

Prepare for the Common Core State Standards with Mathematical Fact Fluency

By Paul Cholmsky

Why is automaticity with mathematical facts critical to success in mathematics?

Automaticity refers to students' ability to retrieve answers to mathematical facts from long-term memory, rather than through effortful means. This means that the student can quickly and reliably use mathematical facts without significant involvement from working memory. Working memory is the brain's "scratchpad" for temporary storage and manipulation of information. It has a very limited capacity, and using it to derive the answers to mathematical facts can cause problems when learning more advanced topics in mathematics.

Consider a student who is learning how to add fractions. A problem like $3/8 + 5/6$ can easily involve 14 or more mathematical facts in its solution. Students with automaticity can instantly and accurately retrieve the answers to these facts, and devote their working memory to learning and mastering the new procedure—in this case, adding fractions. Conversely, students without fluency will have to involve their working memory in a significant way to answer the individual mathematical facts and therefore will have less of this precious resource available as they try to learn new material. Homework will also take much more time, and the student will make many more seemingly "careless" errors.

The benefits of mathematical fact automaticity do not cease with fractions, of course. Mathematical fact retrieval speed

has been shown to be a predictor of scores on a wide range of test items at the secondary and college levels, and can even impact performance on standardized tests that allow calculators. Research has also found that fluency in all four operations—not just addition and multiplication—is critical. A recent large-sample longitudinal study found that elementary-age students' proficiency with whole-number division was a significant predictor of their later high school Algebra 1 performance.



Paul Cholmsky

The Common Core State Standards' Spotlight on Mathematical Fact Fluency

In line with this research, the Common Core State Standards (CCSS) for Mathematics specify that students must be fluent with mathematical facts in all four operations by the end of grade 3. The CCSS assessments under development are expected to rigorously evaluate mathematical fact fluency. Both the Partnership for Assessment of Readiness for College and Careers (PARCC) and the Smarter Balanced Assessment Consortium (SBAC) have stressed the importance of mathematical fact fluency and the new potential for computer-based tests to directly evaluate it via measurement of students' response times. The SBAC adaptive tests may even use a student's mathematical fact fluency levels in determining whether he or she will be assessed on advanced content. CCSS curriculum guidelines therefore advise

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Prepare for the Common Core State Standards

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educators to devote significant classroom time to fluency development.

The CCSS is not alone in stressing the critical role of mathematical fact fluency:

- The NCTM's Curriculum Focal Points make fact recall one of the three focal points in grades 2 and 4;
- Automaticity with mathematical facts is one of the National Mathematics Advisory Panel's Core Principles of Mathematics Instruction;
- The What Works Clearinghouse's research-based Recommendations for Response To Intervention (RTI) programs for struggling students in mathematics include 10 minutes per session for developing fluent retrieval;
- Texas recently approved new elementary mathematics standards (TEKS) specifically requiring automaticity.

Achieving Automaticity

Developing students' mathematical fact fluency to a sufficient level for success can present a challenge. Reports such as that of the National Mathematics Advisory Panel have noted that U.S. students lag behind other countries in this critical area, with some students never developing the fluency they need to succeed with more advanced mathematics. One reason for this is that traditional methods such as timed worksheets and flashcards have been shown to be ineffective or even counterproductive for many students.

To achieve automaticity with a given mathematical fact, a student needs to learn the fact in a manner that can eventually lead to retrieval from long-term memory, and then practice that fact using methods that develop and strengthen the retrieval ability so that it becomes robust and will be retained over time.

Today's classrooms also need efficient methods to deal with the widely varying fluency levels that a typical group of students begins the school year with. Achieving rapid gains in mathematical fact fluency requires a new level of differentiation in both instruction and practice.

Reflex: A Revolutionary Mathematical Fact Fluency System

Computer-based adaptive systems offer a powerful solution for mathematical fact fluency development. These systems can accurately assess students' fluency with each mathematical fact by precisely measuring response speed in different situations, and then track the development of fluency over time while continuously adapting instruction and practice based on progress. Reflex is the most advanced adaptive system ever developed for mathematical fact fluency, and allows students to master all four operations through a complete, research-proven model for automaticity:

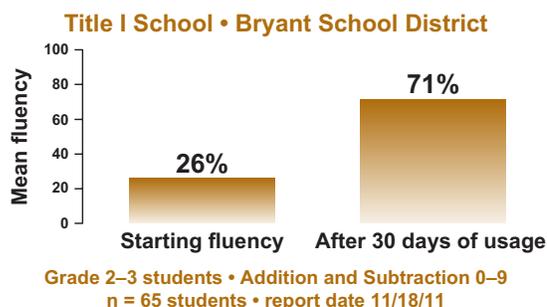
1. Systematic introduction of small sets of new facts using appropriate strategies, including:
 - a. the commutative properties of addition and multiplication;
 - b. the inverse relationship between addition and subtraction, and multiplication and division;
 - c. fact families.
2. Development of the student's preliminary ability to recall these new facts from memory, with progression to timed retrieval once the student has demonstrated readiness;
3. Automatization through game-based practice, wherein facts are recalled while the student's working memory is

increasingly loaded with game-based tasks (e.g., evading enemies). Through these games, students hone the ability to quickly and effortlessly recall mathematical facts so that their working memory can be devoted to learning and mastering new concepts and procedures.

This proven model for automaticity is delivered through a fun, engaging online environment that encourages frequent use and demonstrates that effort leads to success in mathematics. For example, as students master new facts, they receive virtual "tokens" that can be used to customize their avatars within the system. Most students will make significant fluency gains within their first two weeks of Reflex usage. Importantly, gains will continue occurring regularly from that point on. Additional tokens are also awarded specifically for effort. This motivates students to log in more frequently, even on their own from outside the classroom.

The Results

ExploreLearning Reflex now has surpassed major milestones since product launch. Students have logged on more than four million times and have mastered over 10 million new facts. Students using Reflex have made major gains in fluency in as little as 30 days of usage.



In Bryant County School District 25 in Arkansas, Mary Armstrong, an elementary mathematics instruction facilitator was relieved to discover Reflex. The typical student at her Title 1 school only had fluency in about one-quarter of his or her addition and subtraction facts.

"We tested every child in first and second grade before and after using Reflex and have had amazing results," said Armstrong. "If [students] are doing well on Reflex, we know they are doing well with their fluency. If they are having trouble, Reflex tells us the facts we have to concentrate on. Number sense is a big part of the CCSS. Reflex helps our students really break down numbers." Students in grades 2 and 3 at this school went from a starting fluency of 26% with addition and subtraction facts (0-9), and after 30 days of usage, they reached 71%!

"Our teachers are completely behind Reflex because they are seeing an amazing change in our students' mathematics skills, and much of it can be traced back to the understanding of fact fluency as taught and practiced in Reflex," added Armstrong. Find more success stories, read a white paper on the research behind Reflex, and take a free trial today [reflexmath.com]. (Use promo code NCSM12 for an extended 30-day trial.)

Paul Cholmsky is the Vice President of Research & Development at ExploreLearning, where he leads a multi-year research program in mathematical fact fluency. A frequent speaker at education conferences across the United States on STEM-related topics, he has also served as Principal Investigator on NSF-funded research developing innovative methods for pedagogical analysis of students' interactions with virtual manipulatives and simulations.