New Physics Curricula

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"By applying the principles of twenty-first-century learning, educators should be able to produce scientists better prepared for the modern, multidisciplinary workforce and a more science-literate populace in general."

THE PRINCIPLES

INQUIRY BASED LEARNING

be able to reproduce - on a small scale - the scientific method (i.e. concrete physics experiments, making models and testing them). Inquiry based learning - hands-on

Encourage model building, controversial discussion, falsification of models

THE SCIENTIFIC METHOD

Observation/Experiment - Result - Creating models (math.) - Predictions - New observation/ experiment - Verification/Falsification - possible modification of the model - new predictions - etc

~~Failure~~

is a **natural** part of scientific progress; students should not be afraid of making models that are proven wrong - this happens all the time in real science!

The ‘**psychology**’ of scientists

very conservative(!)

and try to **stick** to - previously successful - models, unless they absolutely have to accept the **EVIDENCE** from new **experiments/observations**.

However, scientists are also characterized by their ability to **doubt**, **ask** questions, and their will to reproduce experiments in order to check that the results are correct.

Story telling is important!

This could also be combined with stories from the **HISTORY OF PHYSICS** tales of trial, error, and success.
Show how often scientists found the **correct answers** but had to **wait** for years (or decades) until they were **accepted** by their peers!

THOUGHT EXPERIMENTS

(such as Einstein's elevator)
are deemed to be **useful** too,
but
they require already a **good understanding** of the underlying physics.

How do we keep student **attention** over the full program?

Point out
surprising results or implications;

consider gender interest;

curricular content must be relevant
and age appropriate;

as students age
new phenomena related to previously learned ones
are presented ('spiral');

find concrete examples based on guiding principle (e.g. astronomical observations; climate change; Rosetta landing; physics in medical diagnostics/therapy).

Most **important** things to take home:

The values

Connection between experiment and theory

All natural processes have their origin in (and have to obey) **natural laws**.

Learning about physics develops logical thinking and helps to find **solution** also in daily life

All sciences -biology, chemistry, physics- are **connected** with the same laws of Nature,
just at different **length scales**
and with different ("emergent") phenomena

The content

'Basic principles' should be introduced early – later used as 'building blocks' for teaching.

The World consists of tiny, moving particles that build up increasingly complex objects.

The Universe came into existence 13.8 billion years ago and we can explain it.

Natural processes are driven by an exchange/ transformation of energy.

EXAMPLES

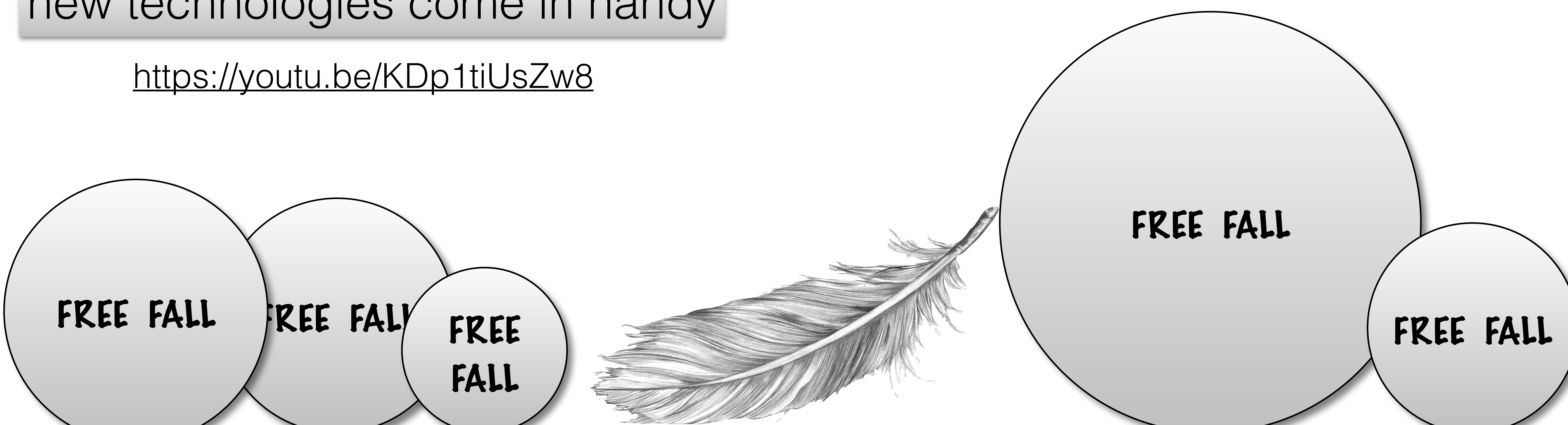
controversial discussion

falsification of models

Hands on experience

new technologies come in handy

https://youtu.be/KDp1tiUsZw8



A GREAT ANALOGY

Using **money** as an analogy for **energy**

You can have different sources or stores of money.	You can have different sources or stores of energy.
The amount of money in the store sets a limit on what you can buy.	The amount of energy in the store sets a limit on what can happen.
Money shows itself in different forms.	Energy shows itself in different forms
The spread of money sets limit on what you can buy.	The spread of energy sets limit on what can happen.
When you buy something, money is transferred from one store to another.	When something happens, energy is transferred from one store to another.
We measure money and no money is lost.	We measure energy and no energy is lost.

Kinetic theory of gases

Encourage model building

Use animations, simulations
to build imagination;
new technologies come in handy

controversial discussion,
falsification of models

Encourage students to give
short presentations
about specific topics
(e.g. 10 min) followed by discussion

THOUGHT EXPERIMENTS (such as Einstein's elevator) are deemed to be useful, too, but they require already a good understanding of the underlying physics.

SPEED OF LIGHT = constant (in vacuum)

Moving light clock (photon bounces between mirrors) - time dilation for moving system!

Time dilation: muons in cosmic rays

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Implementing such changes will not be easy — and many academics may question whether they are even necessary. Lecture-based education has been successful for hundreds of years, after all, and — almost by definition — today's university instructors are the people who thrived on it.

But change is essential. The standard system also threw away far too many students who did not thrive. In an era when more of us now work with our heads, rather than our hands, the world can no longer afford to support poor learning systems that allow too few people to achieve their goals.

The potential pay-off is large — whether it is measured by the increased number of promising students who finish their degrees in science, technology, engineering and mathematics (STEM) disciplines instead of being driven out by the sheer boredom of rote memorization, or by the non-STEM students who get first-hand experience in enquiry, experimentation and reasoning on the basis of evidence.