Reflector ★
Reviewing the experience

Pragmatist ★
Planning the next steps

Activist ★
Having an experience

Theorist ★
Concluding from the experience

David A. Kolb
(1939-)

Honey & Mumford’s
(1982) interpretation of Kolb’s Learning Styles
Axiom: From an early age, stories play a major part in our development of abstract reasoning, indeed how we comprehend ideas

• Reflecting on a direct or imagined experience
• Making conclusions and committing the experience to memory
• Planning the next steps (What happens in the next chapter?!)
In the beginning.....

.... was a short quiz

Guess the story from the opening sentence

[1 mark each, 10 marks available. Answers at the end. No scrubbing allowed]
A long time ago in a galaxy far, far away
A Mouse took a stroll through a deep dark wood
Mr and Mrs Dursley, of number four, Privet Drive, were proud to say that they were perfectly normal, thank you very much.
Two households, both alike in dignity, In fair Verona, where we lay our scene, From ancient grudge break to new mutiny, Where civil blood makes civil hands unclean.
It is a truth universally acknowledged, that a single man in possession of a good fortune, must be in want of a wife
A squat gray building of only thirty-four stories. Over the main entrance the words, CENTRAL LONDON HATCHERY AND CONDITIONING CENTRE, and in a shield, the World State's motto, Community, Identity, Stability.
Far Out in the uncharted backwaters of the unfashionable end of the Western Spiral arm of the galaxy lies a small unregarded yellow sun
Dhritarashtra said: O Sanjaya, after my sons and the sons of Pandu assembled in the place of pilgrimage at Kurukshetra, desiring to fight, what did they do?
"So now get up."
Felled, dazed, silent, he has fallen; knocked full length on the cobbles of the yard. His head turns sideways; his eyes are turned toward the gate, as if someone might arrive to help him out. One blow, properly placed, could kill him now.
There was Eru, the One, who in Arda is called Ilúvatar; and he made first the Ainur, the Holy Ones, that were the offspring of his thought, and they were with him before aught else was made. And he spoke to them, propounding to them themes of music; and they sang before him, and he was glad.
ANSWERS
1. Star Wars (All of them! But firstly in Episode IV: *A New Hope*)
2. The Gruffalo
3. Harry Potter and the Philosopher’s Stone
4. Romeo and Juliet
5. Pride and Prejudice
6. Brave New World
7. The Hitch Hikers Guide to the Galaxy
8. The Bhagavad Gita
9. Wolf Hall
10. The Silmarillion
Science by Storytelling: The Pedagogical Power of Context

A hierarchy of motivation?

Compare a story structure to strict syllabus adherence

Case study 1: The Epidemiology of Eyam

Case study 2: Navigating the Sphere

Case study 3: Teaching modern Physics: Quantum Mechanics Special Relativity

Case study 4: Mr Bayes’ 95% correct test for Teenageitus

Case study 5: Chaotic bunnies

Case study 6: Hurricanes and Typhoons

Some concluding thoughts

• Physics Educ. papers
• Science by Simulation
A hierarchy of motivation?

Be inspired
This is really interesting, I can’t resist having a go at it. Who cares what else is happening!

Compete
Compare and despair in relation to peers, siblings, family, reputation, expectation...

Don’t mess up
Fear of cultural/scholastic/professional failure

Maslow’s foundation: Desire to meet basic physical needs (warmth, food, shelter etc)
Compare a story structure to strict syllabus adherence

**Story**
Set the scene. Main characters. Heroes, villains, beasts...
Define the problem, quest, challenge
Overcome challenges ingeniously, or via serendipity. Use honed craft, or develop new tricks
Live happily ever after .... .... Or an unexpected problem is revealed, which motivates another story!

- Ideas are placed in a rich context
- Easy to visualize and relate to
- Most stories directly involve the lives of people (or anthropomorphised animals!)

**Syllabus**
Here is a fact. It is in the exam, so learn it!
Here is a possibly related fact. Learn this too. It is very important.
Tomorrow we begin a new topic. It might be related to what we covered a month ago. Obviously you will remember what we did then.

*I’m deliberately being provocative here! Syllabuses are of course important structurally, but without stories I suggest they can be somewhat soulless.*
Epidemiology of *Eyam*: The Village of the Damned

Eyam model: $\alpha = 2.98$, $\beta = 0.0182$, $dt = 0.01$
1665. A bale of damp cloth is delivered to the Derbyshire village of Eyam... George Viccars, the tailor's assistant, dries the cloth and releases fleas infected with *Yersinia Pestis* bacteria – Plague

Rector William Mompesson quarantines Eyam and records *Infected*, *Susceptible* and *Dead* populations as time progresses.

Can we develop a mathematical model to predict *I*, *S*, *D* vs time? What does this tell us about *Epidemiology* in general?

Calculus methods, differential equations, numerical methods, line of best fit, iteration, loops...
“How best to motivate students to expand their mathematical toolbox, and perhaps more importantly, gain experience of applying these ideas in the construction of quantitative models? A narrow focus on memorizing a long list of abstract procedures sufficient to pass an examination is a poor mechanism for producing the original thinkers of the future. It is also particularly harsh on those who have to struggle more than their peers to embed syllabus content in their minds. In this paper we celebrate the pedagogical power of context and storytelling, with the introduction of calculus ideas in an epidemiological scenario as an example.”

Eratosthenes
276BC-194BC

Navigating the Sphere

\[ R \theta \approx 5,000 \text{ stadia} \quad \text{1 stadia} \approx 185 \text{m} \]

\[ \theta \approx 7.2 \times \frac{\pi}{180} \text{ rad} \quad \therefore R \approx \frac{5,000 \times 185}{7.2 \times \frac{\pi}{180}} = 7.36 \times 10^6 \text{m} \]

\[ \frac{R - R_\oplus}{R_\oplus} = \frac{7.36 - 6.371}{6.371} \approx 16\% \]
\[ R = \frac{h \cos \gamma}{1 - \cos \gamma} \]
\[ R_\oplus = 6.371 \times 10^6 \text{ m} \]

\[
\begin{align*}
\alpha &= 1,000 \text{ m} \\
\alpha &= 30.00^\circ, \quad \beta = 45.00^\circ \\
\therefore h &= 1,366 \text{ m} \\
\gamma &= 1.19^\circ \quad \therefore R = 6.33 \times 10^6 \text{ m} \\
\text{only 0.6\% in error!}
\end{align*}
\]
How do we draw a circle on a sphere?

Satellite orbits

Aircraft routing

Sphere circle: $\alpha = 30^\circ$, lat = $42^\circ$, long = $102^\circ$

$r(t) = 1.3 + 0.1\sin(t)$
$\text{lat}(t) = t + 0.1\cos(3^t)$
$\text{long}(t) = 2^t$

$\text{latA} = 52^\circ$, $\text{longA} = 1^\circ$, $\text{latB} = 22^\circ$, $\text{longB} = 114^\circ$, arc length = 1.5
Equivalent Earth arc length = 9547.5km

Damn! Freddie’s not Cook’s!
Is the Force strong enough to give me a parabolic indent in my Death Star? 

Mimas – a Moon of Saturn (Diameter 396 km)

Death Star: $\alpha = 15^\circ$, $\text{lat} = 21.2^\circ$, $\text{long} = -63^\circ$, $k = 0.2$

Don’t forget to distort the lines of latitude and longitude too...

The Death Star from Star Wars (Diameter 120 km)
Give the Death Star a ‘nose’ if $k < 0$

Now that Disney has bought the rights to Star Wars...

Death Star: $\alpha = 15^\circ$, lat = $-219^\circ$, long = $195^\circ$, $k = -0.75$

Pinocchio has experienced the dark side of the Force....
An Introduction to Special Relativity

\[ \gamma = \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} \]
Light – the best understood physical phenomena
Huygens, Fresnel, Young... – the Wave model of light
Electricity & Magnetism become Electromagnetism

- Foucault and Fizeau use cunning clockwork to measure the speed of light

If light is a wave, what medium does it propagate in?

- Maxwell predicts Electromagnetic Waves, with an invariant speed $c$
- Faraday, Helmholtz, Hertz, Lorentz confirm Maxwell experimentally.

Michelson & Morely show that light can propagate in a vacuum
No “aether” is needed. “Light is not a duck”*

*A radiating hot duck in space will do just fine though. But a duck in a river is not a good model for ‘ripples’ of light

Galileo and Newton predict the motion of hamsters** between frames of reference in relative motion. Is light like a beam of hamsters?

**No hamsters were actually hurled by these great Physicists

Einstein considers his reflection in a mirror if he were to travel at the speed of light. He concludes that light is not like a beam of hamsters. (Although with help from Planck, Bohr et al he will later conclude that you can divide the energy of light into discrete quanta)

The Feynman light clock thought (Gedanken) experiment shows that moving clocks run slow in order to ensure the speed of light is constant in all frames of reference

Experiments with pions show emitted gamma rays travel at the speed of light regardless of the speed of the pion which emits them
A history of Quantum Theory
Bayes-O-Meter


P(H|T) (Probability of hypothesis true given pass of test) = 0.161

P(H'|T) (False positive) = 0.839

P(H|T') (False negative) = 0.000531

P(H'|T') (Probability of hypothesis false given fail of test) = 0.999

Thomas Bayes
1701-1761
Assume an ecosystem can support a maximum number of rabbits. Let $x$ be the fraction of this maximum at year $n$.

To account for reproduction, next year’s population is proportional to the previous.

To account for starvation, next year’s population is also proportional to the fraction of the maximum population as yet unfilled.

The population next year is predicted using this iterative equation called a logistic map:

$$x_{n+1} = rx_n (1 - x_n)$$

The pattern of $x$ values with $n$ is not always simple.....
One solution

Next bifurcation

Chaos.

\[ x_{n+1} = rx_n (1 - x_n) \]

Tracking the bifurcations maps the ‘road to chaos’. The ratio of successive bifurcation intervals is a universal constant! 4.669201609...
It turns out the ratio of successive bifurcation intervals is a universal constant!

4.669201609...

\[ x_{n+1} = r x_n (1 - x_n) \]
$r = ae^{b\theta}$
Sir James Lighthill
1924-1988
Typhoons and Hurricanes 2018

Soulik & Cimaron

Jebi

Paeng

Mangkhut

Florence

Paeng
Some concluding thoughts

Stories are a natural way of packaging ideas, making the associated methods/lessons etc memorable, relatable and contextualized.

Most students will find it tough to engage with an idea that is not placed in the context of their previous experience.

Stories interlink ideas into a tangible, and hopefully coherent, whole. They are necessarily cross-curricular.

New ideas are incorporated when the narrative demands it. This is good motivation for learning. Nobody reads a textbook cover to cover, but you can happily devour *The Hobbit/Sense & Sensibility/Bring up the Bodies*/Ulysses* in a day.

*Well maybe two  **!