Science Forward—Uncertainty

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Summer Ash: In the late 19th century, Sir George Jessel, a British judge, was challenged about one of his decisions. He said, "I may be wrong, and often am, but I never doubt." We see this attitude a lot in judges, in politicians, and even among our friends and classmates.

In early 2015, a joint study by NASA and NOAA found that 2014 was the warmest year on record. How did scientists come to this conclusion? Data from over 3,000 recording stations around the world were gathered and averaged, and compared to temperature records that go back to the 1800s. Even with that amount of data, there's still a margin of error associated with this scientific claim.

In some places that margin of error, and not the actual finding, became the focus of the story. Scientists like to be upfront about these margins and the strengths and weaknesses of their methods, but it's a mistake to think that when scientists are clear and explicit about the uncertainties in their research, it means that their research is unreliable or inaccurate.

What's the disconnect between what scientists report and how it's interpreted? Does this mean we really don't know, that nobody knows? This kind of confusion can be very troubling for scientists, and for all of us, and not just on issues like climate change, but with other scientific questions as well.

In this video, we'll hear from scientists across different fields, from biologists to astrophysicists, and from chemists to geologists. We'll even have some philosophers of science weigh in. Let's start with the scientists. What do they mean when they say they're uncertain?

Brett Branco: People should understand that uncertainty in science doesn't mean that we don't know something. It just means that the answer is more complicated than what the average person is comfortable with.

We're quite comfortable knowing, for example, that if we go out and measure water quality in one spot today, it could be a very different measurement tomorrow, or even if we measure in two different spots we might get a different answer.

Uncertainty is a reflection both of the fact that the environment's a very complicated place, and also that there's a lot of variability, both in time, day to day, and also in space, from place to place.

Alan Frei: Dealing with uncertainty is a very quantitative issue in science. So when scientists say we believe something, it's not the same -- honestly, without judgment -- it's not the same as someone who believes something based on their faith or any other issue, which is perfectly fine.

But, when a scientist, speaking about their science, talks about they believe something and there's a particular uncertainty, we refer to quantitative calculations and we try to be very upfront, open, and honest about, we know that there's no way we can measure what's happening in every square meter of that watershed.

The scientific community in general has an understanding of how physical processes work, and that's what goes into these models. We know the parts of the physical process that we don't understand as well as other parts, and it's in those areas where we assign uncertainty.

Summer Ash: How do scientists deal with this uncertainty? Often, they'll try to quantify it using statistics, to put a number on how confident they are in a given result. Then they'll publish these numbers along with their results.

(Merry) Yue Cai: When you make a measurement, you always report position. So you repeat the measurement many times, and that gives you a range and you can measure the standard deviation. That kind of uncertainty, we're always trying to improve by making better machines, taking more measurements, or improving our methods.

Karin Block: There are a lot of challenges in communicating geoscience research, because of the inherent uncertainty with natural processes. Because a lot of these processes happen on a very small-time scale, there is a tremendous amount of noise in the data record associated with it.

In the sciences, we sometimes refer to those uncertainties as errors. Unfortunately, to the lay person that sounds like a mistake, but error in the sciences refers to that little bit that we don't really know, and the things about the measurement that we're not sure about.

It's not about a mistake in the measurement. Generally, we incorporate those errors or those uncertainties into everything that we do, in order to make some sound conclusions. A good scientist is a good skeptic for their own data set.

Caleb Scharf: If we detect a planet as it transits its parent star, there's always uncertainty about the measurement that we make. That translates into uncertainties about things like the sizes of planets, how big they are, and how fast they're moving in their orbit.

Part of the key piece of modern science is quantifying uncertainty. So we will always say that we think this planet is this size, but we have this percentage uncertainty in that number. That uncertainty allows you to weight information with different strengths, and to combine it in a way that gives you an optimal answer, a probabilistic answer to a question.

Scientists speak really in terms of probabilities and confidences, in whether or not something is this way, or this size, or of this nature. It's very interesting, because it's how science works.

It's not really how most of us work on a day-to-day basis. But that quantification of uncertainty, it's fine to say I don't know, but in science you say, "I don't know at the 50-percent level," or "I don't know at the 90-percent level." Those numbers are absolutely critical.

Summer Ash: Scientists are OK with all of this uncertainty. In fact, it's part of what makes our work so exciting, and it helps us move science forward.

Laura Juszczak: There's never a hundred percent certainty. We can have some result which is thought to be the paradigm of some particular phenomenon, and then 50 years later someone will say, "Aha! Well, that's not quite true. There's an exception to this rule." There is no 100-percent certainty, even in the most established rules.

Derek Tan: Uncertainty plays a huge role in the scientific process. To me, that's always the most exciting part of being a scientist, is the unexpected. Finding things that we didn't anticipate would happen, but are really interesting.

Mandë Holford: Uncertainty plays a big role in our research, because a lot of what we're doing is new science. We are identifying new species, we're identifying new peptides, and we're identifying new targets for these peptides. What I try to tell all of my students in the lab is, we have our game plan, but we're going to look for that Hail Mary pass at the end, if it happens, because sometimes we'll need that.

Uncertainty is very, very important, because it forces you to be observant and to look for other ideas besides the ones that you think are great and fabulous, that you've made up on your own.

Summer Ash: What should the public do when faced with uncertainties around a specific claim? First, take a look at the evidence and see what the experts are saying. Science journals are a good place to start. Scientific papers include descriptions of the methods and analyses performed, as well as how confident the authors are in their results.

Massimo Pigliucci: How much do you want to understand about the actual issue before you can make up your mind? There's different levels at which you can approach the issue. You can say, "Well, I don't have enough time and therefore the next best thing to do is for me to read about whether there is a consensus in the appropriate community of experts."

The appropriate community of experts in this case would be climate scientists. So, what is it that climate scientists say about climate change? You find out that 98 percent of them actually agree that climate change is happening, and it is caused at least in part by human intervention.

You can stop there. That would be a perfectly safe way of making a complex decision. Basically, this is the same way in which, let's say, you have a problem with your car and you're not a mechanic. What do you do?

You go to a mechanic, so you go to an expert. If the mechanic can solve the problem, great. If the mechanic cannot solve the problem, then you don't go to your dentist. You go to another mechanic. You keep going to whoever the community of experts is to solve that problem.

You can also say, "No. I don't want to go to the experts. I want to actually fix the car myself." It will take time. You have to learn how to become a proficient mechanic, but you can do it.

So, I think that as regular citizens, we find ourselves constantly in a situation where we are on a sliding scale. We can just take the readily easy but still reasonable way out, and say, "Well, let me see what the relevant consensus...if there is a consensus among the relevant community of experts." Or, you can go all the way up to the point of becoming sufficiently literate yourself, that you can make that decision in an autonomous way.

Justin Garson: Again, science isn't necessarily about certainty. One of the real hallmarks of science is that it revises itself in light of the best available evidence. That's the kind of thing that I want to rely on in my day-to-day life.

Karin Block: There is a quote attributed to Walt Whitman that talks a little bit about uncertainty.

"I like the scientific spirit -- the holding off, the being sure but not too sure, the willingness to surrender ideas when the evidence is against them: this is ultimately fine -- it always keeps the way beyond open -- always gives life, thought, affection, the whole man a chance to try over again after a mistake -- after a wrong guess."

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