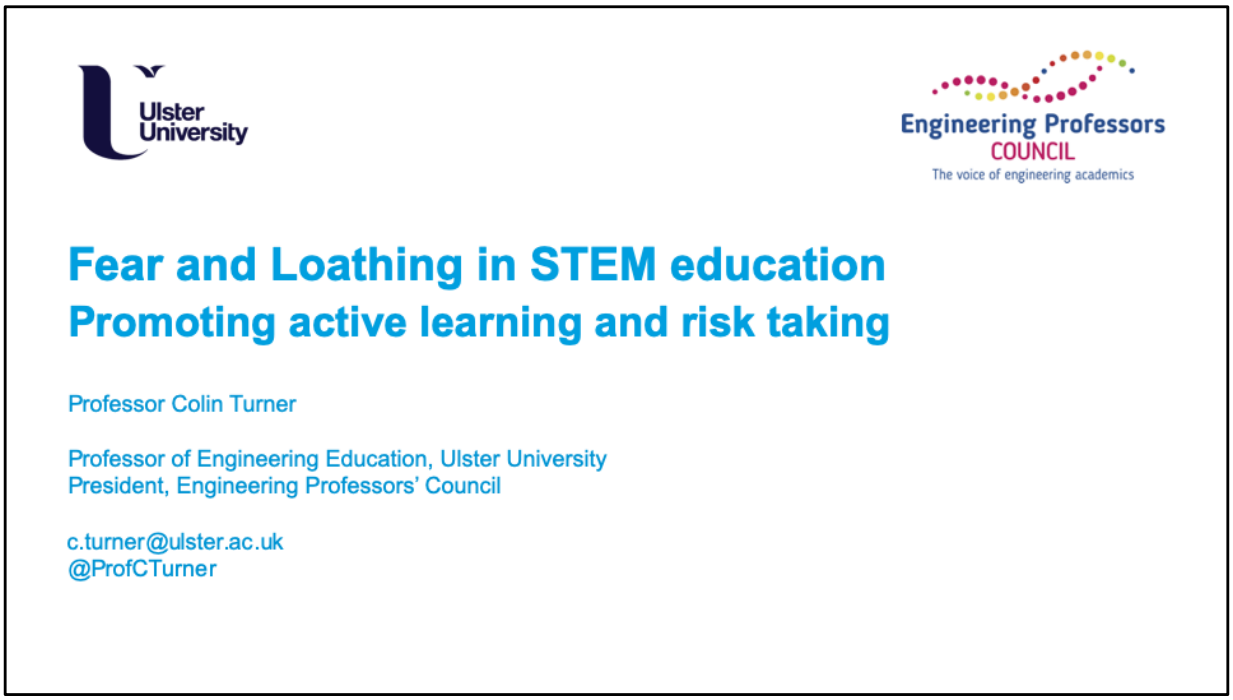


Good afternoon Everyone

I'm Colin Turner, Professor of Engineering Education at Ulster University. I am also the President of the Engineering Professors' Council

The Engineering Professors' Council (EPC) is the representative body for engineering in higher education. Our primary purpose is to provide a forum at which engineers working in UK higher education can exchange ideas about engineering education, research and other matters of common interest and to come together to provide an influential voice and authoritative conduit through which engineering departments' interests can be represented to key audiences such as funders, influencers, employers, professional bodies and Government.

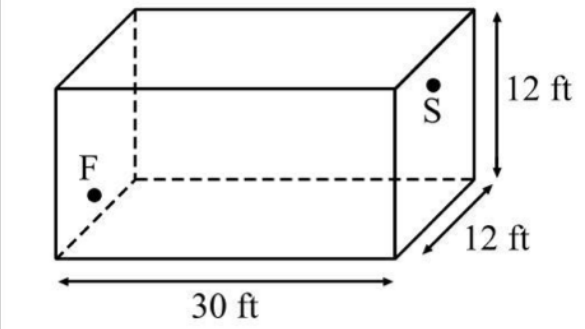
We are a unique network: all branches of engineering are represented within the membership: Aeronautical, Civil, Chemical, Electrical, Electronic, Manufacturing and Mechanical Engineering, as well as Minerals, Metallurgy and Marine Engineering and the broad areas of general engineering studies and those in which engineering is combined with a range of other topics. In some universities, frequently those where computing forms part of an Engineering School or Faculty, academic staff in

Computer Science are also members. There are currently 81 institutional members encompassing c. 7,500 academic staff (permanent FTE).

The Royal Academy of Engineering is also a member, and we work closely with the PEIs for engineering.

Time for some Active Learning!

- What is the shortest distance the spider must walk to get the fly?
- The spider stays on the walls / floor / ceiling at all times
- She walks all the way there
- She has a degree in a STEM subject



Spider centered on one wall, one foot from the ceiling.
Fly centered on opposite wall, one foot from the floor.

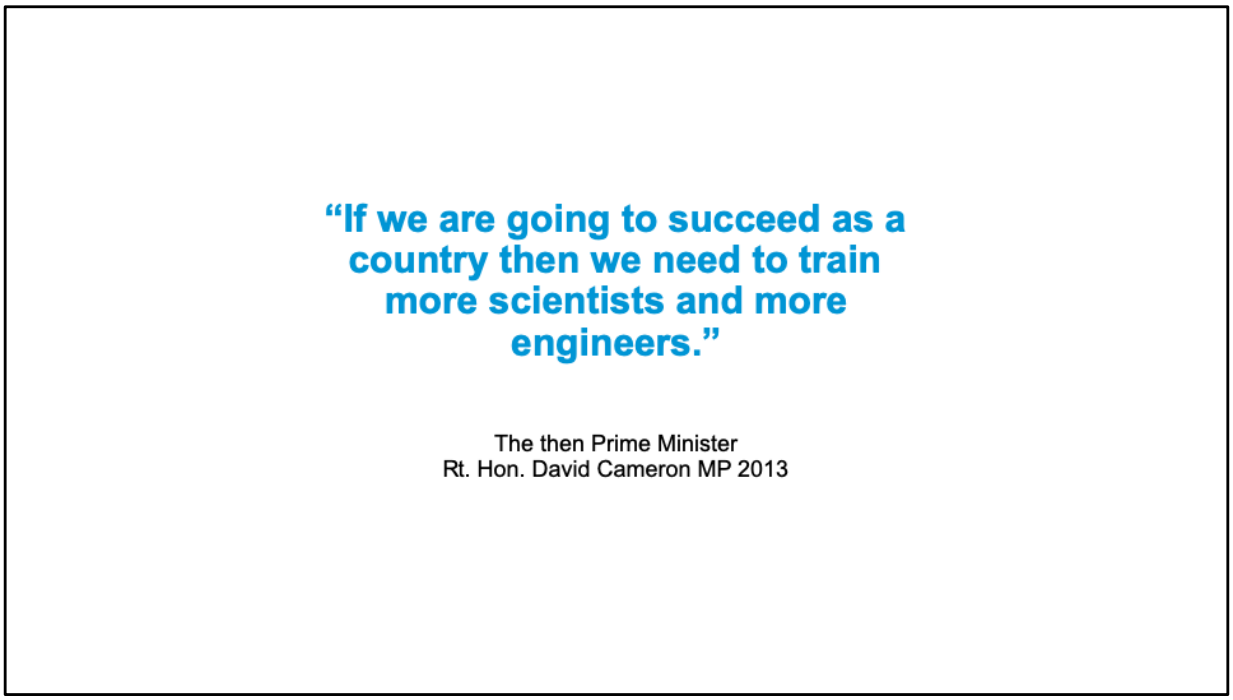
Let's start with a little active learning problem.

This is a quite old puzzle, hence you'll see it's not in SI units.

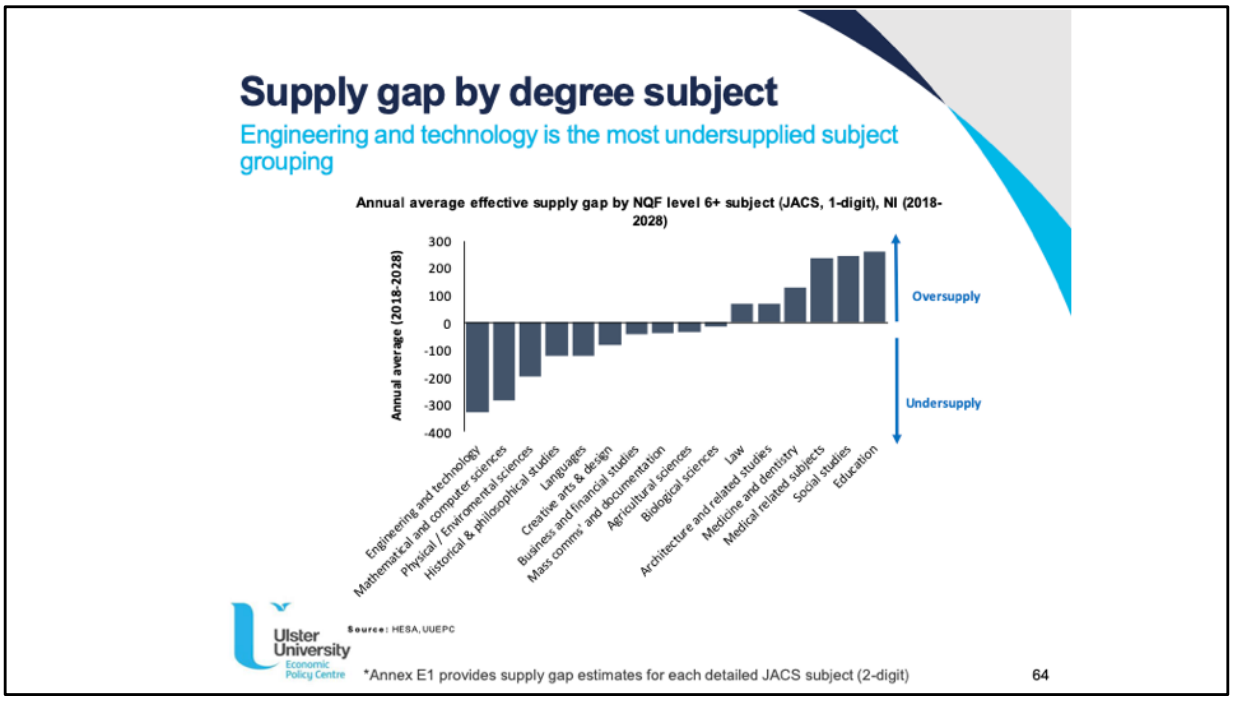
Imagine a box shaped room, 30 feet by 12 feet by 12 feet. In one of the end walls (12 ft by 12 ft) there is a Spider, 1 foot from the ceiling and in the centre of the wall, horizontally speaking. On the opposite wall, there is a fly. It is one foot from the floor but otherwise also centred horizontally.

The Spider has a degree in some mathematically literate disciple, is very hungry and wishes to walk the minimum distance to obtain the Fly, trapped in her web. She always walks along the walls, or floor of ceiling. What is the shortest distance she can travel to reach the fly?

The "obvious" answer is for her to walk to the ceiling, directly across, and walk down. That's 1 + 30 + 11 = 42. Or to walk down, across the floor and up, which is also 42 feet. But this is NOT the shortest distance. Can you improve on this?



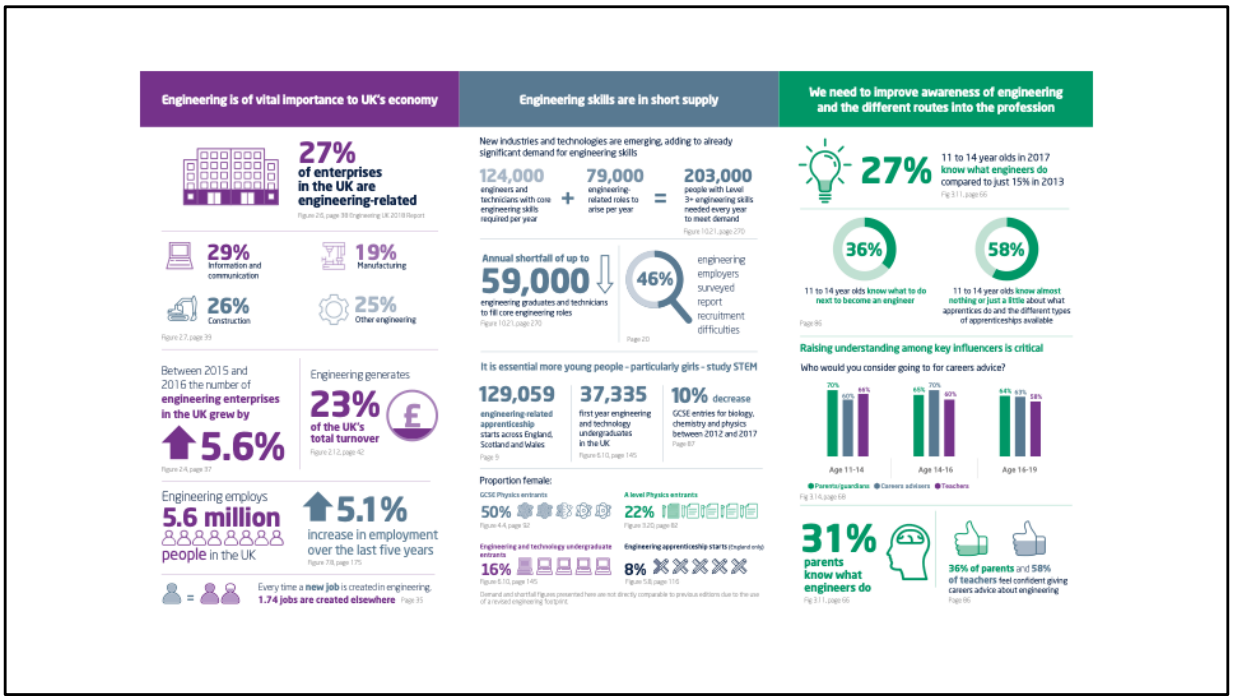
If the present company and location will forgive me, quoting politicians can be hazardous, as things can change a lot. And a great deal has changed in the UK and in Northern Ireland since 2013 but the data bears out the previous PM on this quote.



This slide is from the 2019 Northern Ireland skills barometer update - available online and well worth reading.

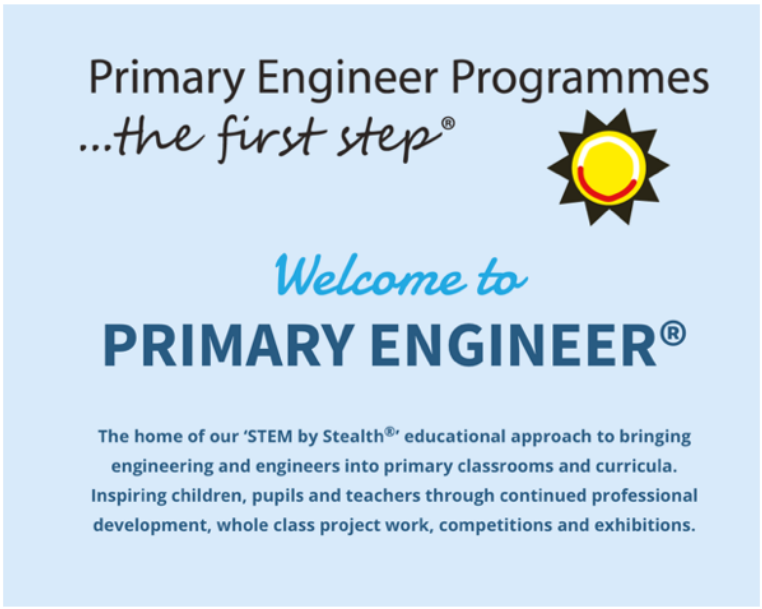
This important chart shows the gap between supply and demand in Northern Ireland as level 6 + (in other words degree level). As you can see, we have a significant issue with undersupply of graduates in particular key areas – especially STEM areas. This is despite increasing success in uptake of STEM qualifications at GCSE and 'A' Level – especially in mathematics.

But Northern Ireland needs more STEM graduates, especially with the Belfast area emerging as an important technology hub, which is not to diminish the demand elsewhere in NI. For instance there's a need to grow initiatives such as the CARL data analytics hub mainly based in Derry / Londonderry. The City Deals are set to address this, but we need to keep the pipeline going.



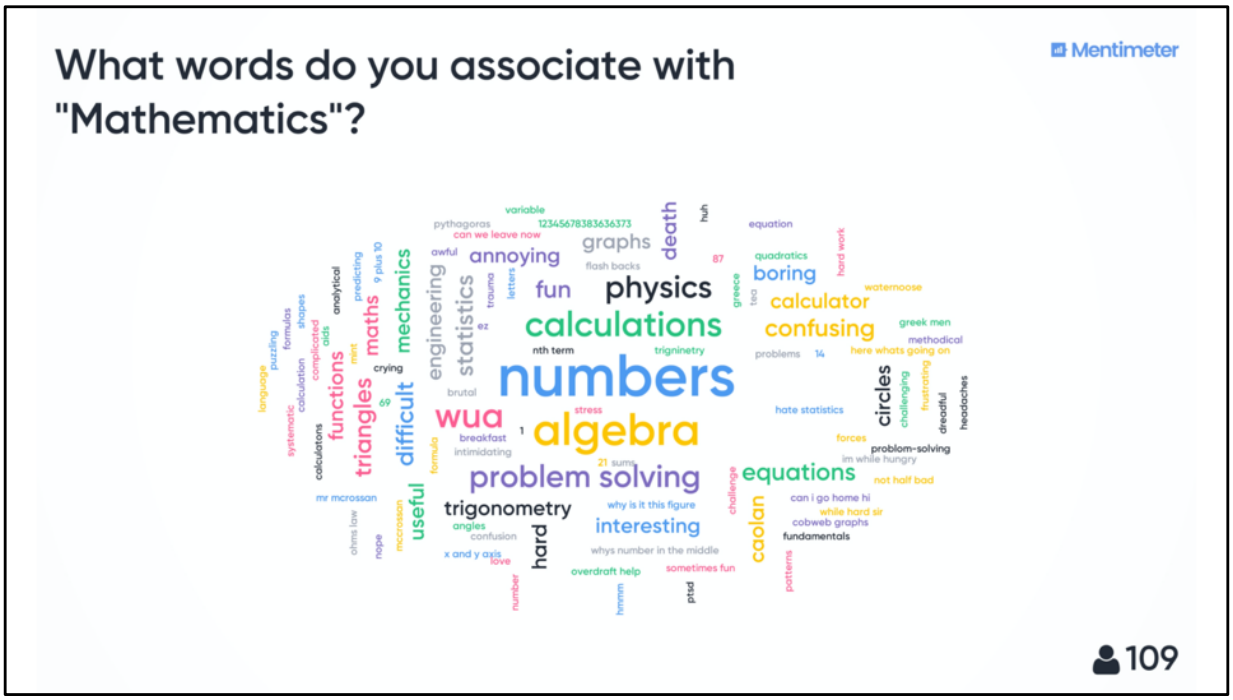
Nationally, Engineering UK produces an annual report. This is the infographic summary from the 2018 report. Again, you will note the significant under supply issue – this is made more serious by the leaky nature of the pipeline.

There is some important progress in educating young people about the nature of Engineering. Whether or not they consider it as a possible career choice, it is a national problem that so few people understand what engineering is and its importance to society and the economy. Of course, Science and Engineering live in a very important symbiosis. Science informs future Engineering and Engineering research provides the infrastructure for Science research.



At this point, I would like to just make a note about Primary Engineer and Secondary Engineer. This is an initiative, currently covering England, Scotland and Northern Ireland to ensure Primary and Secondary school pupils get to understand engineering. They interview an engineer in the School either in person or by video link – and then they enter a competition to design the product or service they would invent if they were an engineer. Some winning items are then prototyped by University partners up and down the country.

Such initiatives are important to explain the "ingenious" nature of Engineering – coming from the same word stem. Much research has shown that we need to address perceptions about STEM from an early age to have a maximum effectiveness.



But the supply pipe is very leaky. Lots of people drop out of STEM on their educational journey, especially at degree level. To make things more problematic, many STEM degrees like engineering have such excellent transferrable skills that their graduates can leave to work in non STEM sectors at the very end of their studies, or at least non engineering sectors.

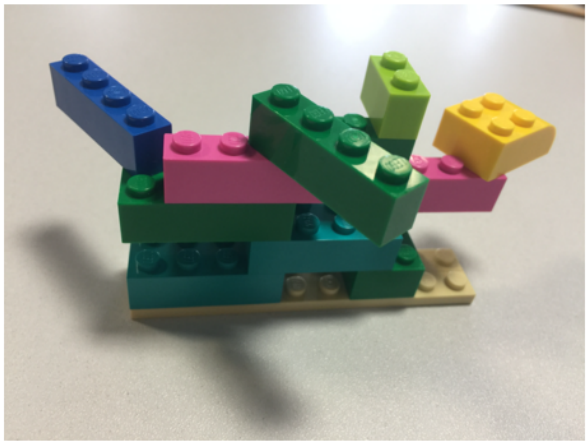
So why is this? The most prized 'A' level for admission into various degrees is Mathematics, and it could be argued (and I will argue) that in many engineering degrees, for instance, other subjects such as Physics are seen as vitally helpful, but partly because of their role as a surrogate for Mathematics – that they demonstrate strong analytical skills.

But we can't solve the engineering supply problem alone, let alone the rest of STEM by requiring 'A' level mathematics for all engineering degrees. And even it we do, it doesn't mean there aren't problems.

This word cloud is taken from a real class of first year engineers – studying a highly mathematical discipline. Setting aside the joke answers – and a shout out to Mr McCrossan whoever we is – some things are quite interesting. First that the

perception is that mathematics is about “numbers” which it really is not - any more than English literature is about “letters” – we can see some interesting words : “boring”, “crying”, “death”, “trauma”, “ptsd”, “confusion”, “awful” and “nope”.

This isn’t the whole story, but why does mathematics provoke so much fear?

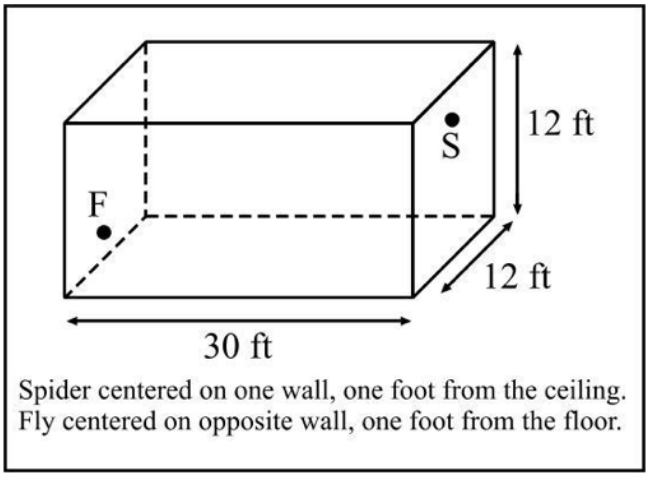


This is my output from a LEGO serious play session. I recommend such activities to you if you haven't tried them. I was asked to represent my thoughts about engineering education in maths.

This is my analogy – what should be a fairly solid structure – a student's mathematical understanding often has significant holes in it, as well as all sorts of extraneous bits and pieces that probably don't contribute much.

Mathematics is a profoundly logical, cumulative subject and is very prone to cause problems for students when some important fundamental has been overlooked or poorly understood.

How are you getting on?



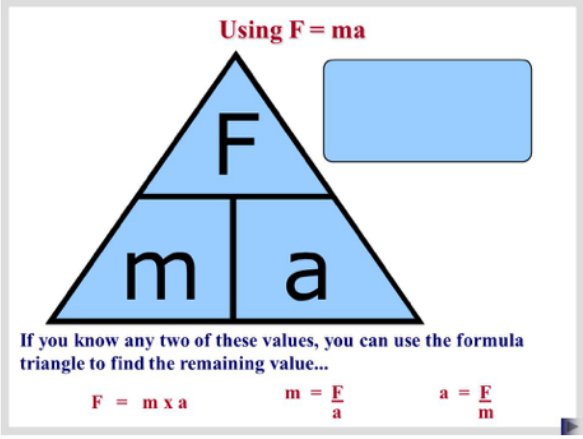
Spider centered on one wall, one foot from the ceiling.
Fly centered on opposite wall, one foot from the floor.

How are you getting on? Do you need a hint?

I'd normally give my students a number of hints, but we're short on time so I'll switch to the big one.

If you do, you might want to consider that the puzzle looks to you as a three dimensional problem. But the Spider lives really in a two dimensional system – she only stays on the surfaces of the walls, floors and ceiling. Does that help?

Short Term Fixes can Make Long Term Problems



I believe that one of the biggest problems we face in our current education system is that we often lose focus on the biggest picture of skills development, in favour of surrogate measures – exam marks, league tables and the like.

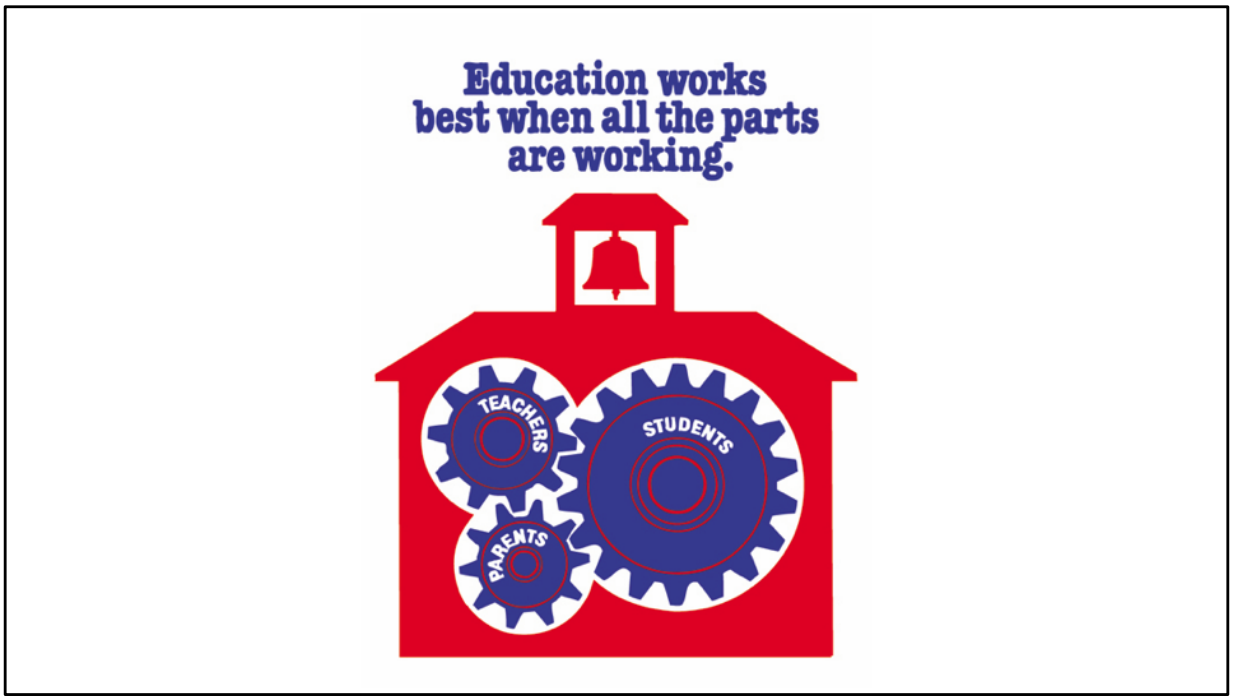
Take this diagram. About half my students are taught Newton's second law of motion, using this triangle. But this triangle is really a way of avoiding the fundamental understanding of algebra needed to rearrange an equation.

If we use short cuts like this, students begin to see things like algebra as something unpleasant, mysterious and difficult and to be avoided. Rather than an 1000 year old Arabic technology that makes discussion of STEM problems immeasurable easier.

This kind of short cut does damage in my opinion – if we take the time to explain what is really going on, we deepen understanding. Otherwise we reduce mathematical understanding to countless rules of thumb, each of which only works in their own narrow and particular circumstances – and which obscures the simpler (not necessarily easier) and more profound truth below.

There's nothing wrong with shortcuts taken by students as such, but it helps when

they have discovered them for themselves.

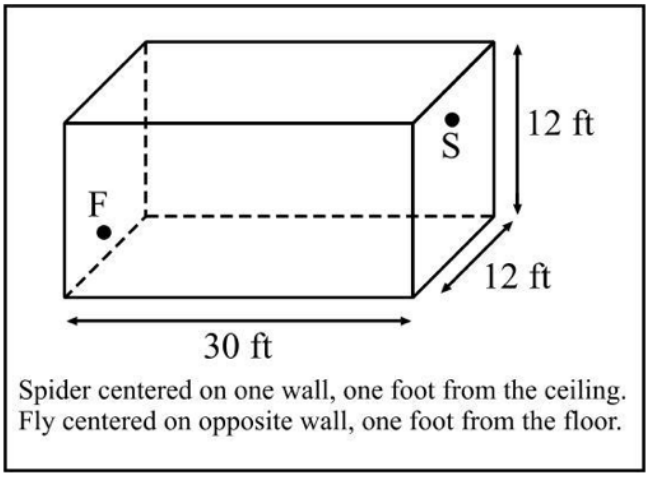


When I first saw a photo of this educational poster someone had taken I assumed it was intended as a biting satire. But apparently not as I found the website where it's for sale. Undoubtedly well intentioned, the design is someone hampered by the fact that the cogs shown would oppose each other to bring this system to a complete halt.

But in a way it makes a more profound point, if these cogs represented Higher Education, Industry and Primary and Secondary Education it shows that good intentions aren't always enough for a proper pipeline.

Schools and Universities alike have improved performance in many key metrics. A significant proportion of this has been through a much clearer and transparent explanation of assessment. This reduced the effect of privilege and allows students to have a much clearer idea of what success looks like. It probably has the unintended consequence that they focus more on the criteria for success than the task.

How are you getting on?



Spider centered on one wall, one foot from the ceiling.
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I believe this failure to promote deeper understanding leads in turn to confusion and indeed fear.

Students too are concentrating on surrogate goals rather than the real thing. Many are increasingly focused on their grades first and their learning second. These two things combined can make them fearful of unknown scenarios – and hesitant to act if they can't see a clear route to a successful outcome from the start.

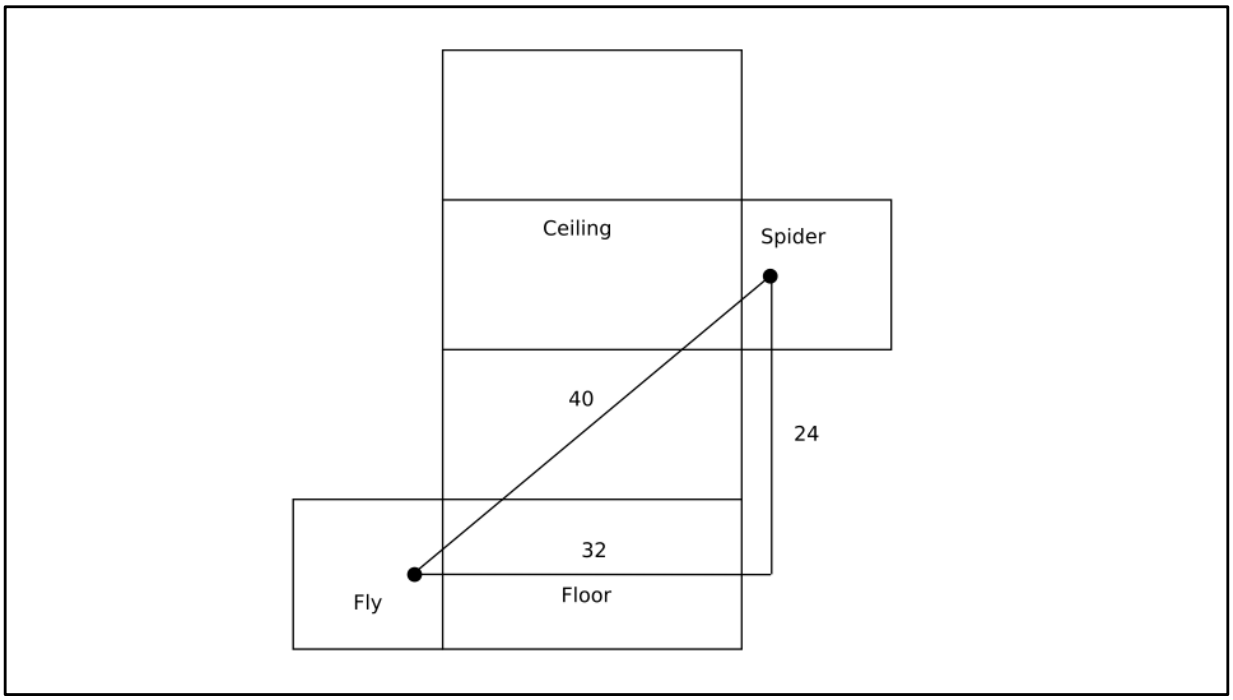
But we of all people understand the important of experimentation, and of the serendipity of mistakes. We learn most from the things that go a bit wrong, oftentimes.

So what is the antidote? I believe we need to encourage students back to the mind state they often enjoyed in Primary Education, where playfulness was seen as a profoundly important part of their education. Where the freedom to make mistakes (in a controlled setting) was a vital part of the process and they didn't feel penalized by this.

So more active learning can be a part of this, but also we need to design assessment

so that failure is not just flatly punished – especially if students can express the reflection and improvement that came from this. In other words, that we use assessment for learning and not just of learning.

These aren't really new ideas, but it's pretty clear we aren't applying them as successfully as we could and must.



Here's the solution for the puzzle. It only really gets arrived at after lots of blind alleys, approaches taken that didn't work. Yet each of those approaches was vital for the end solution.

Another notable metaphor here is that this solution is a straight line between the start and finish. The thing is ... There's more than one possible straight line, and this non obvious one turns out to be the best. Letting our students see that there is, in real discovery in Science and Engineering an untidy history of exploring dead ends before we find the final solution.

We need to allow our students the freedom to explore – the activity to help them deepen understanding, and teach them not to fear mistakes so that they improve their core skills and knowledge, with their other metrics merely being a side effect of this.

Ulster University

Engineering Professors COUNCIL
The voice of engineering academics

Thank you...

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