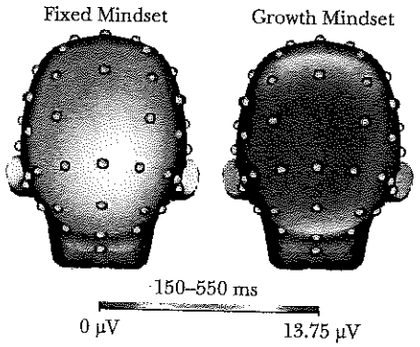

FIGURE 2.1 Brain activity in individuals with a fixed and a growth mindset
Source: Moser et al., 2011.

are not aware of it, because it is a time of struggle; the brain is challenged, and this is the time when the brain grows the most.

In Moser and his colleagues' study, the scientists looked at people's mindsets and compared mindsets with their ERN and Pe responses when they made mistakes on questions. Moser's study produced two important results. First, the researchers found that the students' brains reacted with greater ERN and Pe responses—electrical activity—when they made mistakes than when their answers were correct. Second, they found that the brain activity was greater following mistakes for individuals with a growth mindset than for individuals with a fixed mindset. Figure 2.1 represents brain activity in individuals with a fixed or growth mindset, with the growth mindset brains lighting up to a much greater extent when mistakes were made.

The fact that our brains react with increased activity when we make a mistake is hugely important. I will return to this finding in a moment.

The study also found that individuals with a growth mindset had a greater awareness of errors than individuals with a fixed mindset, so they were more likely to go back and correct errors. This study supported other studies (Mangels, Butterfield, Lamb, Good, & Dweck, 2006) showing that students with a growth mindset show enhanced brain reaction and attention to mistakes. All students responded with a brain spark—a synapse—when they made mistakes, but having a growth mindset meant that the brain was more likely to spark again, showing awareness that a mistake had been made. Whether it is mathematics, teaching, parenting, or other areas of your life, it is really important to believe in yourself, to believe that you can do anything. Those beliefs can change everything.

The recent neurological research on the brain and mistakes is hugely important for us as math teachers and parents, as it tells us that making a mistake is a very good thing. When we make mistakes, our brains spark and grow. Mistakes are not only opportunities for learning, as students consider the mistakes, but also times when our brains grow, even if we don't know we have made a mistake. The power of mistakes is critical information, as children and adults everywhere often feel terrible when they make a mistake in math. They think it means they are not a math person, because they have been brought up in a performance culture (see Boaler, 2014b) in which mistakes are not valued—or worse, they are

classrooms are designed to give students work that they will get correct. Later in the book I will show the sorts of math questions that engage students and enable their brains to grow, along with the teaching and parent messages that need to accompany them.

Countries that top the world in math achievement, such as China, deal with mistakes very differently. I recently watched a math lesson in a second-grade classroom in Shanghai, the area of China where students score at the highest levels in the country and the world. The teacher gave the students deep conceptual problems to work on and then called on them for their answers. As the students happily shared their work, the interpreter leaned over and told me that the teacher was choosing students who had made mistakes. The students were proud to share their mistakes, as mistakes were valued by the teacher. In Chapter Nine I share a short and very interesting extract from one of the lessons in China.

The various research studies on mistakes and the brain not only show us the value of mistakes for everyone; they also show us that students with a growth mindset have greater brain activity related to error recognition than those with a fixed mindset. This is yet another reason why a growth mindset is so important to students as they learn mathematics as well as other subjects.

Moser's study, showing that individuals with a growth mindset have more brain activity when they make a mistake than those with a fixed mindset, tells us something else very important. It tells us that the ideas we hold about ourselves—in particular, whether we believe in ourselves or not—change the workings of our brains. If we believe that we can learn, and that mistakes are valuable, our brains grow to a greater extent when we make a mistake. This result is highly significant, telling us again how important it is that all students believe in themselves—and how important it is for all of us to believe in ourselves, particularly when we approach something challenging.

Mistakes in Life

Studies of successful and unsuccessful business people show something surprising: what separates the more successful people from the less successful people is not the number of their successes but the number of mistakes they make, with the more successful people making *more* mistakes. Starbucks is one of the world's most successful companies, and Howard Schultz, its founder, one of the most successful entrepreneurs of our time. When Schultz started what would later became Starbucks, he modeled the stores on Italian coffee shops. The United States did not have many coffee shops at the time, and Schultz had admired the coffee shops of Italy. He set up the early stores with servers wearing bow ties, which they found uncomfortable, and opera music played loudly as customers drank their coffee. The approach was not well received by American customers, and the team went back to the drawing board, making many more mistakes before eventually producing the Starbucks brand.

Peter Sims, a writer for the *New York Times*, has written widely about the importance of mistakes for creative, entrepreneurial thinking (Sims, 2011). He points out: "Imperfection is a part of any creative process and of life, yet for some reason we live in a culture that has a paralyzing fear of failure, which prevents action and hardens a rigid perfectionism. It's the single most disempow-

FIGURE 2.2 Feel comfortable being wrong

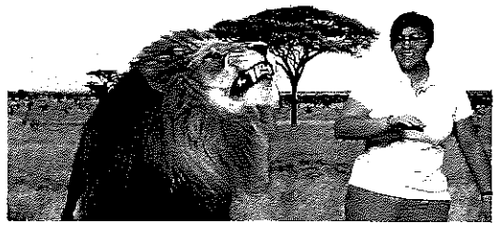

FIGURE 2.3 Try seemingly wild ideas

FIGURE 2.4 Are open to different experiences

FIGURE 2.5 Play with ideas without judging them

He also summarizes the habits of successful people in general, saying that successful people:

Feel comfortable being wrong

Try seemingly wild ideas

Are open to different experiences

Play with ideas without judging them

Are willing to go against traditional ideas

Keep going through difficulties

This summer I taught a new online class for students, How to Learn Math: For Students; at the time of this writing it has been taken by over 100,000 students. The class is designed to give students a growth mindset, to show them math as engaging and exciting, and to teach them important math strategies that I will share in this book. (The course can be easily accessed at https://www.youcubed.org/category/mooc/.)

I taught the class with some of my Stanford undergraduates, who acted out the different habits that Peter Sims described, which Colin, the course producer, made more interesting with the addition of some props and characters! The undergraduates featured are Carinne Gale (Figure 2.2), Montse Cordero (Figures 2.3, 2.4, and 2.7), Devin Guillory (Figure 2.5), and Hugo Valdivia (Figure 2.6).

These different habits are just as important in math class as they are in life, but they are often startlingly absent in math class and when students work on math at home. We want students to feel free as they work on math, free to try different ideas, not fearing that they might be wrong. We want students to be open to approaching mathematics differently, being willing to play with mathematics tasks, trying "seemingly wild ideas" (see Chapter Five). We want them to go against traditional ideas—rejecting notions that some people can do math and some can't, and of course keeping going when math is hard, even when they cannot see an immediate solution.

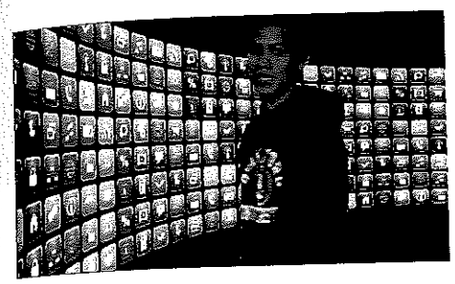

FIGURE 2.6 Are willing to go against traditional ideas

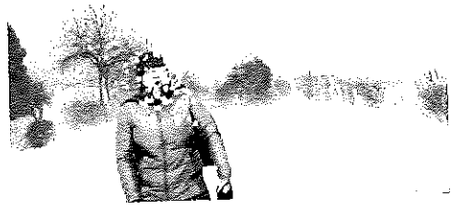

FIGURE 2.7 Keep going through difficulties
Source: Images from *How to Learn Math: For Students*. Jo Boaler Standford Online Course. Featuring, in order: Carinne Gale, Montse Cordero, Devine Guillory, Hugo Valdivia

How Can We Change the Ways Students View Mistakes?

One of the most powerful moves a teacher or parent can make is in changing the messages they give about mistakes and wrong answers in mathematics. I recently received a very moving video from a teacher who took my online class and started the year teaching a class of failing students the importance and value of mistakes. The students completely changed over the year, picking themselves up from past failures and reengaging positively with math. The teacher sent a video of the students reflecting, in which they talk about the message that mistakes grow your brain, changing everything for them. They said that they had previously thought of themselves as failures, a mindset that had hampered their progress. Their new teacher gave them messages and teaching methods that caused them to shed their years of mathematics fear and approach the subject with new drive. When we teach students that mistakes are positive, it has an incredibly liberating effect on them.

In my online class for teachers and parents I shared the new information about mistakes and posed a challenge as one of the class activities. I asked participants to design a new activity that would reposition mistakes in classrooms or in homes. One of my favorite responses to this question came from a teacher who told me she would start the class by asking students to crumple up a piece of paper and throw it at the board with the feelings they had when they made a mistake in math. The students were invited to let out their feelings—usually ones of frustration—by hurling their crumpled paper at the board (see Figure 2.8). She then asked students to retrieve their paper, smooth it out, and trace all the crumple lines on the paper with colored markers, which represented their brain growth. The students were asked to keep the pieces of paper in their folders during the school year as a reminder of the importance of mistakes.

A few years ago I started working with Kim Halliwell, an inspirational teacher who is one of a group of teachers in Vista Unified School district with whom I have worked closely for over two years. When I visited Kim's classroom last year I saw the walls covered with lovely student drawings of brains, filled with positive messages about brain growth and mistakes (see Figure 2.9).