math find problem solving difficult. Most children come to school with an intuitive sense of numbers. Frequently, however, they do not connect what they already know with the more formal presentation of math in the school curriculum. This disconnect is even stronger in students with disabilities, who often view math as a set of arbitrary rules that have no relation to the real world. The curriculum itself may reinforce this perception; some students with academic disabilities may receive a remedial curriculum that focuses almost exclusively on learning basic skills. They may have little opportunity to develop strategies for solving problems or to relate math to their own experiences.

Anchored instruction is one approach that helps students learn to apply math in real-world contexts. Problems are embedded—or anchored—in rich, authentic contexts. More specifically, stories are embedded with the information students need, and frequently there is more than one way to reach a solution.

Anchored instruction lessons are enhanced through real-world activities that require students to apply what they are learning. Although an enhanced anchored instruction lesson may take longer than a typical math lesson, students have been found to benefit from these lessons and teachers have reported that they are worth the time because students learn the concepts at a deeper level and with more engagement (Bottge et al., 2001).

How Technology Can Help

Using real-world scenarios can help students understand the implications and applications of mathematics concepts and engage them in a problem-solving activity where their skills and knowledge can be challenged and applied. Using video technology to present these stories can support students with language disorders who would struggle with text-based presentations. To enhance effectiveness, teachers should debrief the activities and make the mathematics involved explicit to ensure that students see the connections.

The following sites provide resources for creating inquiry-based stories that can engage students in problem-solving activities:

- The **Jasper Woodbury Project** (**http://peabody.vanderbilt.edu/projects/funded/jasper/**) is the basis for much of the research on enhanced anchored instruction. Pioneered by the Cognition and Technology Group at Vanderbilt University, this method uses interactive video so that students can engage with the material, not just watch or listen. For example, in one story students must determine the best way to move a wounded eagle to safety using an ultralight plane. The task requires determining a flight route, computing the amount of gasoline the plane will require, calculating the weight of cargo, and deciding on a landing area. The story is presented via videodisc so that students can pause and review the information at any time. Resource materials are available for purchase.
- The **Webquest Project** (**www.webquest.org**) is maintained by San Diego State University. It contains a database of more than 2,500 teacher-submitted lessons, searchable by subject and grade level. Webquest is a set of student-centered, inquiry-based scenarios in which students explore the web to find the information they need to complete their quest. The database provides a brief description of each quest and ratings by others who have used it. Many are cross curricular. Most projects include a description of the activity, procedures for students to follow, an assessment, and web-based resources for students to use.

Technology for Students with Visual Impairments

Students with visual impairments (VI) present unique challenges for teachers. In order for students to understand the concepts being taught, they must be provided with the means to explore, question, and represent their learning.

Techniques such as translating visual images into spoken language or providing raised line drawings may not be enough, and they have the potential to be confusing. Technology can help teachers and students represent mathematics and geometric concepts in ways that make sense. Teachers may want to consider helping students learn the following types of technology to ensure success with mathematics:

- **Calculators**, specifically scientific calculators, are becoming a necessity for mathematics instruction across the country, and there are now several stand-alone **talking standard** and **scientific calculators** for students with VI. (See reviews of commercially available calculators in the Talking Scientific Calculator matrix on the Texas School for the Blind and Visually Impaired (TSBVI) website at **www.tsbvi.edu/math/talk-sci-calc.htm.**) There are several large display solutions and a limited number of totally accessible graphing calculators (in the form of software) for students with VI. These can be used alongside regular calculators for classroom instruction.
- Facility with **Nemeth Braille**, a method for encoding mathematical and scientific notation linearly using a standard six-dot Braille cell, is a must for students learning higher order mathematics. Learning Nemeth code in advance of enrolling in an advanced mathematics class is imperative. An online tutorial for students of all ages and their teachers is available as a free download at **www.tsbvi.edu/math/math-resources.htm#Download** (Computerized Nemeth Code Tutor for Sighted Individuals) and **www.freedomscientific.com/fs_downloads/notenemeth.asp** (Nemeth Code Self-Study for Blind Individuals).
- **Screen readers** with text-to-speech engines are designed specifically to read mathematical equations and/or output to Braille. Such software packages may include the ability to read equations, word problems, and equations and solutions spoken with voice recognition technology. For more information, see the MathMatrix at **www.techmatrix.org**.
- **Tactile graphics** of maps, charts, etc. can be created with embossing equipment. See **www.tsbvi.edu/math/tactile.htm** for information on how to help students make their own tactile representations, reviews of graphing products, and a decisionmaking checklist for determining which graphics should be considered for representation in a tactile format.
- **Raised line graph and other paper or a rubberized graph board** aid students in creating geometric representations. Teachers also should consider low-tech classroom tools such as **adaptive rulers, compasses, protractors, and drawing boards** along with existing experiential activities such as geo-boards, 2-D and 3-D manipulatives, and modeling with paper or clay so students can participate fully in geometry lessons.
- For young children, **practice software** and **integrated technology solutions** that provide computer access, as well as instructional activities such as those provided through Intellitools can draw students into mathematics in a fun and interactive way. See the products reviewed in the Math Matrix (**www.techmatrix.org**) and instructional suggestions on the TSVBI website (**http://www.tsbvi.edu/technology/tech-institute/at-eci.htm**).

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Conclusion

Each day, teachers face the challenge of teaching mathematics to students with varied abilities, needs, and motivation levels. By using technology designed to increase mathematics fluency, improve problem-solving ability, and support conceptual understanding, teachers can help all students experience excitement, engagement, and greater success with mathematics.

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