THE BLACK BOX

Introduction

The goal of science is the acquisition of new knowledge. But there are rules, rules which tend to make science seem cold and impersonal, and there is a process, something which tends to make science appear to be the boring domain of eggheads. But to those who “do” science it is a series of puzzles to assemble, discoveries to be made, a grand quest to understand our universe. This experiment is designed to give you an introduction to the rules and the process, and a taste of what it is like to participate in this quest. The books listed in the references offer additional perspectives, both amusing and very serious, on the goals, nature and issues confronting modern science.

Science is a social activity practiced by individuals, groups and nations. It is essentially a debate in which theories, hypothesis, experiments, objective observations, things people associate with science, are merely elements. As a debate it is very demanding, with some hard rules and strict requirements: rigorous logic, testable hypothesis, and most of all the requirement that you must be able to back up your claims with hard evidence.

It may seem that there are different sorts of science. In some fields, the thing being studied can be held in your hand, poked and prodded, and disassembled on the laboratory bench. In others it may be trillions of miles away and billions of years in the past. In geology, the earth itself is the specimen and the processes being studied may require from seconds to eons to run to completion. In the social sciences the “specimens” are so complex that it seems unlikely that they will ever be able to enjoy the level of success enjoyed by the physical sciences. Some science is data-driven, others theory-driven. Some sciences are quantitative while others are mostly qualitative; some are data-rich and others data-poor. Furthermore, the tools and methods the scientist uses can be as unique as any particular investigation, as unique as each scientist, and as unique as the field of study.

<u>The Experimental Method:</u> One might say that science is a product of the experimental method, the process of isolating the variables important to the study and investigating the relationship of each variable to the phenomenon in question. This is indeed one of the main tools of scientists and it has also provided us with sound theories that can explain the nature of extraordinary things we deal with in everyday life, things we will never be able to see with our five senses, but theories so convincing, so well explained and so well supported by experiment and employed in things we use everyday that we may have come to think of as ordinary.

<u>Scientific Theory:</u> The product of science is the scientific theory. A theory is a statement that attempts to explain the nature of something. It is the end product of a series of tests performed that prove or disprove a series of more general statements, or propositions (hypotheses). It is not, as many people tend to think, a guess.

Most scientists will agree that for a theory to be considered a scientific theory it must possess the following characteristics:

- Falsifiability, or refutability, or testability
- Supported by the evidence

- Makes predictions

Besides defining scientific theory, these three requirements place restrictions on the things that can be investigated scientifically. Many questions simply can not be answered by scientific investigations.

The Scientific Method: Many of us have been taught that the scientific method involves the following:

- Select something in nature to study
- Develop hypotheses about how it works or how it relates to other things
- Pursue this hypothesis until it yields unique and testable predictions
- Test the hypothesis
- Repeat, refining the hypothesis until a theory can be formulated

In practice, the actual method of doing scientific is hardly as neat and tidy as the one described above. While the process of acquiring this new knowledge almost always requires careful, focused effort, scientific discoveries may also involve luck and even fortuitous accidents, or a unique way of looking at things, or knowledge and experience that few other people have. So while it may seem like a grand personal adventure while you are "doing" science, it becomes a public debate when you publish it.

The Scientific Publication: The appearance of tidiness in the scientific method can be blamed on the published scientific paper. In it one describes the evidence, the methods and observations in clear, concise and logical manner so as to build a solid argument that supports your conclusions. In these papers one does not describe the accidents, the dead ends and the early mistakes that produced no results. The scientific publication also tends to make science appear cold, dry and impersonal. But as mentioned above, doing science isn't cold, dry and impersonal, and scientists aren't, but the results must be.

Each author is aware that the publication is not only an announcement of new findings, it is also an invitation to one's peers to criticize the work. And they will. It is not fun to have one's own theory, the product of hours (or years) of work, shot down in flames in a public arena. But when it happens it is both necessary and healthy. And always remember, the burden of proof is always on the author a fact that makes doing science as difficult and demanding as it is rewarding.

Preparation

The following questions should help you as you prepare to do this experiment:

1. Can you describe the difference between a theory and a hypothesis?
2. What would it take to convince you a theory is correct?
3. Is it possible to postulate a theories on phenomena never observed directly?
4. Are theories facts, guesses, always correct, or none of the above?
5. How do cultural, economic and political forces influence science? Can you think of any examples?
6. How do science, engineering and technology differ?

Procedure

Examine the box and record the tests you perform and the results from each test. Start by finding out what you can about the box itself and then devise ways to determine what is inside the box. Once you have made a few observations you will be able to formulate an initial hypothesis. With further testing you will be able to refine your hypothesis until you have learned as much as you can about the object in the box. While you are not allowed to open the box, you are welcome to use any tool and instrument in the laboratory to help gather the information you need to be able to make a final, definitive statement as to what the object is.

Results

What do your tests indicate regarding the mass, size, shape, material and other properties of the object in your black box? What do your tests tell you about the black box itself? What do you think the object is?

The Report: Now that you have decided what the object probably is, you'll need to write a formal report that tells your peers about your investigation and how you determined what the object is. Before you start writing, review the goal of the experiment. A well thought out and well stated objective is essential to the writing process and for the reader's understanding of your report. Next, review each of the tests you performed and the information you got from each. Using this information, develop the argument for the conclusion you will make. Finally, state clearly what you think the object is, if you can. Now, write it up.

Peer Review: Share your report with your colleagues. Loan them your box and watch them do the same experiments you did, using your report as a guide. Or maybe they will use the techniques they used when studying their box and will be able to teach you something new about your mystery object. If your colleagues agree with you, well that is reassuring, but there still remains a certain amount of uncertainty as to what the object or objects really are. That is one of the characteristics of even the best of theories. If, on the other hand, someone disagrees and can show you good evidence that is contrary to your findings, errors in your logic, or can offer an alternative explanation that is consistent with your observations, then that when the fun really begins.

References and Additional Reading

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