

Promoting a Growth Mindset Through Personalized Mindset Coaching A Promising Experiment with Motion Math

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Introduction.

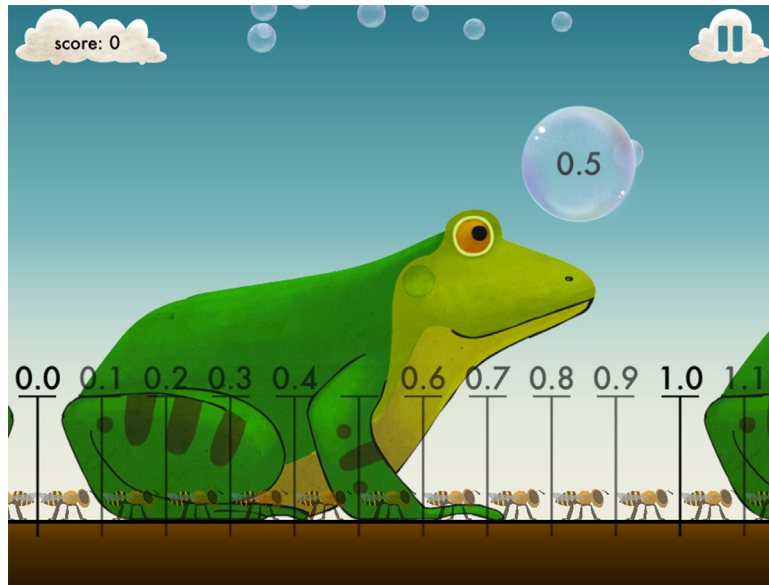
Knowledgeable and caring teachers are the most important resource in any learning environment, but I am excited about the potential of technology, particularly for engaging students in visual mathematics. The market has been flooded by math apps and games in the last decade but many of them offer low quality mathematics experiences – inviting students to calculate against a clock, reflecting the traditional, limited view of mathematics that is so pervasive in US culture (Boaler, 2016). A few notable apps, games and websites do something different – offering students a powerful means to visualize and manipulate mathematical ideas and gain deep understanding of complex mathematics (Pope, 2016). Desmos and Wolfram Alpha are both examples of high quality mathematical environments giving students access to ideas they probably will not get in other ways.

I advise a math game company called Motion Math. I have chosen to work with Motion Math because they offer high quality mathematical experiences, inviting students to engage in key mathematical ideas visually and interactively, often using motion. The latest research in brain science communicates not only the importance of visual thinking in mathematics, but also the importance of students physically moving to help ideas build in the sensory-motor area of the brain (see Boaler & Chen, 2016; Beilock, 2015). Motion Math was founded at Stanford's Graduate School of Education and it offers a suite of mathematical games that engage students in really interesting ways, as I share below. A few months ago the CEO of Motion Math, Jacob Klein, asked me what I thought about putting growth mindset messages into the games, particularly for those students who seem afraid of failure, which I thought was a brilliant idea. The developers took a really careful research approach and made two experimental conditions – with one group of students receiving the usual performance-based feedback in the games and the others receiving a personalized mindset coaching experience. [Their study](#) included over five thousand students and the results showed something highly significant for us all to think about – something that will help teachers of mathematics as well as other digital developers. This paper shares some of the main results.

What is Motion Math?

Motion Math offers a suite of games, currently available through a subscription and a [free trial](#), plus a teacher data dashboard. It is currently designed for use on iPads, but will soon be available on the web. The games cover many of the important ideas in elementary mathematics, including number sense, the number line, place value, operations, fractions, and estimation. To give you a sense of the different games, I'll briefly describe three of them.

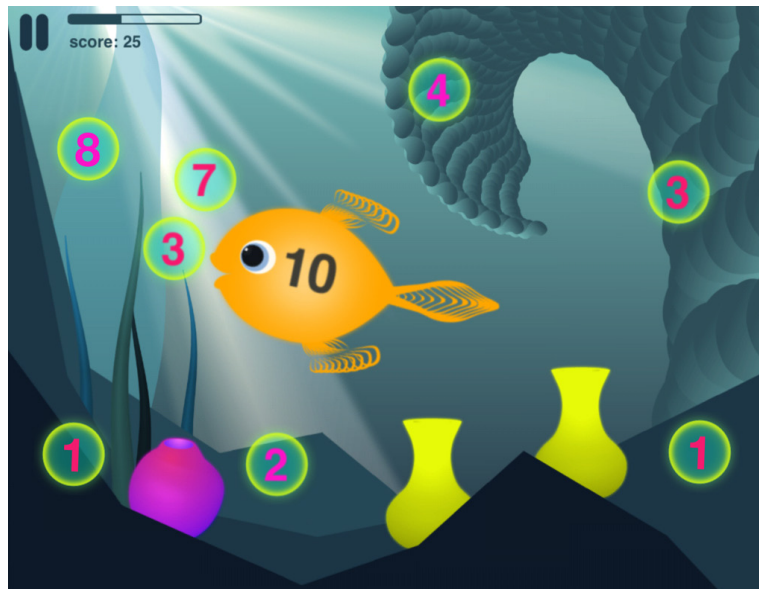
Zoom invites players to explore a tangibly interactive number line to master the important idea of place value. To find the correct location of the number in the bubble, students scroll back and forth on the number line and can also zoom in and out between different place values. The animals correspond to each order of magnitude (bees for tenths, frogs for ones, dogs for tens, etc.) helping to make the abstract idea of place value more concrete.



Cupcake is a mini-simulation. Students run a virtual cupcake delivery business, exploring important mathematical concepts to generate a profit. They compare unit rates while buying ingredients, set profit margins for their menu, and deliver orders using Cartesian coordinates. When customers come in to order cupcakes, they make sense of diverse and increasingly complex situations, as shown in the example below. Because the students feel ownership over the different situations (they own the store!), they are more likely to engage and persist in working out the correct quantity of cupcakes to sell.



The last example I will share is the game in which Motion Math performed their growth mindset experiment. Hungry Fish aims to help students develop a flexible approach to addition. Players merge integer bubbles together to feed a target sum to a fish; in the example shown below the target sum is 10. In contrast to most addition practice, which asks students, “what is the one correct answer of $3 + 7$?”, this game challenges students to find all the possible ways to create a 10, using two or more addends. More difficult levels feature larger sums and negative numbers, and, importantly, players have the freedom to choose among 18 levels of difficulty.



Encouraging Students to Embrace Challenge.

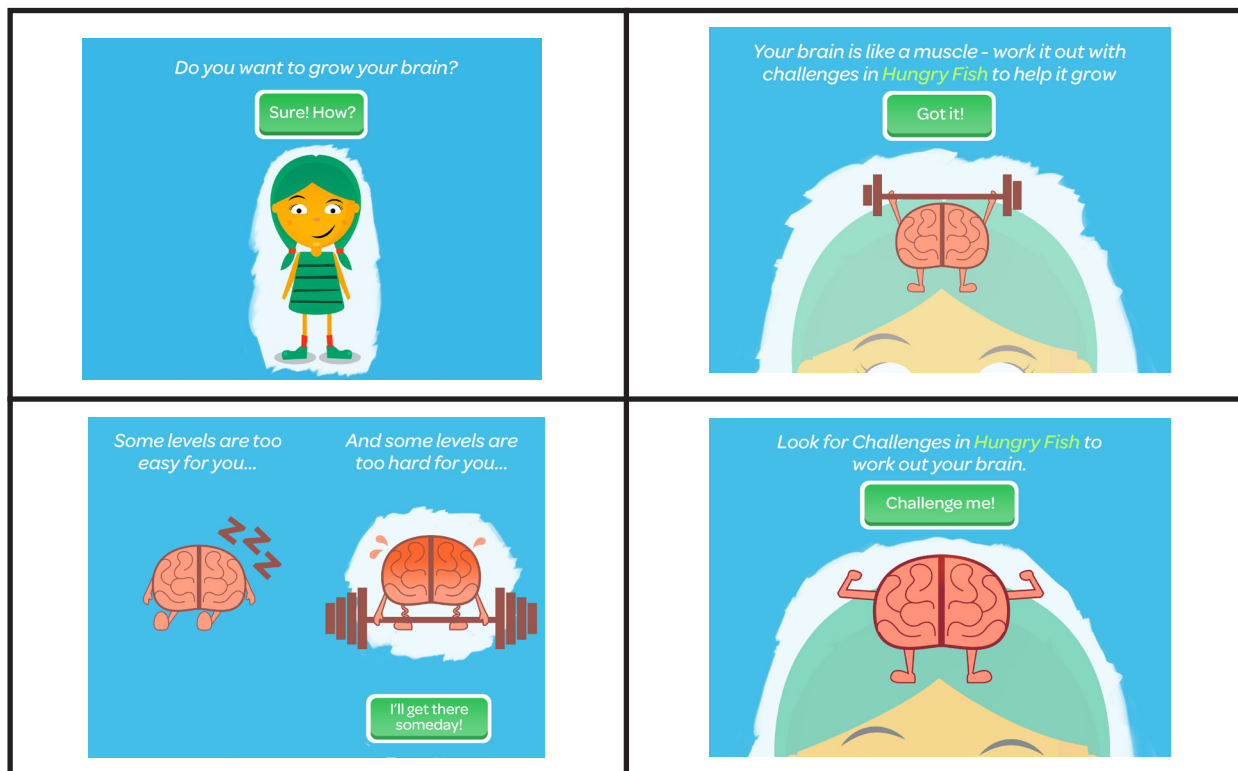
One of the challenges of teachers and tech companies is the design of conditions that will encourage students to work at an optimal challenge level. In my work as a teacher I see repeatedly that the most wonderful learning moments come when students experience the right level of challenge – when they find something hard but within their grasp. But how do teachers and tech designers encourage students to work at that ideal level? The Motion Math team decided that growth mindset messages might be the key to students taking on appropriate challenge levels. They had seen instances of players moving up the levels, taking increasing challenge, then failing at the next level and choosing to go back to the beginning of the games. They wanted to stop this kind of defeatist approach and replace it with a wiser approach to challenge, and to study their attempts through a carefully designed experiment.

Students with a growth mindset are those who believe they can grow their intelligence through effort and hard work. Students with a fixed mindset believe that their intelligence is more or less fixed (Dweck, 2006). Student mindsets matter as it is students with a growth mindset who have been found to persist for longer, embrace challenge and achieve at higher levels (Blackwell et al, 2007). Students with a fixed mindset often crumble when they fail, deciding that they just cannot do something. We wanted to help students develop a growth mindset through the game, by not only teaching them about the potential of their brains to grow and change but intervening at important times to help them see the importance of mistakes and challenge.

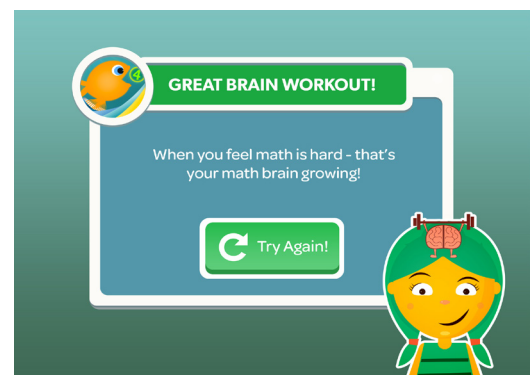
The team chose to design their experiment inside their game Hungry Fish. To see if students could be encouraged to take on an appropriate level of challenge, the team randomly assigned classrooms of students to three different experimental conditions of Hungry Fish. One group of students (the Control) played the normal Hungry Fish game, a second group experienced Mindset Coaching inside the game, and a third group experienced Rewards-driven coaching (n = 5731). (The details of the entire experiment, which built on previous exploration by BrainPop, are available at motionmathgames.com/mindsetexperiment.) The study showed that mindset coaching resulted in significant changes in behavior and achievement compared to the control, which we outline below.

In the control version of Hungry Fish, when students encounter key times of victory or defeat they see straightforward messages that summarize their score and tell them whether they won or lost. "Uh-oh. Your fish needed more food. Try again!" is a typical "lose" message.

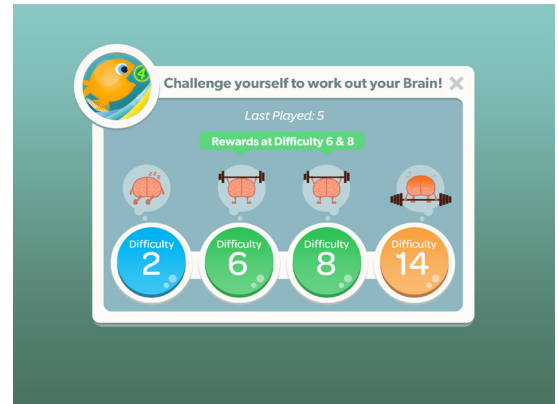
Students in the Mindset Coaching group, in contrast, experienced three differences in their version of the game. First, they saw a brief introductory slideshow, which coached them about the principles of growth mindset using the metaphor of a brain which grows by lifting heavy weights.



Second, at the important moment of victory or defeat, results were presented in terms of growth mindset and brain growth ideas, rather than traditional portrayals of success or failure. Students who won a level that was too easy (based on their previous record of wins and losses) were encouraged to try something more challenging, while students who lost an appropriately challenging level were encouraged with the message, "Great brain workout!"



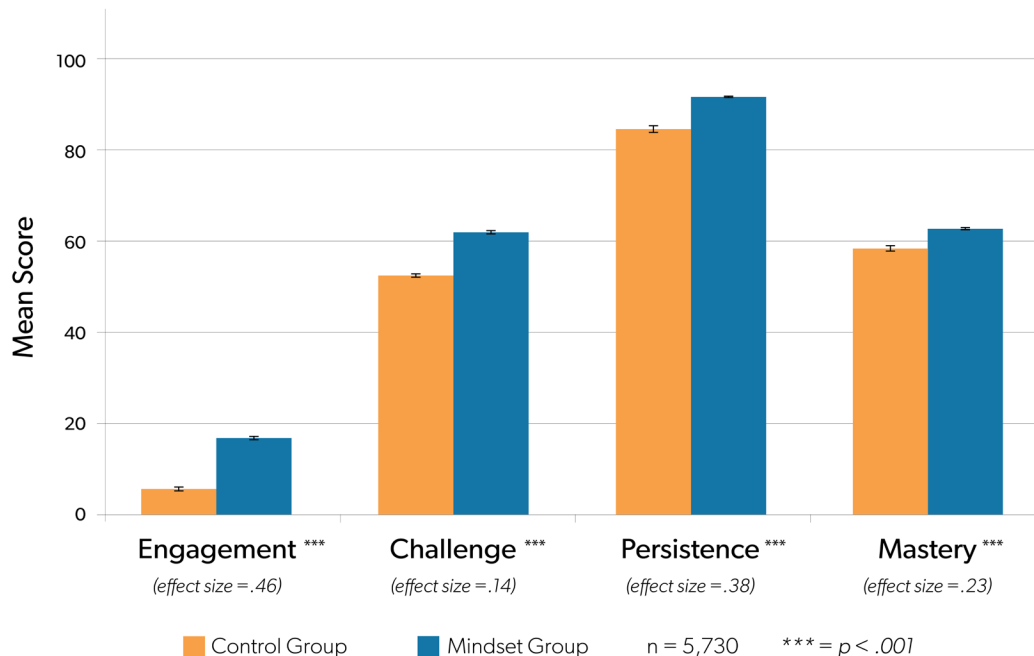
Finally, while students in the Control group chose any level between 1 to 18 using a slider, Mindset Coaching students had their choices reduced and framed in the language of growth mindset. These students chose between four levels: one below their appropriate challenge (symbolized by a sleeping brain), two within (a brain successfully lifting weights), and one that may be above their ideal level (a brain unable to lift the heavy weight).



More than 5,000 students in grades 2-6 participated in the experiment over a period of three months. To understand the impact of the mindset coaching we considered four variables:

- Engagement: the percentage of time each student chose to play Hungry Fish within the nine-game suite
- Challenge: the percentage of levels a student chose to play that were challenging
- Persistence: the percentage of challenging levels a student completed without quitting
- Mastery: the highest level a student consistently won (expressed as a percentage of the total levels)

The comparison of students in the Control and Mindset Coaching condition showed that students who received the mindset coaching were significantly more successful in their engagement, their approach to challenge, their persistence and their level of success, as shown below ($n = 5730$, $p < 0.001$).



Importantly, the positive impact of mindset coaching on challenge, persistence and mastery did not come at the cost of engagement. We initially feared that mindset coaching might dampen the enthusiasm of players by appearing pedantic or disrupting game flow. Instead the mindset coaching significantly increased engagement, which is a particularly exciting and interesting outcome. Engagement is the gateway to learning and one of the core promises of digital learning. Significantly, the positive effects were consistent across genders.

Follow-up investigations will tease apart the individual effects of mindset messaging, choice constraints, choice framing, and results framing. For now, the experiment demonstrates that embedded, personalized mindset coaching can help students move past feelings of defeat and replace them with motivation to persist and be challenged, an important finding for teachers and for developers of digital learning environments.

Discussion.

Some of the most important classroom moments come when students struggle – in those instances many students give up, telling themselves they are not a “math person”. Students’ lack of persistence in the face of challenge is a well known classroom problem, and is the main reason many teachers give for not using more open and challenging mathematics tasks and questions. New research on the potential of small interventions in critical moments (Lin-Siegler, Xiaodong, Dweck, & Cohen, 2016) tells us that teachers can change everything at those times; this research study adds to that important knowledge base.

Research tells us that the most effective students are those who see mathematics as a set of ideas, not methods to memorize (Boaler & Zoido, 2016), and those who engage in metacognition, thinking about what they know and what they need to know (Black & Wiliam, 1998). Learners have ideas and approaches to work that change their engagement and learning (Boaler, 2016). Students make numerous choices as they work, even in the most restrictive of classrooms, and those choices change their learning pathways. The interventions designed by the Motion Math team – telling students in moments of struggle that their brains are benefiting, and their learning is maximized – are useable by any teacher of mathematics. In my own teaching of mathematics I have found it useful to celebrate students’ struggles. When students say to me “this is hard, I am stuck” I choose not to jump in and help but to say to students “that is really good, your brain is growing, these are the most important times for you”. In most instances the students go back to their work and end up solving the problem they are working on.

Teaching students mathematics in a way that promotes positive mindset thinking means a lot more than changing the messages we give to students. Messages are important but when teachers put mindset posters on walls and tell students to “try harder” but do not offer students new strategies, or provide coaching to them in moments of uncertainty, those messages fall flat (Dweck, 2016). Personalized mindset coaching – encouraging students in key moments of struggle – is an important part of any mindset approach, especially when the work students are given is open enough for students to see a pathway towards growth (Boaler, 2016). In addition to empowering teachers, mindset coaching serves to leverage the most underutilized resource in education: students themselves.

Future work.

The Motion Math team is building on this experiment by exploring additional ways to impact learning within a digital environment, with promising early results. Importantly, they are designing a digital environment that mimics something a teacher can do in a classroom yet many tech products fail to do – provide personalized coaching. For students who seem to display low confidence, they encourage them by showing them their past successes. For students who seem to have low self-regulation (e.g. they jumped around and gave up often), they encourage them to reflect and reconsider before they quit a level. For students who seem to lack a level progression plan, they provide an interactive brain visualization, which students grow by “feeding” it challenging levels. For students who seem to display low effort, they appeal to altruistic motivation by changing language from “show what you can do; try your best” to “help us improve our software by trying your best.” This small change improved learner effort on formative assessments by 5% ($p < .05$, across 1120 assessments). It is not helpful to give the same interventions to every student because students who already exhibit great focus and self-regulation, for example, are not helped by telling them not to quit. Such messages are unnecessary and potentially counter-productive. Personalized coaching allows us to intervene at the right time, in carefully chosen ways, with the students who most need it.

The ambitious long-term goal of personalized coaching is to help students become self-directed learners. This will partially be achieved by empowering teachers with the learning pathways and choices of their students as they work in digital learning environments. During normal classroom work, teachers can readily observe visible signs of student behavior that need help, such as low confidence, challenge-avoidance, or lack of persistence, but these vital signs (Jansen, 2011) are more difficult to observe and correct when students work digitally. Carefully designed digital interventions can bridge the gap, and actionable data for educators can reveal digital patterns. Motion Math has started this communication to teachers with a summary of each student’s growth mindset, confidence, productive strategy, and self-regulation.

After decades of effort in the development of digital learning, the promise of personalization – enabling students to be given questions and coaching that supports their interests and goals– remains captivating, but is yet unrealized. We are confident that personalized mindset coaching, in teaching and in digital approaches, is a critical part of that promise. One of the most important tasks for teachers is to end defeatist and unproductive thinking among students, which students develop when they get the idea that they cannot learn at high levels. To change these unproductive thoughts teachers need to give students different messages, more open mathematical experiences and targeted coaching (as set out in Boaler, 2016). This paper offers hopeful ideas for coaching, in digital and teaching environments, that can encourage the development of confident learners who take on challenges, embrace difficulty and enjoy struggle. As educators who believe in all students and want to inspire them to the highest places they can reach, this is perhaps the most important goal for all of us.

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Acknowledgements.

Motion Math's research was funded with generous support from the Bill and Melinda Gates Foundation and the Noyce Foundation.

Thank you to Michael Carter, Jack Dieckmann, Jeffrey Klein, Dave Paunesku, and Cathy Williams for their helpful comments.