The nature of science, and the effect on attitudes and language

Lecture notes

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Introduction

How someone views the world will significantly influence what evidence they look for and how they will interpret it. The world of science is dominated by some form of "critical realism" whereas it is very common in the linguistic research to give higher credence to the Social Construction of Knowledge.

In the world of humanities critical realism is not well known, yet science students will generally follow something like critical realism. Therefore it is important for the ESP teacher to have some understanding of the scientists.

This article is based upon two contrasting viewpoints as expressed by Hodson D (1986) Philosophy of science and science education. *J Philosophy of Education* 20(2):215-225, and Sutton C (1996) Beliefs about science and beliefs about language. *International Journal of Science Education* 18(1):1-18. Sutton sets out a series of steps between initial observation and the community accepting the observation. Hodson sets out the traditional view of science.

1. Your views. How is science objective? [Passive tense? Impersonal? Facts?]

> "The objectivity of science is ensured not by requiring individuals to be free of personal preferences or interests, but by insisting that hypotheses are open to experimental testing and are made available for criticism by fellow practitioners". (Hodson 1986:221.)

2. The accepted view of science (Based on Hodson 1986)

(I have followed the numbering conventions of Hodson in his original paper, and added my commentary within square brackets)

Hodson (1986) explains that while there is no single, universally accepted, view of science, he can state the consensus as being:

(1) Observations are dependent on our sometimes inadequate sense perceptions and, therefore, may be unreliable and fallible. Observations need checking.

(2) Observations are (to some extent) theory dependent and theory often, though not always, precedes observation. All this is to say that all of us live by making assumptions [axioms?], and our observations are in the context of the assumptions we make. Eg Temperature, in degrees Celsius. Our framework determines what we measure.

(3) Science often uses indirect observation which, in turn, depends on a **theory of instrumentation**. In other words, we often use tools, and we assume the tools are measuring what we set out to measure. The tools are often the <intervening variable> especially when the dimensions or phenomena are not seeable. Eg we cannot see or feel radioactivity, but it shows up on photographic film. The chemical reactions in the film are a tool for observing the radioactivity.

[For instance, in linguistics, sometimes we want to measure motivation. But motivation as such cannot be directly measured, therefore researchers rely on lists of questions, which indirectly form some measure of motivation. Use of indirect tools presupposes that you are measuring what you set out to measure, therefore the measuring tools themselves (questionnaires) have to be tested, evaluated, and developed.]

(4) Observations do not provide automatic access to secure factual knowledge; they must be interpreted in the light of current theoretical beliefs.

(5) Concepts and theories are produced by creative acts of abstraction and invention. They do not arise directly from observations by a process of inductive generalisation. Once produced they have an objective existence, independent of individual minds.

(6) Theories are often justified post hoc [1] by experimental evidence, but for a theory to be accepted there must be (conceivable) supporting evidence.

(7) Competing theories may give rise to non-identical observations when confronting the same phenomenon. [or interpretations of the same data!! Lowe] Also, you tend to see or notice or consider important whatever you are looking for. Penicillin is an example where a major discovery took place when someone saw and realised the significance of a well known phenomena. Some doctors noticed that bacteria did not grow in the presence of some contamination. Many people had probably seen this and not guessed the significance, until Alexander Fleming did in 1928 [commercialised 1941ff], and started investigating more. In general a trained observer will see things that other observers will not. If an artist and a botanist look at a tree, the artist will see the forms and colours, the botanist will see the species and other biological phenomena.

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1. Post hoc, ergo propter hoc, a Latin phrase meaning "after this, therefore because of this," is a logical fallacy confusing cause and effect with chronology. Just because Irving wakes up every morning before the sun rises doesn't mean that the sun rises because Irving wakes up.
www.pearsoned.ca/text/flachmann4/gloss_iframe.html

(8) Some scientific knowledge (observational data and theories) has only temporary status. Concepts and theories change and develop; some are discarded. There is no one method of science applicable at all times. But contrary to some who see the knowledge of science as a product of the community, the science community is about the task of establishing the truth, and this truth, which is often incomplete, and only an approximation to reality, is still truth.

(9) Induction is inadequate as a description of scientific method and so the discovery learning methods often employed by science teachers project a distorted image of science. (p216-7).

(10) A new theory may have to be introduced to provide the evidence for the rejection of an existing theory. So long as the old theory is retained there may be no counter evidence. New theories enable scientists to view the world in new ways. (p220).

Remember, new ideas are tested experimentally: they are not just debated.

Noticing the unusual: tunnelling nanotubes
In point 7 above there is the example of Fleming, who noticed and took seriously the contamination of the plates. A recent example of this would be tunnelling nanotubes. Amin Rustom in 2000 saw under his microscope that a long thin tube had formed between two of the rat cells he was studying. His supervisor asked him to repeat the experiment, and nothing similar could be seen.

Most people would have rejected the observation as an 'artefact', and off the subject therefore of little interest. His supervisor, Hans-Hermann Gerdes deserves great credit for pursuing the matter further. Rustom was grilled and admitted that the first time round the normal experimental protocol had not been followed. Rustom was made to repeat the experiments including the 'mistakes', and sure enough, long delicate connections between cells were seen.

It took another four years to produce convincing evidence for publication in 2004. Since then, many other groups have found nanotubes, in widely different areas, such as the immune system, and damaged heart muscle cells.

http://www.newscientist.com/article/mg20026821.400-tunnelling-nanotubes-lifes-secret-network.html

3. Homework questions: Hodson 1986:218

a. What is a "naive realist"? Why is the name given?
b. What is an "instrumentalist"? Why is the name given?
c. What is a "critical realist"? Why is the name given?
d. What are you? Why? What are your students? What are the textbooks of your students? What are the other (science) teachers of your students?

(see end of document for brief answers, which are put there so that teachers can use these notes without providing the answers)

4. Sutton 1996

Sutton takes the view that facts are what the community decides is true. My opposition to this is in [square brackets] and in my commentary.

Remember: Induction means observations ➜theories.
Deduction means theories lead to new statements.

a. There are two ideas about a scientific fact:
   1) **The commonsense view**. Facts are the starting point, they are discovered by observation and experiment. These facts are then summarised in textbooks etc.

   2) **The alternative view.** Facts are the end-product of science. First there is human speculation, and a struggle for suitable words, which, combined with repeated checks (observation and experiment) leads to 'claims' which then fossilise into facts.

      [No! Observations and experiments are repeated and argued about because human reasoning is frequently fallible, and only through struggle and confrontation can the truth be established. The repeated argument and testing is to see if the facts are true or not.]

      [To make this clearer I have set out the alternative view, with my opposition to it, in the table below.]

Sutton's alternative (relativist) view	**Normal, (critical realist) view**
Facts are the end point of science	Facts are the starting point of science
first there is human speculation	there is often speculation and creative thinking and hypothesising
the speculation is checked by observation and experiment which then	the speculation leads to testable hypotheses and experiment and observation
leads to claims	leads to repeated observation, experiment and empirical testing followed by submission of work and reasoning to peer review
these claims fossilise into facts	the facts are confirmed and established

b. Sutton argues that there are changes in language and in the status of knowledge as an area of science matures, and tentative ideas are transformed into firm facts, as illustrated by the following progression. He presents **a progression in the writing of scientists** which is superficially very attractive, especially for those looking to describe science in relativistic terms.

Sutton's views on the progression in the writing of scientists	**Commentary from a Critical Realist**
1. In the first publications of scientists we have CLAIMS supported by evidence. Primary sources.	Not so simple. First publications can have a variety of purposes. They can for instance report on new observations, or the testing of a new hypothesis, or competing hypotheses, or modified hypotheses. A theory needs to make testable predictions. Experiments are performed to see if the predictions are true. A good theory makes very specific predictions about reality (one of the tests of a good theory in science is how specific and practical are the predictions).
2. In reviews etc we have ATTRIBUTED CLAIMS	Not exactly. Reviews frequently evaluate published work, point out weaknesses, and present reasons why some conclusions are more likely than others. Reviews function to check, verify, and summarise work by many authors, and in so doing can sometimes draw attention to facts not previously considered.
3. When ideas are widely accepted and arranged in textbooks they become ACCEPTED FACTS If you say it often enough people will believe it.	This is a distortion. Widely accepted facts obviously filter down into the textbooks because they have been established as facts by the expert research community, and no longer need research to test them or develop them.
4. If taken for granted, they may disappear into the TACIT KNOWLEDGE	Agreed

5. The critical realist would say the progression is as follows:

a. Speculation, questions, or observations, lead to:
b. New data: observations, experiments, etc
c. Claims are derived and supported, and in turn subject to further test
d. These claims, with the evidence and reasoning, are subject to thorough review by the community of experts
e. In this way new facts are confirmed/established.
f. Over time, these new facts become the tacit knowledge of the wider community, a tacit knowledge that needs little justification, since that would mean endlessly repeating the justification.
g. Scientists try to get closer and closer to an accurate description of reality.

A good example of the testing process that new claims go through was the phenomena known as cold fusion. In the box below I have highlighted the way the claims were examined by the professionals. Notice that in this case there were good theoretical reasons why cold fusion could not exist. In other words, there was a body of experiment, data, and theory, which was open to the new, but likely to be firmly sceptical. What is novel may be true, but if it is, then a lot of established work needs revising. In addition, the experiments could not be replicated, sources of experimental error were identified, and finally, it turned out that the advocates had not actually seen what they had originally claimed to have found.

I submit that the example of cold fusion is a good example of how the scientific community wished it were true, therefore was willing to give the benefit of the doubt enough to take the claims seriously enough to investigate them, but the community eventually rejected the claims because the evidence and the reasoning obliged them to do so.

Cold Fusion (extracted and slightly adapted from Wikipedia, 1 January 2009)
In the broadest sense, cold fusion is any type of nuclear fusion accomplished without the high temperatures (millions of degrees Celsius) required for thermonuclear fusion. In common usage, "cold fusion" refers more narrowly to a postulated fusion process of unknown mechanism offered to explain a group of experimental results first reported by electrochemists Stanley Pons of the University of Utah and Martin Fleischmann of the University of Southampton.

Cold fusion gained attention in 1989 when Fleischmann and Pons held a news conference in which they reported producing nuclear fusion in a tabletop experiment involving electrolysis of heavy water on a palladium (Pd) electrode.[1]They reported anomalous heat production ("excess heat") of a magnitude they asserted would defy explanation except in terms of nuclear processes.[2] They further reported measuring small amounts of nuclear reaction byproducts, including neutrons and tritium.[3] These reports raised hopes of a cheap and abundant source of energy.[4]

Enthusiasm turned to skepticism and ultimately scorn as a long series of **failed replication attempts** along with **several theoretical reasons** cold fusion should not be possible, the discovery of possible **sources of experimental error**, and finally the discovery that Fleishmann and Pons had **not actually detected nuclear reaction byproducts**.[5] Although cold fusion has gained a reputation as pathological science, some researchers continue to investigate cold fusion and publish their findings at conferences, in books, and scientific journals.[6] The field is sometimes referred to as low energy nuclear reaction (LENR) studies or condensed matter nuclear science.[7]

The majority of a review panel organized by the US Department of Energy (DOE) in 1989 found that the evidence for the discovery of a new nuclear process was not persuasive. In 2004, the DOE convened a second cold fusion review panel which reached conclusions that were similar to those of the 1989 panel.[8]

1. Voss 1999
2. Fleischmann & Pons 1989, p. 301 ("It is inconceivable that this [amount of heat] could be due to anything but nuclear processes.")
3. Fleischmann & Pons 1989, p. 301 ("We realise that the results reported here raise more questions than they provide answers . . .")
4. Browne 1989, para. 1
5. Browne 1989,Close 1992, Huizenga 1993,Taubes 1993
6. Voss 1999
7. Biberian 2007,Hagelstein et al. 2004
8. Choi 2005,Feder 2005,US DOE 2004

Biberian, Jean-Paul (2007), "Condensed Matter Nuclear Science (Cold Fusion): An Update" (PDF), International Journal of Nuclear Energy Science and Technology 3 (1): 31–42, doi:10.1504/IJNEST.2007.012439
Browne, M. (May 3, 1989), "Physicists Debunk Claim Of a New Kind of Fusion", New York Times, retrieved on 25 May 2008
Choi, Charles (2005), "Back to Square One", Scientific American, retrieved on 25 November 2008
Fleischmann, Martin; Pons, Stanley (1989), "Electrochemically induced nuclear fusion of deuterium",

Remember, incomplete truth, or approximate truth, can still be true. Approximate truth is truth which lacks a high degree of precision, but it is still true, within known limits of approximation.

QUESTIONS.
1. Where are your students at?
2. Apply the concept of genres to this explanation

Beware Social Constructivism
It is rampant as a theory, especially in ESP. There is an element of truth in the notion that facts are established by agreement among the scientific community (socially constructed). But this element is minor and secondary. Facts are actually established by observation, discovery, and experiment, along with careful logical reasoning. Here I just give two short examples.

A naive example often given is that first we had **Newton** with his theory of gravity, then Einstein came along and overturned the theory of Newton and replaced it with the theory of relativity. This is a complete misinterpretation of the reality. Newton's laws stand. They were good enough and accurate enough for men to be sent to the moon based upon them. Now it turns out that Newton's laws did not consider all the factors. **Einstein** saw a bigger picture, such that Newton's laws become an accurate subset of his own theories. Newton's laws turn out to be a <special case>. Given certain restrictions, Newton's laws are true. Einstein's laws are broader: they have not replaced Newton, rather, they have subsumed (absorbed) Newton.

The second example comes from my own research. Basically, **a line** in French is defined as coming from infinity and going to infinity. In British school English, a line is usually defined as the shortest distance between two points. Now at advanced level, both definitions are known in both languages, but at school level different choices are made depending on the language. These different definitions lead to different language and different concepts. The French can talk about a *demi-droite* which in English, 'a half line' or 'half a straight line' is a nonsense, because when a line is divided in two there are two lines. In fact, the English line would be called a *segment de droite* in French, or 'line segment' in English. In this case, 'line segment' does exist in English, but it has the sense of one part of a longer line.

Now all this could easily be interpreted in terms of knowledge being relative, as a good example of how different languages by their different definitions have not just a different understanding of reality, but are constructing a different reality. But this would be unfair to the evidence. When the definitions are unpacked and explained, we realise that we are talking about different things. A line coming from infinity and going to infinity can and does exist independently of the language used or the label. A line which is the shortest distance between two points can and does exist independently of the language used or the label. In addition, in both languages both definitions are possible. The reality does not change. **What does change is the preferred way of dividing up reality, of categorising, of defining.** And this can lead to different ways of describing and perceiving the reality, of different emphases.

Brief answers to questions

a. What is a "naive realist"? Why is the name given?
[Scientific theories are true descriptions of reality]

Naïve realism claims that the world is pretty much as common sense would have it. All objects are composed of matter, they occupy space, and have properties such as size, shape, texture, smell, taste and colour. These properties are usually perceived correctly. So, when we look at and touch things we see and feel those things directly, and so perceive them as they really are. Objects continue to obey the laws of physics and retain all their properties whether or not there is anyone present to observe them doing so. http://en.wikipedia.org/wiki/Naïve_realism accessed 1 Nov 2007

b. What is an "instrumentalist"? Why is the name given?
[The real world is described in terms of models. Theories are useful fictions whose value is judged by their usefulness, or by the way they make good predictions.]

Instrumentalism is the view that concepts and theories are merely useful instruments whose worth is measured not by whether the concepts and theories are true or false (or correctly depict reality), but by how effective they are in explaining and predicting phenomena. http://en.wikipedia.org/wiki/Instrumentalism accessed 1 November 2007

c. What is a "critical realist"? Why is the name given?
[Theories are intelligent guesses, subject to testing by reality]

Critical realism is the theory that some of our sense-data (for example, those of primary qualities) can and do accurately represent external objects, properties, and events, while other of our sense-data (for example, those of secondary qualities and perceptual illusions) do not accurately represent any external objects, properties, and events. In short, critical realism refers to any position that maintains that there exists an objectively knowable, mind-independent reality, whilst acknowledging the roles of perception and cognition. http://en.wikipedia.org/wiki/Critical_realism accessed 1 November 2007

d. What are you? Why? What are your students? What are the textbooks of your students? What are the other (science) teachers of your students?