Constructing Knowledge: The Role of Human Limitations in Scientific Reasoning

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Humans have always relished organizing the world into neat and definite quantities, to which they can easily relate. It is a pursuit that has consumed man throughout the ages. Modern scientists feverishly search for the governing laws of the universe, just as Chinese scholars once scanned the stars, and Greek philosophers debated the meaning of life. Science is born out of speculation and observation. It provides a means for mankind to grasp at the divine, and explain the inexplicable. Like an artist molds a work of art from a formless wedge of clay, so science seeks to press the universe into quantitative models. These models reflect the complex interactions within nature, as the artist's sculpture attempts to embody emotion. However, no artist possesses the skill to define `devotion' or 'grief into physical depiction. An artist is limited by the nature of the medium, and the complexity of the concept. The emotion is too intricate, and although it may be copied, it can never be fully replicated. It follows that in this way no scientific model can be completely accurate. A model is simply "an object of imitation ... an idealized description or conception of a particular system" (Oxford). Science is built upon the strength of its models in approximating the universe. So although science may provide a good representation of the way things are, it provides nothing more, and may not be taken as an absolute. Models are applied to the world in attempts to understand it. Sir Isaac Newton utilized models in his attempt to understand the complicated concept of gravity. He took the force and described it simply and concisely, in a way we as humans could understand. Yet it eventually fell short of describing the full properties of the force, and it has been long since replaced.

In its beginnings science was more likened to what is now named philosophy. It was a discipline founded purely upon speculation; the models invented to describe the world were based on reason rather than experimentation. One example of this is the heliocentric model of the universe, founded by the ancient Greeks. This model was based in the idea that the earth was holy, and therefore in the center of things. The concept was completely devoid of observational backing, and stood merely as the product of excellent argumentation. Later on, mathematics was invented as the language of science. Man no longer simply reasoned the logic behind models, but instead sought to describe (or translate, if you will) the world using this new language. Scientists began to measure the world around them, developing the models around their quantitative observations, testing and fixing the models as the data dictated. Often the models were very crude, describing only select situations and successfully predicting a minute amount of scientific problems. Science today is almost unrecognizable from the scientific processes of the past. Current models are inconceivably complex, attempting to account for even the most minuscule aspect of nature. However, complex as these theories may be, they still fall short of accurately predicting the way the universe interacts.

What this analysis of the progression of scientific thought establishes is that models evolve from `guess and check' reasoning. Models must be built upon as our understanding of the universe increases, in order to encompass its complex nature. Beginning "from observations in limited domains and formulating laws based on them, and then extending the observations and arriving at laws that contain the earlier laws as special cases" (Haber-Schaim 66) is fundamental to the progression of scientific models. Old models die when they are no longer consistent enough with numerical data to persuade the public of their validity. It is because of this that no model goes for long without modification. The Sophists of ancient Greece saw "knowledge as human and changeable" (Gross 394). Mankind is continually replacing the old models with `better', newer ones, constantly using mathematics to test the model and persuade others that the model is accurate. When the two no longer agree, the old model must be revised. Taking a look at the past and current models for the force we call gravity provides a good example for demonstrating this natural progression of the scientific model. In the last 350 years, science has developed over three models for describing the force of gravity (Greene). Two of these models were deemed not comprehensive enough to describe the force's full implications, however the current model is rooted solely in complex mathematical theory, which is itself not completely proven. This model is based on a tiny, massless particle named a graviton, which has never been observed inside a laboratory setting (Greene).

The idea of gravity is immensely complex in itself. Out of three high school-level physics textbooks (*Physics*, *Physics Made Simple*, and *Physics: Teacher's Resource Book*), there were zero listing in glossaries for the term "gravity"., and one textbook failed to list the word in its index. Indeed up to Newton's time, physicists generally ignored gravity, insisting only that it existed, never attempting to derive its properties (Greene). When Newton finally tackled the problem in the late 1600's he stated that "any two bodies in the universe attract each other with a force that is directly proportional to their masses and inversely proportional to the square of their distances apart" (Freeman 26). This definition is the one commonly taught to a high school junior or senior, and is often the first time the student has been introduced to a formal definition of the word "gravity". Although introduced to the concept of gravity, younger students, like Newton's forefathers, are taught to ignore the concepts behind gravity and instead

embrace only the fact that it exists. Young students therefore are taught to take the force for granted, seeing it as a given rather than one of the universe's grand mysteries.

The model of gravity that replaced Newton's is so frightfully complex that most people are exposed to it for the first time in college level physics classes (if they are exposed to it at all). This model is named General Relativity, invented by Albert Einstein in the earlier part of the last century, and states that what we perceive of as gravity is the effect of objects following curvatures in the fabric of space and time (Martin). An object of larger mass creates a larger bend in this fabric, causing smaller objects nearby to be drawn nearer to the larger object (Martin). This view of gravity is usually not taught until the students are fluent enough in the mathematical language needed to understand it. Although this model describes the effect of the force here on earth just as well as a middle school student's "things fall", and a high school student's "two masses attract one another" mentality, Einstein's theory is more accurate at describing the complex processes of the force at the cosmic level. It was the natural progression of the `guess and check' process of the scientific model; there were things that Newton's model could not describe, so a new model had to be invented. One problem with Newton's theory is that, in order for it to work, gravity must be instantaneously conveyed. However, in the real world `instantaneous' is a problem. `Instantaneous' implies that something happens without taking any time. That means no time to travel from place to place, no time to accelerate or decelerate; indeed it is everywhere, all at once, exactly where it needs to be. `Instantaneous' is simply not an option. Einstein solved the problem, stating that gravity, like anything else, took time to travel from point `A' to point `B' (Greene).

As complex as Einstein's theory is, it too leaves holes in its argument. Where General Relativity leaves off, the model of the super-string picks up. This is currently the last in a series of progressively more complex models for the effect we called gravity. This last theory is usually reserved for graduate students in the field of physics. It states that the universe and all its elements are composed of tiny (10e-33cm) one dimensional, massless strings of energy (Greene). Down, in the depths of this complex model, is the mathematical equation which predicts that all forces are conveyed via tiny "messenger particles", which includes the particle responsible for gravity, the graviton (Greene). However, this particular model is virtually un-testable. It is founded in such complex theoretical mathematics and physics that many physicists today consider it a product of philosophy, rather than of the scientific process. Its authority as it stands today relies almost entirely in its rhetoric.

Even the model of string theory itself is not without a few limitations that mathematics alone could not `smooth' out:

> "Nevertheless, describing the spacetime fabric in this string-stitched form does lead us to contemplate the following question. An ordinary piece of fabric is the end product of someone having carefully woven together individual threads, the raw material of common textiles. Similarly we can ask ourselves whether there is a raw precursor to the fabric of spacetime . . . But in the raw state, before the strings that make up the cosmic fabric engage in the orderly, coherent vibrational dance we are discussing, *there is no realization of space or time.* Even our language is too coarse to handle these ideas, for, in fact, there is even no notion of *before.* In a sense it's as if individual strings are "shards" of space and time, and only when they appropriately undergo sympathetic vibrations do the conventional notions of space and time emerge" [emphasis original] (Greene 378).

This passage illustrates another of the limitations of scientific models, language. Here, string theory uses the metaphor of a piece

of cloth to describe the bends and folds of spacetime. However, since fabric itself is composed of smaller bits of "raw material", it begs the question whether spacetime is also composed of such basic pieces. The metaphor is directing the future of string theory. Researchers in the field look to relations like this one to guide their research. Language limits human knowledge, since language is of our own creation. This model, like all models, initially relies on the language of mathematics to take shape, and later of the languages of people to continue. Science is limited by the means with which we are able to communicate it to others, since "the creation of knowledge begins with self persuasion and ends with the persuasion of others" (Gross 391). In this way, the model can take on new directions and meanings, apart from its intended simplified depiction of nature. The model associates the concepts found in the natural world to separate concepts in the human world, such as spacetime and cloth, which, outside of the realm of the limitations of human comprehension, are completely unrelated. Since models must be conveyed using language, and language is limiting, models can never be full representations of the universe.

In the end, models are nothing more than simplistic representations of the way the world works. As humans, we can not comprehend the true properties of nature. Our minds and bodies limit us in our ability to comprehend the "why" that makes things happen. Instead we must translate what we see into models, via the language of mathematics, as accurately as (ironically) humanly possible. We see apples fall, light casting shadows, and electricity running from the power company to our homes. We invented the graviton, the photon, and electrical current as models to describe these processes happening around us, and label it as truth, since our brains cannot see it any other way. In the case of gravity, no one ever has seen what made that fateful apple fall on Newton's head, but what we have done is take a reflection of the fact, things fall, and brought it down into the human sphere.

Science is only our interpretation of the truth - a way of bringing the transcendent down to a human level of comprehension. Since it is only a statement about how the world may work, and "only statements have meaning, and of the truth of statements we must be persuaded" (Gross 392), our explanation of the world is limited in our ability to describe it, in models. However a model is just that, and "any model is an approximation by its very nature and bound to fail at some point" (Zumdahl 154). The truth behind science lies in its rhetoric. It is "not speculative, but social; the result not of revelation, but of persuasion" (Gross 407). It holds no truth beyond that which society it willing to give it. Rather, science is nothing more than a good approximation of what may possibly be.

Works Cited

Freeman, Ira. *Physics Made Simple*. USA: Doubleday, 1990.

Greene, Brian. *The Elegant Universe*. USA: Vintage Books, 2003.

Gross, Alan. "Rhetorical Analysis." *Academic Discourse*. Ed. Gail Stygall. Mason, OH: Thomson Custom Publishing, 2003. 391-408.

Haber-Schaim, Uri, et al. *Physics*. USA: D.C. Heath and Co., 1981.

Haber-Schaim, Uri, et al. *Physics: Teacher's Resource Book*. USA: D.C. Heath and Co., 1981.

Martin, J. L. *General relativity : a guide to its consequences for gravity and cosmology*. New York: Halsted Press, 1988.

"Model." *The Oxford American College Dictionary*. 2002 ed.

Zumdahl, Steven. *Chemical Principles*. USA: Houghton Mifflin, 2002.