Scientific Methodology

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Science

- What is science?
  - A process for evaluating empirical observations, and organizing it into knowledge.
  - A philosophical technique (scientific methodology) to explain the world about us
- Applied science
  - The application of knowledge from one or more scientific fields to practical problems
  - Information Technology is applied science integrating:
    - Mathematics
    - Psychology
    - Semantics
    - Etc.

Scientific writing vs journalism

- Science must always be objective
  - Based upon hard evidence not opinions
- Science must be transparent
  - Methodologies must be fully explained
  - Studies must be repeatable
- Scientific work should always be placed in context
  - What other relevant work has been done (literature)
  - Cite primary sources as far as possible
  - Secondary citations if not possible
- Journalism is a subjective interpretation of facts – frequently without citation (i.e. little transparency)

The scientific process

- The procedures used to investigate a scientific problem
- A universal approach
  - Used by all “scientific” disciplines
  - Can be used to attempt to get an answer to almost any question
- Steps in the process
  - Define the problem
  - Search the literature
  - Form a hypothesis
  - Test the hypothesis
  - Develop conclusions
  - Publish

The scientific process (2)

- Define the problem
  - Think about this very carefully
  - The nature of the problem must be clear
  - Usually based upon an observation
  - Must be soluble
- Search relevant literature
  - Use the library!
  - Use the internet – but this is a secondary source
  - Ask local experts
  - Avoid duplication

The scientific process (3)

- Form a hypothesis
  - An educated guess about a likely solution to the problem
  - Keep an open mind – don’t assume that your hypothesis is right!
- Test the hypothesis
  - Gather evidence (e.g. conduct experiment)
  - Remember a hypothesis is rarely, if ever, proven
  - Evidence may support the hypothesis
  - Evidence may refute the hypothesis
The scientific process (4)

- Reach conclusions
  - A possible answer to the question based upon the evidence collected
  - Compare the conclusions to other people’s conclusions (i.e. from the literature)
  - Compare the conclusions to theory
    - A theory is a conclusion based upon many investigations
    - A theory is stronger than a conclusion
- Publication
  - Sharing information is a part of the scientific process
  - Thesis/dissertations
  - Journal papers
  - Conferences
  - Informal private publication (e.g. the web)

Characterisation

- The subject of a study must be carefully defined and characterised
  - The “problem”
  - The “unknown”
- The definition of the problem needs to be very precise
  - There is no room for ambiguity – a scientist needs to know exactly what problem he/she is investigating
  - New theories can arise from defining something that has previously not been defined
- Example – “what is the moon made of?”

Hypothesis

- A tentative solution to the problem – may be:
  - Usually a causal explanation or correlation
  - Ideally should be based upon some evidence, but can be a guess (often a “hunch”)
  - Does not matter whether a hypothesis is right or wrong
- Example – “the moon is made of cheese”

Falsifiability

- Hypotheses must be falsifiable
  - It is never possible to prove a hypothesis
  - It is only possible to disprove a hypothesis
- If a hypothesis cannot be falsified, then it is not useful – ultimately this is not science
- Null hypotheses are thus often used
  - Much science is about the attempt to disprove null hypotheses
- Example – “the moon is not made of cheese”

Predictions

- Based upon a hypothesis
- Deductive reasoning is used to predict the behaviour of currently unknown phenomena
- Predictions must be testable (i.e. falsifiable)
- Testing a prediction
  - If the prediction does not hold true, then the hypothesis is refuted
  - If the prediction does hold true, then the hypothesis is supported
  - This does not necessarily mean that it is true, it remains a hypothesis
- Example: “the moon is edible”
Experiments are activities designed to test predictions
- Do this carefully – it is a non-trivial area
- Support by several experiments
- Controlled experiments
- Different prediction
- Changing a hypothesis often requires repeating the experiment
- Example: “go to the moon, and try to eat it”

Hypothesis to Theory
- Experiment does not support a prediction
  - The hypothesis is rejected.
  - A new hypothesis is then required
- Experiment supports the prediction
  - The hypothesis is retained – not proved
  - This is considered evidence to support the hypothesis
- Theory is developed from hypothesis
  - Support by several experiments
  - Experiments must be independently repeated
  - Testing different factors

Iteration in Science
- The scientific process is iterative
- Hypotheses are continually refined
- Changing a hypothesis often requires repeating the process
- Verification of a hypothesis/theory
  - Repeating experiment (same experiment, same observer)
  - Repeating experiment (same experiment, different observer)
  - Repeating experiment (different observation, same prediction)
  - Different prediction

Competing Hypotheses
- Sometimes there is more than one possible explanation of observed facts
  - Principle of parsimony
    - Do not make more assumptions than are needed
    - The simplest explanation is the one that should be used
  - Occam’s Razor
    - Named after William of Occam (1287-1347)
    - NB spelling - Occam, Okham or Ockham
    - *Entia non sunt multiplicanda praeter necessitatem*
    - Entities are not to be multiplied beyond necessity
    - This is a useful tool, but not a guarantee of correctness