Scientific and Experimental Literacy

Assessment

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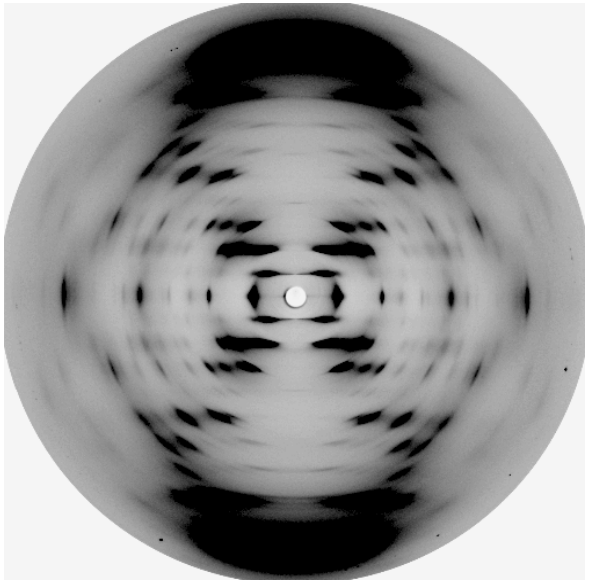
Molecular, Cellular and Developmental Biology

Overview

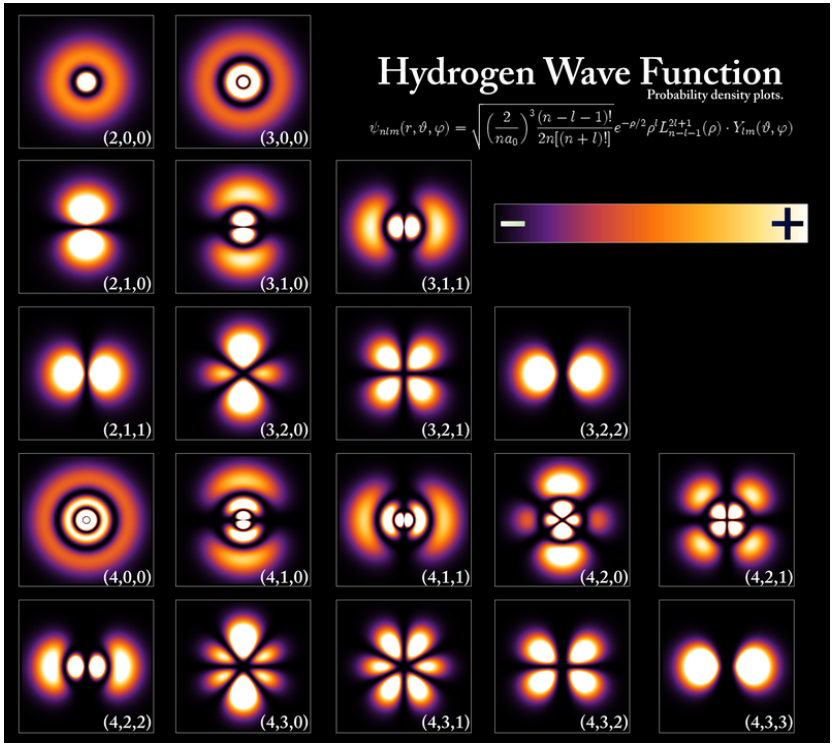
- Definitions of science literacy
- Some common difficulties my students & I are facing
- My approach to increase scientific literacy and problem solving skills

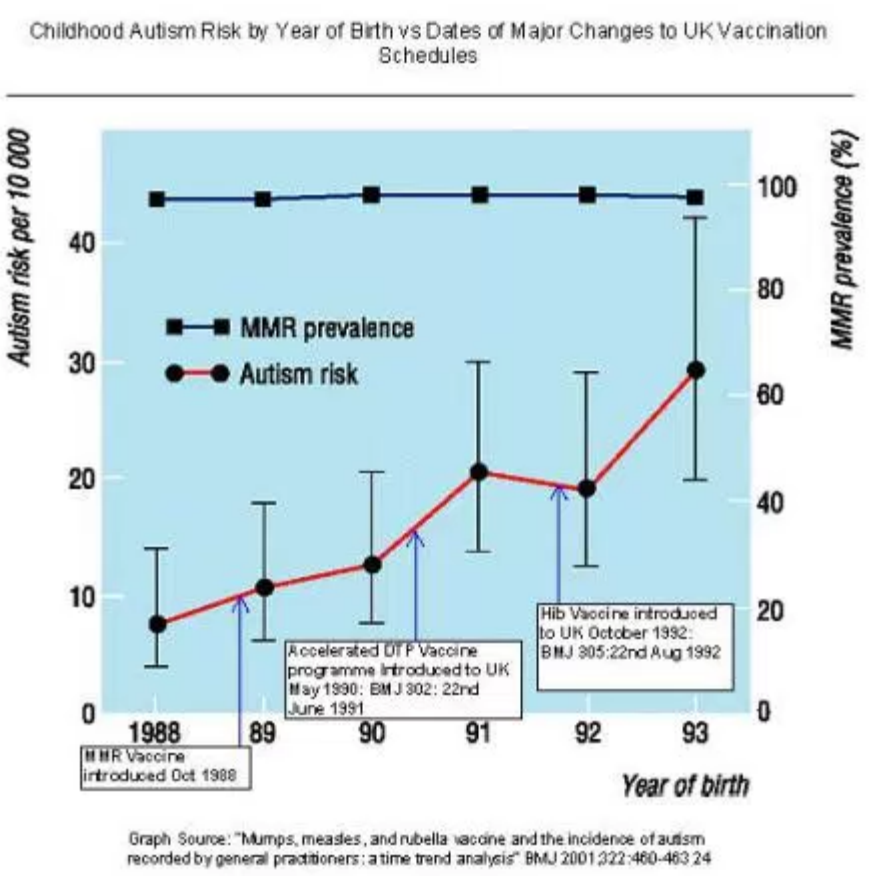
Literacy

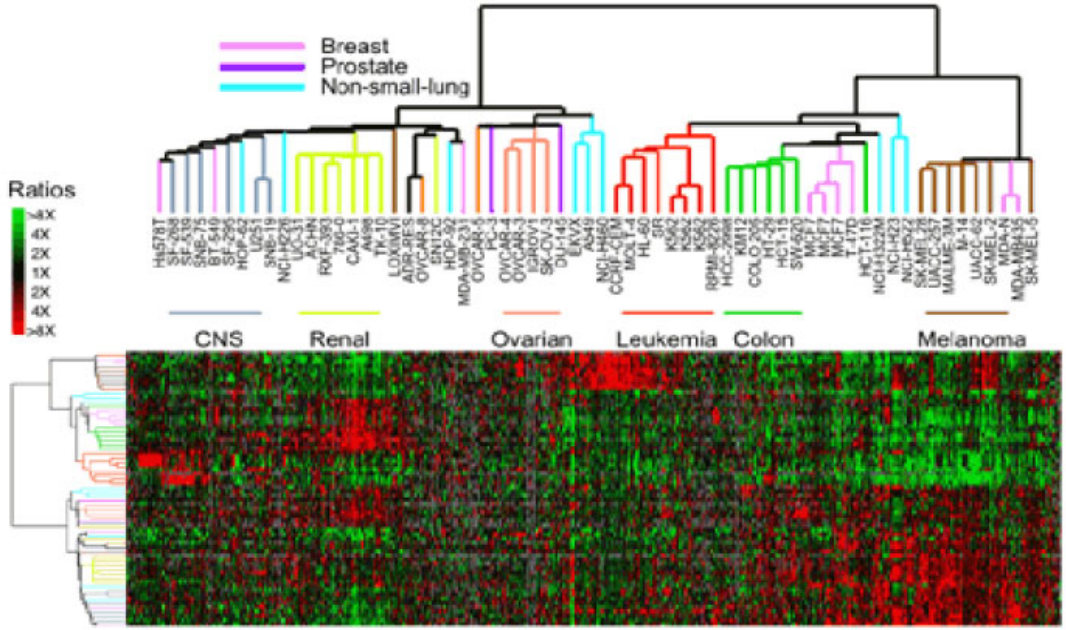
If you can read this, thank a teacher.



Can you read these ?







Science as a way of understanding the universe around us and the universe within us.

Process of Science as a collection of different means to this end.

Scientific Literacy (NSF)

- knowledge and understanding of scientific concepts and processes required to optimize economic productivity, inform personal decision-making, and participate in civic decision-making.
- less about knowing **scientific facts** than being able to **ask**, **find** or **determine** answers to questions derived from curiosity about everyday experiences.
- ability to **describe**, **explain** and **predict** natural phenomena.
- able to **read** with understanding **articles** about science in the popular press and to engage in social conversation about the validity of the conclusions.
- able to **evaluate** the **quality** of scientific **information** on the basis of its source, have the capacity to pose and evaluate arguments based on **evidence** and to apply conclusions from such arguments.

Science literate vs illiterate knowledge?, skills?, attitudes?

Word Cloud from DBER community's responses to discussion about what differentiates a scientifically literate person from an illiterate one in terms of knowledge, skills and attitudes?

My ideal “science literate”

- **Inquisitive**: asking questions, wanting to learn and think more
- **Skeptical**: but trusting of science and scientists
- **Open minded**: but able to discern a good argument from a bad one

- Disposed to gather and analyze evidence and data
- Able to gather and analyze evidence and data

- Able to make economical and moral decisions (e.g. cost benefit analysis)

3Rs of Education

What a literate person can do

Reading

'riting

'rithmetic

For Science Literacy

- Reading
- Writing
- Arithmetic

- Talking: Asking, Explaining, Presenting
- Doing: Experiments, Discovery lab

For Science Literacy

- Reading: Instructions (protocol), Primary research and News articles
- Writing: Essays, proposals, lab notebooks
- Talking: Group discussions, oral presentations

while

- Doing: Research and Discovery labs

MCDB4100: Mutating *Xenopus*

Discovery-based laboratory course

Upper-division, MCDB majors

5-6 students

Using CRISPR-Cas9 mutagenesis, target a gene of **unknown function** to determine its role in early development

Student motivations: Lab experience (grad school, biotech job), Rec letters, Coolness factor

Learning Outcomes

1) Become a more inquisitive and critical thinker
2) Understand the scientific process and become science literate
3) Learn about major concepts and advances in molecular biology
4) Troubleshoot problems and come up with alternative solutions
5) Learn how to read a research article and evaluate it critically
6) Learn how to design experiments and write a scientific proposal
7) Develop both oral and written science communication skills

Last Semester

Achievements

Student satisfaction

Integrating core concepts to practices

Nature of science and experimentation

Actually “doing” science

Struggles

Poor fundamentals (Core Concepts, math, lab skills)

Big picture vs critical details

Trial and errors

Time management

Assessment

Problem Solution Activity

Imagine you are a medical doctor.

A patient presents with fever as complaint.

Write down the step-by-step process by which you figure out

Cause of fever

Cure for fever

Problem Solving Algorithm

1) What is the problem? Have I encountered same/similar problem before?

2) What do I know and not know about this? What are my assumptions?

3) What is the universe of possibilities?

4) What is the most likely explanation and solution? Make Predictions and Formulate a Hypothesis

5) Apply and test explanation/solution

6a) Why is my solution/answer correct? Why are other solutions/answers incorrect?

6b) Why is my solution/answer incorrect? What are alternative explanations/ solutions?

6b2) Apply and test new explanation/solution

6c) Does my solution/answer make sense? Double-check, Triple-check

7) What do I learn from this? Can I make new predictions? Can I apply my knowledge elsewhere?

Medical Problem Activity

Patient complaint: Fever

1) Check vitals: Does the patient actually have elevated body temperature?

2) What are the most common causes of fever for the patients demographic?

3)What is the best solution to "fever"? Simple antipyretics or antibiotics or steroids?

4) If first solution fails, what is the next step?

1) Need to know how to take T

2) Know stuff about mechanism and causes of fever

3) Ask questions, gather more information

4) Know what counts in this particular scenario

4) Most effective-safe-cheap solution

Main goals

- Identify/define interdisciplinary (discipline-independent) scientific literacy
- Identify crosscutting interdisciplinary problem solving approaches

Note to readers who did not attend the DBER presentation

This activity highlighted once again the difference between scientifically literate experts (audience and novices (my students).

Though the audience has no professional expertise in medical sciences, they were able to

Ask questions (take history, look for other symptoms)

Gather unbiased and quantitative evidence and data (take temperature (how high?), ask patient's parents/relatives for additional history, do further diagnostics (e.g. blood test))

Retrieve and apply relevant knowledge (common causes of fever: viral vs bacterial?, common and sensible cures of fever)

My students struggle with “process of science” and “problem solving” even with familiar situations/problems.

I suggest that unfamiliar and ideally interdisciplinary scenarios to challenge them as opposed to assessing them on scenarios that they have “memorized”.

As Jenny suggested “metacognition” on how we approach and solve problems would likely be helpful.

Struggling with

Knowledge

Fundamentals

Cross-cutting concepts

Energy-Matter: Matter is made up of atoms

Cause-effect

Skills

Reading and following instructions

Verbalizing the problem

Making sense of information

Arithmetic

Attributes

Inquisitive

Analytic

Self-confidence

Failure to retrieve or apply knowledge

Failure to explain answer or reasoning

Failure to see the forest for the trees and sometimes the different trees in the forest

Problem

You received 23.7nmoles of dried DNA, how many uL (microliters) of water would you need to add onto it to end up with 100uMolarity of solution?

What do you need to know to solve this?

To solve this

Definition of a mole

Definition of Molarity (moles/L)

Basic math skills and knowledge of units.

And much more...

Definition of a mole

Definition of Molarity (moles/L)

Basic math skills and knowledge of units.

Matter is made up of atoms, it has mass and it takes up volume.

DNA is made up of matter.

Water is made up of matter.

Conservation of matter and energy.

Failure to Retrieve or Apply their knowledge

Cannot connect core and crosscutting ideas/ concept

- “How do we figure out the mass of DNA?”

Cannot apply the Molarity formula and struggle with arithmetic

Confused about units (milli vs micro)

Failure to Correctly Justify their Answers

May get the correct answer but cannot define the formula (cannot explain what it means) or explain how they got the answer

When given a slightly different question, cannot apply the same formula

The Forest vs the Trees

DNA is matter, made up of atoms and molecular subunits that give the DNA molecule its structure and function.

Deoxyribonucleic **acid**

In an electrical field, DNA migrates to the positive charge.

My solution

Get them to ask and explain

Remind with clues

Restate with analogies, real world problems and applications

Reiterate and apply to unfamiliar and interdisciplinary problems

Re-assess

To be continued...

Assessment