Scientific Method

Speaker: Chad Gatlin

The true sciences like biology, chemistry, and physics have one thing that unifies them. They all gather information about the natural universe using a specific, methodic approach. This approach is known as the scientific method. Scientists follow the scientific method very rigorously when working on their projects. However, the basic concepts of the scientific method are easily understood. In fact, you probably use the scientific method in its simplest form every day.

The scientific method can have anywhere from 5 to 10 steps. Now, this doesn't mean there are different kinds of scientific methods. The steps are actually all the same. The difference is how a particular scientist lumps steps together or splits steps apart when reporting them. I like to split the scientific method into six steps. They are: observation, question, hypothesis, experimentation, conclusions, and reporting.

Scientific inquiry always starts with observation. Observation is using your senses to notice the natural world around you or events happening in the natural world. Sometimes we need to use tools like microscopes or telescopes to allow our senses to detect things that they otherwise couldn't. A good scientist does more than simply notice things, but also pays close attention to details when observing.

Let's think of an example as we go through the scientific method. Many people like to fish, so I'm going to use a fishing example. (If you don't like to fish, then just pretend that you do). Let's say that we go to a farm to fish in a couple of farm ponds. We fish all day and at the end of the day we OBSERVE that all of the fish we caught in one of the ponds are over five pounds each, and that all of the fish we caught out of the other pond are well under one pound each. That's the first step in the scientific method. We made an observation.

The very next thing almost anyone would do is wonder, "why?" That's fortunate, because that's the second step in the scientific method, QUESTION. The human brain is naturally very curious. When we see something happen that we don't understand, we want to know "why?" Scientists also question, but scientific questions need to be more specific than just "why?" Scientists ask specific questions based on the careful observations they made. But even then, at the end of the day what they're trying to find out is basically, "why?"

So, back to our fishing trip. We now have a pile of fish from our day's efforts, and we have astutely noticed that all of the fish from the first pond are over five pounds, and that all of the fish from the second pond are under one pound. We most likely are going to question that. "Hmmm, I wonder why the fish from the first pond are so much bigger than those of the second pond?"

Before we even have the question formed in our mind, we are already going to be trying to come up with answers to the question. These answers will be based on our previous experiences in life, but will essentially be guesses. An educated guess trying to answer a scientific question is called a HYPOTHESIS. Now, these are guesses, but they are educated guesses, which means they are based on knowledge you already have on the subject. This knowledge may be knowledge you already have through your life experiences and learning, or you may need to go to the library and look up information about it to learn what other people already know about the subject. Either way, your hypothesis should be based on good knowledge, and is therefore not simply a guess, but an educated guess. The second rule about scientific hypotheses is that they have to be testable. It's possible to have an educated guess that's not testable, but if that's the case then the question is not approachable scientifically. Any hypothesis that is not testable is not part of science. This is the reason that religion is not taught in science. Religious hypotheses are based on faith. Faith is the belief in something without proof. Therefore, religious hypotheses are not testable and are not part of science. It is also possible to come up with several hypotheses for the same question, and that's fine. However, we have to choose just one to go with, and you always choose the one that you honestly believe is most likely to be the correct answer.

Now we could come up with hundreds of ideas about our fish size discrepancy (in fact, you may have already thought of several). However, since you're not here to call on, I'm going to throw a couple out there. At this point, we don't have a lot of data about our observation, so that doesn't allow us to weed out very much when trying to come up with our hypothesis. I have one hypothesis that the fish are larger in the first pond because the fish in it are a different species than those in the other pond. I have another hypothesis that the fish are bigger in the first pond because an alien space ship came down and shot a ray gun into the pond, making the fish grow extra big. However many hypotheses we come up with, we have to choose what we consider the most likely to be correct and go with it. Since the space alien hypothesis is both unlikely and untestable, we are going to choose the fish species hypothesis with which to continue.

The next step in the scientific method is EXPERIMENTATION, or hypothesis testing. This is the hardest part of the scientific method (but usually the most fun). The scientists must design and conduct one or several experiments to test their hypothesis. This step includes designing an experiment, conducting the experiment, and collecting data. This is what most people think of when they think of scientists. This is the hands-on part of science and research. Now, this may sound strange, but the point of the testing is to prove the hypothesis wrong. You see, in science we can never prove anything is right, but we can prove that things are wrong. For example, if your car won't start and you think it's the battery, then you change the battery (wow, that was an observation, question, hypothesis, and experiment). If the car now starts, does that prove that it was the battery? No, it supports the idea that is was the battery, but it doesn't prove it. You may have moved some loose wires while changing the battery, or any number of other things. So, the point of scientific experiments is to try to prove your hypothesis is wrong. Every time you run an experiment and fail to prove your hypothesis wrong, then that supports your hypothesis. If, after many experiments, the hypothesis has never been proven wrong, then you may start to accept the hypothesis, but it is never "proven" correct. Even after much testing, a hypothesis can still be proven wrong, and it only takes being proven wrong once to disprove the hypothesis.

Our hypothesis we want to test in our fish example is: the fish are larger in the first pond because the fish in it are a different species than those in the other pond. We can easily test this hypothesis by getting a fish identification book (yes, they do make such things) and identifying the species in each of the ponds. For our example, let's say we find that all of the fish in the first pond are northern pike (which can grow to over 30 pounds) and all the fish in the second pond are bluegill (which rarely reach one pound). Now, this does not prove our hypothesis, but it pretty strongly supports it.

The next step in the scientific method is ANALYZING DATA. It is very important that scientists be able to set up their experiments so that valid statistical tests can be run on them. Because of this, it is important for scientists to have a strong background in statistics. The statistics are used to analyze the data and then draw conclusions based on the data. This can be extremely complicated, but in the end it basically tells the scientist whether the experiment supported or rejected the hypothesis.

In our example we are not going to use actual statistics. Our data showed all of the fish in the two different ponds to be two different species, so we will simply draw the conclusion that we supported our hypothesis.

The last step in the scientific method is to report findings. Scientists find out about our universe so that they can share this information with other scientists, and anyone else in the world who is interested. It would do a scientist (or mankind) no good if they, for instance discovered a cure for cancer, and then simply said, “Oh, that’s neat,” and went on to the next thing without telling anyone!

There are two main ways that scientists share their findings. The first is through professional meetings were the scientists give short presentations over their research. The advantage to this is that they can then get feedback and have discussions with other scientists who are at the meeting. The second method is by publishing articles in journals. Before an article is published, it must be critiqued and approved by two or more scientists from the same field to check it for validity and errors. Journals that publish articles such as these are called peer reviewed journals, and are considered to be the best source for getting information. The advantage to publishing is that the research can reach very large audiences.

In our example, we wouldn’t need to publish our data, but we would probably share with some of our closest friends to fish the first pond because it has bigger fish (or maybe in this case we would want to keep it a secret).