

*Not what to think but how to
think: teaching science as a
process*

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The Problems

- *Scientists have difficulty in identifying the hypotheses they want to test (or indeed question they are asking)*
- *Graduates in science lack even basic knowledge of epistemology*
- *“I’m a biologist why do I need to study statistics?”*

Mere anecdotes! what is the evidence?

- *Survey*
- 1. Have you heard of Occam's Razor?
- 2. Correctly recognise flaws in reasoning?



Some examples

- In an observational study of the effect of obesity in heart disease 122, 18 stone people had the healthiness of their hearts investigated. 90% of them had one or more heart abnormalities. The researchers concluded that obesity was a major cause of their heart problems.
- You overhear someone in the pub say “I find it absolutely shocking that about half of all doctors are below average. I demand the government does something about it.”
- A climate scientist remarks “One of the consequences of global warming will be increased flooding events. We have seen increased flooding events thus global warming is happening.”
- A palaeontologist reasons “*Tyrannosaurus rex* is a dinosaur. These bones are not from a *T. rex* so they are not dinosaur bones.”
- Bigfoot must exist because there have been tracks and sounds detected, made by Bigfoot.
- Professor Smith is reviewing the characteristics of all the extra-solar planets [*i.e. planets orbiting other stars*] so far discovered. He finds that 174 extra-solar planets have been discovered of which 2 appear to be rocky Earth-type worlds whereas the rest are gas-giants [*massive gaseous planets like Jupiter*]. Smith concludes that gas-giants are 86 times more frequent in the galaxy and that it is a feature of solar system formation that rocky planets are seldom formed compared to gas giants.
- A doctor remarks “Many patients in their 30s are coming to me with hearing difficulties. Rave/dance culture was very popular in the 1990s, therefore exposure to loud music is the source of their hearing problems.”

Heard of Occam's Razor

Year	Yes	No	%
1 st	9	98	8
2 nd	25	65	28
3 rd	2	1	66
4 th	3	3	50

$P=0.003$ Things do get better.

Know what Occam's Razor is

Year	Yes	No	%
1 st	5	102	5
2 nd	14	76	16
3 rd	2	1	66
4 th	2	4	50

$P=0.009$ Things do get better again

Question	1st	2 nd
No control	65%	44%
Innumeracy	12%	10%
Affirming the consequent	36%	18%
Denying the antecedent	2%	7%
Circular	19%	16%
Availability Bias	63%	54%
Post hoc ergo propter hoc	22%	19%

More investigation required

Science as a process falls between the cracks

- Students are taught discipline specific facts and methods but not general principles. It is assumed they are either not necessary or will be picked up anyway
- Only partially achieved

In short St Andrews undergrads
don't know the how of science

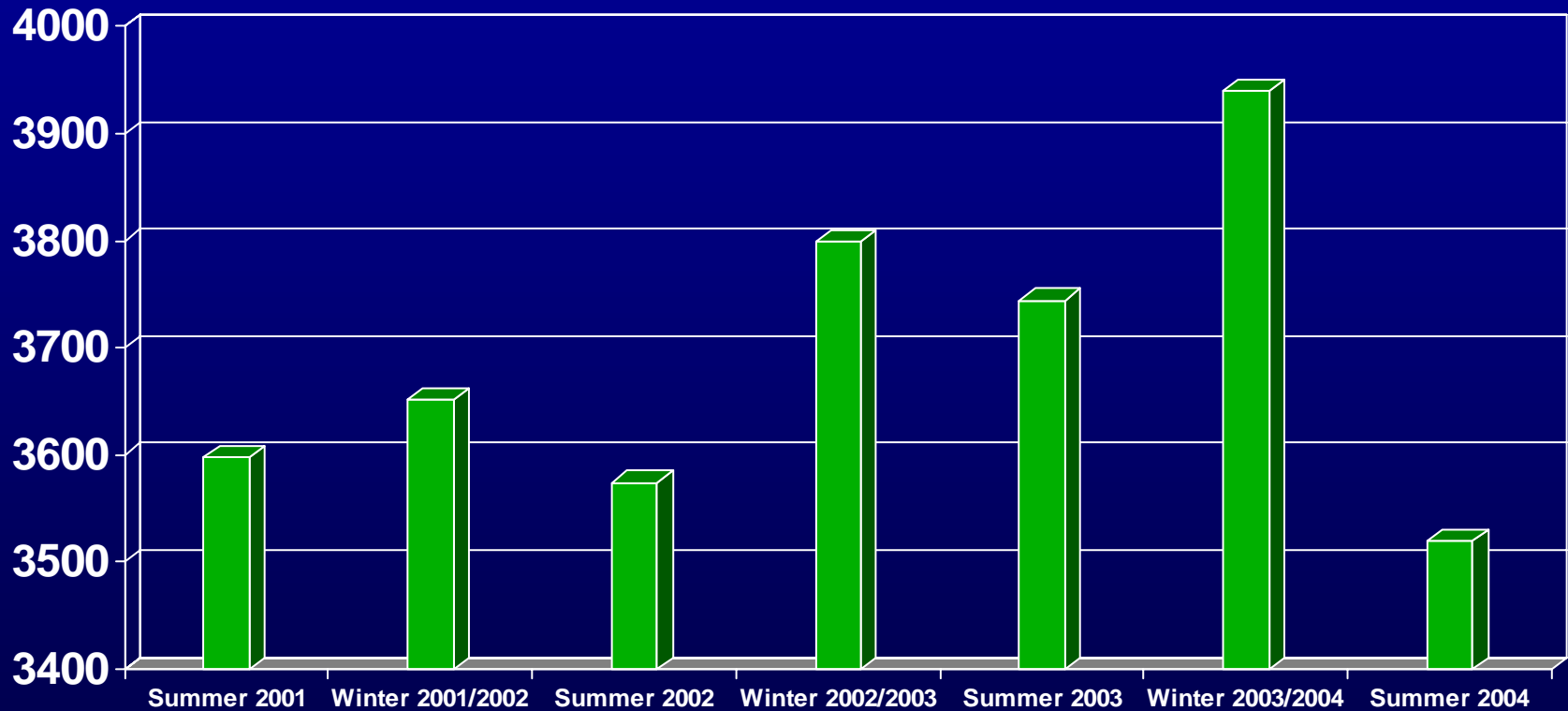
P.S. Nor do Liverpool students or Oxford students either (or those a Napier?!)

Consequences

- Woeful ignorance of science as good citizens
 - a) risk and probability (possible versus the probable)
 - b) peer reviewed science papers versus newspaper reports
 - c) dodgy arguments (should people do basic logic?)
 - d) Statistical/graphical bamboozlement by pressure groups and politicians

MRSA cases lowest ever recorded as NHS actions begin to take effect

(March 2005)



More consequences

- Not given the epistemological tools to discern different sorts of arguments
e.g. young earth creationism verses evolution.
(39% of people in UK regard themselves as creationist/intelligent design supporters Jan. 2006 opinion poll)
- Bad science (unclear questions, badly designed experiments etc. **WRONG CONCLUSIONS**)

Solution: teach science as a method of thinking and doing

Science Methods

An interdisciplinary module with contributions from Philosophy, Statistics, Computer Science, Psychology, Geoscience and Biology

Teaches basic epistemology, logic, experimental design, illustration of data, science ethics, a little bit history of science.

Used to include ethics.

A voice crying in the wilderness?

- University of Sheffield
- Review in *Science* Nov 2004
- This meeting
- <http://groups.yahoo.com/group/ScienceMethods/>

- Different definitions of science, scientist and the scientific method(s) (non-science and pseudo science)
- Science not about certainty but is systematic and strives for objectivity
- Introduction to logic, logical fallacies, deduction, induction, abduction and the problem of induction

- Formulating and testing hypotheses and experimental design
- Controls and contrasts, placebos and blind testing
- Observational verses experimental studies
- Inference errors

- The peer review process, difference between science articles and newspaper articles
- Paper criticism
- Illustrating data
- Anomalies and wonder in science
- Popper and falsification
- Kühn and paradigm shifts etc.
- Case studies: MMR vaccine, gulf war syndrome & continental drift

Not a statistics module

- Although does explain why scientists strive to be objective and use statistics

Did it help?

- Yes in terms of knowing about Occam' Razor
- (Sign Test Test, $n=10$, $P=0.0039$)

- Improved score in science questions
(Wilcoxon Sign Rank Test, $n=10$, $P=0.007$)

But ***availability bias*** as post-module sampling relied mainly on voluntary return of questionnaire.

Overcoming student prejudices

- Idealism: scientific opinions are foolproof
- Science is about certainty and learning facts
- “Too much like an arts class”

Humanities students do well in science methods.

Resistance

- Not much
- Some schools don't encourage students to take modules outside their own schools
- Teaching science as a process "is a luxury"

Future challenges

- Not getting through to all students
- Subtleties lost on students who are not doing their own research – need to introduce practical work
- Should it be a core module? Should some of the material be taught in schools or first year
- Moved to final year?
- Advanced science methods: meta-analysis, bayesian methods etc.
- Integration with statistics teaching or keep separate.

Not what to think but how to think!

- For example: the creation science/evolutionary biology debate should be taught in school science lessons