BLUESTREAK
math

BlueStreak Math Fact Fluency

Research Paper 2020

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Welcome BlueStreak Math School Leaders, Families, and Students

Our 2020 BlueStreak Math White Paper offers school updates for researched evidence of the student success that can be expected when using BlueStreak Math with fidelity. In addition, an emphasis on one of the most prolific voices in educational mathematical studies is featured. Dr. Jo Boaler's thinking is clear that learning "number sense" in concert with "math fact fluency" is the best way for students to learn mathematics. In this way, the learning is ground in conceptual understanding and in practical ways for immediate success.

The Story of the Hubble Telescope Disaster
LA Times, 1990

NASA's 1990 Discovery Spaceship launched the Hubble Telescope Mission into space without an obvious hitch. Yet, the actual performance of the famously celebrated, Hubble Telescope, proved to be a catastrophic disaster due to one tiny, mathematical error. After three trouble-shooting missions to clear the fuzziness and the distortion of one of the mirror's images, it was discovered that the malfunction was caused by an arithmetic error in the grinding measurements of one of the lenses. That's a story about how much math matters.

PART I: Making the Case: Fluency & Flexibility—Boaler

Dr. Jo Boaler, Stanford Mathematics Education Professor, leads the field in noted publications regarding how to teach math fact fluency. While many may recall their childhood routine of learning their times tables by flipping through flash cards, most, perhaps, did not yet fully understand the urgency and power of this fundamental skill set referenced in academia as Math Fact Fluency.

Interestingly, Boaler's next statement is surprising, if not shocking. "There is a common and damaging misconception in mathematics – the idea that strong math students are fast math students" (Boaler 2015). This gets the attention of unsuspecting educators. The statement seems to go in the face of conventional wisdom about memorized flash cards, the faster the better for learning the times tables. Yes, there is more to this and Jo Boaler's words send her math learning messages to educators.

The Case is Made by Boaler

"Fluency comes about when students develop number sense, when they are mathematically confident because they understand numbers" (Boaler, 2015). In her book, Fluency without Fear, she talks about fluency with this highly urgent caveat. As professor and author of mathematics, with expertise in math fluency, Boaler, writes copiously about the effect math fact fluency has in smoothing out the flow of computation, that is, especially when used in combination with problem-solving flexibility, an essential byproduct of knowing and using number sense strategies.

It's like saying, when looking at a final calculation, "Does this make sense? Is it reasonable? Way off? How do I know? What's my reasoning?" This is where the BlueStreak Math Student Strategy Logs for Addition, Subtraction, Multiplication and Division with Whole Numbers, and Fractions come into play and consist of the principles or "rules" of mathematical understandings. These powerful strategies, central to the Student Strategy Logs, provide another mode of input for understanding what math is actually all about. These are the principles and practices that underlie the operations and thinking in all mathematics (Boaler, 2015). In this way, the explicit focus on number sense is supplemented by these series of BlueStreak Math Student Strategy Logs. The various levels of student logs feature standards-based strategies that are essential to understanding and manipulating math equations, problems, and solutions.

In the end, Boaler's expertise in the fluency area, leaves readers with her most conclusive understanding to fully support and refine the use of this remarkable skill set of both math fact fluency and number sense flexibility for untamed math success for our students. To be optimally

effective, the combination of Math Fact Fluency and Flexibility with Number Sense Strategies is best. Fact fluency means knowing the math facts mentally, and with automaticity and accuracy. When math facts are in your head, on the tip of your tongue, or in your immediate short-term memory for recall, retrieval is instantaneous, giving learners more time to think and move along with the more complex reasoning and computational solutions needed (https://www.youcubed.org/evidence/fluency-without-fear/).

That said, let's take a deeper look at Fluency and then another dive into Number Sense Flexibility. More specifically, Boaler's studies concerning math fact fluency among the entire field of experts, recognizes and advocates math fact fluency as a blended model of memorization for automaticity and number sense for flexibility in solution finding.

Brain Science and Mathematics

When scientists examined the brains of students as they were taught to memorize math facts, they saw that some memorized much more easily than others. Some might think that the higher performing students memorized more quickly. But they would be wrong. The only differences the science showed was found in the region of the brain called the hippocampus, where rote memory is stored (Supekar et al, 2013).

While the brain is a highly complex organ for cognitive scientists, one of their most phenomenal findings from the neuroscientists is quality of plasticity that the human brain contains. Marion Diamond of the University of California, Berkeley, produced the first scientific evidence of anatomical brain plasticity. Plasticity is the ability of the human brain to change its chemistry and its structure as one learns . . . and as one teaches. That is the phenomenon that occurs when students learn by memorizing and when they are learning to use logic and reasoning in mathematics. It's both pathways of learning that create deeper understanding and enduring learning. Here is where the cognitive scientists and the neurological scientists seem to agree (1964).

BlueStreak Math's Response to Boaler's Evidence

A brief discussion follows about learning math fact fluency and an additional look at how one learns number sense for logical reasoning, when it's necessary to go deeper than mere memorized facts. The brain works through two pathways of learning: one is concrete, sensory, and visceral and the other abstract and conceptual. The enduring power of learning duo of facts and strategies renders clear and precise calculated mathematical solutions, just as "reading fluency" energizes the reading process into a smooth flow of words that render a clear and comprehensive statement that can be understood. Grounded in Boaler's research, as well as the brain science, the founders of BlueStreak Math boldly integrate these touchstones of Fact Fluency for automaticity and Math Strategies for Number Sense and Flexibility with reasoning pathways.

Boaler, in this area of math fact fluency, is a highly applauded voice in mathematics education, in concert with a number of fellow colleagues (Berg, 2016; Feikes & Schwingendorf, 2008; Delazer et al, 2005) in similar mathematics studies. BlueStreak Math honors Boaler's work as one of the most influential voices guiding their product development of BlueStreak Math's advancements in technology-enhanced mathematics study.

The results are well documented. BlueStreak Math fact fluency and number sense design produces student results that show the expected growth. BlueStreak Math's response to Boaler's findings include constant measurement and monitored data that trace evidential data in reports for the student, the class, the grade level, and the school and are readily accessible for viewing.

Following Boaler's conclusions and BlueStreak Math's design, both math fact fluency and enhanced memorization are engineered into the gaming platform of BlueStreak Math, as well as extensive attention to learning number sense to support their math learning.

Five innovative math fact fluency games, with innovative designs comprise our ever-expanding product line for student math fact learning and number sense logic with reasoning addressed by strategy cards and Student Learning Logs. The logs contain additional practice pages, strategy instructions, student goal setting, reflective student responses, and partner conversations in social emotional interactions.

PART II: Math Fact Fluency

Dr. Jo Boaler, Stanford Mathematics Education Professor, leads the field in noted publications regarding how to teach math fact fluency. While many may recall their childhood routine of learning their times tables by flipping through flash cards, most, perhaps, did not yet fully understand the urgency and power of this fundamental skill set referenced in academia as Math Fact Fluency.

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Memorization

Memorization or learning by rote memory through practice, repetition, and multiple iterations, imprints the information input in concrete ways on the human brain. It can be captured by using one's sense of sight or ability to visualize the math facts. Or it might use the sense of sound, hearing the sound of the facts and sensing the rhythm of the number facts repeated over and over, and eventually captured through visceral or bodily kinesthetic sense. Memorization can be a powerful tool in our memory mailbox, when it's working well for the learners.

Automaticity

When you learn something that stays in your mind, long term. If you can recite it at the drop of hat, you are demonstrating automaticity. It's like turning on a switch and the light goes on. Kids show automaticity when they learn the alphabet, nursery rhymes, songs, and hopefully, their math facts for all four operations—addition, subtraction, multiplication, and division. It's magic. Memorization is learning to the extent that the words or numbers are on the tip of your tongue, instantly available to your work, lying in waiting for you to use the chunked information.

Timed Tests

When this Stanford math professor, Jo Boaler said, "Timed math tests can discourage students, leading to math anxiety and a long-term fear of the subject" (2014). It did cause quite a ruckus at the time, as the flash cards and times tables traditional approach used timed rounds as part of the methodology.

However, traditionally, experienced teachers use a variety of strategies to mitigate the stress

for kids. Many educators regularly use simple games to liven up practice sessions—recasting timed testing as an engaging race against the clock. Of course, when realizing that the point of timed testing is to create a sense of attentive focus for the memorization routine, transforming it into a game of sorts, readily optimizes the experience as kids respond instantly to the fast finish goal.

BlueStreak Math, as a digital platform for math fact fluency, takes full advantage of perceived benefits by using a gaming platform with adaptability for sprints, testing rounds, and the games themselves. Thus, the timing becomes a huge benefit and keeps students on their toes throughout the lesson.

Math Anxiety

Math anxiety is an emotion discussed in the new SEL standards for social emotional learning. Boaler (2015) comments that math is one of the very few subjects that causes students to cry. She actually goes on to say that many of these anxious incidents occur when students face their initial learning of their math facts. Sometimes it gets better, but the negative feelings about math can persist for certain students. In fact, there are enough learners who sense such extreme stress that the term math anxiety is real. Students get nervous, confused, and agitated with math anxiety, and cannot perform the math tasks clearly or with any sense of confidence.

"Deliberate Practice"

BlueStreak Math supports learning math fact fluency with a best practice called "deliberate practice" (Ericsson, and Pool 2018). Deliberate practice, based on the author's work around building learner expertise, professors advocate a proven method called, "reach and repeat" cycles of multiple repetitions, followed by a brief break (or short resting period). By using the deliberate practice routines with BlueStreak Math's digital gaming platform, students have moments of mental calculations flashing on the screen as the game proceeds. Then based on digital-fed feedback, virtual coaching begins with repeated sprints on the facts missed. It's exciting and engaging, or better yet, for students it's motivating and mindful as they learn their facts, and gain confidence in a growth mindset (Dweck, 2017).

In sum, BlueStreak Math's space-age, galaxy platform for digital practice sprints with a set of predetermined facts, indicating student needs. This activity is buffered by the exquisite gaming component that diverts students with a gaming or resting period by changing the action. The motivation is extended with options for 5 different games, 3 single player and 2 multiplayer games, designed for competitive rounds and for teamwork tasks with special feats. Again, this is another example of how BlueStreak Math addresses the SEL standards for social emotional learning.

In addition, BlueStreak Math supports learning math fact fluency with number sense using "deliberate practice" (Ericsson, and Pool 2018), buffered by a huge dose of learning number sense (Boaler, 2015) through student-friendly math strategies. The strategy cards used for teaching number sense, taken from the standards-based math principles are designed with the students in mind. BlueStreak Math gives each principle a clever and memorable "nickname" to help anchor it for the students.

In the end, Boaler's expertise in the fluency area, leaves readers with her most conclusive understanding to fully support and refine the use of this remarkable skill set of both math fact fluency and number sense flexibility for untamed math success for our students. To be optimally effective, the combination of Math Fact Fluency and Flexibility with Number Sense Strategies is best. Fact fluency means knowing the math facts mentally, and with automaticity and accuracy. When math facts are in your head, on the tip of your tongue, or in your immediate short-term memory for recall, retrieval is instantaneous, giving learners more time to think and move along with the more complex reasoning and computational solutions needed (https://www.youcubed.org/evidence/fluency-without-fear/).

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> ***Number Sense-Nickname Examples***
> *Addition Principle: You can use the multiplication strategies that you know to find the missing number. It will make the equation true.*
>
> *Multiplication: Solving Equations*
> *"Kid-friendly Name, "Mystery Number"*

The examples are taken from the student logs, BlueStreak Math Strategies of the Galaxy: Learn New Math Strategies to Improve Math Fact Fluency and Accuracy–Multiplication and Division (BlueStreak Math 2019). Explicit focus on number sense is supplemented by the series of BlueStreak Math Strategy Logs.

PART III: Number Sense Flexibility Using Math Strategies

Knowing how to manage math problems with clever strategic approaches and correct, easily understood answers is what haunts math students throughout their schooling. Yet, it is exactly the kind of critical thinking that serves students in every subject and many circumstances in life.

Number Sense

Number sense is far more complicated than simply learning your times tables or memorizing math facts. In fact, the memorized facts become more meaningful, when the student has a sense of how the equation or problem makes sense and is clearly understandable. Number Sense is defined as just that, having an understanding of numbers and their relationship to others in a way that it all "adds up" or makes sense. It makes meaning that can be comprehended.

In short, students develop "Number Sense" when they feel mathematically knowledgeable and confident because they understand and can make sense of numbers in logical and reasoned ways.

More specifically, number sense is knowing about numbers (bigger or smaller); whole number (fraction or part); put together (more or bigger), take apart (less or fewer); tens matter (10 x 10 = 100; 100 x 100 = 10,000; 10,000 x 10,000 = 1,000,000,000); perpendicular or parallel; graphs are easier to understand than a narrative about the data, etc. It truly is knowing about math in ways that you can easily explain. It's logical and true.

Logical Reasoning

Step by step, direct line from beginning to end, deductive thinking—if this is this; that is that. A level of proficiency in logic and reasoning when you're doing complex mathematics problem solving.

Math Fact Strategies

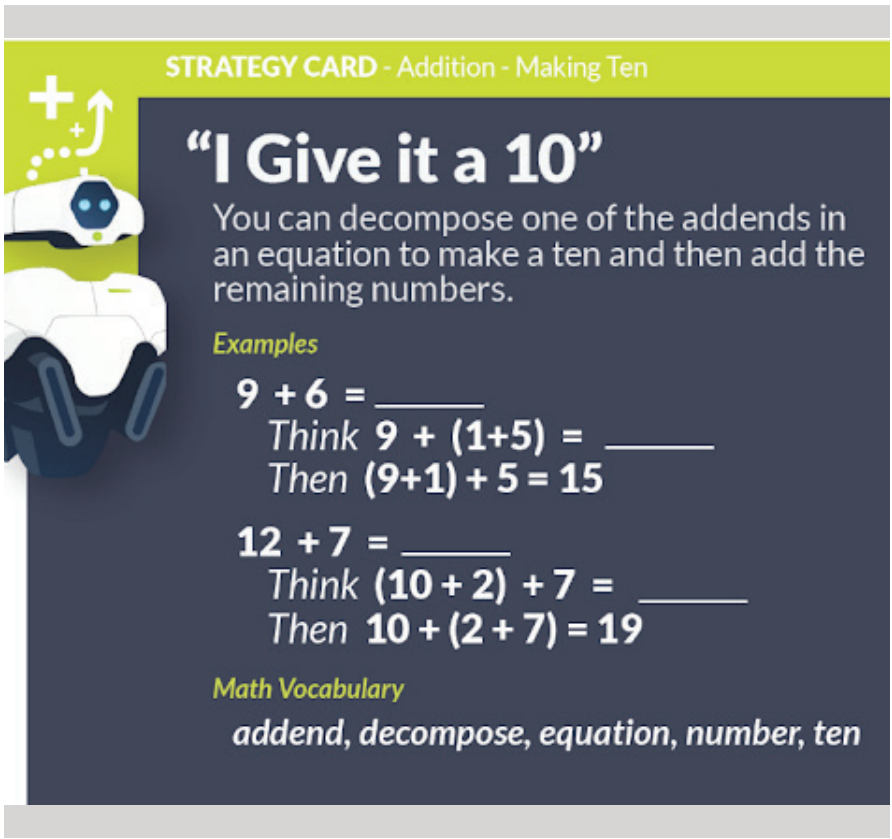
Standards-based math principles are the guidelines one follows when using mathematics to solve numerical problems properly and accurately. These strategies are used to execute the math solution needed, demonstrate a fact, record a metric, or show data of sorts. Strategies have a regularity, but they are often mixed and matched when doing complex mathematical solutions.

PART IV: High- and Low-Achieving Math Students

After math education articles, too numerous to name, Boaler's conclusion about the best way to learn math fact fluency is by practicing "math facts" for fluency. However, Boaler makes a point—the mere memorization or rote learning is not the same as learning and using "number sense strategies" for logical reasoning and deep understanding of mathematics. The studies are supported by other mathematics education research professors in the field as illustrated in the following study example.

In a critical mathematics project, researchers studied students as they solved number problems (Gray & Tall, 1994). The students, aged 7 to 13, had been nominated by their teachers as being low, middle, or high achieving. The researchers found an important difference between the low- and high-achieving students. The high-achieving students used number sense, the low-achieving students did not. The high achievers approached problems such as 19 + 7 by changing the problem into 20 + 6. Students who had been nominated as low achieving did not use number sense.

BlueStreak Math Strategy Logs develop students' Number teSense by teaching math strategies explicitly. Using "kid- friendly" language helps the students remember the Strategy and when to use it so that they develop Number Sense.



Additional Principle Strategy Card – "I Give It a Ten"

The BlueStreak Strategy for the example above is "I Give It a Ten". This strategy aligns with the foundational skills of Operations and Algebraic Thinking.

Subtraction Strategy Card – "What's Up?"

When the low-achieving students were given subtraction problems such as 21-16, they counted backwards, starting at 21 and counting down, which is extremely difficult to do. The high- achieving students used strategies such as changing the numbers into 20-15 which is much easier to do. The researchers concluded that low achievers are often low achievers not because they know less but because they don't use numbers flexibly. They have been set on the wrong path, often from an early age, of trying to memorize methods instead of interacting with numbers flexibly (Boaler, 2009). This incorrect pathway means that they are often learning harder mathematics and sadly, they often face a lifetime of mathematics problems.

In this example, a teacher would teach the students the BlueStreak Strategy: "What's Up?". Math strategies teach students to use numbers flexibly and encourages them to think critically and not to just guess or to attempt counting down. As with most situations in school, students are different in so many ways. They like certain subjects best. They have a range of study habits from poor to excellent. They have very different academic needs such as their own particular social emotional needs and a spectrum of behaviors that make each student unique. Yet, within that uniqueness, teachers also are aware of enough similarities to craft various pathways that seem the right fit for a group of students.

PART V: Demystifying Math Fact Myths

Many of the mathematical elements introduced through the discussion of Boaler's work, are explained and illustrated through a compendium of mathematical terms framed around a set of myths about math fact fluency.

Myth #1: Fact fluency is memorization of all math facts up to 12x12 for proficiency.

It's expedient to have basic math facts in your head, on the tip of your tongue, recalled with automaticity, but that is not all. BlueStreak Math ensures understanding of number sense with explicit strategies so it's easy to be flexible and figure out forgotten facts (National Numeracy, 2014).

Myth #2: Math fact fluency is doing math fast!

Not necessarily. The sign of a good math student is a misinterpretation that fluency is the mistaken goal of speed with math facts. In BlueStreak Math, students seem to work very deliberately, yet they are responsive to striving for their personal best in improving their sprint time as well as competing fully in games that may require speeding up play (Gray & Tall, 1994).

Myth #3: Math facts are like the tools of sight words in reading.

Math facts are more like sight words in reading. When learning to read students accumulate a growing set of sight words that provide recognizable signs along the road to comprehension (Fogarty, Kerns, & Pete, 2020). In BlueStreak Math, facts accumulate and offer the same recognizable signals that trigger number sense strategies to use in the math journey.

Myth #4: Flash Cards are the BEST way to learn math facts!

Not so! According to experts, FLASH CARDS use two unhelpful math practices. One is memorization without understanding and second, the time pressure for speed that is not necessary. BlueStreak Math supplements fact fluency with a huge dose of number sense through kid-friendly strategies to build student accuracy. (This can avoid catastrophic errors like the Hubble Telescope that missed the target star because of an arithmetic error [LA Times, 1990]).

Myth #5: Memorization is a positive way to learn by rote practice, repetition, and rehearsal.

Without the benefit of number sense flexibility, memorization can be damaging and limiting without real understanding (Boaler, 2015). In fact, brain researchers have studied students learning math facts in two ways—through strategies or memorization. They concluded that automaticity development needs both pathways—understanding of numerical relations and knowing math facts (Delazer et al, 2005).

Math #6: Brain Science does not relate to math fact fluency!

Not so, it does. Park and Bannon (2013), brain researchers discovered that numerical and symbolic language and one's intuition with spatial reasoning are two distinct pathways in the brain that support mastery of math fact fluency.

Myth #7: Math may be the only subject kids "hate", especially as they move into higher-level mathematics.

"Mathematics already has a huge image problem. Students rarely cry about other subjects, nor do they believe that other subjects are all about memorization or speed" (Boaler 2013). In the old days, "knowing your times table" did cause the level of anxiety to rise and kids were noticeably emotional. Yet, with BlueStreak Math, students are motivated about accomplishing math fact fluency on their digital devices. They are encouraged by the BlueStreak Galaxy gaming platform that provides constant personal feedback on progress from five different games—three single player and 2 multiplayer options. And, most importantly, "The core of mathematics is reasoning—thinking through why methods make sense and talking about reasons for the use of different methods" (Boaler, 2013). Isn't this the essence of schooling outcomes? Don't we want kids to reason, compare, and think critically in all subject areas? BlueStreak Math addresses this with real-world scenarios in the gaming component. Yet, math programs tend to be extremely strict about the scope and sequence that is the norm; even though there are easier ways to plan math around the sciences, social studies, and other subjects to make math more relevant.

Myth #8: For learning Fact Fluency, Digital Games are the best for automaticity.

Possibly, digital applications can be extremely helpful, with their adaptive programming. But, whether we realize it or not, the importance of automaticity with fact fluency is basic to the foundations for all higher-level math, however we learn it, by flash cards or digital tools.

Myth #9: Facts Stand Alone.

"Fluency: Students are expected to have speed and accuracy with simple calculations; teachers structure class time and/or homework time for students to memorize, through repetition, core functions such as multiplication tables so that they are more able to understand and manipulate more complex functions" (Engage New York, Third Grade Math, 2014). "Fluency comes about when students develop number sense and are mathematically confident because they understand numbers. Unfortunately, the word fluency is often misinterpreted (Boaler, 2009, p. 5). For example, the facts are supreme when YOU REMEMBER THEM. But, 7 × 8 = 54 is wrong. With strategy flexibility 7 × 7 = 49 is memorized. 7 × 7 = 49 + 7 = 56 (forty-nine plus one more 7 is 56). BlueStreak Math has all these major points covered. Facts are fun, motivating, and integrated into real-world scenarios to illustrate applications using fluent facts and flexible strategies.

Myth #10 Math Anxiety is not as common as it used to be.

Math still has an image problem that translates into emotions of anxiety and trepidation at the prospect of math quizzes, tests, exams, and reluctance to move into higher-level math classes. "Many people will argue that math is different from other subjects and it just has to be that way— that math is all about getting correct answers, not interpretation or meaning (Boaler, 2013).

Myth #11: Times tables or fact fluency don't need to be learned because calculators do the arithmetic.

Whether we realize it or not, the importance of automaticity with fact fluency is basic to the foundations for all high-level math, in our course work, careers, or on the job. In fact, fact fluency may well be one of the most frequently applied mathematics functions throughout the entire spectrum of advanced calculations and problem-solving performances students do.

Myth #12: Math skill and drill practice is over-rated.

Practice in the form of "skill and drill" is definitely overused, and perhaps over-rated, as a learning methodology. Yet, some say, "Practice makes perfect." Others believe, "Practice makes permanent." Whatever you think, we do know that practice is an age-old strategy that helps students learn successfully.

BlueStreak Math addresses the latest evidenced-based work by Ericsson and Pool (2018) with "deliberate practice" that includes cycles of short, timed practices with feedback for coaching, followed by recovery or rest in gaming. This combination of deliberate practice allows movement from gaming to practice with what is called a reach and repeat component. This means students are virtually coached, with instant feedback, to go beyond and reach for that personal best each time.

From our galaxy to yours...

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