NATURAL HISTORY MUSEUM

Nature of Science terms

'Almost all of what we customarily call knowledge is language, which means that the key to understanding a subject is to understand its language' (sic)

Introduction

Science, like all professional disciplines has its own set of specialist terms and vocabulary. These are used to create speedy and, above all, precise communication of scientific ideas. Some writers have gone as far as Postman and Weingartner (1971) who said: *"Almost all of what we customarily call knowledge is language, which means that the key to understanding a subject is to understand its language."*

While most would not go so far, more recently, Wellington and Osborne (2001) write: *"[Learners] should learn the language of science so that they can read critically and actively and develop an interest in reading about science."* Many specialist science words (e.g. chondrite, ploidy, neotony) will be utterly unfamiliar to the lay person. Such terms, when used with a public audience require substantial explanation or other scaffolding to support their meaning. This may mean giving a definition before or after using a term, inserting an image or a diagram to support the interpretation of an unfamiliar word, having a glossary for visitors to refer to, or checking understanding in face to face encounters. Such terms are easy to spot and awareness is high amongst those working in science communication that the public will largely struggle to decode them.

More problematic are science terms that have a common vernacular usage that differs from the scientific usage. These are far less easy to recognise and can be a source of serious misunderstanding if used without explanation. The set of terms in this booklet all relate widely to the nature of science and are highly likely to feature in any given presentation of scientific ideas. They have a precise meaning when used in the context of science, but have a different meaning in colloquial speech.

We regard it as essential that students and visitors should be inducted into the language of science, and for developers and deliverers of scientific content to be aware that the meaning that public visitors take from a sentence, such as "Evolution is a theory to explain the diversity of life" may be very different from what is intended. In no way would we support attempts to replace or eradicate these terms from our presentations of science.

On the contrary, we think it essential that all citizens become aware of the scientific usage of these terms and increase their understanding of the nature of science. This is part of a balanced and informed science education.

Science

Vernacular usage
A school subject comprising Biology, Physics and Chemistry, where experiments are carried out to demonstrate things that are already known to be true. A fixed and reliable body of knowledge to be memorised.

Scientific usage
The systematic study of the natural world. Science is a process we use to find out how the Universe works. It is a method (or a series of methods) that are used to investigate and explain reality rather than an accumulation of discovered facts.

Huxley (1875) said *"The true teaching of science is not merely... the facts of science, but... to observe, to reason... and to check conclusions by further observation or experiment".*

Some explanation
People's experience of school science and the requirements of formal examination lead them to believe that Science is about discovering 'Truth' about reality. Once Science has discovered the 'Truth' of a particular situation, there is no need for further study as the Truth cannot change. This leads to problems when communicating Science, because as new techniques and evidence are found, Science changes.

The public are confused when scientific statements change over time or when there is a lack of consensus amongst scientists because they perceive these as lacking the certainty that they expect and want from Science. This can result in the public simply dismissing certain scientific claims on the grounds that: scientists are not convinced, so why should they be (Shuckburgh, Robinson and Pidgeon, 2012).

Science does not claim to discover 'Truth'; if anything, the opposite is the case. Science rests on falsifiability, so it's in the business of proving things wrong rather than right. Science progresses because ideas that have not been disproved (falsified) persist and become the basis for more Science. For many, Science is confined to Chemistry, Physics and Biology (school science). Thus Natural History may not be viewed as 'Science'.

Recommendation
It is always worth emphasising to visitors that Science is not about finding absolute proof, 100% certainty or discovering Truth. We should strive to present Science as an on-going and dynamic process of enquiry where answers always generate more questions. This is part of what makes Science exciting, but can be frustrating for visitors expecting unequivocal and unchanging answers.

Richard Feynman in 1964 explained the scientific method
www.youtube.com/watch?v=0KmimDq4cSU.

This is still a benchmark cited and referred to constantly. His examples concern physics, but the general principles are exactly that, general. Everyone should watch these 10 minutes.

Please paste the link into a browser.

Fact

Vernacular usage
A piece of data of which we are 100% certain.

Truth.

Scientific usage
Nothing in Science is 100% certain. Stephen Jay Gould (1994) said that a scientific fact was *"confirmed to such a degree that it would be perverse to withhold provisional assent."* Acceptance of positive scientific findings (i.e. truth claims) is always provisional, even for the most well-established and least contentious findings.

It is always possible that the development of new techniques and technologies or the discovery of new evidence will overturn something that we now accept as most likely true. Science will disprove assertions, but not prove them.

Some explanation
Facts in science are observations or descriptions of reality. They are never certain. Even in Gould's (1994) quotation, the most well attested can only be given provisional assent. They do not speak for themselves but need to be fitted into an explanatory, theoretical framework.

Facts are the foundation of Theory which is one reason why science changes and progresses; newly discovered facts lead to the evolution of scientific theories. The primacy of 'fact' in our culture is wide and pervasive. Phrases, such as "The facts of the matter" and "The facts speak for themselves" reveal that fact is a close synonym for truth for many of us.

Recommendation
One option for communicators of science would be to replace the word fact with 'current thinking' or with 'findings/observations to date'. This does deal with the immediate communication issue, but fails to address the misconceptions around the provisional nature of the knowledge that science produces.

It does take time to explain this so you'd need to have the time/space to get into this with visitors, but if there's an opportunity, it should be taken.

Hypothesis

Vernacular usage
A guess

Scientific usage
A hypothesis is an informed prediction that can be tested. Hypotheses can originate from many sources; they may stem from predictions from existing theories, or be the result of new observations of the natural world.

Some explanation
The defining characteristic of an hypothesis is that it should be testable. It is rarely just a random guess. Scientific theories can provide the source of an hypothesis, as can observation of phenomena in nature. The usage of hypothesis in the context of a 'hypothetical situation' may contribute to people's confusion. An hypothetical situation is often assumed to be imaginary and not based in reality.

Law

Vernacular usage
A legal mandate or prescription.

Scientific usage
A Law in science is a fundamental, and general, descriptive principle.

Some explanation
There is a confusion in the minds of people here about distinguishing laws that are prescriptive (you must/ must not do something under threat of sanction) and those of science which are descriptive (describing the way things have been regularly observed to happen).

One commonly reported misapprehension is how Law in science relates to Theory. It is mistakenly thought that once a Theory has been proven to be true it becomes a Law. In some instances, the two terms are used interchangeably since both rely upon facts and observations, but the most usual distinction is that Laws are descriptive of reality while Theories explain reality (Law equals What, Theory equals Why).

Recommendation
Science communicators should avoid using the terms law and theory interchangeably.

Model

Vernacular usage
In everyday speech a model is most likely to be thought of as a diorama, a fashion model or a small plastic train, airfix etc

Scientific usage
Models in science can refer to many different types of things. Computer simulations, mathematical equations that have been tested against known quantities, for example, capturing a specific situation.

Physical models, conceptual models and mathematical models are all valid usages of the term.

Some explanation
The risk of confusion arising from the use of this word is often less about the vernacular vs. the scientific, but between different scientific usages. In science we can speak of models, conceptual models, mathematical models computer models, physical models etc etc.

All are representations of reality, but we need to be careful to explain what we are talking about and careful to ensure that visitors have the skills, or support, necessary to understand the model. Mathematical models framed as equations will baffle most visitors.

Recommendation
Science communicators should specify what kind of model we are talking about. eg. computer model, physical model, fashion model.

Observation

Vernacular usage
Watching something. Most often, observations are exclusively visual.

Scientific usage
An observation in science is a targetted examination of a phenomena or to answer a specific question.

Some explanation
Notes recorded during experimentation are also referred to as observations. In science, observations are not necessarily visual; a measurement would also be an observation.

It is often impossible to carry out repeatable, controlled experiments in natural science, so meticulous observation and measurement of natural phenomena has become the basis of Theory and the means of falsification.

Recommendation
As educators we should always be careful to explain the basis of science research. This would include educating people in how to make accurate observations of the natural world and why we should do so.

Prediction

Vernacular usage
Prophesy.

The ability to see the future

Scientific usage
Calculated guess based on previous data to be tested

Some explanation
Predictions are the outputs of a Theory and also the way in which theories can be proved wrong (falsified). See entries for Science and for Fact for related discussions.

Recommendation
It is always worth emphasising to visitors that science is not about finding absolute proof, 100% certainty or discovering Truth.

Proof

Vernacular usage
Absolute evidence that something is true or correct

Scientific usage
Validation of a statement by specified rules

Some explanation
Proof (in a positive sense of proving something to be true or correct) only exists in mathematics. Scientific ideas and answers are always provisional. Ideas in science can be demonstrated to be wrong (falsification).

"It doesn't matter how beautiful your Theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong." Feynman (1964)

But scientific answers are always provisional, proving something true cannot be done. It is always possible that new evidence will appear that will falsify existing ideas.

Recommendation
Science does 'prove' things, but only in the sense of proving them to be wrong. Truth statements should be prefaced by a statement such as...

"our current understanding is..."

"the data so far supports (or at least does not refute...)".

Scientific Law

Vernacular usage
A Scientific Law is the next phase for a Theory. Once it has been proven to be true, the Theory becomes a Law.

Scientific usage
It's not really an upgraded Theory. A Law is more like a generalization. The Law of energy conservation is general in that it can be applied in many different cases. It can be used when looking at the collision of two particles, or light produced from a lightbulb or a pot of water boiling on a stove.

Some explanation
Many scientists use Law and Theory interchangeably. Both are explanatory frameworks that account for observable phenomena. Both make predictions that can then be tested (by observation and/or experiment) resulting in their potential falsification.

Recommendation
We should strive for a consistent usage of terms within our descriptions of scientific ideas. In an exhibition, the development team should set aside some time to agree how terms such as this will be used in the text.

It might be best to add a line or two when a term first appears to explain how a theory is different from a law. In face to face encounters, visitors' understandings should be checked.

Theory

Vernacular usage
An educated guess, sometimes not even that educated! (Hassol, 2008, p1).

Scientific usage
An explanation for a set of facts, that has been well-supported and never disproved by observation and experiment. Fact supported theories are not guesses but reliable accounts of reality. Carl Popper (The Growth of Scientific Knowledge, 1963) maintained that a scientific Theory had to be falsifiable, at least in principle. This means that it must be possible to imagine a piece of evidence that could potentially prove a given Theory to be false.

When asked what could falsify evolution, JBS Haldane (1892-1962) is alleged to have said "Fossil rabbits in the Pre-Cambrian". Typically, ill-defined, vague, unmeasurable ideas do not make good theories. For example while magic could never be disproved, its unfalsifiability precludes it from being a scientific Theory. A Theory can be one source of predictions of what should be seen in nature if the Theory is correct.

Some explanation
Theory is a Greek word meaning 'Insight'. The vernacular usage of Theory is actually quite close to a scientific usage of Hypothesis (Hassol, 2008).

The confusion between the vernacular and the scientific usages of this word has proved fruitful ground for those who wish to deny or oppose evolution by natural selection. They say... *"Evolution is just a Theory, it has never been proved to be true, it's just a theory"*.

What they're not telling you is that nothing in science is ever proved to be true and that scientists use the word Theory to apply to ideas that are well supported by repeated testing and evidence from various fields and specialisms and have never been disproved.

A Theory should make testable predictions...*"if this Theory is true then we should expect to see/find..."* if this is not what is seen then the Theory has been falsified. In this regard, science follows an evolutionary model, with observations selecting against unfit theories.

Recommendation
We should always present the evidence that supports a Theory. There is no reason why visitors should accept an explanation merely because we (or anyone else) says that it is true. Science is evidence based and we should portray it as such. It is honest to add a caveat that acceptance of any scientific explanation can only ever be provisional.

New evidence can always overturn existing thinking. The best scientific explanations contain the seeds of their own destruction by explaining how the explanation could be proven wrong (falsified).

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