The Nature of Science

Myths and misconceptions

Declan Cathcart

SAILS
Strategies for Assessment of Inquiry Learning in Science

CASTeL
Centre for the Advancement of STEM Teaching and Learning

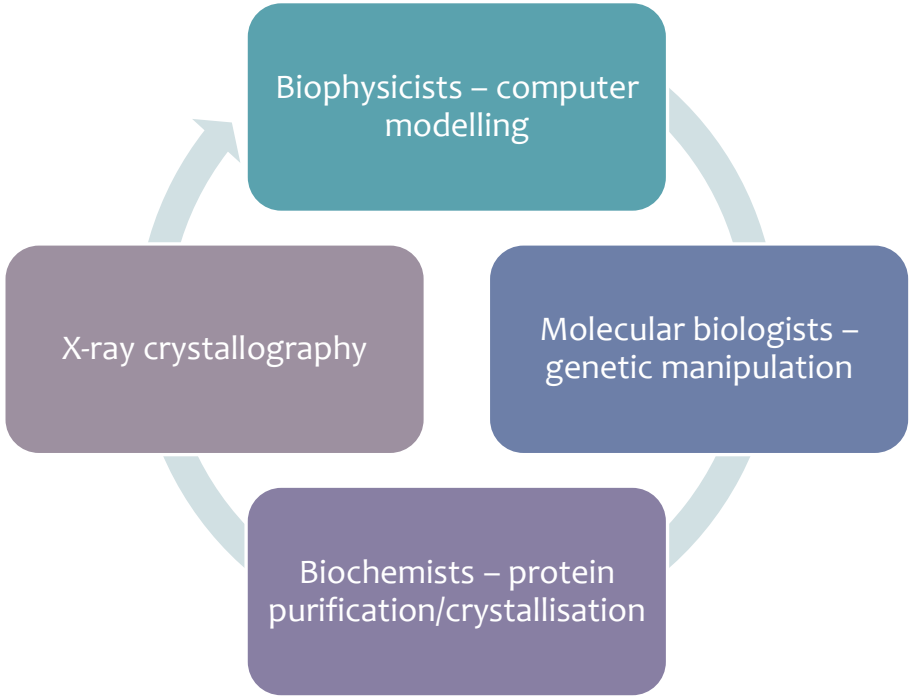
TEMPLE CARRIG SCHOOL

Background

CELLTECH

Erythropoeitin
(EPO)

Department of Protein Engineering



Cranfield UNIVERSITY

Biotechnology Centre

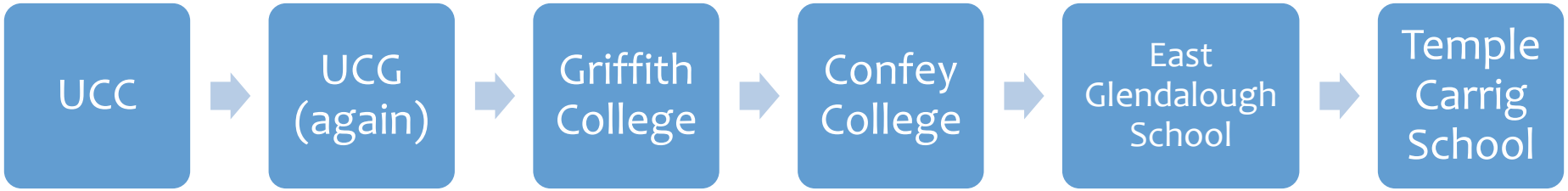
- 6 research teams
- 35 PhD students
- 17 different nationalities
- Funding
- Facilities
- Expertise
- Opportunities
- No undergraduates

University College Galway

National Diagnostics Centre

Rapid detection of pathogenic bacteria in environmental samples

Teaching



Food Microbiology
Genetic Concern

TCD Moyne Institute
Prof Gregory Atkins
MMR

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Establish

SAILS

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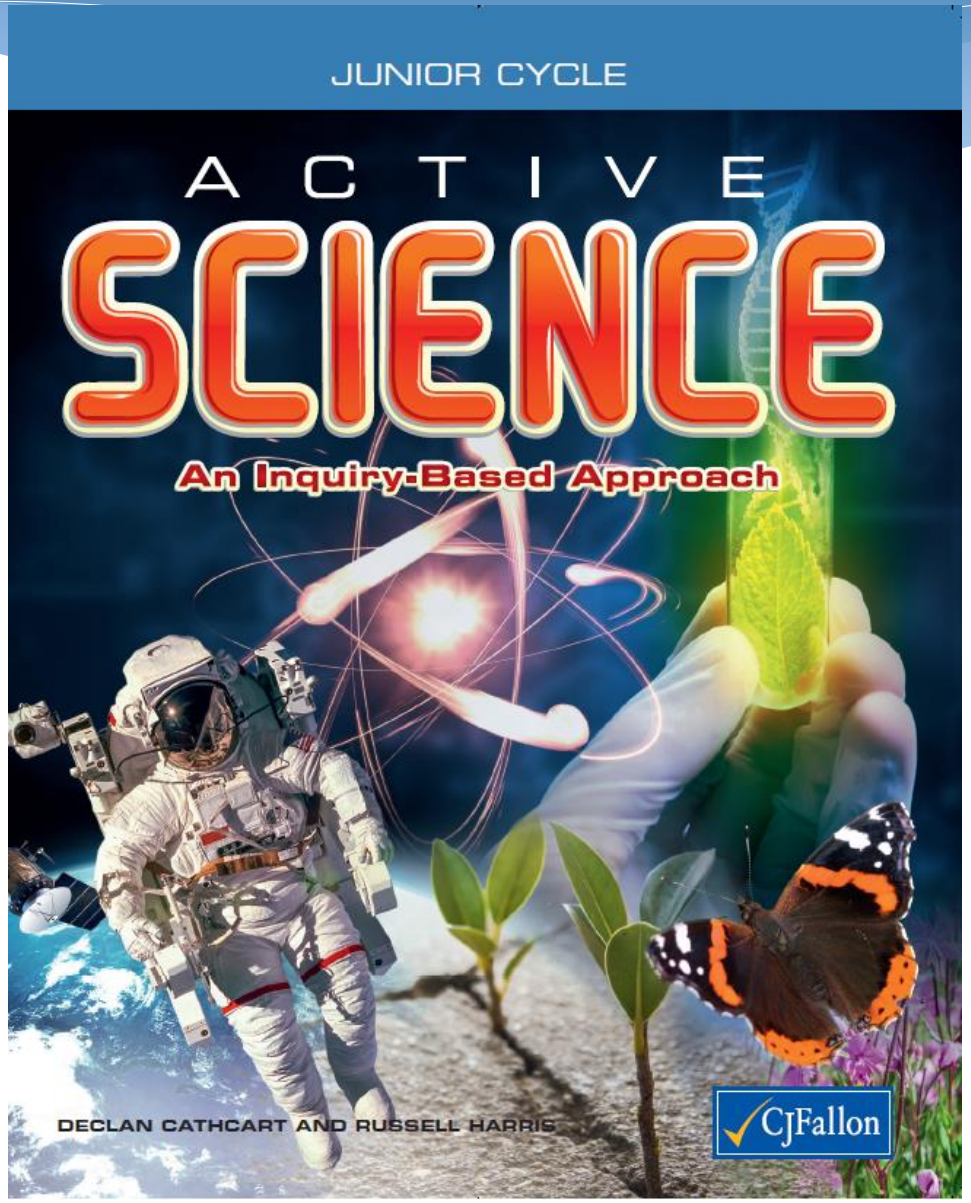


Why teach NOS?

* Students should be able to:
  * make informed decisions on ethical and social issues in science.
  * appreciate the cultural value of science.
  * make sense of everyday technology
  * gain a better understanding of science content
  * clarify strongly-held misconceptions about NOS

(Driver, Leach, Millar, and Scott , 1996; Lederman, 2006)

Scientific Literacy

Students should be able to:

* Explain phenomena scientifically
* Evaluate and design scientific investigations
* Interpret data and evidence scientifically

"*An accumulation of facts is no more science than a heap of stones is a house*"

- Henri Poincaré

Understanding NOS

* "Science teachers must come to understand just how inquiry is in fact conducted in the sciences. Until science teachers have acquired a rather thorough grounding in the history and philosophy of the sciences they teach, this kind of understanding will elude them, in which event not much progress toward the teaching of science as inquiry can be expected." (Rutherford, 1964)

Scientific Inquiry

* Chinn & Malhotra (2001)
  * Inquiry tasks in schools often oversimplified
  * Authenticity requires more complexity in school inquiry
  * Development and critique of methodologies is often overlooked
* Authentic scientific process
  * Multiple sources of evidence
  * Researching and analysing existing information
  * Planning and designing investigations

Teaching NOS

* **Explicit vs Implicit Strategies**
  * Implicit approaches assume that school inquiry is an authentic representation of scientific process.

    (Chinn & Malhotra, 2001)
  * Implicit approaches are not as effective in promoting NOS conceptions.

    (Khishfe & Abd-El-Khalick, 2001)
  * NOS teaching is most effective when carried out explicitly. (Abd-El-Khalick, 2013)

Explicit-reflective approach

* Planned deliberate inclusion of specific NOS learning intentions in lessons (*i.e. explicit*)
* Structured opportunities to allow students to examine their understanding of targeted aspects of NOS (*i.e. reflective*)

(Abd-El-Khalick, 2013)

Teaching NOS

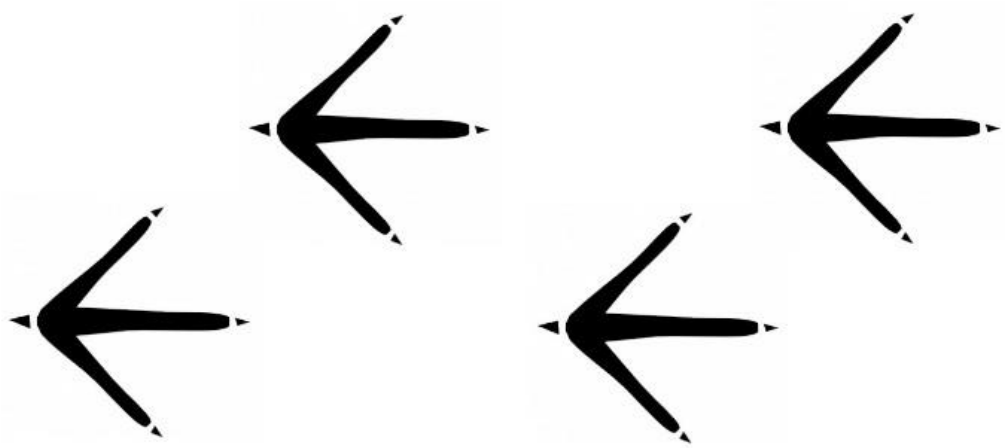
* Teaching **about** NOS is instruction aimed at helping learners (both students and science teachers) develop informed epistemological understandings about the generation and validation of scientific knowledge, and the nature of the resultant knowledge
* Teachers equipped with such understandings can be enabled to enact learning environments commensurate with those that approximate authentic scientific practice, that is, teach **with** NOS.

(Abd-El-Khalick, 2013)

Terminology

* Observation *vs.* Inference
* Prediction *vs.* Hypothesis
* Theory *vs.* Law
* Explicit and reflective approach to clarify students' understanding of these terms

Observations…?



- Bird footprints?
  - Left to right?
- Birds flying?
  - Right to left?

.. inferences?

Observation Skills

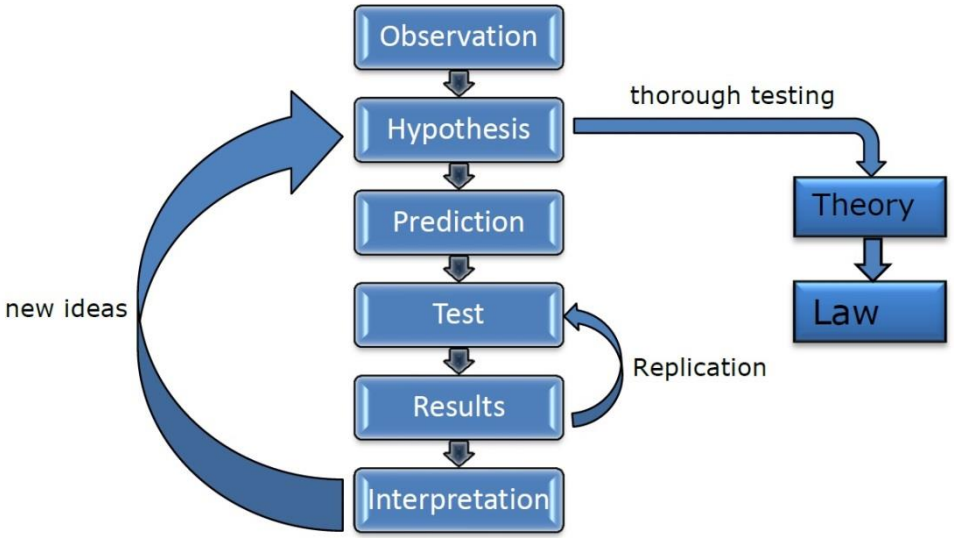
Count the number of passes made by the players in white *only*

Where is this?

The Scientific Method

- "There is a universally accepted scientific method"

- There is no *one* scientific method
- Scientists' methods often do not follow these steps in this order
- Many scientists do not carry out experiments at all
- However, all science involves evidence



Scientific ideas

* 1. Students should be able to appreciate ***how scientists work*** and ***how*** scientific ideas are modified over time.

JC Science NOS Learning Outcomes

Experiments

* "Science always involves experiments" 

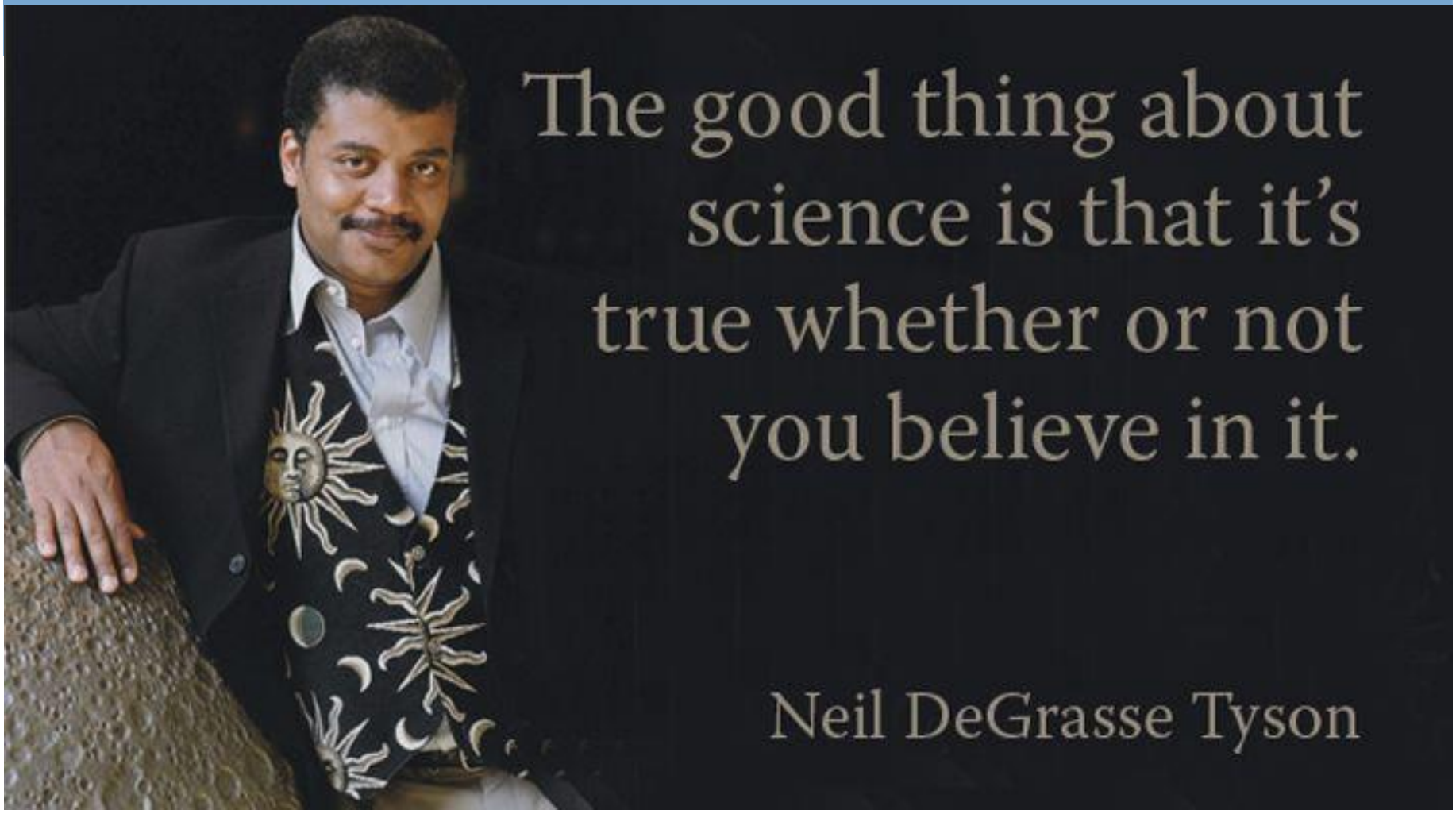
* Controlled experiments are not always possible
  * Climate science
  * Volcano science
  * Studying mountain gorillas in the wild
  * Einstein

Forming a hypothesis

* “A hypothesis is an educated guess” 

* A hypothesis is
  * a temporary explanation
  * testable
  * based on careful observation and previous scientific knowledge.

Scientific truth



Scientific truth

* "Science offers certainty and proof" 

* Science is tentative in nature
* Science does not set out to prove anything
* Evidence can ***support*** a theory or a law, but will never prove them to be *true*

"Just a theory"

* In everyday language we use the word "theory" to describe an idea that is not well supported. 

* A scientific theory is very different
* A **theory** is a well-established explanation that has been repeatedly tested and confirmed (remains unfalsified) in many different ways, and usually over a long period of time.
* A theory is the pinnacle of scientific endeavour

Natural selection

* *"I just don't believe in evolution".*
* *"It's only a theory"*
* *"Scientists can't prove that natural selection is a fact"*
* *"If it was, it wouldn't be called a theory, it would be 'the law of evolution'"*
* Very important that student can distinguish the ***fact*** of evolution from the ***theory*** of evolution by natural selection.

(McComas, 2015)

The Theory of Evolution by Natural Selection

* Thoroughly tested and examined for >150 years.
* Enormous mass of supporting evidence from a wide variety of independent areas
* Successfully used to predict the results of various investigations in a wide variety of scientific disciplines.
* Has been improved upon through minor adaptations that take account of new data.

Theories and Laws

* "A theory becomes a law after enough time has passed" 

* A theory **never** becomes a law
* Scientific Laws are statements, based on repeated observations, that describe relationships among the observed phenomena.
* Laws *describe*, theories *explain.*

Newton's Law of Universal Gravitation

* Newton provides a description of gravitation
* In *Philosophiæ Naturalis Principia Mathematica*, Newton does not offer a theory of gravitation:

  "But hitherto I have not been able to discover the cause of those properties of gravity from phænomena" Isaac Newton, c. 1726

Bias

* "Good scientists are objective and free from bias"
* Science is theory-laden

  * the theories held by the investigator, at a very basic cognitive level, impinge on the perceptions of the investigator
* Paradigm allegiance (Kuhn, 1970)
* Bias is not necessarily a negative influence
  * perspective, inspiration, creativity, imagination

Creativity in Science

* "Science is a solitary, dispassionate pursuit in which scientists carry out routine tests" 

* School lab activities often recipe-following to achieve an expected outcome (McComas, 2015)
* Many students reject science as a career because it is dry, clinical and uninteresting (Tobias, 1990)

Brussels, 1927

* “Science is generally a male endeavour.” MYTH

Gender

* Scientist role-models

‘Bad Science’

(Goldacre, 2008)

“Well, all I know is that it works for me.”