RENAISSANCE®

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The Research Foundation for MathFacts in a Flash®

The critical role of automaticity in accelerating math achievement

Note: Software visuals may vary from those shown as enhancements are made.

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8/18

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Introduction

The math problem and what we can do about it

The large number of K–12 students in the United States falling short of math proficiency benchmarks raises serious concerns about them meeting the demands of modern living and international competition. A recent authoritative analysis of national and international testing data gives America a math "grade" of C to C+, and concludes: "The typical student in the United States is learning basic mathematics rather than the more complex mathematics required to meet global expectations" (Phillips, 2009, p. 2).

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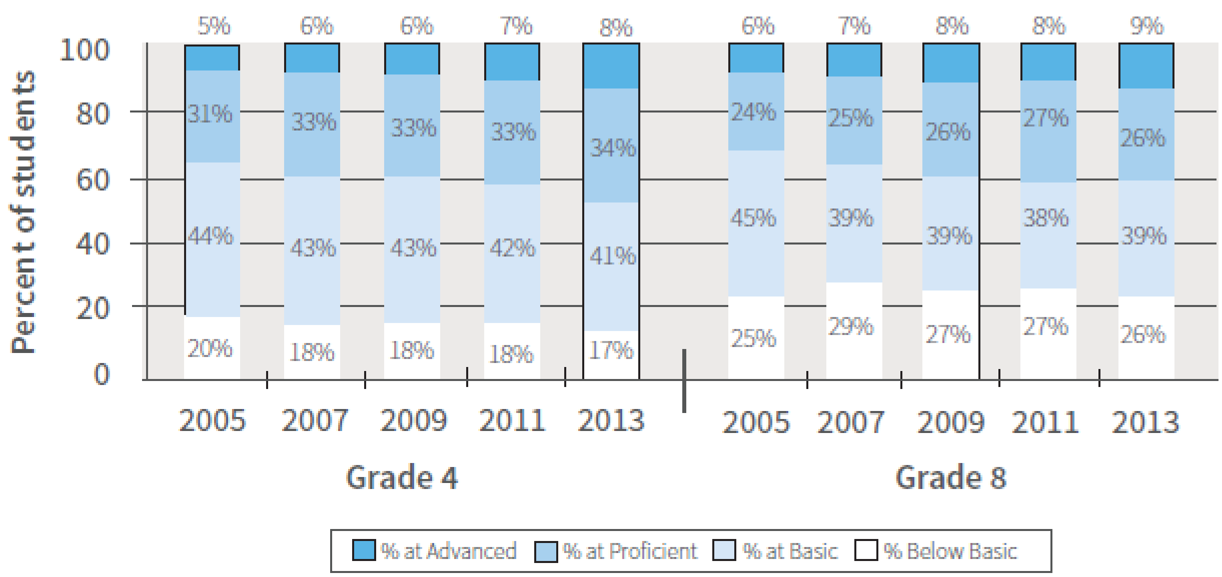
> - Phillips, 2009, p. 2

This problem is widely acknowledged. A subject of more debate, and considerable frustration for educators, is what to do about it. Years of school-improvement efforts have produced some results, but not nearly enough. In figure 1, the most recent results from the National Assessment of Educational Progress (NAEP), called the "nation's report card," show modest improvements over the past decade in fourth-grade and eighth-grade achievement of benchmarks (Lee, Grigg, & Dion, 2007).

Figure 1. NAEP progress charts: Trend in mathematics achievement-level performance



Source: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2005, 2007, 2009, 2011 and 2013 Mathematics Assessments.

The problem is that this progress is clearly insufficient, for two reasons:

- Even after years of effort, fewer than 40% of our math students display "proficiency"—defined as "competency over challenging subject matter, including subject-matter knowledge, application of such knowledge to real-world situations, and analytical skills appropriate to the subject matter" (U.S. Department of Education, 2008).

- Proficiency levels decline as students move through the grades. As shown in figure 1 above, far fewer students are proficient in eighth grade than in fourth. By 12th grade, only 23% of students are proficient (Grigg, Donahue, & Dion, 2007). The highest-performing countries, by comparison, show no such upper-grade decline (Phillips, 2009).

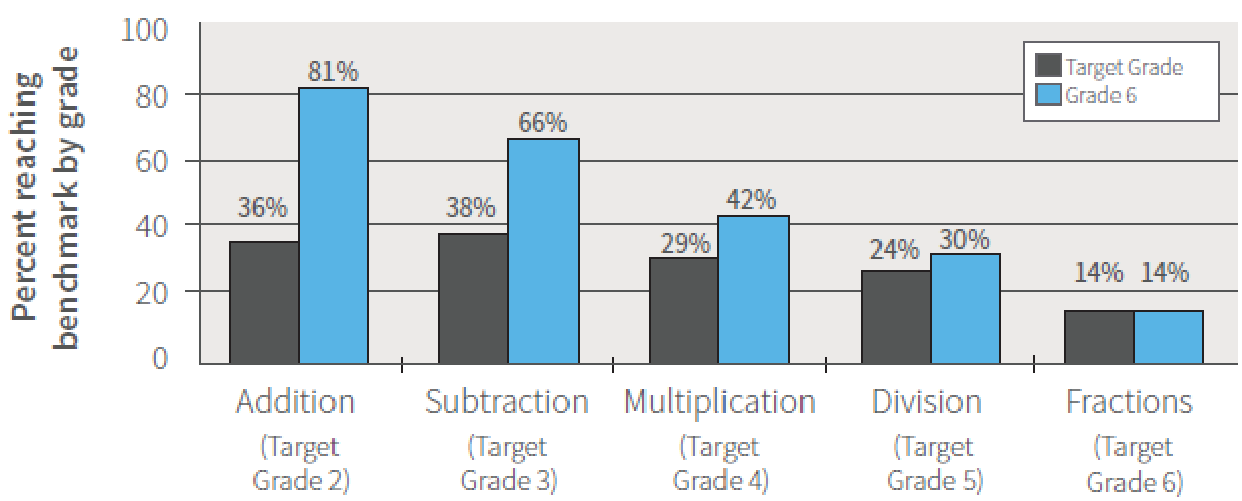
What accounts for these disappointing results at higher levels of performance and in the upper grades? We believe that part of the answer is a simple but underappreciated fact: students' preparation in the core number skills, while enabling them to handle basic requirements at their grade level, is not strong enough to provide an adequate foundation as they advance and tackle more challenging concepts and operations.

Insufficient math fact foundation

Consider the statistics on math-skill mastery derived from Renaissance's online database of student mathematics activity. The data in figure 2 show that nationwide not only do most students score below benchmarks in the target grades for the four operations and fractions—a distressingly high proportion do not even master them by middle school. On entering seventh grade, *only 42 percent of students have demonstrated mastery of multiplication facts, and less than a third have demonstrated mastery of division*. And because there is little if any focus on these facts after fifth grade, it is a safe assumption that many never master them at all (Baroody, 1985; Isaacs & Carroll, 1999).

> Students' preparation in the core number skills, while enabling them to handle basic requirements at their grade level, is not strong enough to provide an adequate foundation as they advance and tackle more

Figure 2. Math facts mastery by grade level—End-of-year progress (*n* = 436,627)



Note: Goal at Target Grade is 100% by end of year. For an explanation of grade-level benchmarks, see pp. 15–17.

This is not to say that most students do not know how to add, subtract, multiply, and divide. Clearly they do, or they would not score even as well as they do on benchmark assessments. But they have not achieved mastery—or more strictly speaking, they have not achieved automaticity, the essential foundation of computational fluency. Their knowledge of these core operations, which undergird all of mathematics, is "procedural" rather than "declarative." That is, students know *how* to multiply 8 x 7, but they do not know *that* 8 x 7 is 56, so they must calculate or use strategies that take time and mental resources away from higher-level operations (Ashlock, 2009).

The importance of automaticity, even more than fluency, cannot be stressed too much.

> As a student learns a new skill, he/she will become increasingly fluent … until it becomes automatic. *Automaticity* refers to the phenomenon that a skill can be performed with minimal awareness of its use (Hartnedy, Mozzoni, & Fahoum, 2005; Howell & Larson-Howell, 1990)….The ability … to *automatically* respond … may free limited cognitive resources that can be applied to the more complex computations and concepts….If each component of a complex, multistep problem requires sustained attention, the completion of the problem will likely be impossible due to the limited capacity of working memory. (Axtell, 2009, p. 527, emphases added)

Needed: More concentrated emphasis

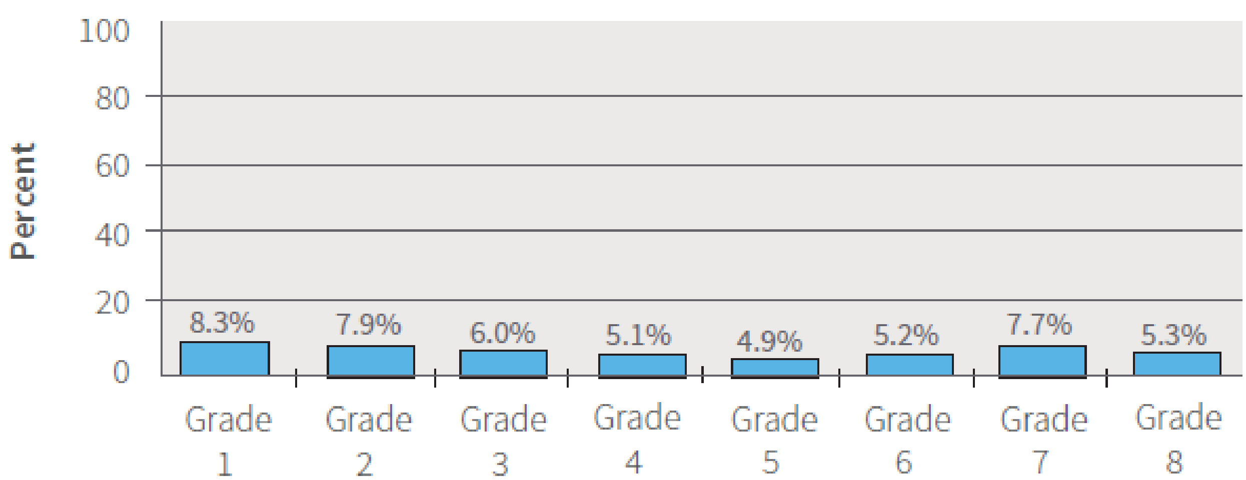
There seem to be two reasons why math facts mastery is so low:

- **The curriculum gap.** This issue is widely recognized by such bodies as the National Mathematics Advisory Panel, commonly called the National Math Panel, which states: "Few curricula in the United States provide sufficient practice to ensure fast and efficient solving of basic fact combinations and execution of the standard algorithms" (2008, p. 27). Therefore, most schools provide supplemental means of practicing math facts, such as flash cards, worksheets, and computer software.
- **Too little emphasis.** What math fact practice is provided is not frequent enough, nor given enough emphasis, to produce math fact automaticity. This is partly because such programs are regarded as "supplements," and partly because most math fact programs are not designed to provide the detailed feedback necessary to ensure every child is really attaining automaticity.

A look at the frequency of math fact practice dramatically supports this second point. The Renaissance Learning database of more than 400,000 students shows that at no grade level do more than 35% of students practice math facts more than once per week—and practicing three times or more per week, the minimum benchmark based on a consensus of the research, is almost unheard of (see figure 3).

> Math facts automaticity is the essential foundation of computational fluency.

Figure 3. Percent of students practicing math facts three or more times per week (*n* = 454,027)

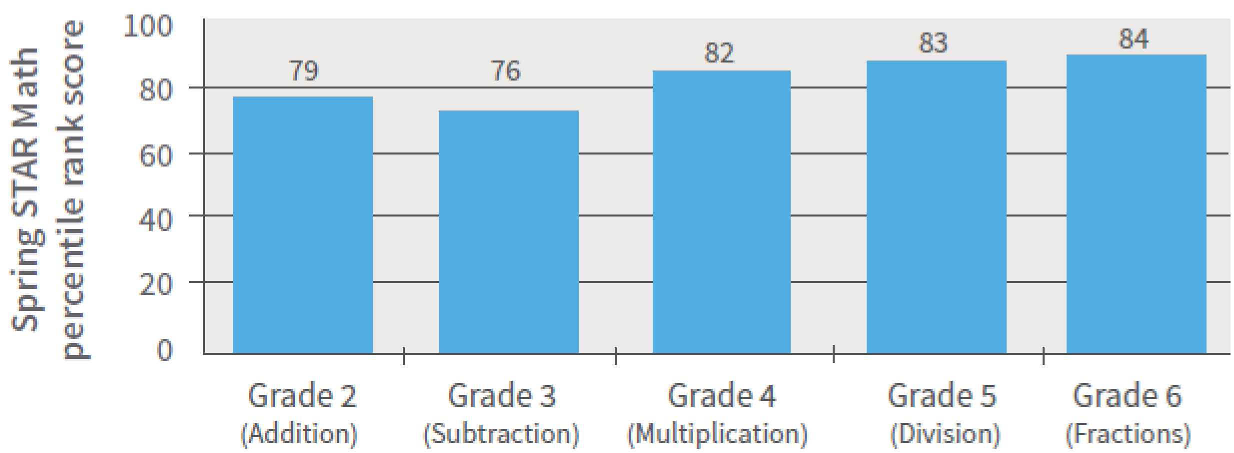


While these statistics do not measure any offline practice that may have occurred—flash cards, for instance—it is hard to imagine that these less powerful, less intensive activities would add significant time in many cases. So even though schools may believe they have math fact mastery “covered,” true mastery never occurs because math facts are not practiced enough.

Dramatic improvements are possible

Math fact automaticity is not supplemental, but rather fundamental to improving math achievement—and more time must be devoted to deliberate, measurable practice in order to attain automaticity. As seen in figure 4 (next page), students who meet the benchmarks in Renaissance MathFacts in a Flash® generally perform very well and are scoring around the 80th percentile in math by the end of the year. Although these students were slightly above the norm to begin with, on average (beginning the year scoring at the 60th percentile), students at all quartiles were able to master the benchmarks. With sufficient time for practice and instructional support, MathFacts in a Flash benchmarks are achievable for all students.

Figure 4. Students who master math facts score near the 80th percentile in math
(*n* = 67,162; Average fall to spring percentile rank gain = +21)



On the pages that follow are three sections devoted to explaining how MathFacts in a Flash can help students gain the invaluable practice necessary to develop automaticity of math facts:

- A review of the role math fact mastery plays in developing computational fluency, and the research behind it.
- An outline of how MathFacts in a Flash supports sufficient and proper practice to assure that mastery takes place.
- An examination of the growing body of research that shows the dramatic improvements possible when the missing element of math fact mastery is restored.

Why math facts mastery is so important—And what it takes

As mentioned in the previous section, there is a growing consensus that automatic recall of math facts is an indispensable element in building computational fluency, preparing students for math success, both present and future (National Research Council, 2001). Just as phonemic awareness and decoding are the crucial elements in learning to read, automaticity and conceptual understanding go hand in hand in mathematics development (Gersten & Chard, 1999). Failure to develop automatic retrieval, on the other hand, leads to mathematical difficulties (Bryant, Bryant, Gersten, Scammacca, & Chavez, 2008).

Learning facts is not enough

It is not enough that students simply "learn" their number facts—they must be committed to memory, just as letter sounds must be memorized in development of phonics automaticity (Willingham, 2009). Automaticity is a different type of knowledge; it is "based on memory retrieval, whereas nonautomatic performance is based on an algorithm" (Logan, 1988, p. 494). Learning starts with understanding of concepts, to be sure, but memory skills must develop simultaneously. "Children need both procedural knowledge about how to do things and declarative knowledge of facts" (Pellegrino & Goldman, 1987, p. 31). Declarative memory (which recalls *that* things are so) not only speeds up the basic arithmetic operations themselves (Garnett & Fleischner, 1983), it also acts to "free up working memory capacity that then becomes available to address more difficult mathematical tasks" (Pegg, Graham, & Bellert, 2005, p.50; see also Gersten, Jordan, & Flojo, 2005).

The key to automaticity is practice, and lots of it (Willingham, 2009). The National Math Panel Report in 2008 put it this way:

> To prepare students for Algebra, the curriculum must simultaneously develop conceptual understanding, *computational fluency,* and problem-solving skills … Computational fluency with whole number operations is dependent on sufficient and appropriate *practice* to develop *automatic recall* of addition and related subtraction facts, and of multiplication and related division facts. (p. xix, emphases added)

To move a fact (or skill) from short-term to long-term memory requires "overlearning"—not just getting an item right, but getting it right repeatedly (Willingham, 2004). And retaining the memory for a long interval requires spacing out additional practice after initial mastery—emphasizing the importance of regular review of learned material (Rohrer, Taylor, Pashler, Wixted, & Cepeda, 2005). Brain research indicates that repetitions actually produce changes in the brain, thickening the neurons' myelin sheath and creating more "bandwidth" for faster retrieval (Hill & Schneider, 2006).

> The key to automaticity is practice, and lots of it.

For all of these reasons, the federal What Works Clearinghouse (WWC) recommends math facts fluency remediations for students *at all grade levels* in Response to Intervention (RTI) schools. The WWC math Practice Guide (Gersten et al., 2009) states:

> Quick retrieval of basic arithmetic facts is critical for success in mathematics. Yet research has found that many students with difficulties in mathematics are not fluent in such facts….We recommend that about 10 minutes be devoted to building this proficiency during each intervention session. (p. 37)

The importance of timed practice

Another critical element in automaticity practice is timing. Timing the student's response, and setting time limits, focuses attention on speed of processing, which helps students stop calculating facts and progress to simply recalling them (Isaacs & Carroll, 1999). Timing is also important in review and reinforcement, where accuracy is assumed to be 100% and further improvement takes the form of reduced response time, as the fact becomes more firmly established in memory (Miller & Heward, 1992).

Educators are sometimes reluctant to time tests for fear that it will be demotivational for students, but research actually shows that time trials improve accuracy and fluency, and students enjoy being timed (Miller, Hall, & Heward, 1995). The What Works Clearinghouse Practice Guide (Gersten et al., 2009) states that students may be motivated as they watch their scores rise and challenge level increase.

The need for technology

Traditional methods of math facts practice—such as flash cards—are not bad in themselves, but they are insufficient. They require far too much paperwork and teacher time to administer the necessary number of items at the desired frequency to produce mastery. Such methods also do not keep track of which facts have been mastered and should be reinforced over time, and which new facts to introduce next, so that the student can move through the full sequence on a timely basis. For this reason, properly designed software tools are recommended by the National Math Panel (2008):

> The Panel recommends that *high-quality* computer-assisted instruction (CAI) drill and practice, *implemented with fidelity*, be considered as a useful tool in developing students' automaticity (i.e., fast, accurate, and effortless performance on computation), freeing working memory so that attention can be directed to the more complicated aspects of complex tasks. (p. 51, emphases added)

The terms we have highlighted in the above recommendation—*high-quality* and *implemented with fidelity*—are very important. They stress that the software you select to help assure math facts mastery should be thoughtfully and carefully designed based on the automaticity research—and come with usage guidelines based on substantive experience with students. As the following sections indicate, Renaissance's MathFacts in a Flash meets both these criteria.

How MathFacts in a Flash® builds automaticity for computational fluency

How it works

MathFacts in a Flash is a computerized database of mathematical problems designed to provide intense practice of mental recall skills. The program uses timed trials and multiple-choice questions to quickly and accurately assess students' computational fluency. The 71 levels encompass addition, subtraction, multiplication, division, fractions, decimals, and percents. Although it is primarily intended for students in first through sixth grades, MathFacts in a Flash has also been demonstrated effective for students beyond sixth grade who struggle with basic math facts. MathFacts in a Flash targets specific areas of student need, providing concentrated practice at precisely the right level.

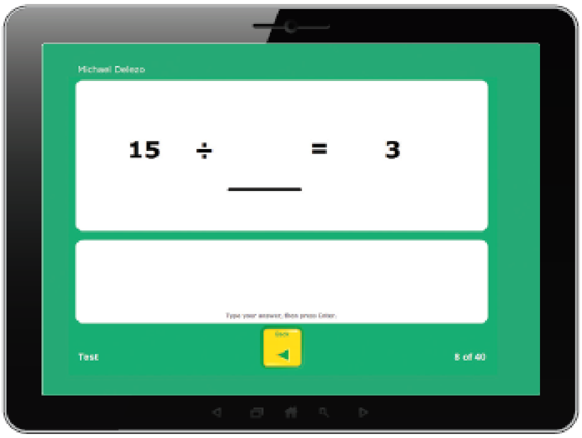
MathFacts in a Flash facilitates working with students in English learner (EL) programs by providing students an option to practice their math facts in English or Spanish. Upon logging in to Renaissance Place (either at school or at home with Renaissance Home Connect), a student can choose to practice in Spanish and all of the text will be in Spanish, including navigation commands, level names, and practice and test results.

This program has been designed for quick implementation and ease of use by both student and teacher. In its online version, it requires no installation or configuration, and can be accessed anywhere, anytime, though secure logins. Its default goals and benchmarks are based on extensive research (see pp. 15–17), but can easily be changed by educators to reflect local standards or revised expectations for students.

There are five basic steps to implementing MathFacts in a Flash:

1. **Baseline test.** Students complete a 40-item timed test at the computer for each new math level. Immediate onscreen feedback provides time and accuracy data and shows any missed facts. If a student answers all 40 items correctly within the mastery time limit, he or she moves on to the next math level. This allows all students to work at their own level of challenge.
2. **Personalized practice.** Math facts not mastered on the baseline test are presented to the student in practice sessions (see example, figure 5). These are intermixed with mastered facts that are typically difficult for students at each level and other known facts, for a minimum of 20 items per practice session. Time allotted per day ranges between 5 and 15 minutes, with a recommended frequency of at least three times per week (Gersten et al., 2009).

Figure 5. MathFacts in a Flash® practice session



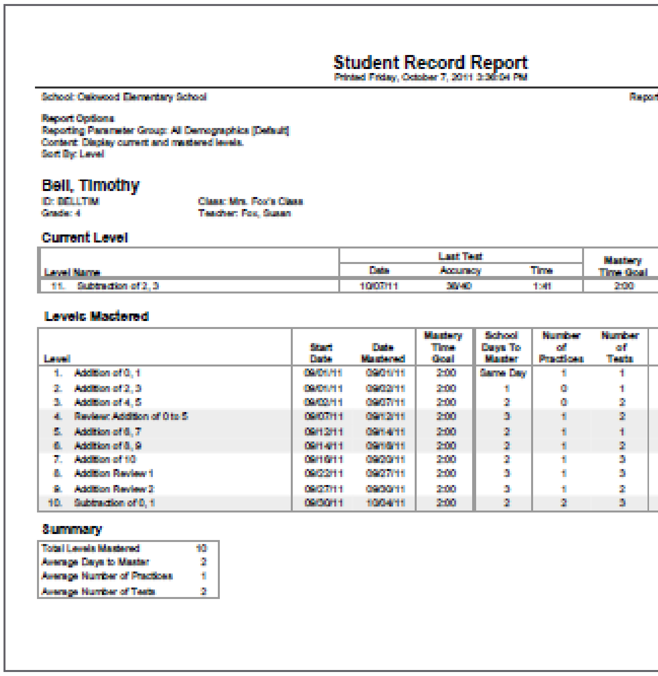
3. **Timed test for mastery.** Once students have successfully completed the practice sessions at a level, they complete a 40-item timed test for that level. Students master a level in MathFacts in a Flash when they are able to complete a test within the mastery time goal with 100% accuracy. Recommended time goals, like frequency recommendations, are based on research (see pp. 16–17).

4. **Instant feedback.** Immediate onscreen feedback after each completed MathFacts in a Flash practice or test provides students with results on accuracy and time goals, allowing them to monitor their own progress. Additional corrective feedback is provided after each question answered incorrectly.

5. **Automatic advancement.** After students master their current level, the software automatically assigns the next math level. The sequence of math levels can be reordered to fit any curriculum. Students also, by default, have other choices: they can re-test on the level just mastered to achieve a lower time goal, or they can try for a new goal—or an improved best time—on a previously mastered level.

Detailed reports, available at any time through secure web logins, give educators immediate, accurate, and reliable feedback on students' computational progress. Figure 6 shows two examples of the reports available.

Figure 6. MathFacts in a Flash® reports



Student Record Report
Printed Friday, October 7, 2011 3:38:04 PM

1 of 2

School: Oakwood Elementary School
Reporting Period: 09/01/2011 - 10/07/2011 (1st Quarter)

Report Options
Reporting Parameter Group: All Demographics [Default]
Content: Display current and mastered levels.
Sort By: Level

Bell, Timothy
ID: BELLTIM
Grade: 4
Class: Mrs. Fox's Class
Teacher: Fox, Susan

Current Level

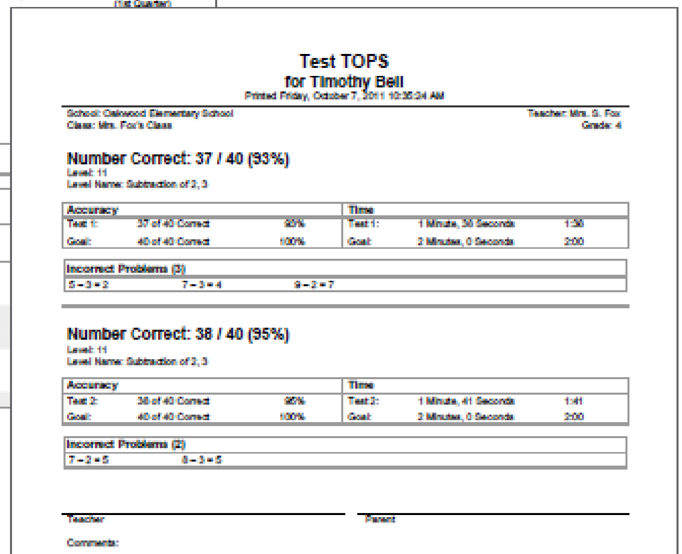
Level Name	Last Test: Date	Last Test: Accuracy	Last Test: Time	Mastery Time Goal
11. Subtraction of 2, 3	10/07/11	38/40	1:41	2:00

Levels Mastered

Level	Start Date	Date Mastered	Mastery Time Goal	School Days To Master	Number of Practices	Number of Tests
1. Addition of 0, 1	09/01/11	09/01/11	2:00	Same Day	1	1
2. Addition of 2, 3	09/01/11	09/02/11	2:00	1	0	1
3. Addition of 4, 5	09/02/11	09/07/11	2:00	2	0	2
4. Review: Addition of 0 to 5	09/07/11	09/12/11	2:00	3	1	2
5. Addition of 6, 7	09/12/11	09/14/11	2:00	2	1	1
6. Addition of 8, 9	09/14/11	09/16/11	2:00	2	1	2
7. Addition of 10	09/16/11	09/20/11	2:00	2	1	3
8. Addition Review 1	09/22/11	09/27/11	2:00	3	1	3
9. Addition Review 2	09/27/11	09/30/11	2:00	3	1	2
10. Subtraction of 0, 1	09/30/11	10/04/11	2:00	2	2	3

Summary

Total Levels Mastered	10
Average Days to Master	2
Average Number of Practices	1
Average Number of Tests	2



Test TOPS
for Timothy Bell
Printed Friday, October 7, 2011 10:35:34 AM

School: Oakwood Elementary School
Class: Mrs. Fox's Class
Teacher: Mrs. S. Fox
Grade: 4

Number Correct: 37 / 40 (93%)
Level: 11
Level Name: Subtraction of 2, 3

Accuracy			Time		
Test 1:	37 of 40 Correct	93%	Test 1:	1 Minute, 38 Seconds	1:38
Goal:	40 of 40 Correct	100%	Goal:	2 Minutes, 0 Seconds	2:00

Incorrect Problems (3)		
$5 - 3 = 2$	$7 - 3 = 4$	$9 - 2 = 7$

Number Correct: 38 / 40 (95%)
Level: 11
Level Name: Subtraction of 2, 3

Accuracy			Time		
Test 2:	38 of 40 Correct	95%	Test 2:	1 Minute, 41 Seconds	1:41
Goal:	40 of 40 Correct	100%	Goal:	2 Minutes, 0 Seconds	2:00

Incorrect Problems (2)	
$7 - 2 = 5$	$8 - 3 = 5$

Teacher
Parent

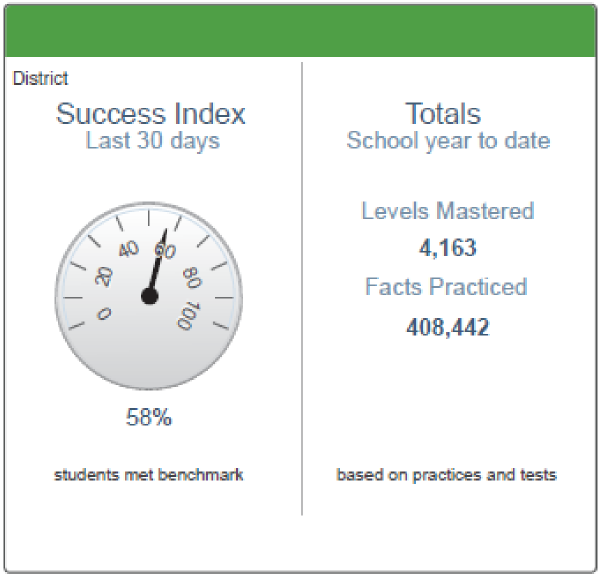
Comments:

Teachers use the Student Record Report to track each student's levels mastered, as well as time and frequency goals.

The TOPS Report prints after each session, providing students with immediate feedback.

The MathFacts in a Flash Summary Dashboard provides administrators with an online tool to closely monitor student mastery of benchmarks for a district, grade, building, or class. This dashboard allows administrators to check progress at any moment, literally in real time, as their students' proficiency increases (see figure 7).

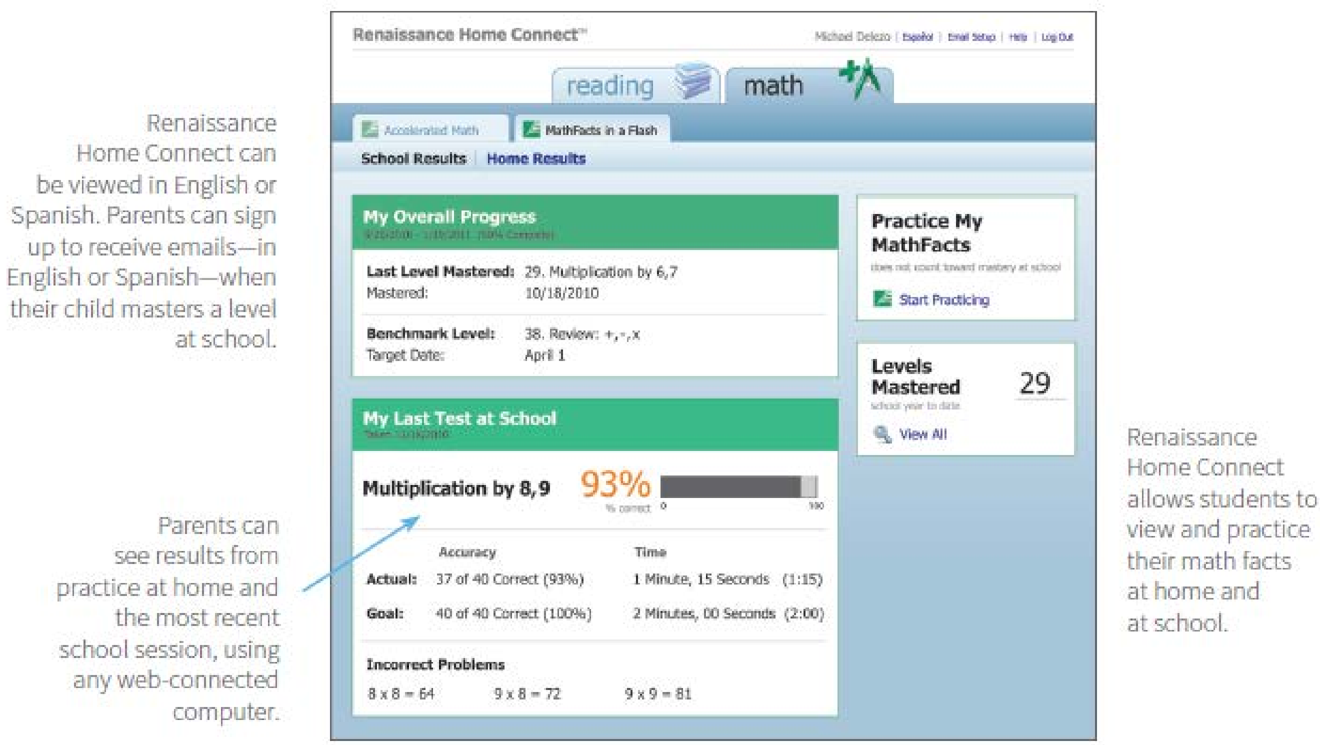
Figure 7. Summary Dashboard—MathFacts in a Flash® screen



The result of all this readily accessible data is that all educators can easily keep track of the math facts fluency process, know that sufficient practice and progress are taking place, and can intervene sooner where necessary.

Reports can be shared with parents to show student progress and improve the quality of parent communications about students' academic achievement. As shown in figure 8, parents can also log into Renaissance Home Connect to view their child's progress or receive email notifications as each math facts level is mastered.

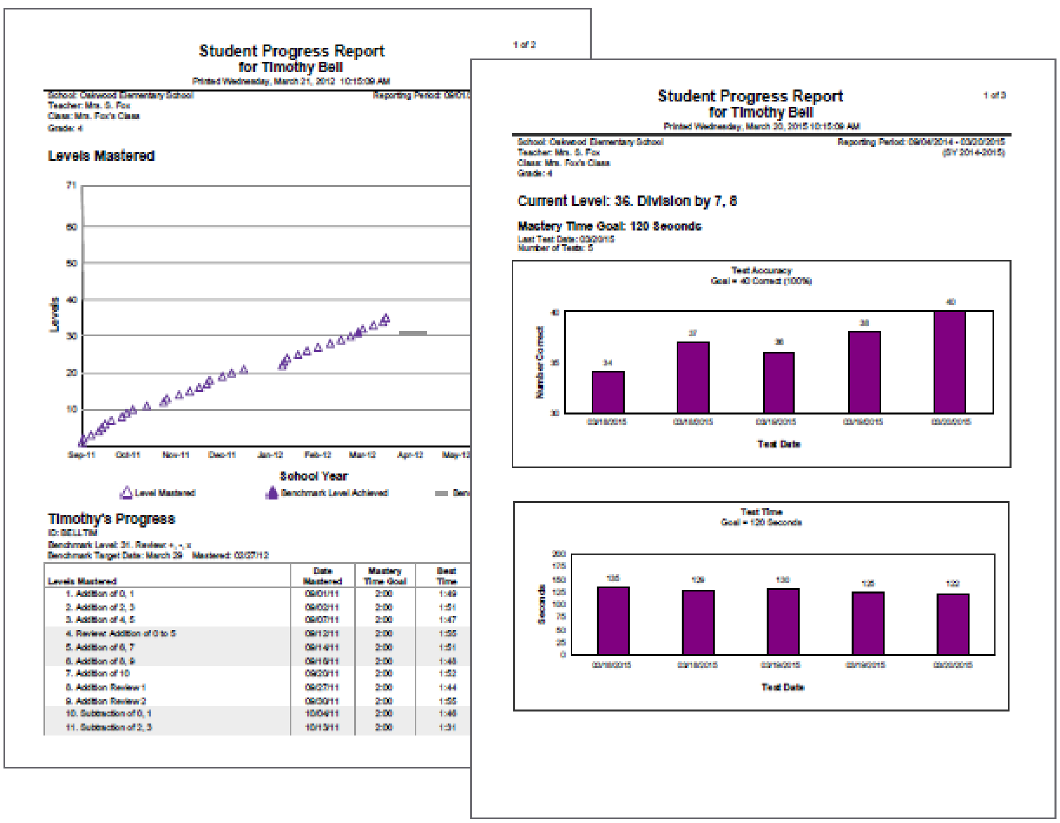
Figure 8. Renaissance Home Connect®—MathFacts in a Flash® screen



Perfect for RTI

MathFacts in a Flash supports Response to Intervention implementations in two ways: as a progress monitoring assessment, and as an intervention for all Tiers. The program is highest rated for progress-monitoring mastery measurement by the National Center on Response to Intervention (2010), with perfect scores in all categories reviewed. For progress monitoring, MathFacts in a Flash provides mastery measurement of each student's progress through 71 levels of math facts. The program can be administered weekly or more frequently to track the level of mastery and rate of growth. Figure 9 shows the Student Progress Report, which educators use to closely track each student's progress.

Figure 9. MathFacts in a Flash® Student Progress Report



Using the Student Progress Report, teachers can see an overall picture of each student's progress toward mastery.

For struggling students in Tier 1, or for any student in Tier 2 or Tier 3, MathFacts in a Flash fits all the requirements for a "standard protocol" intervention:

- Evidence-based
- Directly addresses one of the most common and central causes of math achievement deficits (math fact automaticity)
- Easy to implement
- Adaptable to the needs of each student
- Requires little classroom time
- Includes instructional resources

To aid teachers in an intervention setting, MathFacts in a Flash comes with the *Numeracy Development and Intervention Guide* and the *Fractions, Decimals, and Percents Development and Intervention Guide*, both by Dr. Kenneth

E. Vos of St. Catherine University in St. Paul, MN. For a study that specifically demonstrates MathFacts in a Flash as an effective RTI tool, see p. 18.

Aligns with research

In the previous section *Why Math Facts Mastery Is So Important—And What It Takes,* we reviewed more than 20 years of research related to the importance of developing math facts automaticity. MathFacts in a Flash works because it was developed with this research in mind:

- Designed for mastery (100% correct) of the math facts that form the foundation of computational fluency.
- Simple practice-oriented interface stresses recall of facts (declarative memory) rather than instruction in strategies or computation (procedural memory).
- Timed testing and practice focus attention on generating automaticity.
- Convenience and multiple practice modes make it easy to find the time for the amount of practice required to reach automaticity.
- Personalization and immediate feedback about accuracy and response times provide motivation and self-directed learning.
- Multiple reports and ready online access to data ensure that educators are always aware of how practice toward mastery is progressing—so they can be sure the "missing element" of automaticity is no longer missing.

Evidence-based usage and best practices

MathFacts in a Flash was introduced in 2002. Throughout development, and ever since introduction, the development team has worked closely with researchers and educators to monitor effectiveness and determine practices that produce the best results. During the 2009–2010 school year, more than 400,000 students, in 49 states plus the District of Columbia, used MathFacts in a Flash through Renaissance's online service— which puts all their performance data at the fingertips of researchers (subject, of course, to stringent privacy-protection standards).

This database is undoubtedly the largest in existence on this topic, and though it may not capture all math facts practice activity, it is clearly a significant sample and allows analysis of trends and correlations linking math facts mastery to achievement. In addition to this massive database, the MathFacts in a Flash team has extensively reviewed research and standards documents relevant to best practices, including:

- National Council of Teachers of Mathematics 2006 Curriculum Focal Points
- National Mathematics Advisory Panel 2008 Benchmarks for the Critical Foundations
- What Works Clearinghouse 2009 Practice Guide
- Common Core State Standards for Mathematics (2010)
- Authoritative sources, literature reviews, and recommendations from mathematics experts

These reviews contributed to and validated product design and benchmarks, including:

- Grade-level mastery goals: table 1 reflects a consensus of targets for mastery of each basic operation—addition, subtraction, multiplication, and division—as well as fractions.

Table 1. MathFacts in a Flash® default end-of-year benchmarks

Skill	Benchmark (master by end of)	MathFacts in a Flash® benchmark level
Addition	Grade 2	Addition Review 2
Subtraction	Grade 3	Review: +, –
Multiplication	Grade 4	Review: +, –, x
Division	Grade 5	Review: +, –, x, /
Fractions	Grade 6	Review: +, –, x, /, fractions, decimals, percents

For grades 6 through 12, the default benchmark level goes beyond the four basic math operations to include work with fractions, decimals, and percents. The fractions and decimals levels in MathFacts in a Flash support the main findings and recommendations of the National Math Panel (2008), that "a major goal for K–8 mathematics education should be proficiency with fractions."

- Target response time for automaticity: The default time goal is 2 minutes on tests at all levels. Research shows that 3 seconds per problem—2 minutes on a 40-item test—is a reasonable target for mastering math facts in the elementary grades; students in fifth grade and above may be able to average 2 seconds per problem (Isaacs & Carroll, 1999; Mercer & Miller, 1992). Time goals are adjustable so teachers can match goals to students' capabilities.

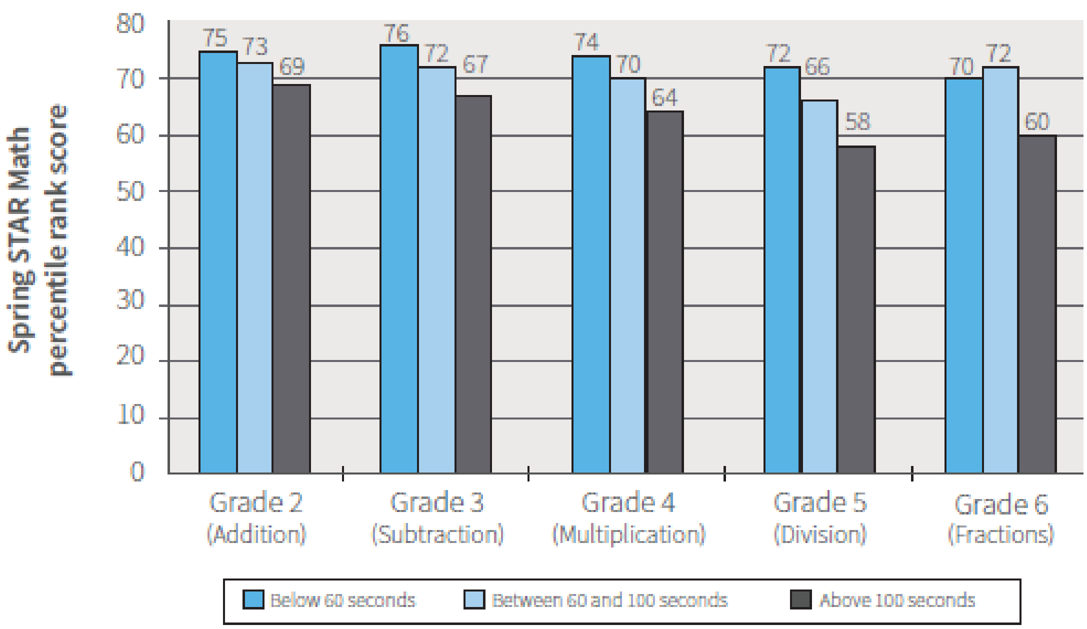
Students can challenge best times on mastered levels to increase fluency, which will lead to automaticity. As shown in figure 10, working toward faster mastery times puts the emphasis on math fact automaticity, or instant recall. Before this stage of declarative knowledge, students may rely on strategies—such as "counting on" or using known facts to derive unknown ones—to figure out the answers for some problems. However, as students move toward automaticity, they rely less on derivation strategies and more on memory. When all facts shift over to long-term memory, students achieve automaticity: they no longer have to think about the answers, they just know them. Going forward in math, they can then rely on automatic recall of basic math facts when developing higher-level skills.

Figure 10. Student progression from procedural to declarative knowledge

Mastery 100% correct in two minutes or less is the minimum criteria to advance in the software.	**Procedural knowledge**	The student is accurate but may still use strategies to derive some of the math facts.
	Fluency (speed and accuracy)	The student is getting faster while remaining accurate. The student relies less on derivation strategies and more on automatic recall.
	Automaticity (declarative knowledge)	The student recalls all of the math facts from long-term memory—accurately, instantly, and effortlessly.
	Computational fluency (requires automaticity)	The student can rely on automatic retrieval of basic math facts when working with higher-level math and using standard algorithms.

An examination of the MathFacts in a Flash database shows that across grades, students with quicker best times on the benchmark MathFacts in a Flash levels also had better Star Math percentile rank scores, suggesting that improved general math ability is associated with quicker, more automatic, recall of basic math facts. Figure 11 shows average spring percentile rank scores for 61,134 students meeting grade-level benchmarks using MathFacts in a Flash during the 2010–2011 school year. Students were placed into one of three categories based on their best time on the benchmarks: below 60 seconds, between 60 and 100 seconds, or above 100 seconds.

Figure 11. Students who master math facts at faster time goals score higher overall (*n* = 61,134)



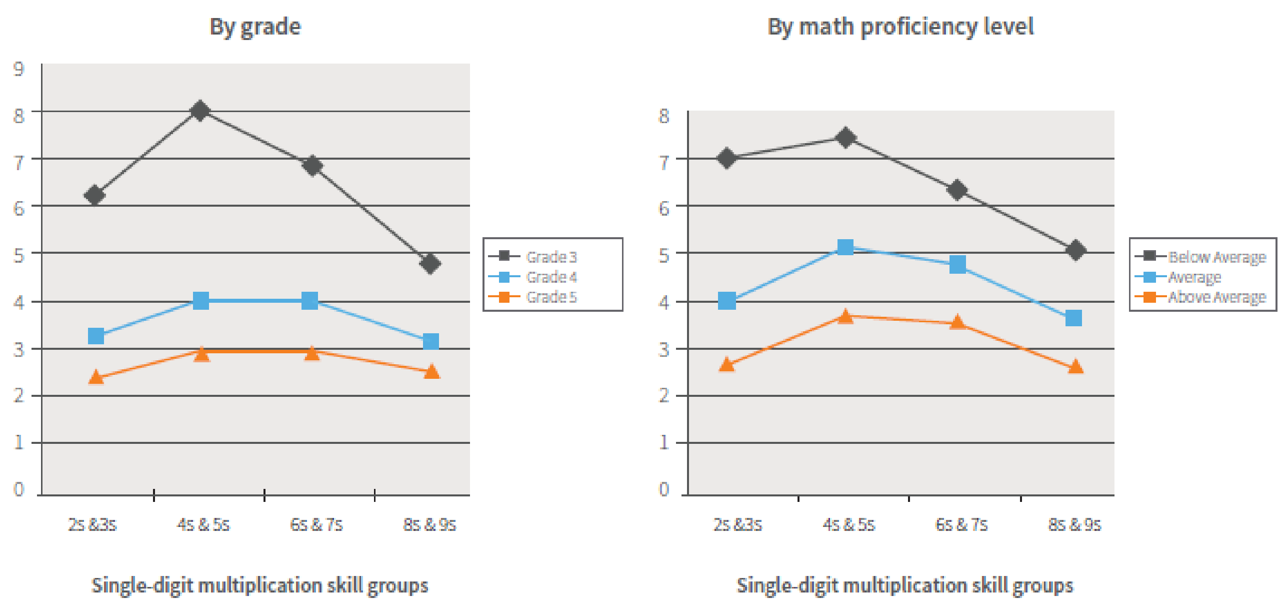
- Length and frequency of practice: We recommend 5–15 minutes per session, at least three times per week— preferably more often especially in remediation (Gersten et al., 2009).

Key research support for MathFacts in a Flash®

MathFacts in a Flash® provides teachers insight into student's development of math fact skills

In a recent study, Burns, Ysseldyke, Nelson, and Kanive (2015) examined the differential difficulty of single-digit multiplication math facts by analyzing the number of repetitions students require to master these facts. Using the MathFacts in a Flash national database, the researchers studied the practice records of 15,402 students in grades 3–5 and found that students from all three grade levels required more attempts to master single-digit multiplication for digits 4, 5, 6, & 7, than they did for digits 2, 3, 8, & 9. This finding held true, regardless of proficiency level. As grade level and proficiency level increased, students needed fewer attempts to master single-digit multiplication skills. Although these results followed a somewhat predictable trajectory, the researchers noted that the breadth of the database studied provided an unprecedented view into single-digit math fact difficulty for students in elementary grades, spanning all skill levels. These results may prove helpful to teachers with instructional planning, such as in understanding which math facts require more instruction and independent practice time to develop computational fluency. In addition the study data support both matching instructional level to student math skills needs and understanding the skills students have mastered versus the ones that are still being developed in order to inform appropriate math interventions.

Figure 12. Attempts needed to fluently complete single-digit multiplication facts

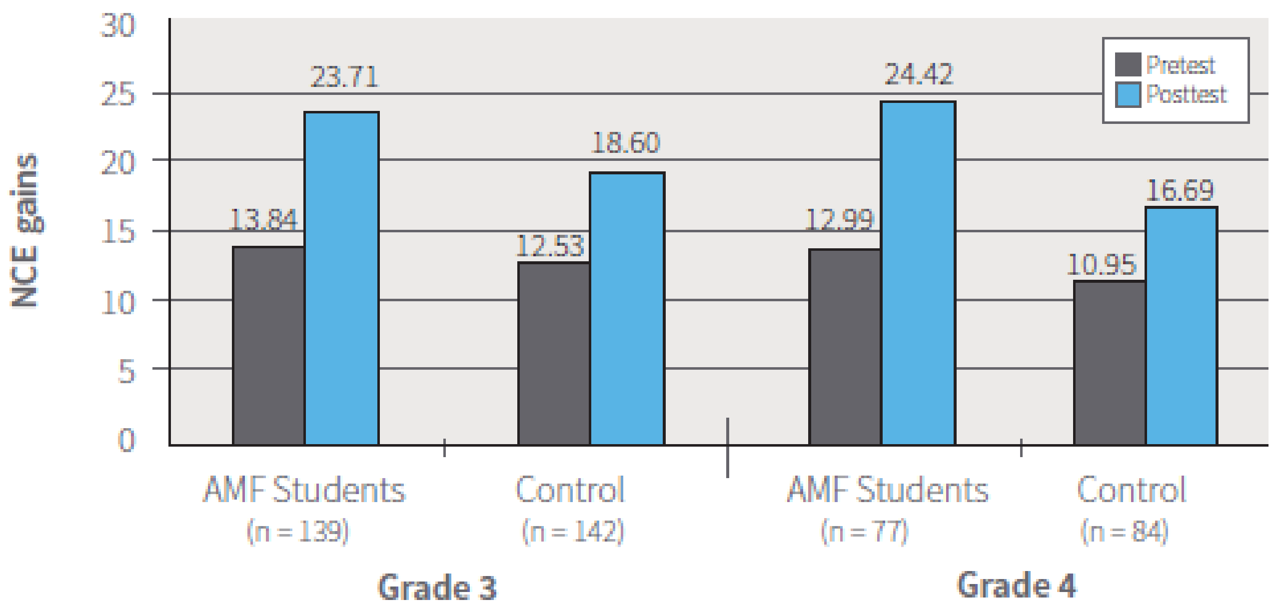


Low-performers' math scores increase almost twofold with MathFacts in a Flash®

Burns, Kanive, and DeGrande (2012) studied the impact of using MathFacts in a Flash with 442 third and fourth graders testing below the 25th percentile on national norms—students who would be candidates for Tier 2 intervention in most Response to Intervention implementations. Of these, 216 were randomly selected from a group of students who used MathFacts in a Flash intensively, similar to what would usually be prescribed in Tier 2 (3–5 sessions per week for 8 to 15 weeks). The other students, who served as a control group, were randomly selected from a group of students who used the program, on average, less than once per week.

All students showed some growth during the period analyzed, probably because of other interventions being administered, but growth was multiplied by intensive use of MathFacts in a Flash—approximately double the normal curve equivalent (NCE) growth compared to control students (see figure 13), with effect sizes of *d* = 0.34 in third grade and *d* = 0.44 in fourth grade. In addition, after participating in the intervention, nearly half of the students who used MathFacts in a Flash three times per week scored above the 25th percentile and out of at-risk status.

Figure 13. Low-performing students nearly double math gains with regular use of MathFacts in a Flash®

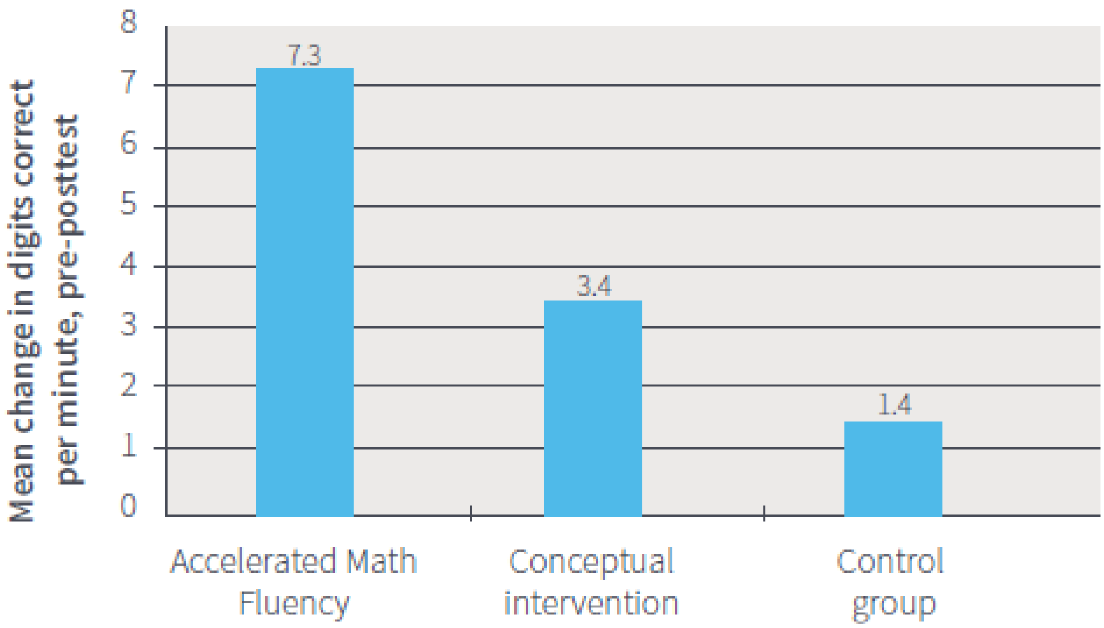


Note: Growth is shown in normal curve equivalent (NCE) units, a way of representing percentile scores so that they can be accurately averaged and compared with each other. Because NCEs are derived from percentiles, they measure growth in comparison to national norms. Positive NCE gains mean student achievement grew at a faster rate than national averages. A gain of zero represents the national average.

MathFacts in a Flash® helps students who struggle with math achieve greater gains

In a 2012 study, Kanive, Nelson, Burns, and Ysseldyle studied 90 students in 1 Minnesota elementary school. Fourth and fifth graders who were identified as struggling with math were randomly assigned to one of three groups: use MathFacts in a Flash, use a conceptual math intervention, or serve in the control group. Students were pre-and posttested with CBM-M and an experimenter-designed word problem text assessing single-digit multiplication. Students using MathFacts in a Flash outperformed students in the control group with a moderate effect size of *d* = 0.60, while students assigned to the conceptual invention did not significantly outperform the control group (*d* = .20) (see figure 14).

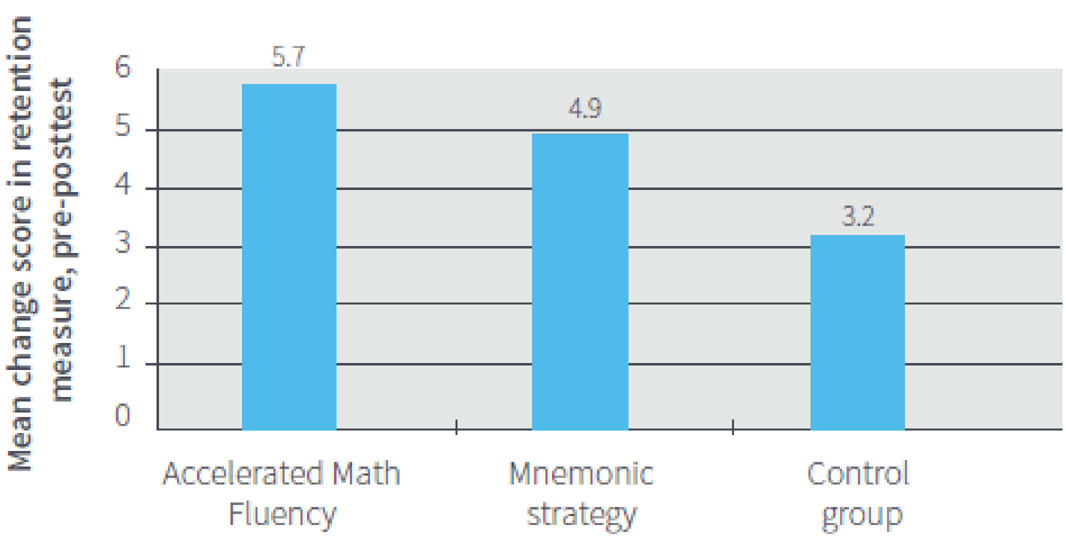
Figure 14. Students struggling with math have greater success with MathFacts in a Flash®



Students struggling with math demonstrate greater growth with MathFacts in a Flash®

In an experimental study of 90 students in two Minnesota elementary schools, Nelson, Burns, Kanive, and Ysseldyke (2012) identified students in grades 3 and 4 who were struggling with math and randomly assigned to use MathFacts in a Flash, a mnemonic strategy (Times Tables the Fun Way), or to serve in the control group. The students were pre- and posttested with retention and generalization probes. Students using MathFacts in a Flash showed more growth in retention scores than students in the control group; the students using the program outperformed the control group with a moderate effect size of $d = 0.65$. Students assigned to the mnemonic strategy condition did not significantly outperform the control group ($d = 0.49$) (see figure 15).

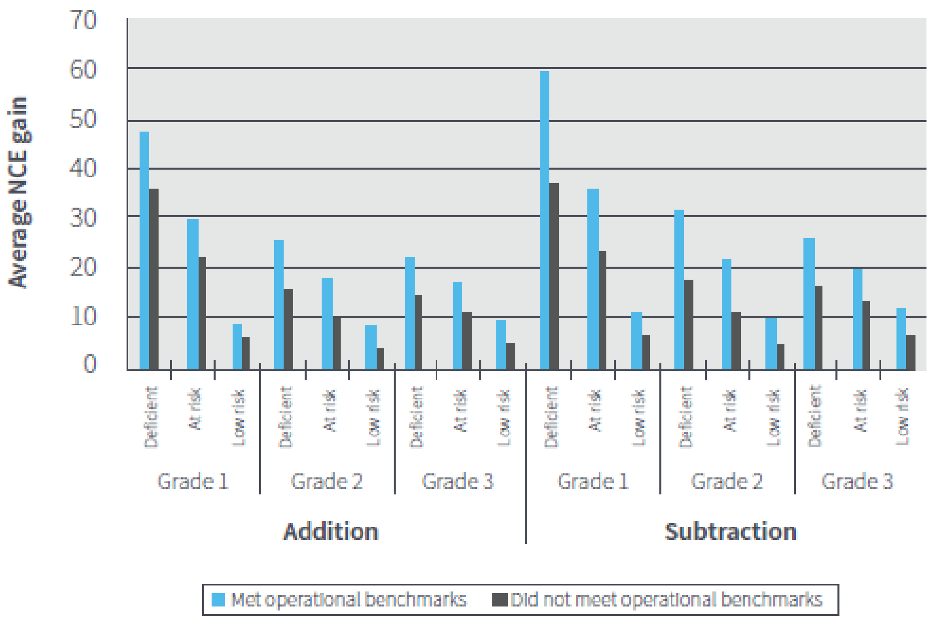
Figure 15. MathFacts in a Flash® users outgain control group



Exceptional growth associated with meeting MathFacts in a Flash® operational benchmarks

This large-scale, peer-reviewed study by Stickney, Sharp, and Kenyon (2012) examines how initial math achievement influences the path to math fact automaticity as well as the relationship between attainment of automaticity and gains in general math achievement. Although most students do not meet grade-level mastery recommendations for addition (39% of the sample) and subtraction (18% of the sample) identified by various standards-setting organizations, such as the National Math Panel and Common Core State Standards, those who do are likely to achieve superior gains in math achievement, controlling for pretest scores (see figure 16). Analysis revealed that students in the higher achieving category mastered more and reached higher MathFacts in a Flash levels than students in the low-achieving categories. Relative to the higher achieving students in the low-risk group, the students in the two lower achieving categories required more attempts to establish automaticity, achieved automaticity later, and demonstrated slower retrieval speeds. The results emphasized the importance of building in extra time for practice. Overall, although it took more time and effort for low-achieving students to master math facts, those who did also experienced particularly large gains in general math achievement, which makes MathFacts in a Flash useful in a Response to Intervention framework.

Figure 16. Students meeting MathFacts in a Flash® operational benchmarks make extraordinary gains

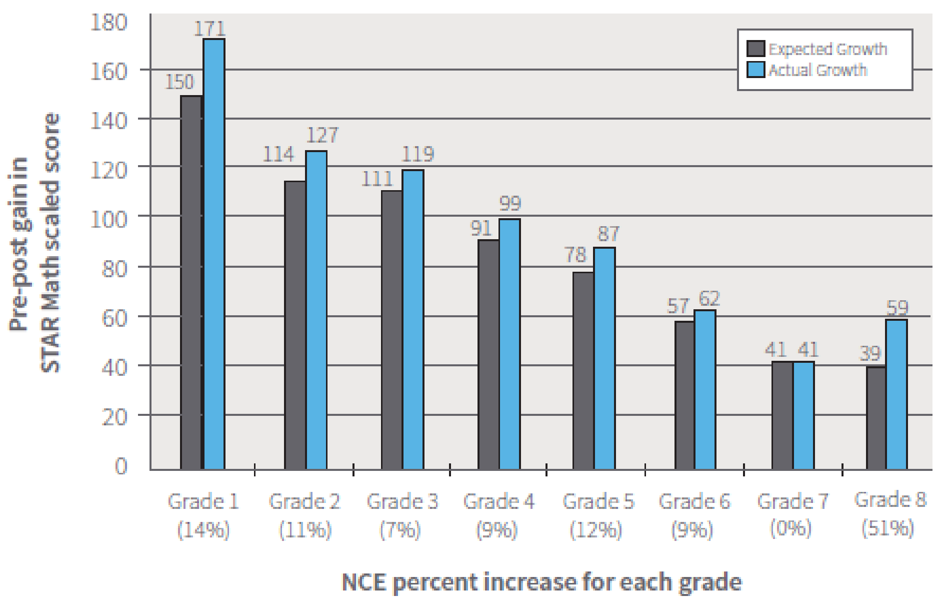


Note: Growth is shown in normal curve equivalent (NCE) units, a way of representing percentile scores so that they can be accurately averaged and compared with each other. Because NCEs are derived from percentiles, they measure growth in comparison to national norms. Positive NCE gains mean student achievement grew at a faster rate than national averages. An NCE gain of zero represents the national average.

Students double expected growth using MathFacts in a Flash®

During the 2009–2010 school year, more than 400,000 K–12 students across the country used MathFacts in a Flash through Renaissance's online service, so the results of all their practice and testing were recorded in the database. Many students used the program intermittently or casually, but more than 100,000 students in grades 1–8 were classified as "active" users—completing a minimum of 10 tests in the program within 30 days. Researchers examined the scores of these students on the nationally normed math test, Star Math, at the beginning and end of the school year. Figure 17 shows annual pre-post growth for students actively using MathFacts in a Flash. Actual rates of growth (in Star Math scaled scores) by grade are presented in comparison to expected rates of growth. Expected growth was determined by using growth norms for Star Math, which are average weekly growth rate expectations based on students' starting pretest percentile rank. Growth norms were determined based on a national math achievement database of nearly 350,000 students.

Figure 17. Students using MathFacts in a Flash® surpass anticipated growth in math
(n = 101,143; Active users, grades 1–8)



Note: Growth is shown in normal curve equivalent (NCE) units, a way of representing percentile scores so that they can be accurately averaged and compared with each other. Because NCEs are derived from percentiles, they measure growth in comparison to national norms. Positive NCE gains mean student achievement grew at a faster rate than national averages. An NCE gain of zero represents the national average.

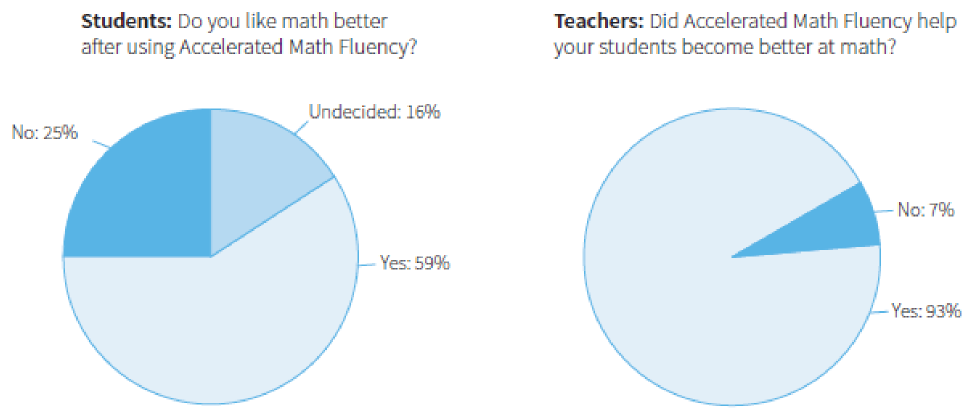
MathFacts in a Flash® improves student attitudes and performance in math

During the 2002–2003 school year, researchers led by Dr. James Ysseldyke of the University of Minnesota investigated the effectiveness of MathFacts in a Flash with 4,224 elementary and secondary students from 13 schools in 10 states (Ysseldyke, Thill, Pohl, & Bolt, 2005). Teachers were asked to provide at least 5–15 minutes of daily practice time for each student, to monitor practice, and to provide appropriate instruction.

To adjust for differences in usage of the program, an indicator of efficiency of use was calculated as the ratio of the total number of levels mastered divided by total time spent using MathFacts in a Flash (in minutes). Results from the analysis show that at all grade levels, students with a higher score on the efficiency indicator had greater gains in math achievement controlling for their pretest scores.

At the end of the study, students and teachers responded to anonymous surveys. Asked whether they liked math better than before using MathFacts in a Flash, 59% of students responded yes; asked whether the program had helped their students become better at math, 93% of teachers reported that it had (see figure 18).

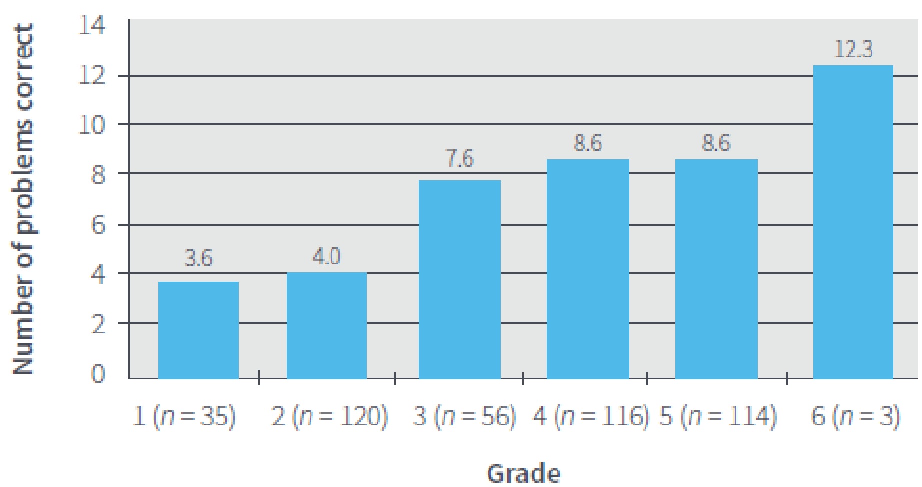
Figure 18. Survey responses from peer-reviewed study of MathFacts in a Flash®



MathFacts in a Flash® increases math facts scores by 17% in 4 weeks

In a 2002 (Renaissance Learning) study, students in grades 1–5 used MathFacts in a Flash for 4 weeks to help determine the effectiveness of the tool and to establish appropriate criteria for mastery time. Initial practice levels were determined with paper-based one-minute pretests, which were scored in terms of "number correct per minute." Students then worked with the MathFacts in a Flash program until they could repeatedly answer all questions correct in a consistent amount of time, at which point they were given a paper posttest. On average, students at all grades improved their "number correct per minute" scores by 6.9 out of 40. The greater growth at higher grade levels shown in figure 19 probably reflects age differences in conceptual understanding and motor-skill development (affecting the paper tests).

Figure 19. Gains on one-minute timed worksheet for students using MathFacts in a Flash® (*n* = 444)



Conclusion

Proficiency in mathematics is one of the essentials in equipping students for success in college and career. Research demonstrates that the foundation of proficiency in math, at all levels, is math fact automaticity. Because even evidence-based math curricula lack the necessary emphasis on sufficient deliberate practice to guarantee automaticity for every child, educators must add that element through regular periods of practice, facilitated and monitored with well-designed computer technology.

MathFacts in a Flash is easy to set up and use, employs procedures and benchmarks based on a huge database of math facts practice, and has been proven effective through years of use. It provides multiple practice modes and superior accessibility for student, teacher, and parent alike. With MathFacts in a Flash, the critical element of math automaticity is no longer missing—but is assured for every child.

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Acknowledgements

Research led by experts in mathematics have tested the utility and effectiveness of Accelerated Math Fluency as a tool to help students develop automaticity of math facts.

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