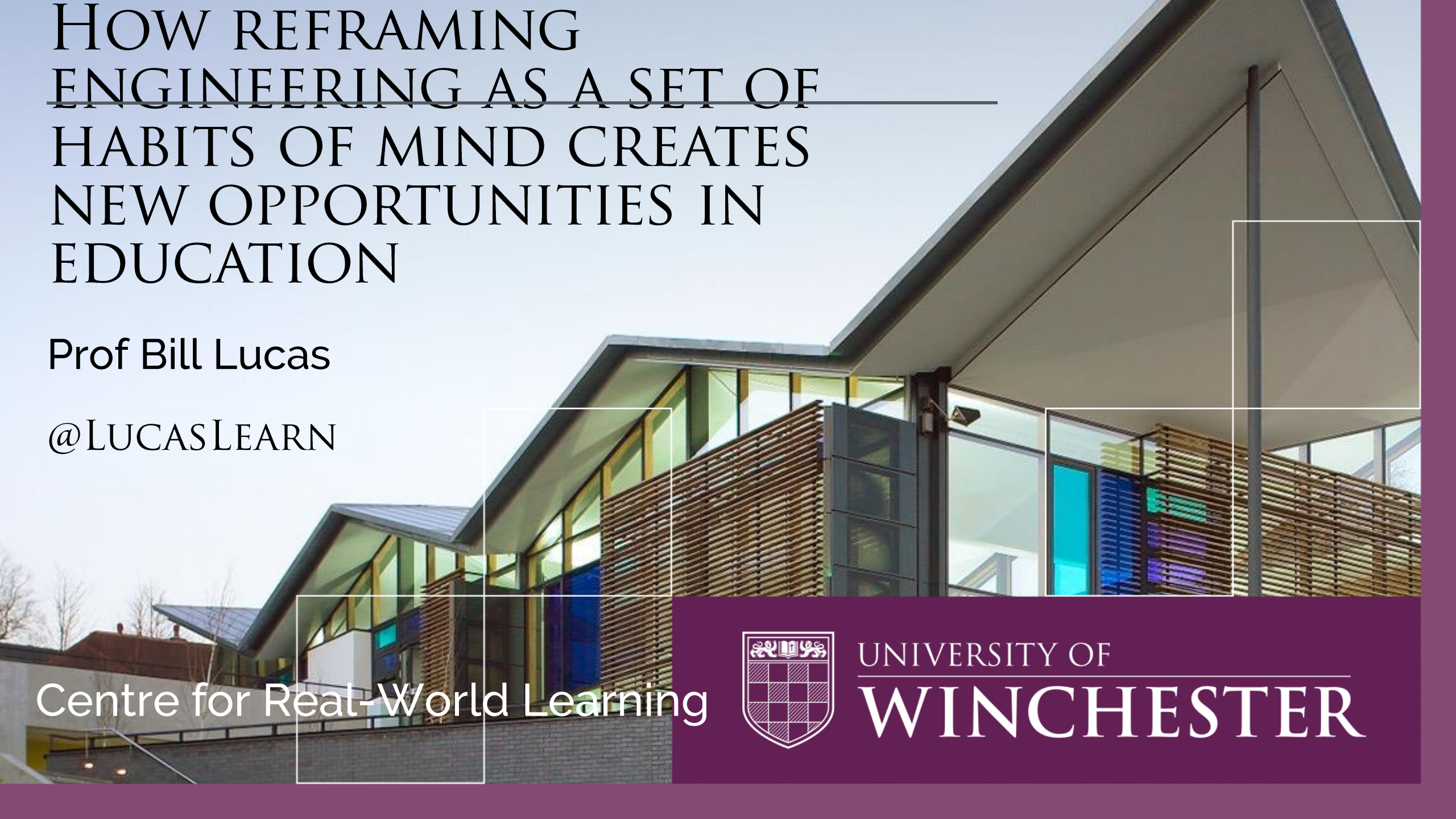
How reframing engineering as a set of habits of mind creates new opportunities in education

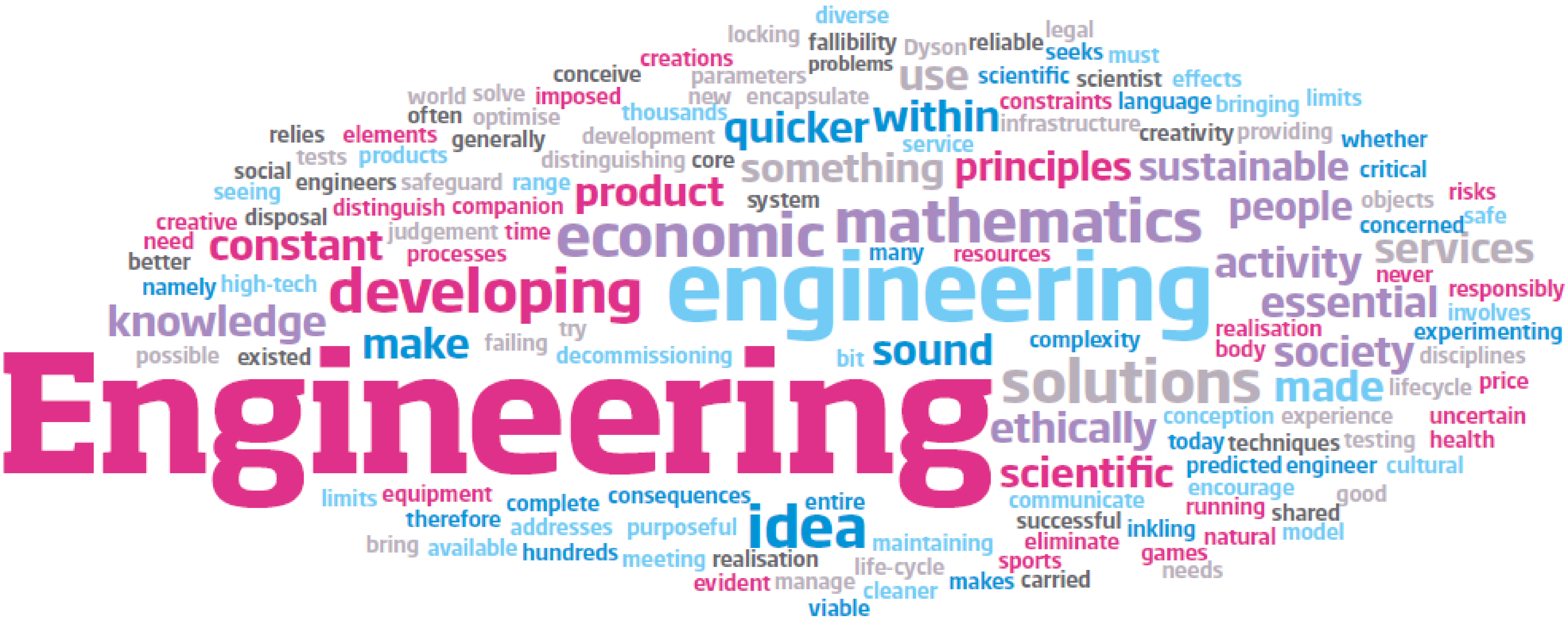
Prof Bill Lucas

@LucasLearn



Centre for Real-World Learning

University of Winchester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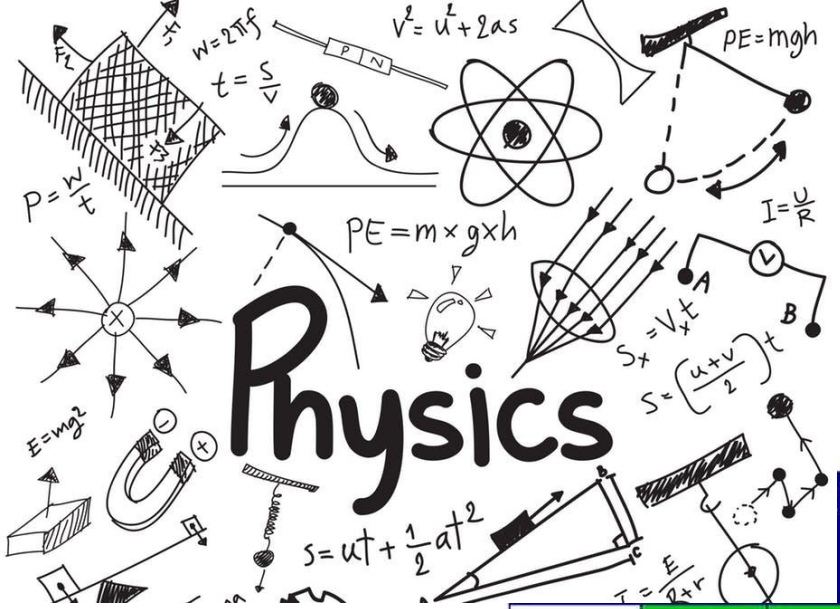

Year 8 Timetable 2016-2017

	3	BREAK 11-11.115	4	5	6	7	LUNCH 1.15-1.55	
MON	MATHS M3	ENG M6	B	ENG M6	HIST M7	HIST M7	RE M4	L
TUES	ENG M6	DRAMA R10	R	DRAMA R10	PE YAN	PE YAN	SCI SC2	U
WED	MATH	RE M4	E	RE M4	CARTE1	FRE R8	FRE R8	N
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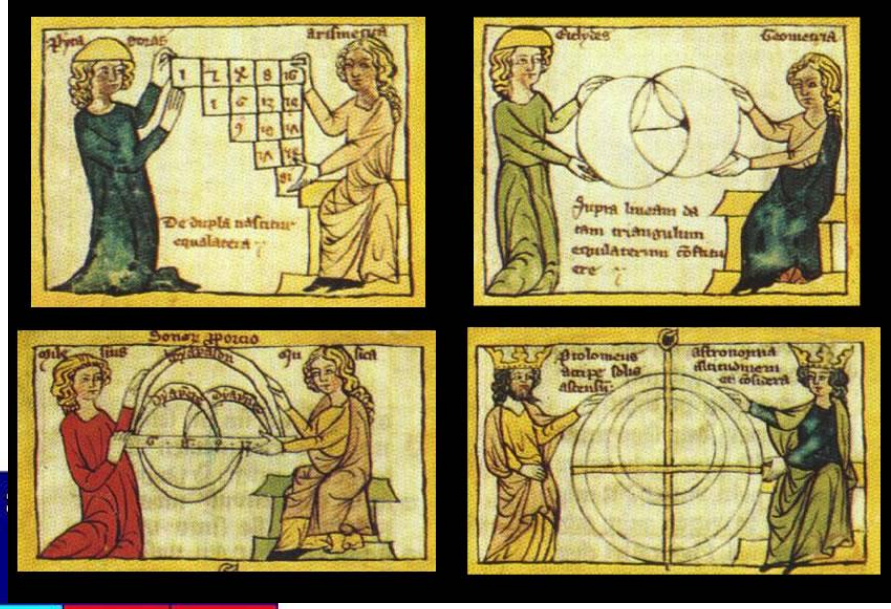
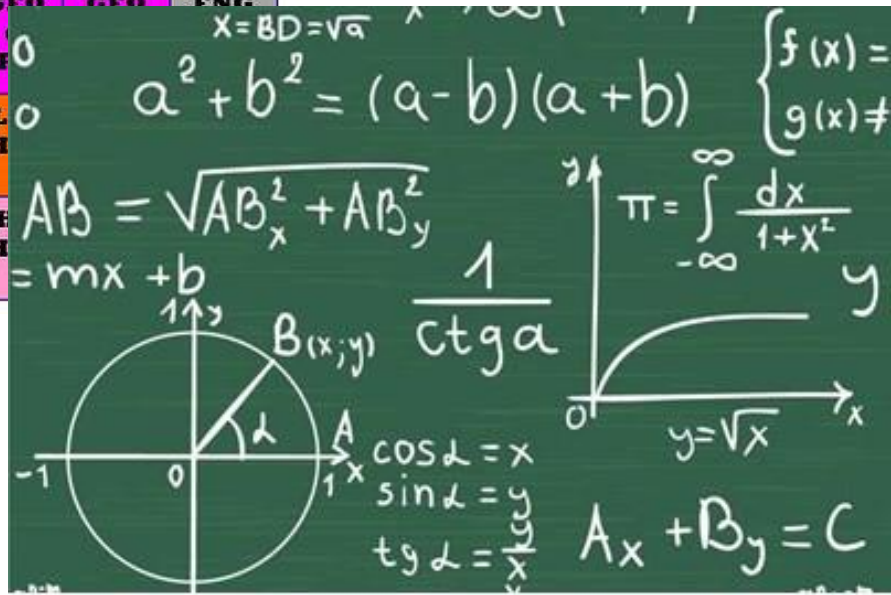




Schools accused of stifling skills of would-be engineers

Greg Hurst Education Editor

Britain's shortage of skilled engineers has been blamed on schools snuffing out a natural instinct among children to design, make and fix things.

Lessons should instead encourage "messy" learning in which children confront practical problems, design prototypes and tinker with them to improve their designs, a report by the Royal Academy of Engineering said.

The engineers urged teachers, especially in primary schools, to allow children to work on projects over several weeks spanning several subjects, such as maths, science, computing and technology, so they could learn to "think like an engineer".

Engineers account for only 8 per cent of the British workforce but employers say they will need more than 1 million new professionals qualified in maths, physics, and design to work in engineering occupations by 2020.

But the report, published today, says the answer should be a more fundamental re-think of the approach to practical and creative learning.

The call was backed last night by Sir James Dyson, one of Britain's most prominent inventors and designers.

He said: "Young people can learn about algebra, angles and forces in the classroom but it's not until they are exposed to industry-relevant equipment that they grasp what engineering is really about."

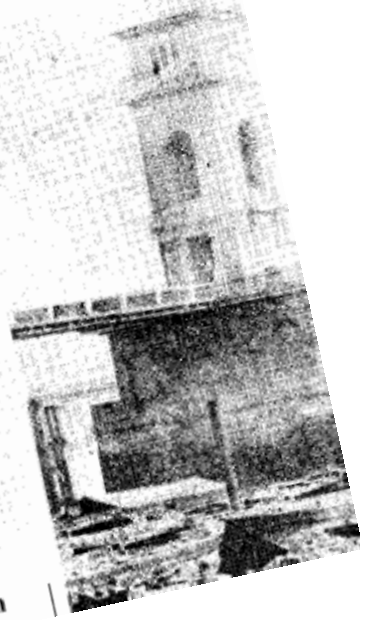
The report found that children, by nature, share many key attributes with engineers, such as creative problem-solving, but they are discouraged by formal classroom teaching.

"Young children are little engineers. Yet the primary school system almost extinguishes any opportunities for them to flourish as engineers," it said.

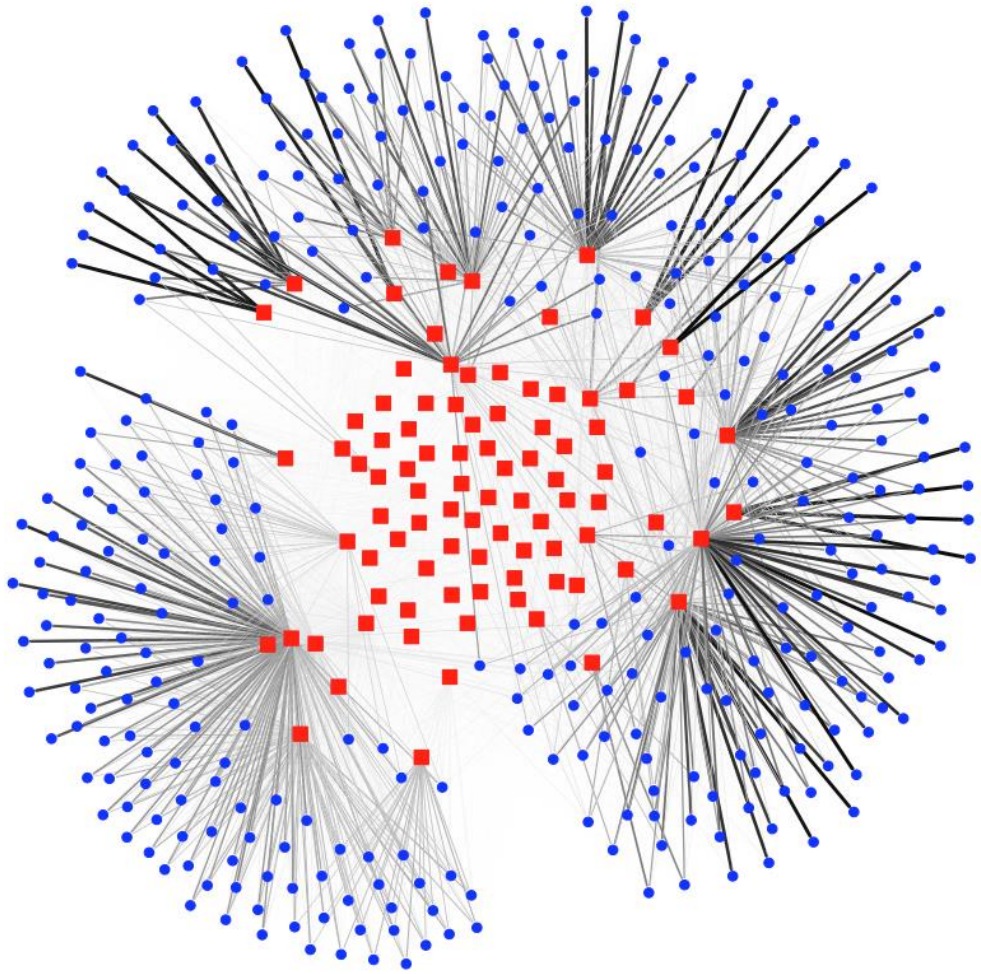
Bill Lucas, professor of learning at the University of Winchester, called on teachers to use the new national curriculum, to be introduced from September, to implement engineering concepts. Asked if such learning could lack rigour, he replied: "Problem-based learning comes from the training of doctors in North America."

"When it is done well — rigorously planned, monitored, supported, structured — it is one of the most effective ways of learning complex concepts."

Brunel's bridge caught on camera by photo pioneer



A rare 19th- | Henry Fox Talbot in



The potential of (re)framing engineering in schools

1. How do engineers think and act?
2. How best can the education system develop learners who think and act like engineers?

The idea of Habits of Mind

‘Intelligence is the habit of persistently trying to understand things and make them function better. Intelligence is working to figure things out, varying strategies until a workable solution is found… One’s intelligence is the sum of one’s habits of mind.’

Lauren Resnick (1999). Making America Smarter. *Education Week Century Series*. 18(40), 38-40

Mathematical Habits of Mind

Figure 2 - Mathematical habits of mind

Students who think like mathematicians should be:

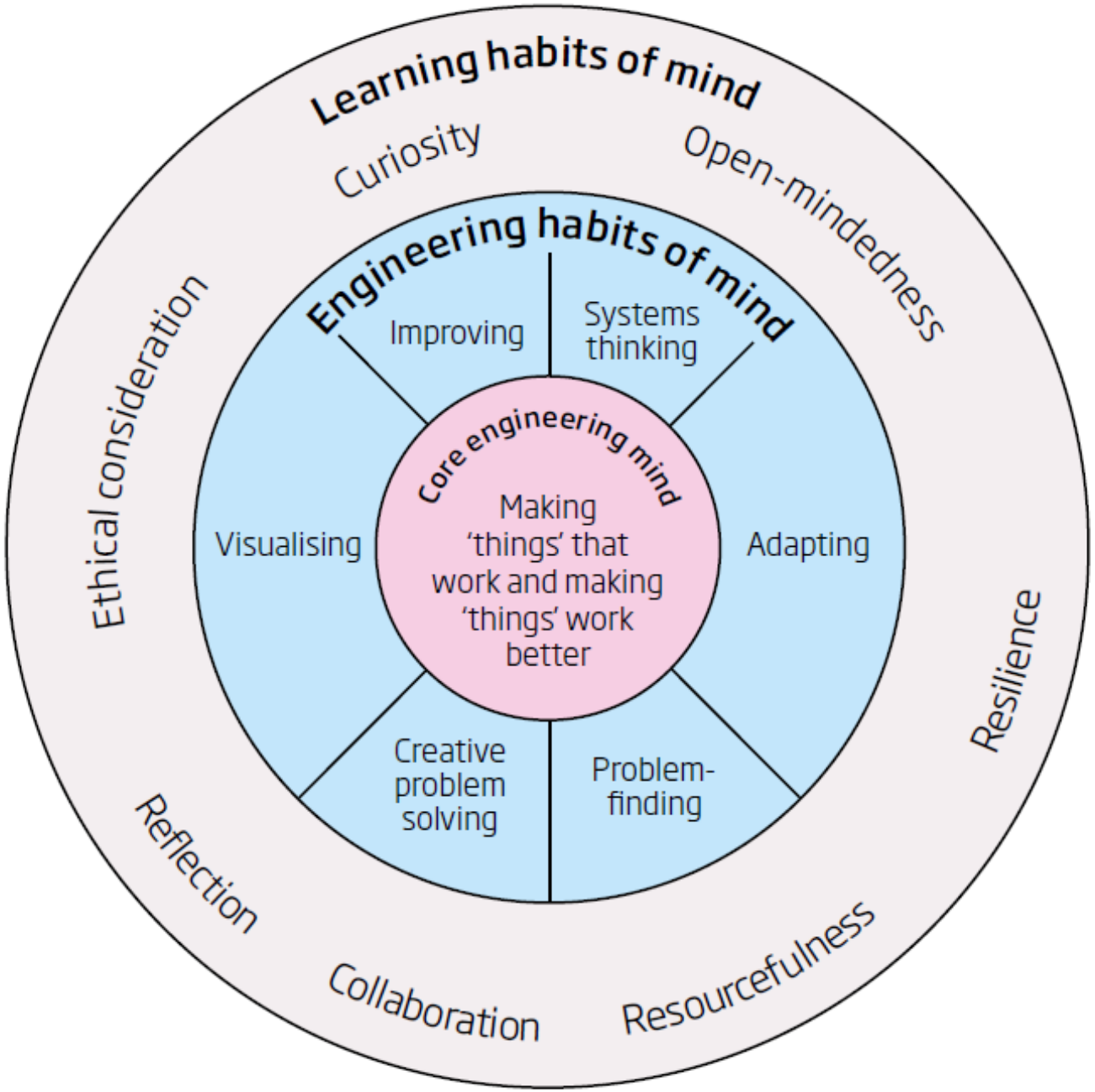
Pattern sniffers	Always on the lookout for patterns and the delight to be derived from finding hidden patterns and then using shortcuts arising from them in their daily lives
Experimenters	Performing experiments, playing with problems, performing thought experiments allied to a healthy scepticism for experimental results
Describers	Able to play the maths language game, for example, giving precise descriptions of the steps in a process, inventing notation, convincing others and writing out proofs, questions, opinions and more polished presentations
Tinkerers	Taking ideas apart and putting them back together again
Inventors	Always inventing things – rules for a game, algorithms for doing things, explanations of how things work, or axioms for a mathematical structure
Visualizers	Being able to visualize things that are inherently visual such as working out how many windows there are on the front of a house by imagining them, or using visualization to solve more theoretical tasks
Conjecturers	Making plausible conjectures, initially using data and increasingly using more experimental evidence
Guessers	Using guessing as a research strategy, starting with a possible solution to a problem and working backward to achieve the answer.

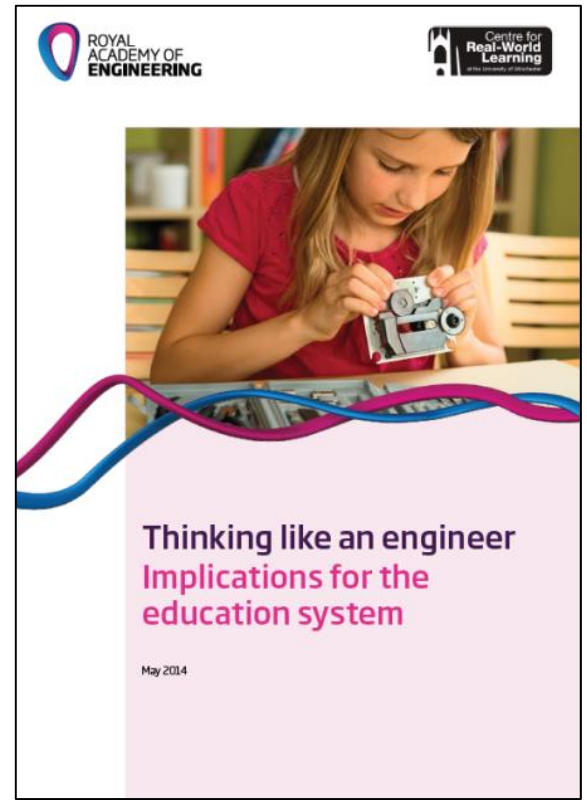
Adapted from Cuoco et al 1996

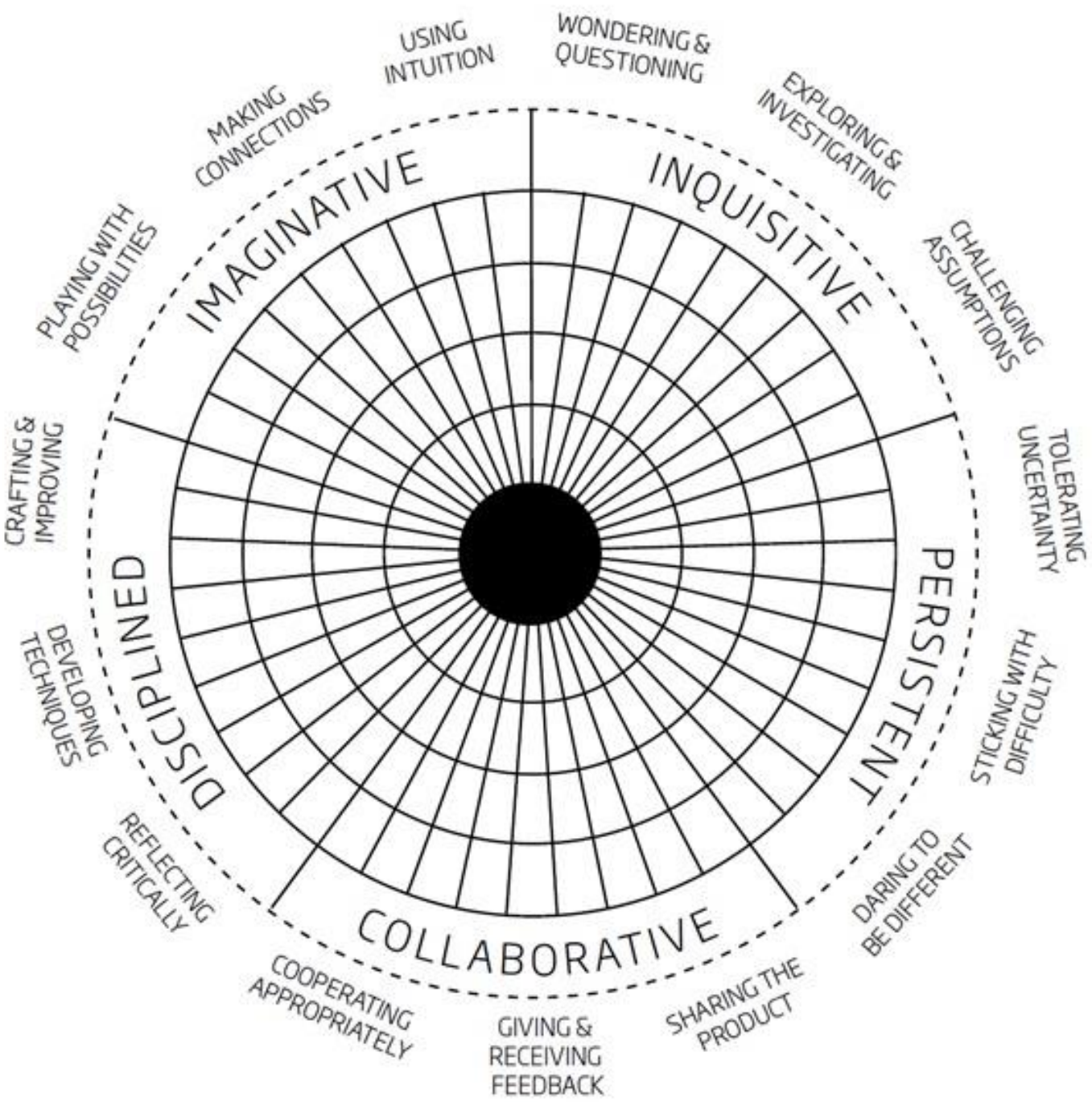
Scientific Habits of Mind

Figure 3 – Scientific habits of mind	
Open-mindedness	Being receptive to new ideas, prepared to consider the possibility that something is true and willing to change ideas in the light of evidence
Scepticism	Using critical questioning, adopting a critical appraisal approach, only according provisional status to claims until proved otherwise
Rationality	Appealing to good reason and logical arguments as well as a need to revise arguments in the light of evidence and argument
Objectivity	Adhering to accepted modes of inquiry in different disciplines and recognising the need to reduce the idiosyncratic contributions of the investigator to a minimum and always looking for peer scrutiny and replication of findings
Mistrust of arguments from authority	Treating arguments sceptically irrespective of the status of the originator
Suspension of belief	Not making immediate judgements if evidence is insufficient
Curiosity	Demonstrating a desire to learn, inquisitiveness and a passion for discovery

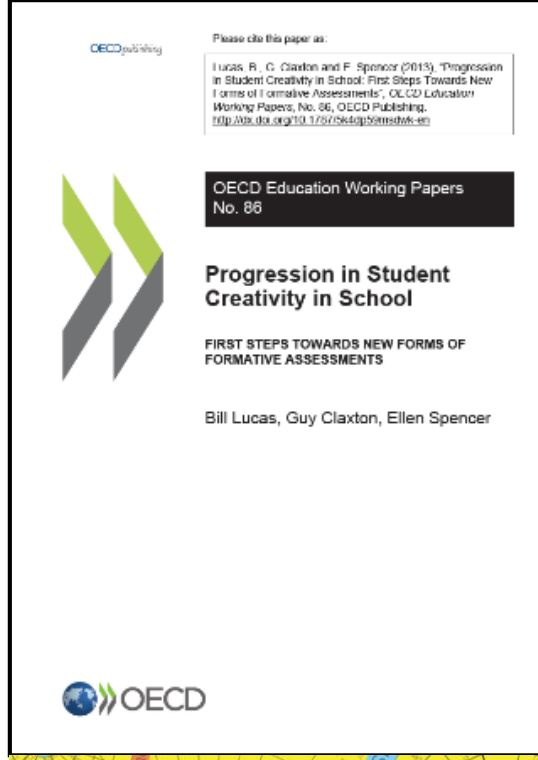
Adapted from Çalik and Coll, 2012


Learning habits of mind
Curiosity
Open-mindedness
Ethical consideration
Resilience
Reflection
Collaboration
Resourcefulness
Engineering habits of mind
Improving
Systems thinking
Visualising
Adapting
Creative problem solving
Problem-finding
Core engineering mind
Making 'things' that work and making 'things' work better


ROYAL ACADEMY OF ENGINEERING
Centre for Real-World Learning
Thinking like an engineer
Implications for the education system
May 2014


USING INTUITION
WONDERING & QUESTIONING
EXPLORING & INVESTIGATING
CHALLENGING ASSUMPTIONS
TOLERATING UNCERTAINTY
STICKING WITH DIFFICULTY
DARING TO BE DIFFERENT
SHARING THE PRODUCT
GIVING & RECEIVING FEEDBACK
COOPERATING APPROPRIATELY
REFLECTING CRITICALLY
DEVELOPING TECHNIQUES
CRAFTING & IMPROVING
PLAYING WITH POSSIBILITIES
MAKING CONNECTIONS
IMAGINATIVE
INQUISITIVE
PERSISTENT
COLLABORATIVE
DISCIPLINED

OECD
PISA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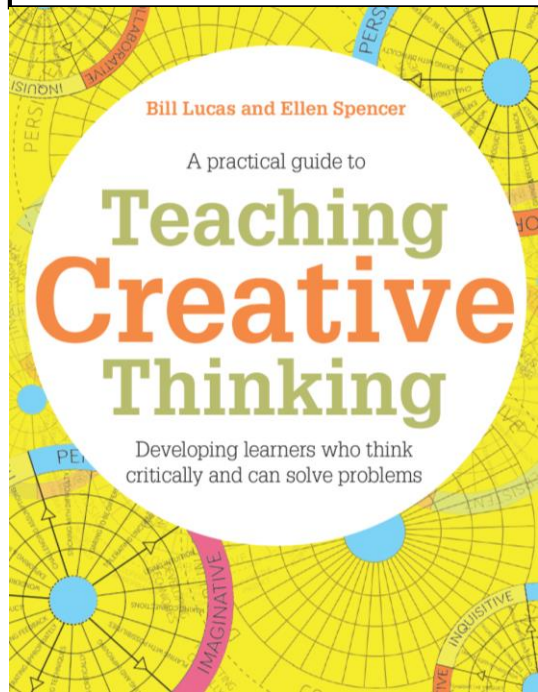
http://dx.doi.org/10.1787/5k4dp59msdwk-en
OECD Education Working Papers
No. 86
Progression in Student Creativity in School
FIRST STEPS TOWARDS NEW FORMS OF FORMATIVE ASSESSMENTS
Bill Lucas, Guy Claxton, Ellen Spencer
OECD


Bill Lucas and Ellen Spencer
A practical guide to
Teaching Creative Thinking
Developing learners who think critically and can solve problems

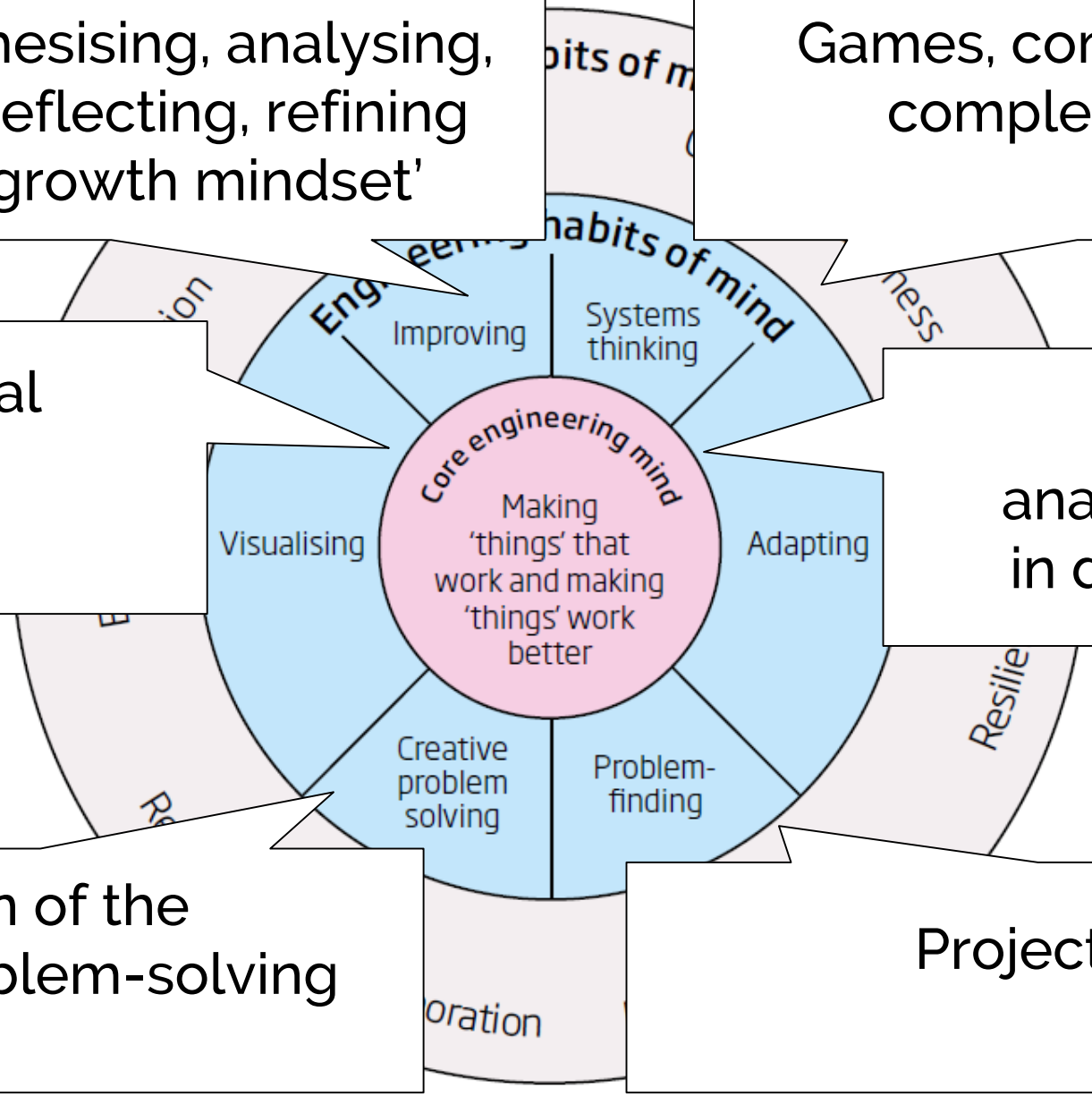
OECD 2030 Framework for Education

The idea of signature pedagogy
What might it be for engineering?

Lee Shulman (2005) Signature pedagogies in the professions. *Daedelus,* 134, 52-59

Planning, hypothesising, analysing, experimenting, reflecting, refining – developing a 'growth mindset'

Games, computer modelling, complex simulations, role playing



Modelling, mental rehearsal, infographics storyboarding

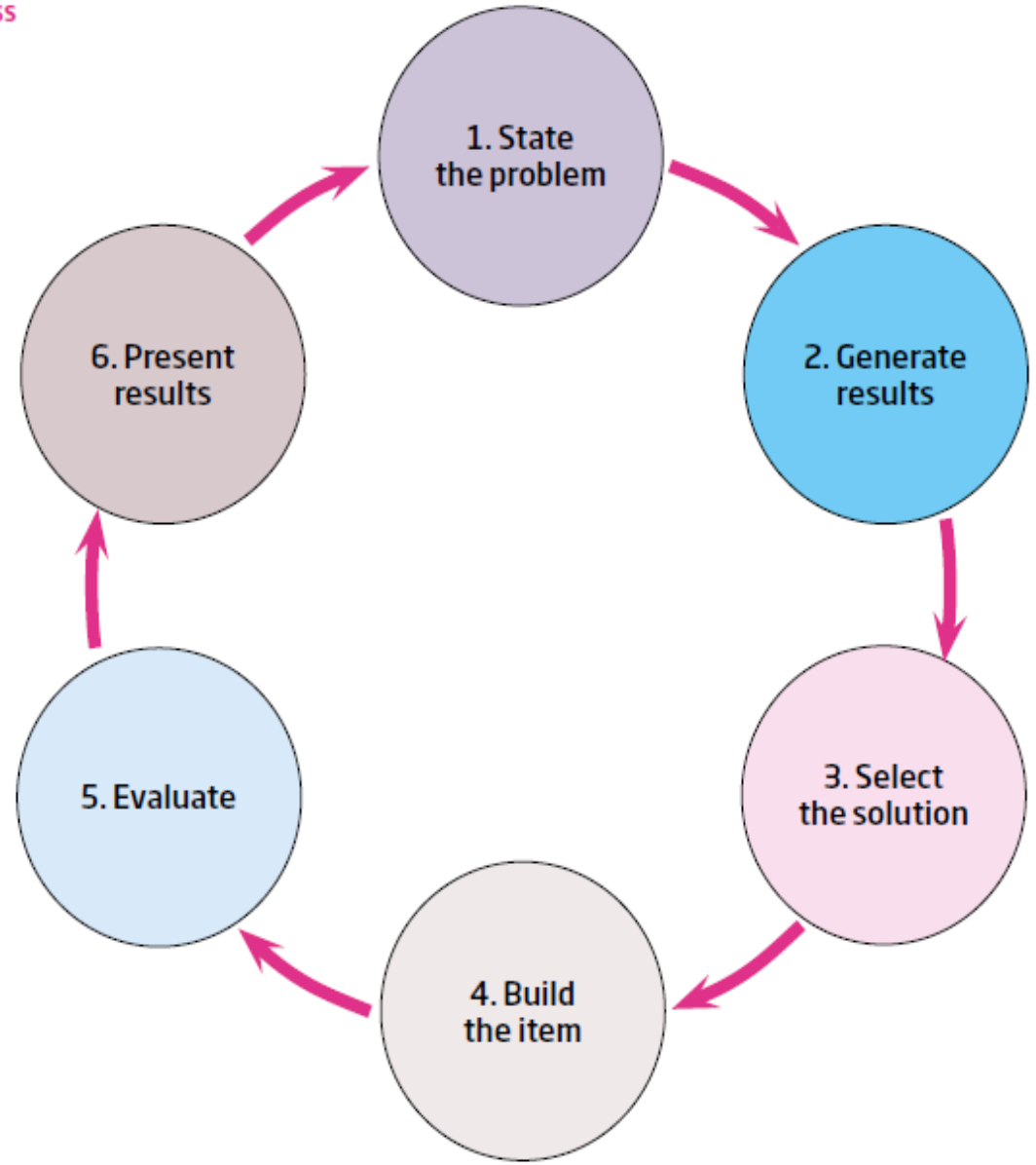
Reframing, analysing, practising in different contexts

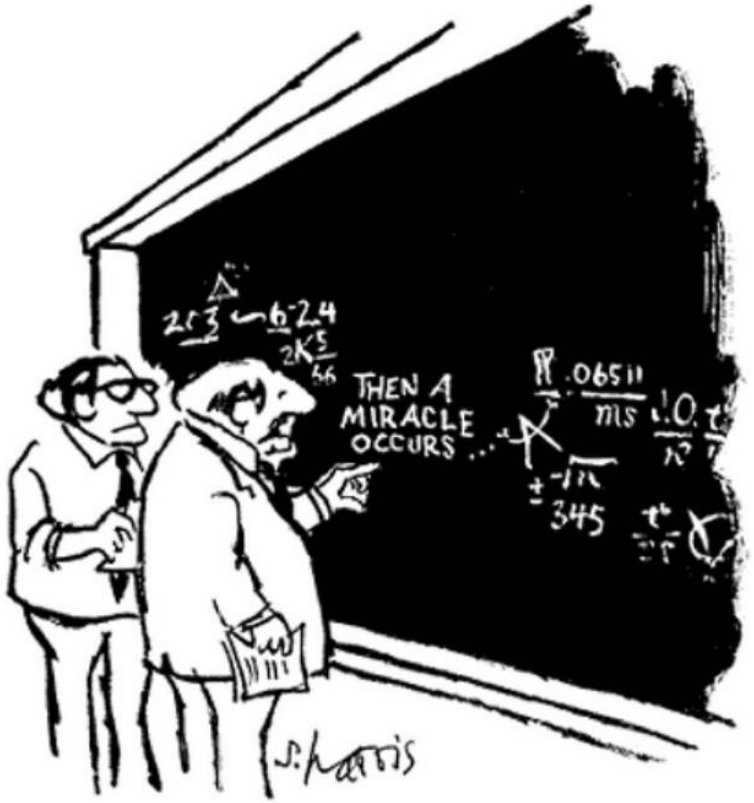
Deep exploration of the engineering problem-solving cycle

Project-based learning, thinking routines

Figure 13 - The engineering design process

Source - NASA[143]





‘I think you should be more explicit about how the miracle occurs…’

If we

- reframe engineering education to include desirable engineering habits of mind (EHoM) in addition to subject knowledge, and
- clearly articulate the principles and practices through which these EHoM can be cultivated in schools, and
- offer teachers targeted support for changing practices along with opportunities to co-design enquiries within the context of a reflective professional learning community

Then

- we can better understand what school leaders and teachers need to do to change their practices to embed more effective engineering education

So that

- we can share this understanding widely, and
- more effectively support the process of successful implementation of engineering education in schools

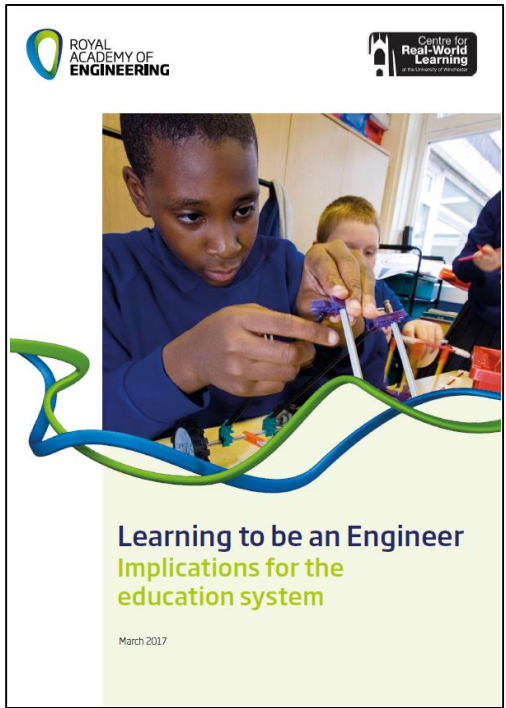
So that

- more schools embrace engineering, and
- more school students have high-quality experiences of engineering education, and
- more students choose to study engineering beyond school and, potentially, choose careers in engineering.

MANCHESTER 1824

The University of Manchester

Primary Engineer®



Four principles for cultivating EHoM

1. Develop understanding of the habit
2. Create climate for it to flourish
3. Choose signature pedagogies to cultivate them
4. Build learner engagement



EHoM	Sub-habit 1	Sub-habit 2
CREATIVE PROBLEM-SOLVING is … Generating ideas and solutions by applying techniques from different traditions, critiquing, giving and receiving feedback, seeing engineering as a 'team sport'	**Generating ideas:** comes up with suggestions in a range of situations	**Working in team:** has good people skills to enable idea and activity sharing; good at giving and receiving critique/feedback
IMPROVING is … Making things better by experimenting, designing, sketching, guessing, conjecturing, thought-experimenting, prototyping	**Experimenting:** makes small tests or changes; sketching, drafting, guessing, prototyping	**Evaluating:** making honest and accurate judgments about 'how it's going'; comfortable with words and numbers as descriptors of progress
PROBLEM-FINDING is … Deciding what the actual question is, finding out if solutions already exist by clarifying needs, checking existing solutions, investigating contexts, verifying, thinking strategically	**Checking and clarifying:** questions apparent solutions methodically and reflectively	**Investigating:** has a questioning, curious and, where appropriate, sceptical attitude
ADAPTING is … Making something designed for one purpose suitable for another purpose, by converting, modifying, transforming, adjusting, changing, re-shaping, re-designing, testing, analysing, reflecting, rethinking	**Critical thinking:** analyses ideas, activities and products; able to defends their own thoughts and ideas in discussion and also to change their mind in light of evidence	**Deliberate practising:** disciplined; able to work at the hard parts
VISUALISING is … Seeing the end product, being able to move from abstract ideas to concrete, manipulating materials, mentally rehearing practical design solutions	**Thinking out loud:** puts 3D ideas into words as they become pictures or rehearses possible lines of thought or action	**Model-making:** moves between abstract and concrete, making models to capture ideas
SYSTEMS-THINKING is … Seeing connections between things, seeking out patterns, seeing whole systems and their parts and how they connect, recognising interdependencies, synthesising	**Connecting:** looks for links, connections, relationships; working across boundaries	**Pattern-making:** uses metaphors, formulae, images etc. to find patterns to illustrate new meaning

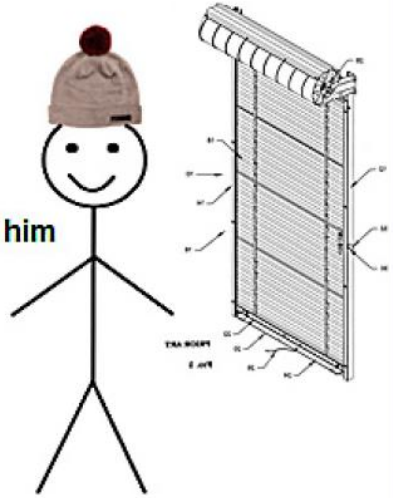
This is Bill.

Bill is a problem finder.

Bill questions the world around him and verifies what is known.

Bill is an Engineer.

Be like Bill.



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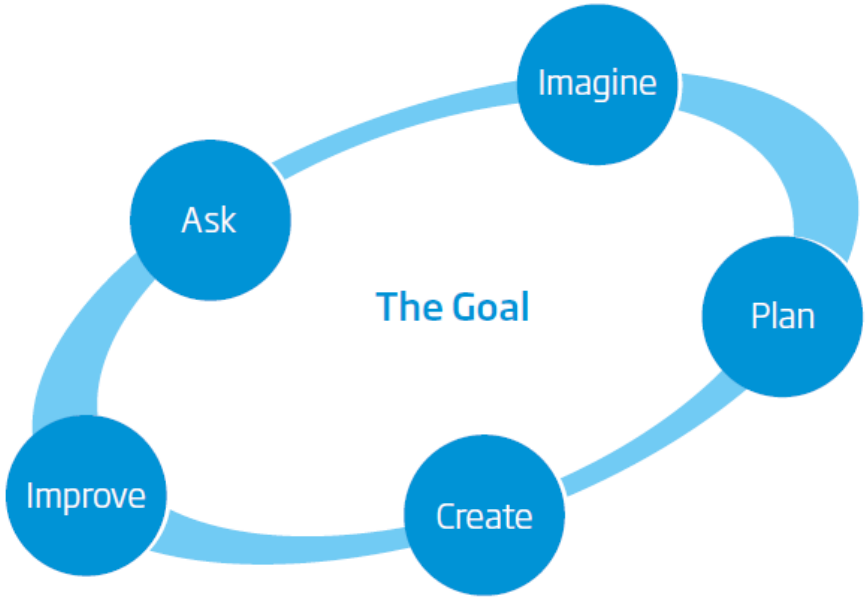
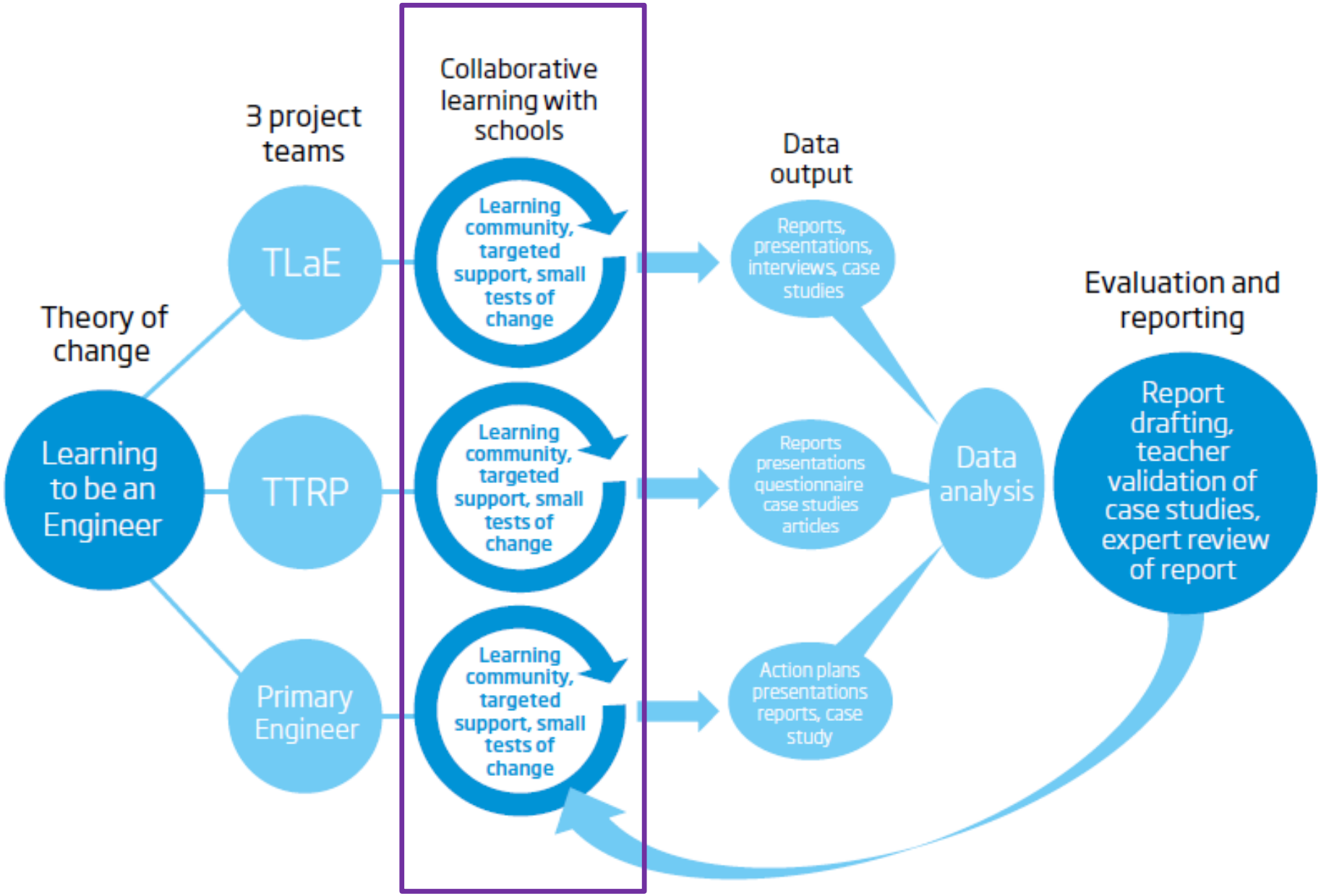
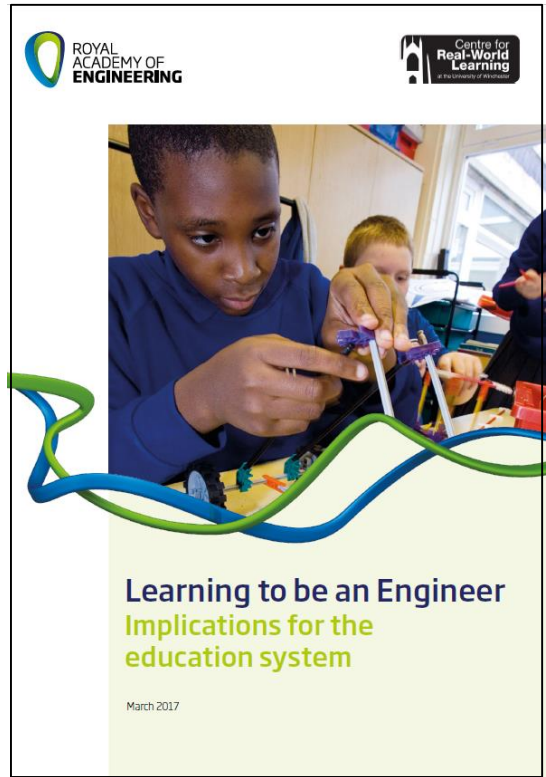
Three signature pedagogies



'Exploring through fiddling, toying, messing, pottering, dabbling and fooling about with a diverse range in things that happen to be available in a creative and productive pursuit to make, mend or improve'.


Theory of change
Learning to be an Engineer
3 project teams
TLaE
TTRP
Primary Engineer
Collaborative learning with schools
Learning community, targeted support, small tests of change
Learning community, targeted support, small tests of change
Learning community, targeted support, small tests of change
Data output
Reports, presentations, interviews, case studies
Reports presentations questionnaire case studies articles
Action plans presentations reports, case study
Data analysis
Evaluation and reporting
Report drafting, teacher validation of case studies, expert review of report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March 2017


4
JCB

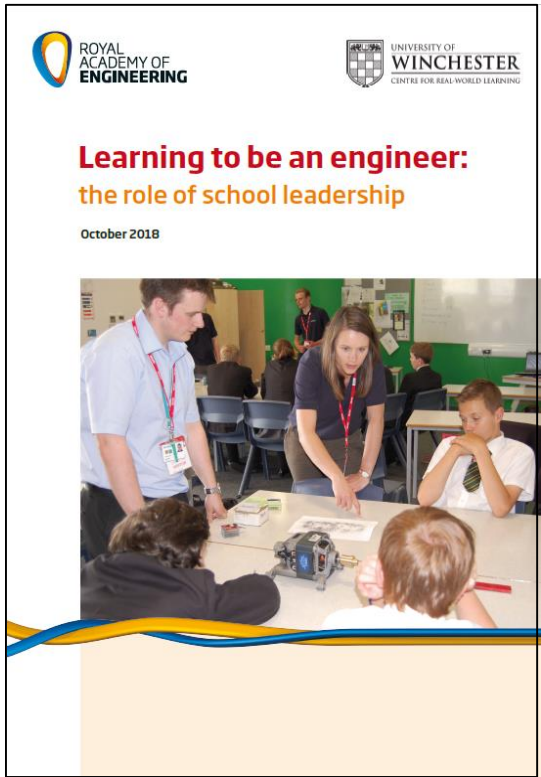

Think like an Engineer

‘I took a step back and although this is so hard to do as a teacher, as you feel you have to always be in control, I began to see the pupils flourish with their new found freedom and their self- belief was huge by the end of this project.’

Learning to be an Engineer teacher

Leading for engineering in schools 3
7 important characteristics

	% Very	Somewhat
Collaborative	76.3	22.0
Flexible	74.6	23.7
Resilient	72.9	25.4
Open-minded	69.5	28.8
Persistent	66.1	28.8
Optimistic	61.0	35.7
Courageous	42.4	35.6

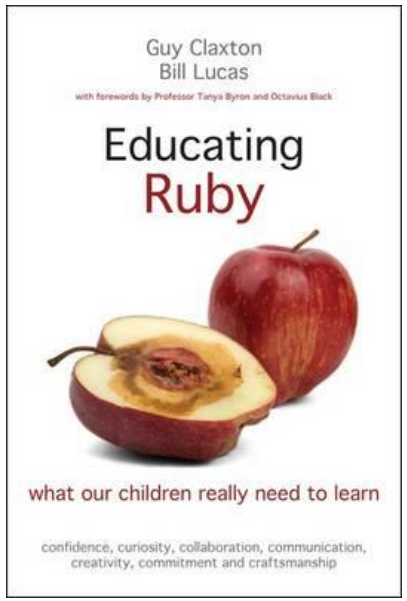


Ruby the engineer

Craftsmanship

Confidence

Commitment



Curiosity

Creativity

Collaboration

Communication

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