Host: Robert Frederick
It involved my body — bodily experiences of science — to become a person of faith.

Interviewee: Sian Beilock
So the idea is rather than thinking about what happens from the neck up and how it affects what happens from the neck down, we're asking how the body — what's going on from the neck down — actually changes our ability to learn and understand.

Host: Robert Frederick
On this episode of The Conjectural — having faith and coming to believe in science.

It was nothing special: just one of those needlepoint pieces that you see framed and hung on a wall at most any country store in the southeastern part of the United States. In this case, it was at the place our family had rented in the mountains of North Carolina for a little holiday — the owner had decorated a wall with it. But unlike the usual kitsch — the usual absurd, comic, religious, or droll phrase done up in needlepoint and framed on a wall — I found myself lingering on its meaning. It said "Faith is not belief without proof, but trust without reservation." My thoughts eventually took me back to when I was nine years old, when I first was aware of experiencing science with my body.

Interviewee: Sian Beilock
We have these systems that have evolved to deal with torques and motion and vectors and balance. We use them everyday.

Host: Robert Frederick
Sian Beilock is a psychology professor at The University of Chicago.

Interviewee: Sian Beilock SB02
And what our research is doing is maybe pushing for a match between the systems that are really there to think about these things, and these abstract concepts that students are learning about in school.

Host: Robert Frederick
I was in school. As a nine-year old, it was the fourth grade at Robert Frost elementary school in Tulsa, Oklahoma. Even though our school was named after a poet, the specialty of the school — a magnet school — was science. I had transferred there at the beginning of the school year, moving from a small Minnesota town to the big city of Tulsa and into this school that had two hours of science class every day. Try keeping 9-year-old kids in their seats reading textbooks or listening to lectures about science for two hours a day. No, the curriculum had us moving around and doing things. Dissecting eyeballs, making sandbox-sized earthquakes, crushing cans with air pressure. But it also had us being moved by things, such as feeling the torque caused by a spinning gyroscope. Through it all, I came to understand science not as facts but as acts. And these acts — these experiments — could be, should be, and would be repeated.

Interviewee: Sian Beilock
We actually show that when students get to feel angular momentum or the consequences of a changing angular momentum — when they get to feel these forces

Host: Robert Frederick
… like we did with our spinning gyroscopes…

Interviewee: Sian Beilock
compared to when they just read about them or watch someone else, it actually changes how the brain processes this information: they end up using more of their motor and sensory cortex to understand this information. And because the motor and sensory cortex are actually poised to deal with momentum/vectors/torque, students end up understanding the concepts better.

Host: Robert Frederick
That needlepoint phrase said that 'faith was not belief without proof.' I think science is 'not belief without proof,' either. That's because there really isn't proof in science — at least not in the way mathematicians talk about proof. Instead, scientific proof is reasoning by induction. In other words, the only evidence in science that something will happen again is that it has happened before. You have to be able to produce the knowledge — do the same act to show the same result — again and again to prove something, scientifically.

And in the fourth grade in elementary school, doing an experiment three times, and getting the same result three times, was enough. But then, of course, there were more than 20 of us in each class. So even if we worked in groups, there were several classes of fourth graders at my school, meaning that if my group repeated the experiment three times, then the experiment was repeated dozens of times just in our school. Of course, the curriculum at my school wasn't unique, and so perhaps was being used at thousands of schools around the country. And that meant the experiment I did three times was repeated hundreds of thousands of times that year, had been repeated hundreds of thousands of times in previous years, and would be repeated hundreds of thousands of times in future years. Like all science, it all started with one experiment — with results that were interesting enough that others wanted to repeat or modify the experiment to see for themselves what was really going on.

Interviewee: Sian Beilock
And so we have the students do this exercise both in classrooms, in the laboratory, and actually before they go into the MRI — the brain scanner. And we ask how feeling this and understanding the consequences of changing angular momentum changes their understanding of this concept. Does having this physical experience enhance their ability to think and reason about it later? And the answer is "yes." Having this physical experience versus even watching someone else have it or read about it in a book, the physical experience itself seems to help push them to understand this concept better. And when we ask why that's the case, when we look at students after they've had this experience in the brain scanner — in the MRI machine — we actually show that these students are activating sensory and motor areas more when they're just thinking about this concept, and that activation actually predicts how well they do on a quiz, say, on the concept, say a day later.

Host: Robert Frederick
The more I ruminated on that phrase — "Faith is not belief without proof, but trust without reservation" — the more I understood that just like other acts of faith, it takes faith to trust in science. No one lives their lives reasoning by scientific proof, by reasoning by induction. For example, you don't decide that just because you walked down a dark alley, say, three times, and no one accosted you, that dark alleys are safe places where you'll never be accosted.

So I trust that over time and through reasoning by induction, current and future scientists will correct previous interpretations of results. I also trust that they'll come up with better, more precise experiments to give more specific and accurate results. But trusting in science without reservation? No. Because science is done by people. And I trust in human nature, too. And people lie. That said, human nature actually plays a very important positive role in the scientific enterprise. I mean, really, imagine for a moment if someone came up with an experiment and could repeatedly demonstrate something was wrong, say, about the theory of evolution by natural selection — disproving Darwin. I trust that human nature would prevail, and that person would tell someone else about it. Eventually, as a result, someone would become probably the most famous scientist in the world for coming up with the repeatable experiment that disproved evolution by natural selection — it's such a well-established scientific theory. And so eventually, that experiment disproving evolution would make it into the textbooks, and perhaps one day there might even be a version of that experiment for future fourth graders to repeat in their science classrooms.

Interviewee: Sian Beilock
Of course, getting the research from the laboratory or from the journals to the classroom is — it's a big divide. And actually the work that we've been doing in the physics classroom is a really, I think, nice example of the pairing. So my co-PI is a physicist who actually teaches introductory physics at DePaul university and we use her classrooms a lot of the time as testbeds for our findings. And the idea is that talking about them and getting them out to teachers and into the classrooms will be a way to take some of what has happened in the classroom that's not necessarily based on sound principles of cognitive science and make changes that will hopefully positively impact learning.

Host: Robert Frederick
In sum, I reckon that it took our civilization thousands of years to come up with reasoning by induction, thousands of years to come up with scientific proof. But just because our civilization did — and did so many centuries ago — that doesn't mean that we should expect each new generation to just naturally latch on to scientific thinking, naturally have faith in it as if scientific thinking were somehow part of being human. It's not. It's part of our human civilization, and history has shown us that human civilizations come and go. Still, to the extent that we choose leaders who have faith in science, who believe in the results generated, tested, and validated by scientists who themselves are also influenced by their very human nature to be social and so have the desire to be thought of highly by others — I think that is going to help our civilization go on a little longer, that is going to help expand how we teach science to future generations, and that is going to help them experience science — as I remember first feeling as a fourth grader — as something that was bodily and physical, literally moving me, and is now for me a matter of faith.

Host: Robert Frederick
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