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Aligning Assessment to Brain Science

by Jo Boaler

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Introduction

The complex ways that children understand mathematics is fascinating to me. Students ask questions, see ideas, draw representations, connect methods, justify, and reason in all sorts of different ways. But recent years have seen all of these different nuanced complexities of student understanding reduced to single numbers and letters that are used to judge students' worth. Teachers are encouraged to test and grade students, to a ridiculous and damaging degree; students start to define themselves – and mathematics – in terms of letters and numbers. Such crude representations of understanding vastly under-describe and in many cases misrepresent children's knowledge.

In the United States students are over-tested to a degree that is nothing short of remarkable, particularly in mathematics. For many years students have been judged by narrow, procedural mathematics questions presented with multiple-choice answers. The knowledge needed for success on such tests is so far from the adaptable, critical and analytical thinking that students need in the modern world that leading employers such as Google have declared that they are no longer interested in students' test performance as it in no way predicts success in the workplace (Bryant, 2013).

One critical principal of good testing is that it assesses what is important.

For many decades in the United States, tests have assessed what is easy to test instead of important and valuable mathematics. This has meant that mathematics teachers have had to focus their teaching on narrow procedural mathematics, not the broad, creative and growth mathematics that is so important. The new common core assessments promise something different, with few multiple-choice questions and assessments of problem solving, but they are being met with considerable opposition from parents.

The damage does not only end with standardized testing, for math teachers are led to believe they should use tests in classrooms that mimic low quality standardized tests, even when they know the tests assess narrow mathematics.

They do this to help prepare students for later success. Some teachers, particularly at the high school level, test weekly or even more frequently. Mathematics teachers feel the need to test regularly, more than any other subject, because they have come to believe that mathematics is about performance, and they usually don't consider the role that tests play in shaping students' views of mathematics and themselves. Many mathematics teachers I know introduce a class with a test, which gives a huge performance message to students on the first day of class, the time when it is so important to be giving growth messages about mathematics and learning.

Finland is one of the highest-scoring countries in the world on international mathematics tests yet students do not take any tests in school. Instead teachers use their rich understanding of their students' knowledge gained through teaching to report to parents and make judgments about student work. In a longitudinal study I conducted in England students worked on open-ended projects for three years (ages 13 through 16) leading to national standardized examinations. They did not take tests nor was their work graded. Students encountered short questions assessing procedures in the last few weeks before the examination, as the teachers gave them examination papers to work through. Despite the students' lack of familiarity with examination questions or working under timed conditions of any kind, they scored at significantly higher levels than a matched cohort of students who spent three years working through questions similar to the national exam questions and taking frequent tests (Boaler, 1998, 2015). The students from the problem solving school did so well in the standardized national exam because they had been taught to believe in their own capabilities; they had been given helpful, diagnostic information on their learning; and they had learned that they could solve any question, as they were mathematical problem solvers.

Students with no experience of examinations and tests can score at the highest levels because the most important preparation we can give students is a growth mindset, positive beliefs about their own ability, and problem-solving mathematical tools to equip them for any mathematical situation.

The testing regime of the last decade has had a large, negative impact on students but it does not end with testing; the communication of grades to students is similarly negative. When students are given a percentage or grade, they can do little else besides compare it to others around them, with half or more deciding that they are not as good as others. This is known as "ego feedback," a form of feedback that has been found to damage learning. Sadly when students are given frequent test scores and grades they start to see themselves as those scores and grades. They do not regard the scores as an indicator of their learning or of what they need to do to achieve, but as indicators of who they are as people. The fact that US students commonly describe themselves saying "I'm an A student" or "I'm a D student" illustrates the ways students define themselves by grades. Ray McDermott wrote a compelling paper about the capturing of a child by a learning disability, describing the ways a student who thought and worked differently was given a label and was then defined by that label (McDermott, 1993). I could give a similar argument about the capturing of students by grades and test scores.

Students describe themselves as A or D students because they have grown up in a performance culture that valued frequent testing and grading, rather than persistence, courage, or problem solving. The traditional methods of assessing students that have been used across the United States for decades were designed in a less enlightened age (Kohn, 2011) when it was believed that grades and test scores would motivate students, and that the information they provided on students' achievement would be useful.

> *Now we know that grades and test scores demotivate rather than motivate students and that they communicate fixed and damaging messages to students that result in lower achievement in classrooms.*

In studies of grading and alternatives to grading researchers have produced consistent results. Study after study shows that grading reduces the achievement of students. Elawar and Corno, for example, contrasted the ways teachers responded to math homework in sixth grade, with half of the students receiving grades and the other half receiving diagnostic comments without a grade (Elawar & Corno, 1985). The students receiving comments learned twice as fast as the control group, the achievement gap between male and female students disappeared, and student attitudes improved.

A study by Ruth Butler added a third condition, which gave students grades and comments –as this could be thought of as the best of both worlds (Butler, 1987, 1988). In this study, students who received grades only and those who received grades and comments scored equally badly, and the group that achieved at significantly higher levels was the comment only group. This showed that when students received a grade and a comment, they focused on only the grade. Butler found that both high-achieving (the top 25% GPA) and low-achieving (the bottom 25% GPA) fifth and sixth graders suffered deficits in performance and motivation in both graded conditions, compared with the students who received only diagnostic comments. Further research showed that that students only needed to think they were working for a grade to lose motivation, resulting in lower levels of achievement (Pulfrey, Butera, and Buchs, 2011).

> *The move from grades to diagnostic comments is a crucial one, and is a move that allows teachers to give students an amazing gift – the gift of their knowledge and insights about ways to improve.*

Teachers, quite rightly, worry about the extra time this can take, as good teachers already work well beyond the hours they are paid for. My recommended solution is to assess less; if teachers replaced grading weekly with diagnostic comments given occasionally, they could spend the same amount of time, remove the fixed mindset messages of a grade, and provide students with insights that would propel

them onto paths of higher achievement. Teachers who have made these changes see increases or no changes in test performance and significant increases in motivation and confidence.

When we give assessments to students we create an important opportunity. Well-crafted tasks and questions accompanied by clear feedback offer students a growth mindset pathway that helps them to know that they can learn to high levels, and, critically, how they can get there. Unfortunately most systems of assessment in U.S. classrooms do the opposite of this, communicating information to students that causes many of them to think they are a failure and they can never learn math. I have worked with teachers in recent years who have shifted their methods of assessment from standard tests with grades and scores to assessments that are focused upon giving students the information they need in order to learn well accompanied with growth mindset messages. This resulted in dramatic changes in their classroom environments.

> *Math anxiety, formerly commonplace among students, disappeared and was replaced by student self-confidence, which led to higher levels of motivation, engagement and achievement.*

I am a strong supporter of teachers and know that the No Child Left Behind era stripped the professionalism and enthusiasm of many teachers as they were forced (and I choose that word carefully) to use teaching methods that they knew to be unhelpful. An important part of my work with teachers now is to help them regain their sense of professionalism. My aim in working with teachers is to help them see themselves as creators again, people who can design teaching environments infused with their own ideas for creative, engaging math. I have watched teachers come alive when they are encouraged in these ways.

In a new film by Vicki Abeles, director of Race to Nowhere (watch the trailer to learn more!), her team interviewed the middle school students in a district I was working in, helping the teachers shift their teaching and assessment. In the film one girl, Delia, talks about getting an F for her homework in the previous year, and how it had caused her to stop trying in math and – shockingly – all of her classes across the school. In the interview she poignantly said:

"When I saw the F on my paper I felt like a nothing. I was failing in that class so I thought I may as well fail in all my other classes too. I didn't even try." Later in the film she talks about the change in her math class and how she now feels encouraged to do well. "I hated math," she says "I absolutely hated it, but now I have a connection with math, I'm open, I feel like I'm alive, I'm more energetic."

Beyond Measure Source: Image courtesy of Reel Link Films

Delia's use of the word "open" in describing how she felt about math is a sentiment I hear frequently from students when they are taught mathematics without the impending fear of low test scores and grades. But it goes further than assessment – when we teach creative, inquiry math students feel an

intellectual freedom that is powerful. In interviews with 3rd graders who experienced number talks in class, I ask the students how they feel about number talks. The first thing young Dylan said in the interview was "I feel free." He went on to describe how the valuing of different mathematics strategies allowed him to feel he could work with mathematics in any way he wanted, to explore ideas and learn about numbers. The students' use of words such as 'free', and 'open' demonstrate the difference that is made when students work on growth mindset mathematics; this goes well beyond math achievement to an intellectual empowerment that will affect students throughout their lives (Boaler, 2015).

The perceptions students develop about their own potential affect their learning, their achievement, and, of equal importance, their motivation and effort—as Delia describes in the film. When she got an F in math, she gave up not only in math but also in all of her other classes; she felt like a failure. This is not an unusual response to grading.

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> *When students are given scores that tell them they rank below other students, they often give up on school, deciding that they will never be able to learn and they take on the identity of an underperforming student.*

The grades and scores given to students who are high achieving are just as damaging. Students develop the idea that they are an "A student" and begin a precarious fixed mindset learning path that makes them avoid harder work or challenges for fear that they will lose their A label. Such students often are devastated if they get a B or lower, for any of their work.

In another research study on grading Deevers found that students who were not given scores but instead given positive constructive feedback were more successful in their future work. He also, sadly, found that as students got older teachers gave less constructive feedback and more fixed grading. He found a clear and unsurprising relationship between teachers' assessment practices and student attitudes as students' beliefs about their own potential and the possibility of improving their learning declined steadily from 5th to 12th grade (Deevers, 2006).

We want students to be excited about and interested in their learning. When students develop interest in the ideas they are learning, they increase their motivation and their achievement. There is a large body of research that has studied two types of motivation. Intrinsic motivation comes from interest in the subject and ideas you are learning; extrinsic motivation is the motivation provided by the thought of getting better scores and grades. Because mathematics has been taught for decades as a performance subject, the students who are most motivated in math classrooms are usually those who are extrinsically motivated. One result of this is that students who feel positive about math class are usually only those students who are getting high scores and grades. Most of the teachers who believe in grades, use them because they think they motivate students to achieve. They do motivate some students – those who would probably achieve at high levels anyway, but they de-motivate the rest. Unfortunately the extrinsic motivation that the high achieving students develop is not helpful in the long term. Study after study shows that students who develop intrinsic motivation achieve at higher levels than those who develop extrinsic motivation (Pulfrey, Buchs, & Butera 2011; Lemos & Verissimo, 2014), and that intrinsic motivation to learn ideas motivates students to pursue subjects to higher levels and to stay in subjects rather than drop out (Stipek, 1993).

Assessment for Learning

A few years ago two professors from England – Paul Black and Dylan Wiliam –conducted a meta-analysis of hundreds of research studies on assessment. They found something amazing: a form of assessment so powerful, that if teachers used it the impact would be so great that it would raise the achievement of a country in international studies from the middle of the pack to a place in the top five. (Sir Paul Black and Professor Dylan Wiliam were both good colleagues of mine at London University; Paul Black was also my dissertation advisor and mentor.) Black and Wiliam found that if teachers were to use what is now called "assessment for learning" the positive impact would be far greater than other educational initiatives such as reductions in class size (Black, Harrison, Lee, Marshall, & Wiliam, 2002; Black & Wiliam, 1998a, 1998b). They published their findings in a small booklet that sold over 20,000 copies in the first few weeks in England. Assessment for Learning is now a national initiative in many countries; it has a huge research evidence base and it communicates growth mindset messages to students.

A little background will be helpful. There are two types of assessment—formative and summative. Formative assessment informs learning and is the essence of assessment for learning or A4L. Formative assessments are used to find out where students are in their learning so that teachers and students can determine what they need to know next. The purpose of summative assessment, in contrast, is to summarize a student's learning—to give a final account of how far a student has gotten, as an end point. One problem in the United States is that many teachers use summative assessment formatively; that is, they give students an end score or grade when they are still learning the materials. In mathematics classrooms teachers often use summative tests weekly and then move on to the next subject without waiting to see what the tests reveal. In A4L, students become knowledgeable about what they know, what they need to know, and ways to close the gap between the two. Students are given information about their flexible and growing learning pathways that contributes to their development of a growth mathematics mindset. In the weeks and months that students are learning in a course, it is very important to assess formatively, not summatively. Further, the A4L approach, which can also be thought of as assessing for a growth mindset, offers a range of strategies and methods.

> *One important principle of A4L is that it teaches students responsibility for their own learning.*

At its core A4L is about empowering students to become autonomous learners who can self-regulate and determine what they most need to learn and who know ways to improve their learning. Assessment for learning can be thought of as having three parts: (1) clearly communicating to students what they have learned, (2) helping students become aware of where they are in their learning journey and where they need to reach, and (3) giving students information on ways to close the gap between where they are now and where they need to be.

Developing Student Self-Awareness and Responsibility

The most powerful learners are those who are reflective, who engage in metacognition – thinking about what they know – and who take control of their own learning (White & Frederiksen, 1998). A major failing of traditional mathematics classes is that students rarely have much idea of what they are learning or where they are in the broader learning landscape. They focus upon methods to remember but often do not even know what area of mathematics they are working on. I have visited math classes many times and stopped at students' desks to ask them what they are working on. In many cases students answer with the question they are working on. Many of my interactions have gone something like this:

JB: What are you working on?

Student: Exercise 2

JB: So what are you actually doing, what math are you working on?

Student: Oh, I'm sorry – question 4

Students are often not thinking about the area of mathematics they are learning, they do not have an idea of the mathematical goals for their learning, and they expect to be passively led through work with teachers telling them whether they are "getting it" or not. Alice White, an assessment expert, likens this situation to workers on a ship who are given jobs to do each day but don't have any idea where the ship is travelling to.

One research study, conducted by Barbara White and John Frederikson (1998), powerfully illustrated the importance of reflection. The researchers studied twelve classes of seventh grade students learning physics. The researchers divided the students into experimental and control groups. All groups were taught a unit on force and motion. The control groups then spent some of each lesson discussing the work whereas the experimental group spent some of each lesson engaging in self- and peer assessment, considering criteria for the science they were learning. The results of the study were dramatic. The experimental groups outperformed the control groups on three different assessments. The previously low-achieving students made the greatest gains. After they spent time considering the science criteria and assessing themselves against them, they began to achieve at the same levels as the highest achievers. The middle school students even scored at higher levels than AP physics students on tests of high school physics. The researchers concluded that a large part of the students' previous low achievement came not from the fact that they lacked ability but that they had not previously known what they should really be focusing upon.

This is true for many students and this is why it is so important to communicate to students what they should be learning. This both helps the students know what success is, and starts a self-reflection process that is an invaluable tool for learning.

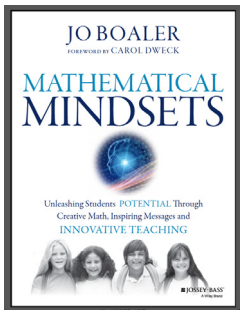
There are many strategies for encouraging students to become more aware of the mathematics they are learning and their place in the learning process, several of which are in Jo's upcoming book, Mathematical Mindsets.

Conclusion

Tests and grading can lead students to disengage from mathematics and even school itself. Assessment for Learning, by contrast, represent an incredible opportunity for teachers to provide students with

information on their learning that accelerates pathways to success and gives students powerful growth mindset messages about mathematics and learning. Research shows that a change from grading and testing to Assessment for Learning has a powerful impact on students' achievement, self-beliefs, motivation and future learning pathways.

> *By using assessments to empower students to learn and grow, we can help our students develop positive attitudes towards mathematics and themselves.*



This article contains excerpts from Jo Boaler's new book, Mathematical Mindsets: Unleashing Students' Potential Through Creative Math, Inspiring Messages and Innovative Teaching

Why are we doing this??

Many students have felt a sense of anxiety/stress when it comes to learning math. Many fear that math is something that you are either good at or not. There is also this sense of pressure that students feel because they view math as something that you are either right or wrong. What many students struggle to understand is that the beauty of math is not so much on the solution but the thinking and creativity that goes into trying to solve the problem. In addition to this, students constantly feel pressure to perform due to grades. The anxiety students feel with regards to grades is like a dark cloud that hangs over them. No matter what is going on in class, or how much they are enjoying the topic they are learning, there is still this looming pressure to perform in order to receive the highest grade possible. Whether it's higher achieving students or lower achieving students, many students' focus is on performing in order to achieve a certain grade. What this has caused is a focus on performing (memorizing) rather than a focus on learning. We want students to enjoy learning. Isn't that the purpose of going to school? With this being, last year we tried to make a shift by encouraging students to take risks and not be afraid to make mistakes. However, when it came time to grading tests, students were still penalized for having wrong answers. How can we encourage students to not be afraid to make mistakes and then penalize them for doing it on a test? This sent mixed messages and has been on our minds over the course of the summer. After careful thought, we're curious to try this. **What would happen if everyone got an A at the beginning of the year?!** *Would students no longer feel pressure or worry about their performance? Would this free students up to be more creative and to take more risks? Would this lead to students being more curious and wanting to go deeper and to understand why things work the way they do? Would this lead to more of an intrinsic motivation of students wanting to do well and to learn?Let's Find Out...*

An extract from letter to parents, from High Tech High Math Department, Chula Vista, San Diego.

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