**After the Fact |** The Future of Learning: What Do We Know About the Brain Today?

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## TRANSCRIPT

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**Liz Toomarian, educational neuroscientist, Stanford University Graduate School of Education:** What do you think it's going to sound like? Think about it first for a sec. Everyone think what you think the sound is going to sound like. And then when I say three, I want to make the sound that you think it's going to sound like. OK? 1, 2, 3.

*[KIDS VOICES.]*

**Liz Toomarian:** Hmm. I heard a lot of cars. *[Laughter.]*

**Ray Suarez, host:** That's Liz Toomarian. She directs the Brainwave Learning Center at Synapse School, a partnership with Stanford University in Menlo Park, California.

Her research assistant Cha Cha Pillai has attached sticky sensors to her arm and they're showing the kids at this unique elementary school what muscle activity sounds like.

What you just heard doesn't sound too different from what you'd hear if you dropped in on any other instructors with their students. But this is a different kind of school, and you figure that out as soon as you walk inside.

*[Music plays.]*

**Ray Suarez:** I'm Ray Suarez and this is "After the Fact," a podcast from The Pew Charitable Trusts. Today, we begin a four-part series exploring how we learn and what the future looks like as scientists learn more about the human brain.

I'll be your guide on this journey as we share fascinating insights from experts and stories from learners at various stages in life.

Our data point may blow your mind—or all 86 billion neurons it contains. That's right—your brain is made up of 86 billion neurons—just shy of the number of stars in the Milky Way. Among them they have about 10 to the fifteenth power connections, and they are working all the time—while you're sleeping, eating, and, of course, while you are learning.

Relatively recent breakthroughs in technology have given us an unprecedented ability to see and understand these neurons. In the early '90s, the advent of functional magnetic resonance imaging (fMRI) allowed researchers to scan parts of the brain and record levels of activity by detecting changes in blood flow. This opened the door to efforts to map the brain and its countless connections, and continued improvements in the technology we have to study it.

Today, we can see how individual neurons function and connect, and that may help us to better understand things like how we store memory; how what we smell, see, hear, and taste can lead to certain behavior; and even how emotions can impact the decisions we make.

Researchers estimate that we may be able to map a mouse brain—which has a whopping 75 million neurons—in the next decade. But using today's technology, it could take thousands of years just to collect enough information to chart the human brain. This essential organ that drives what it is to be human remains more unknown to us than outer space.

Still, many call today the Golden Age of Neuroscience, with revolutionary discoveries being made each year. To understand more, we traveled to the Brainwave Learning Center at Synapse School to see what researchers on the cutting edge are uncovering, and what it may mean for how we learn.

*[Recess noise.]*

**Liz Toomarian:** Synapse is a pretty innovative school. One of their guiding principles is innovation along with social emotional learning, project-based learning, leading-edge academics. And I think that what we're doing in the Brainwave Learning Center really dovetails nicely with their approach to social emotional learning, learning about yourself, and being in touch with yourself in your own learning. It's a totally innovative concept to have a neuroscience lab on-site at a school. And for the students to get to experience that, I think, is really part of the whole mission of the school.

**Ray Suarez:** You heard Liz correctly—neuroscientists and a lab are on-site at the Synapse School in what's called the Brainwave Learning Center. Liz directs the center as part of a collaboration with Stanford University to understand what's happening inside the brain as we learn new skills.

**Liz Toomarian:** There are other insights that we've gained from previous research studies that still are making their way into the classroom. And then what we're doing here in terms of our research is something that might have an impact 10 years from now or multiple years down the line. We're hoping to be able to see how brains are different as a result of the learning experiences and how they're different across these learning differences or learning difficulties. And that might help us down the line understand more about how to intervene and when to intervene.

**Ray Suarez:** Bruce McCandliss, a professor with Stanford's Graduate School of Education, leads the initiative's work. He says that even watching children learn to read can tell us a lot about one of the most important organs in the body.

**Bruce McCandliss, head, Educational Neuroscience Initiative, Stanford University Graduate School of Education:** I like the analogy of a stalk of broccoli. So if you look inside the brain, you see the stalks of broccoli, these white matter tracts, are kind of like moving toward the crown of the broccoli, which is the neocortex, and there have been pretty remarkable discoveries about functional divisions within these neural networks that are being formed between the crown and the broccoli and the white matter tracts that connect them.

So, if you look here in the front of the brain, or maybe even if you make a fist like this—put your hands together like this and cross your thumbs. Now you've got something that's kind of like the model of a human brain. You can take that with you wherever you go. And up here in the front, kind of farthest away from your body, is the frontal lobe, and these regions, together with parietal regions, are crucial for goal-directed activity, for focusing your attention on something, which we know is really, really important for reading and developing skills and all of these things.

If you open your hand, you can look at some of these deep, midline structures, kind of like the base of your palm. These are really crucial areas for consolidating memories. And then if you look at the back of the brain, you can see regions that are specialized for your visual experiences in the world. And up here, which would be behind your left ear, regions that are crucial for understanding the language, the world of language.

Now, reading involves all of these in different ways. So learning to read really requires this very effortful, focused attention of these control networks. It involves really activating these language regions, which are crucial for navigating the language world and also these visual regions. We have to refine and build up new ways of seeing the world through these visual words. So all of these things are coming together right before our eyes in these kids that are surrounding us that are coming in as kindergartners and leaving as expert readers as eighth-graders.

**Ray Suarez:** I sat down with Bruce at the Synapse School to learn more about how we learn.

*[To Bruce:]* Well, I'm going to begin by asking basically the umbrella question that the entire series asks. How do we learn?

**Bruce McCandliss:** That's a fantastic question, and I think that one that's really at the heart of —you know—the entire educational field. How do we support learning? How does learning happen? As a learning scientist, we've also learned an incredible amount about how some forms of learning, which are actually crucial for education, unfold—from the novice, all the way to the expert.

So we've got, for instance, if we study how reading unfolds in the mind of an individual over the life span, kids start off as complete novices. And through their educational schooling experiences, they go through an effortful attention-demanding process of looking at things in a new way and challenging their mind to come up with new ways of seeing it.

This, kind of, early effortful process leads into a really long-term, sort of, what you could call deliberate practice, where you're focusing again and again and again for many, many hours and you're consolidating very specific memories all the way up to the point where you become much like an expert. You have a huge repertoire of expert-like reflexes that allow you to automatically see words and process them with a lightning-fast reflex, or right in the blink of an eye.

**Ray Suarez:** What's going on down at the really fine-grained level that allows me to associate the four-letter word "belt" with a belt, and then the next time I see it, know that it not only says "belt," but also represents this noun, this thing?

**Bruce McCandliss:** There are changes in the brain that must be happening that are encoding that information in your neural networks. Right as a child is recognizing a visual word that they've been studying and seeing how that process is unfolding, sort of, like, moment by moment over the course of a second—so that would be, like, at the level of recognizing a word in the blink of an eye.

A new skill, like reading, may be built upon other skills that we already have, that are already close enough. So, our children, as they enter reading, are typically experts at analyzing spoken language. They can hear all of these words and talk to you. They're, sort of, experts at visual recognition. They can recognize all these incredibly complex things in the visual world. But reading is something special now that asks them to combine those two skills in a novel way, so that you can know exactly what word has been spoken just by looking at the visual signals.

And that's a process of education, bringing together—integrating new skills in new ways, which we're starting to understand through looking at, kind of, changes that are occurring in the brain over the course of an entire year, as kids go through from kindergarten to becoming first-graders. Over the course of a life span, as you look at people becoming expert readers. And even over the course of a few moments, as kids are learning brand new words that they've never seen before.

**Ray Suarez:** Is math different from language in that regard, both the way we acquire it, who acquires it well versus badly, where it gets routed and stored in the head? Is it just a different beast?

**Bruce McCandliss:** I think there's merit to that very idea. So, I think that it's very clear from a number of studies that many, many networks are working together when we're doing complex cognition. But when you really look at which networks are carrying the load the most, it seems that math is pulling out a different network pattern than is typical language activity. Some remarkable studies look at—you know—what activates in the mind of a mathematician if you ask them a math question versus a non-math question, and how does that differ from a novice?

And some of the insights are suggesting that a lot of mathematical thought may engage different neural circuits than other types of thought. And, so, I think this has profound implications for education. How are we engaging children with mathematical thought? And are we doing it well? Are we doing it with a way that's going to encourage this entire, kind of, journey from novice to expert? So, I think we can start to understand and explore, how can education better support the rise of expertise of these mathematical networks?

**Ray Suarez:** Brain plasticity is one of the areas that I think we've had a real rethink on in the last 25 years. It was, sort of, said—you know—"What you got is what you got." What's in the armory by the time your brain is done developing, in your early 20s, that's pretty much it. And then you go into programmed cell death, and if you have more on board, you got more to lose, so you're likely to be a sharper 60-, 70-, and 80-year-old.

**Bruce McCandliss:** Exactly.

**Ray Suarez:** Well, now, all those things seem up for renegotiation, up for re-examination, and in an encouraging kind of way. Is that fair?

**Bruce McCandliss:** I think that's entirely fair. I think that there's been a very, very big shift, really informed by these new technologies, about how plastic the human brain is at different ages, how very deliberate experience practice—kind of, focused skill development—can change these circuits, and even discoveries about how neuroanatomy can be changing on a month-to-month basis based on how you're living your mental life, how well are you sleeping, what particular mental challenges are you engaged in—can have a very profound impact on white matter tracts, structural elements of your brain that are crucial for your brain's function.

*[Music fades in.]*

**Ray Suarez:** We may take it for granted, but as we learn new things, our mysterious and incredible brains are busy silently working to combine skills we already know through these neural networks that Bruce, Liz, and Cha Cha are studying at the Synapse School. But how do they understand what's happening as children learn?

I decided to step into the kids' shoes. They took me into the lab and attached the sensors to my head to monitor my brain activity while I interacted with a software program on a screen—an activity that's pretty normal for some of the students there.

**Liz Toomarian:** So right now, I just measured Ray's head so we know what size net to use. And now I'm making the solution, the kind of soapy, salty solution that we'll use to soak the net in. So it's just—here, I can show you, Ray. It's just—

**Ray Suarez:** Oh, so that's what drives the connectivity, the receptivity—is it saline?

**Liz Toomarian:** Right, so this is just warm water, potassium, chloride salts, and some baby shampoo. Actually, you can give it a smell.

**Ray Suarez:** Mmm.

**Liz Toomarian:** It's comforting, isn't it?

**Ray Suarez:** Yes.

*[Liz laughs.]*

**Ray Suarez:** The familiar scent of baby shampoo as Liz attached the sensors to my head through a net is just one of the thoughtful ways the scientists here are making this an easy and enjoyable experience for students, and it's also the way for the Brainwave Learning Center at Synapse School to obtain first-hand data they need to figure out what's happening inside the children's heads as they learn. Liz handed me a remote while Cha Cha continued attaching the sensors so I could play the same game the kids do while their brainwaves are measured.

**Liz Toomarian:** So, you're going to see things on the screen, flashing on the screen for about 10 seconds at a time, and then you have a bit of a break. So, as you remember from the session we just did with the kids, this machine—or these sensors—will also pick up your facial movements. So that means every time you blink, we're going to get an additional spike. And I'm actually, I'm going to show you that shortly.

And so we give you these breaks every 10 seconds as an encouragement to wait until that break to blink. So when you're ready, after you've had a break of 10 seconds of looking at these flashing words on the screen, when you're ready to move on, then you press this button.

**Ray Suarez:** I see. So I'll prompt the machine by pressing that button.

**Liz Toomarian:** Exactly, so you are pacing the experiment. So try not blinking for a few seconds. You can see it's all flat. And now try to blink several times.

**Ray Suarez:** Oh, wow.

**Liz Toomarian:** All of those waves, those are your—those are the muscles that are getting picked up around your eyes. And, so, that's one of the things that when we do our experiments, we kind of process them out. You can also try, for example, gritting your teeth. So you can see all of those, that's a result of that muscle activity.

*[Ray laughs.]*

**Ray Suarez:** As I blinked or gritted my teeth, or pressed buttons to identify words on a screen, there were up and down movements recorded on a nearby computer—corresponding to my brain waves. It was surprising for me, but it's just a typical day at the Synapse School. The researchers are also studying alpha waves—a cognitive state when the mind is able to rest and then you can return refreshed for a learning activity. The school is putting that learning to practice.

**Cha Cha Pillai, research assistant, Stanford University Graduate School of Education:** So something that at Synapse they do is called "mindful minute." So often in classes or before assembly or before meetings, all of the children from K through eighth get in a relaxed state, and they're led through a mindful minute. And so when they come in here, into the BLC studio, we show them what doing something like that actually does to their brain. And they're often like, "What? That actually happens?" Like, "Me actually closing my eyes and doing something changes something physiologically in my brain that I can now see?"

**Liz Toomarian:** So they essentially, they get to see the proof that the thing that they do every day in school has a signature, that it has a change in their brain.

**Ray Suarez:** Of course, all learners are different, and Bruce emphasized that there's more work to do when it comes to incorporating this learning science into the classroom.

**Bruce McCandliss:** I have a sense that, as we get more and more precise insights into brain networks, how they differ, how they change, we'll start to be able to answer the question of, "How do some educational supports, or some educational interventions, have a really big impact on some children more than others?" So, I think that this would enable us to increasingly differentiate educational supports.

If we start to understand that one particular intervention versus another is going to have a profound impact with a child, we can start trying to give children more of the supports that they actually need and that we gain in evidence for is specifically addressing their challenges.

**Ray Suarez:** Well, that measuring of brain activity—a few minutes ago, I had a cap with salty water on my head. And, yes, absolutely fascinating watching the variables and watching how my activity is changing what's on the screen.

**Bruce McCandliss:** Yeah. So this really creates an exciting opportunity for doing some research that wasn't really possible without this initiative. And that is we're able to measure kids over time as they go through the entire schooling experience. And so we can measure brain activity for basic skills, like, "How is the brain processing reading? How is the brain processing numbers? And how are those changing as they learn to calculate?"

We feel like embedding this research in a school is going to have an impact on how children perceive their own education. It might change the way they conceive of their own learning and their own brain as they start to see these changes unfold over the course of the school year.

We can engage teachers in dialogue and discussion about, "How does all this learning science, how could it interact with what you're doing in your classrooms? What are persistent challenges that you see? What are great successes that you see?" Enabling us to kind of ask new questions.

*[Music plays.]*

**Ray Suarez:** Next week, we travel to a classroom in Frederick County, Maryland, where learning science is being put to work.

**Emily Hood, second-grade teacher, Walkersville Elementary School:** Let's check our filing cabinets together before we get started today to see, where do we need to go to retrieve this information? Some of them are the same as we've been doing. Some of them are ready to dust off your brain even further and stretch it bigger.

**Ray Suarez:** That's second-grade teacher Emily Hood helping her students understand how their brain works as they learn about math. Join us as we continue in our four-part series on the future of learning.

And tell us what sparked your brain in this first episode. Tweet us @pewtrusts or send us an email at podcasts@pewtrusts.org. And to see more resources about the brain and photos from the Brainwave Learning Center at Synapse School, visit www.pewtrusts.org/afterthefact.

*[**Female voice:** "After the Fact" is produced by The Pew Charitable Trusts.]*