EXPANSIVE EDUCATION NETWORK

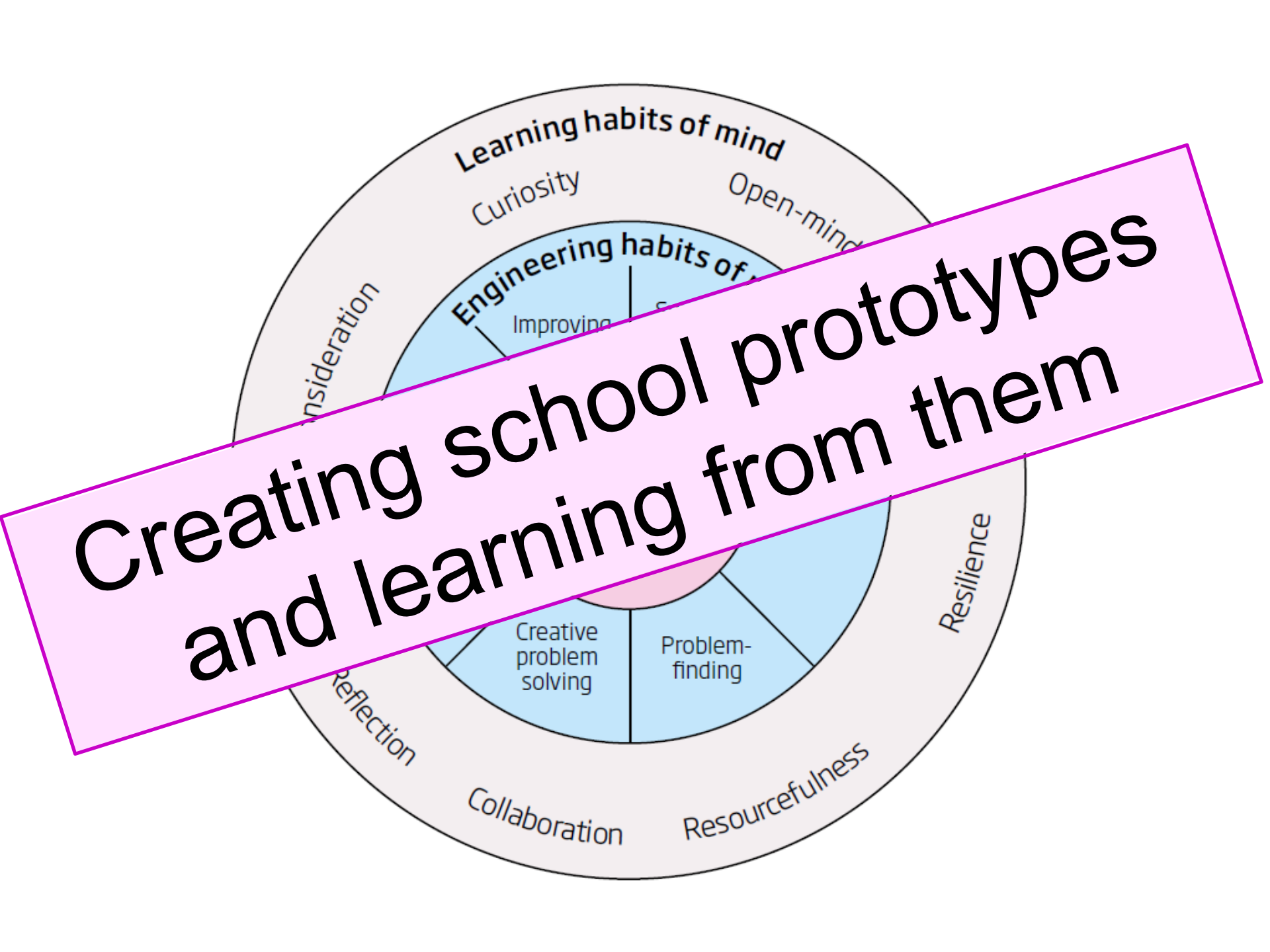
Developing Engineering Habits of Mind in schools and colleges

ROYAL ACADEMY OF ENGINEERING

Centre for Real-World Learning at the University of Winchester

COMINO FOUNDATION

[A round of introductions]



Creating school prototypes and learning from them

Schools and colleges in South

Bohunt School, Liphook
Priory School, Southsea
The Petersfield School
Summerlea School, West Sussex
Camelsdale Primary School, Haslemere

Inspire Enterprise Academy, Southampton

New Forest Academy, Holbury

Reading College

School in the Middle!

JCB Academy

Schools in North-West

Great Moors Junior School
St Chad's Primary School
Christ the King RC Primary
St Mary's RC Primary School
Abraham Moss School
St Ambrose Barlow High School

[Who we are]

ROYAL ACADEMY OF ENGINEERING

WINCHESTER SCIENCE CENTRE AND PLANETARIUM

Science Education Research & Innovation Hub

at The University of Manchester

STEMNET

Contractor 2011-2015

Centre for Real-World Learning

at the University of Winchester

MANCHESTER 1824

The University of Manchester

[Who we are]

[How we got here]

We are born proto-engineers but…

ROYAL ACADEMY OF ENGINEERING

Centre for Real-World Learning

Thinking like an engineer

Implications for the education system

May 2014

A few schools doing great things and wanting to scale up activities

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."

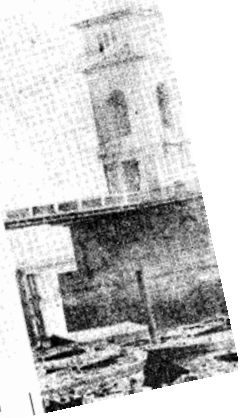
The report found that children, by nature, share many key attributes with engineers, such as creative problem-solving, but they are discouraged by formal classroom teaching.

"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."

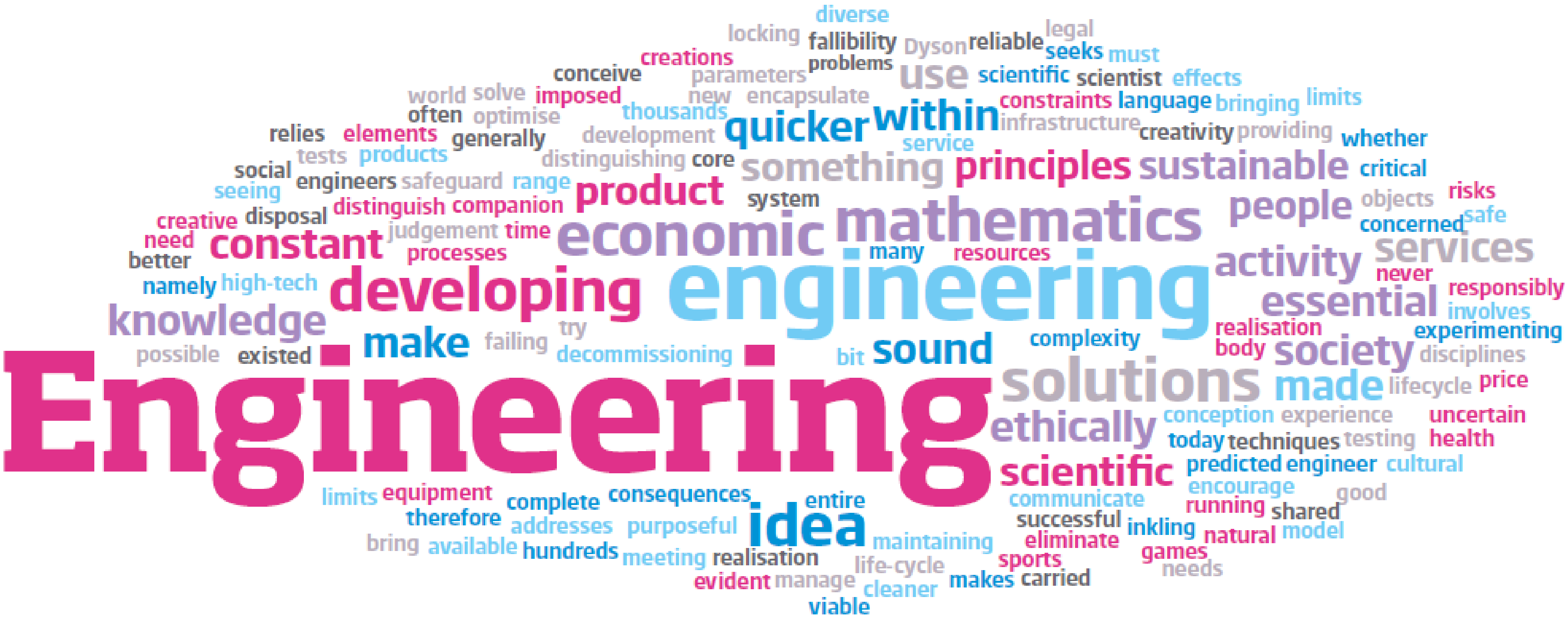
Brunel's bridge caught on camera by photo pioneer



rare 19th-

Henry Fox Talbot in

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


Engineering
engineering
mathematics
economic
developing
constant
knowledge
product
principles
sustainable
something
within
quicker
use
people
activity
services
essential
society
solutions
made
ethically
scientific
idea
make
sound
diverse
locking
fallibility
Dyson
reliable
legal
seeks
must
creations
problems
conceive
parameters
scientific
scientist
effects
world
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limits
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optimise
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infrastructure
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responsibly
involves
realisation
experimenting
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failing
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complexity
possible
existed
decommissioning
bit
disciplines
lifecycle
price
conception
experience
uncertain
today
techniques
testing
health
predicted
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equipment
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bring
available
hundreds
maintaining
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natural
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meeting
realisation
life-cycle
sports
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needs
evident
manage
makes
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cleaner
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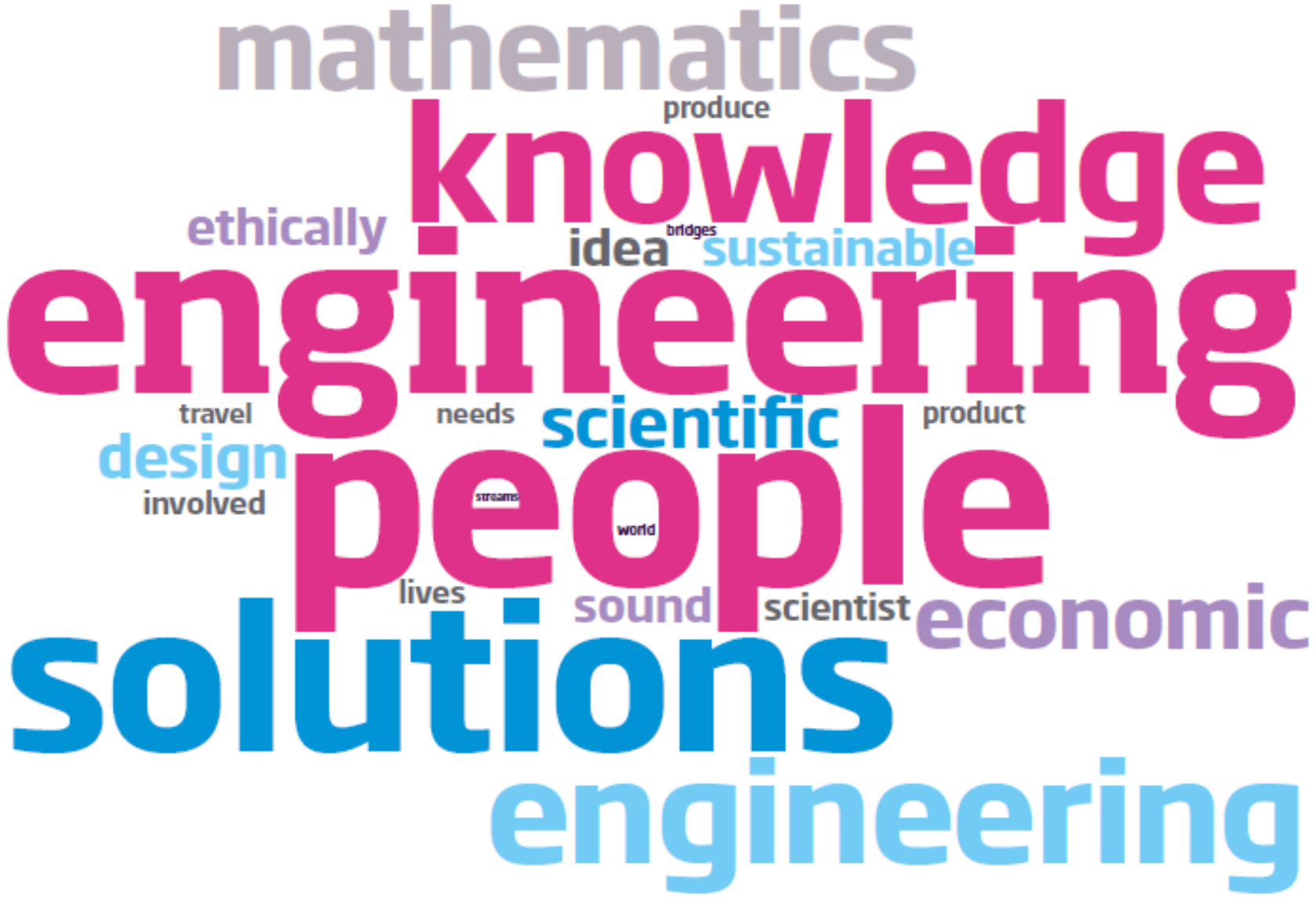

mathematics
produce
knowledge
ethically
bridges
idea
sustainable
engineering
travel
needs
scientific
product
design
people
involved
streams
world
lives
sound
scientist
economic
solutions
engineering

Optimist	The glass is half full
Pessimist	The glass is half empty
Engineer	The glass is twice the size it needs to be

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

…pattern-sniffers, experimenters, describers, tinkerers, inventors, visualizers, conjecturers, guessers

‘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

Figure 5 – Sixteen habits of mind

1	Persisting	9	Thinking about thinking meta-cognition
2	Thinking and communicating with clarity and precision	10	Taking responsible risks
3	Managing impulsivity	11	Striving for accuracy
4	Gathering data through all senses	12	Finding humour
5	Listening with understanding and empathy	13	Questioning and posing problems
6	Creating, imagining, innovating	14	Thinking interdependently
7	Thinking flexibly	15	Applying past knowledge to new situations
8	Responding with wonderment and awe	16	Remaining open to continuous learning

Costa and Kallick 2002

Figure 6 – Building learning power – learning dispositions

Resilience	**Being ready, willing and able to lock on to learning**
Absorption	Flow, the pleasure of being rapt in learning
Managing distractions	Recognising and reducing distractions
Noticing	Really sensing what's out there
Perseverance	Stickability; tolerating the feelings of learning
Resourcefulness	**Being ready, willing and able to learn in different ways**
Questioning	Getting below the surface; playing with situations
Making links	Seeking coherence, relevance and meaning
Imagining	Using the mind's eye as a learning theatre
Reasoning	Thinking rigorously and methodically
Capitalising	Making good use of resources
Reflectiveness	**Being ready, willing and able to become more strategic about learning**
Planning	Working learning out in advance
Revising	Monitoring and adapting along the way
Distilling	Drawing out the lessons from experience
Meta-learning	Understanding learning, and yourself as a learner
Reciprocity	**Being ready, willing and able to learn alone and with others**
Interdependence	Balancing self-reliance and sociability
Collaboration	The skills of learning with others
Empathy and listening	Getting inside others' minds
Imitation	Picking up others' habits and values

Claxton 2002


Resilience
Absorption
Perseverance
Managing distractions
Noticing
Resourcefulness
Questioning
Capitalising
Making links
Reasoning
Imagining
Reciprocity
Imitation
Inter-dependence
Empathy and Listening
Collaboration
Reflectiveness
Planning
Meta-learning
Distilling
Revising

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

…open-mindedness, scepticism, rationality, objectivity, mistrust of arguments from authority, suspension of belief, curiosity

Lucas, B, Spencer, E. and Claxton, G. (2013)
'Progression in student creativity in school: first steps towards new forms of formative assessments',
OECD Education Working Papers, No 86. Paris: OECD Publishing

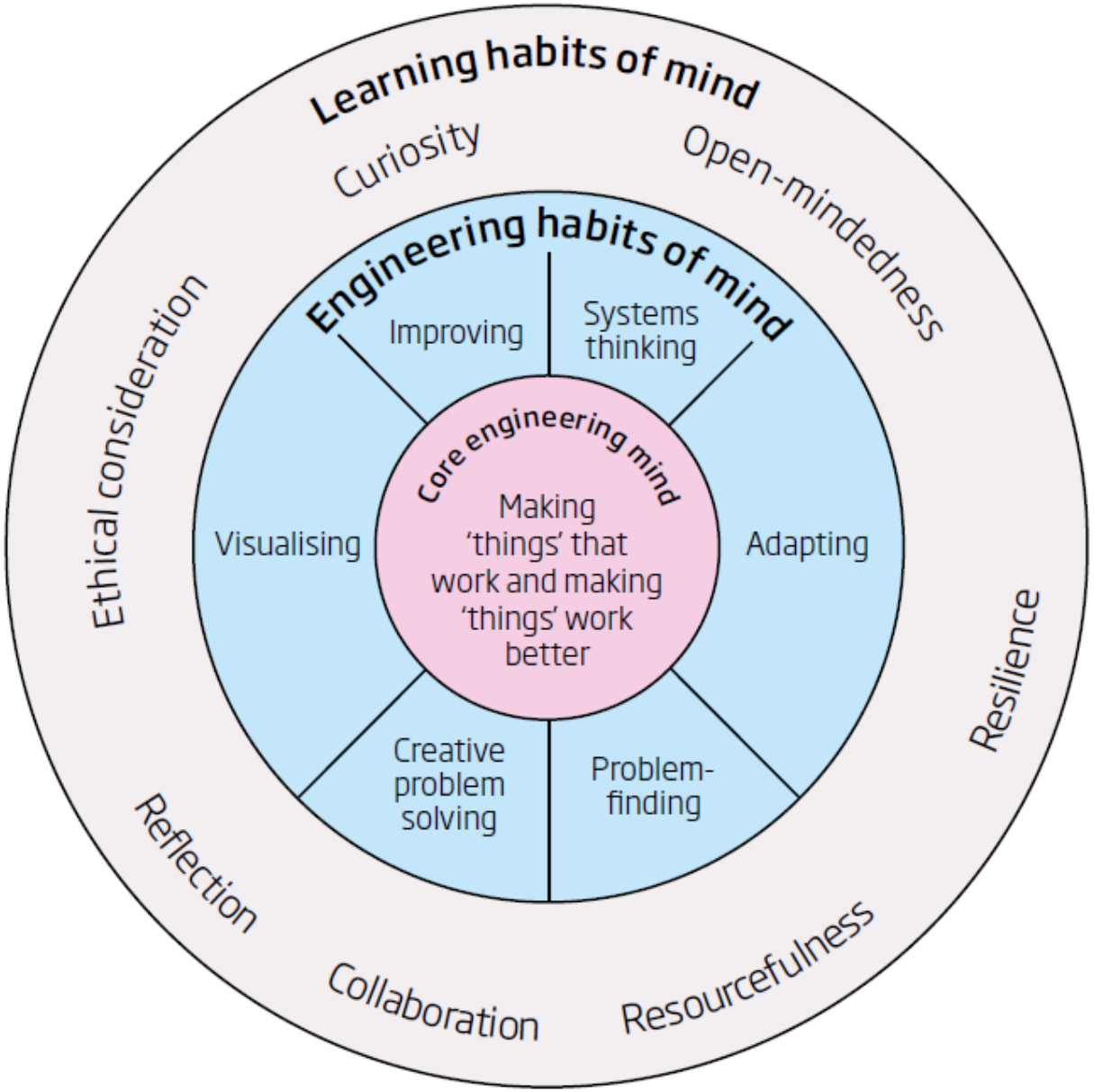
Engineering Habits of Mind

National Academy of Engineering - USA (2009)

1. Systems thinking
2. Creativity
3. Optimism
4. Collaboration
5. Communication
6. Attention to ethical considerations

Centre for Real-World Learning (2014)

1. Systems thinking
2. Problem-finding
3. Visualising
4. Improving
5. Creative problem-solving
6. Adapting


Learning habits of mind
Curiosity
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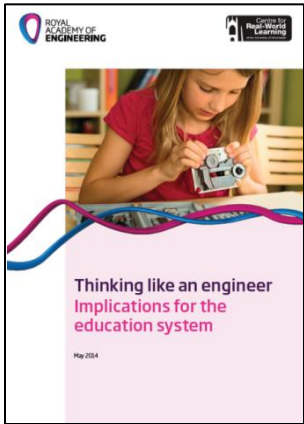

ROYAL ACADEMY OF ENGINEERING
Thinking like an engineer
Implications for the education system
May 2014

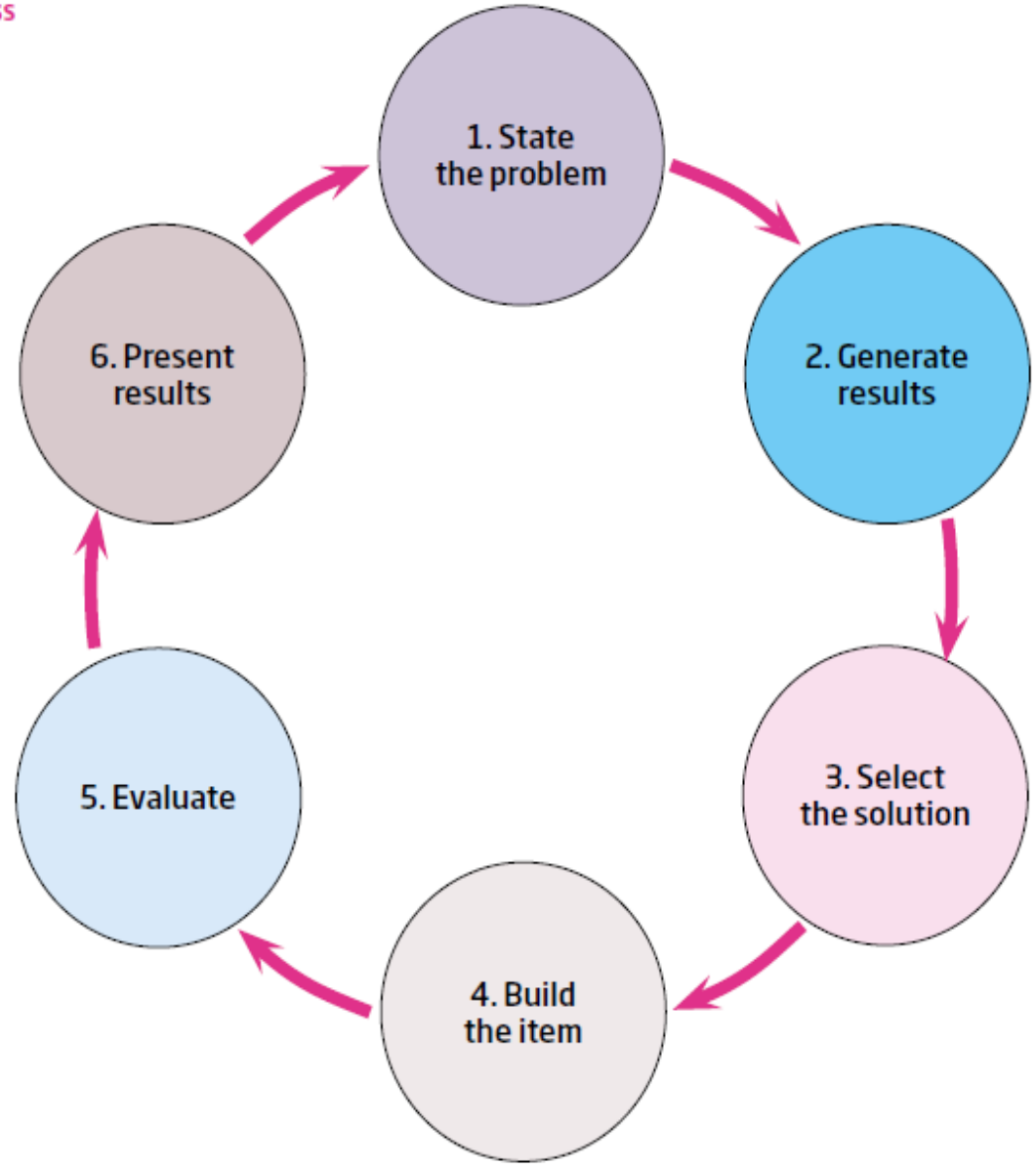
The idea of ‘signature pedagogy’

What might it be for engineering?

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

Figure 13 - The engineering design process

Source - NASA[143]



Two modes of thinking

Creatively different ***v*** Reliably similar

Playing ***v*** Evaluating

Opening up ***v*** Closing down

Synthesis ***v*** Analysis

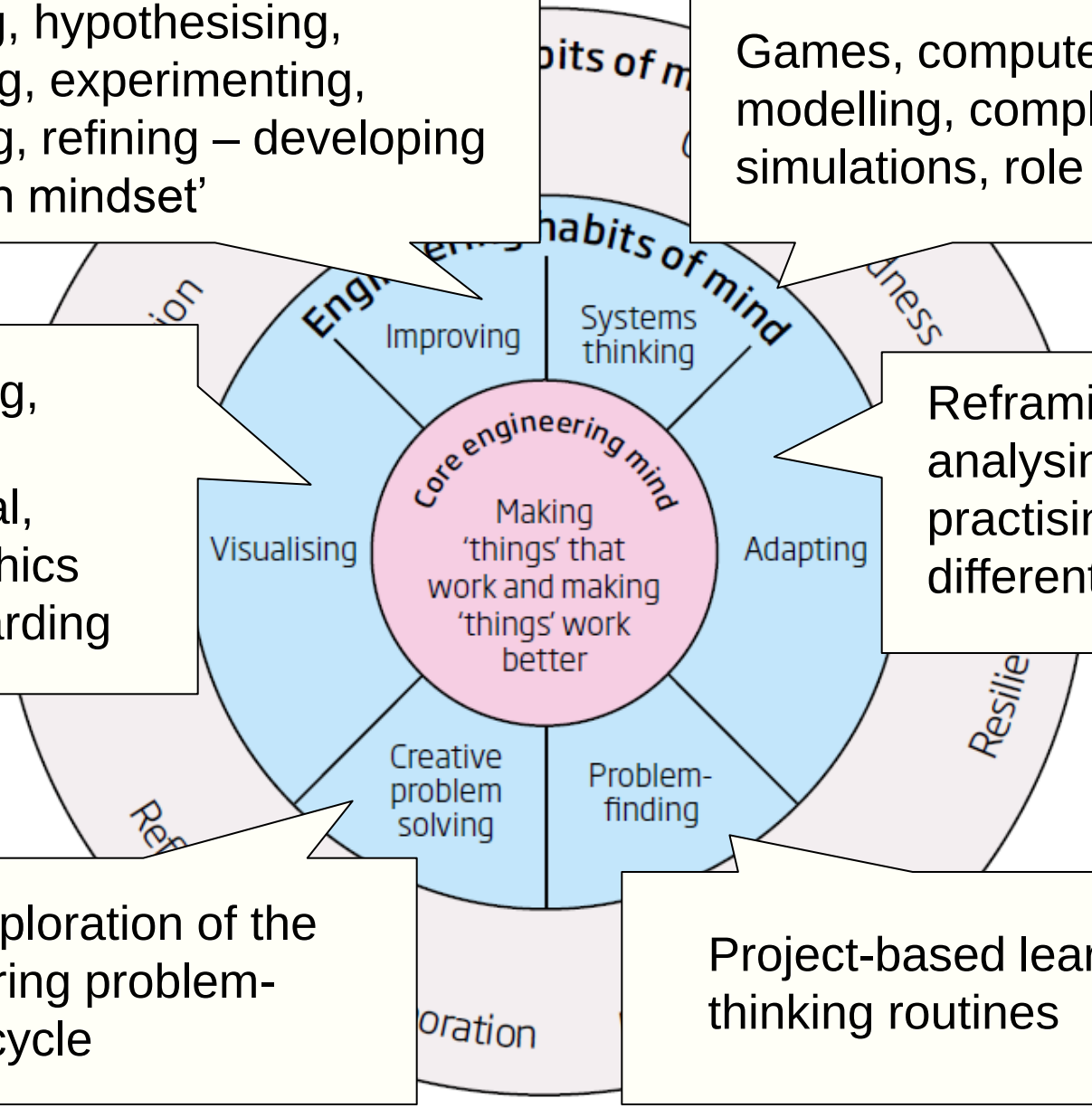
Systems thinking ***v*** Analytical

Intuitive ***v*** Deductive

Idealistic ***v*** Pragmatic

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

Games, computer modelling, complex simulations, role playing



Modelling, mental rehearsal, infographics storyboarding

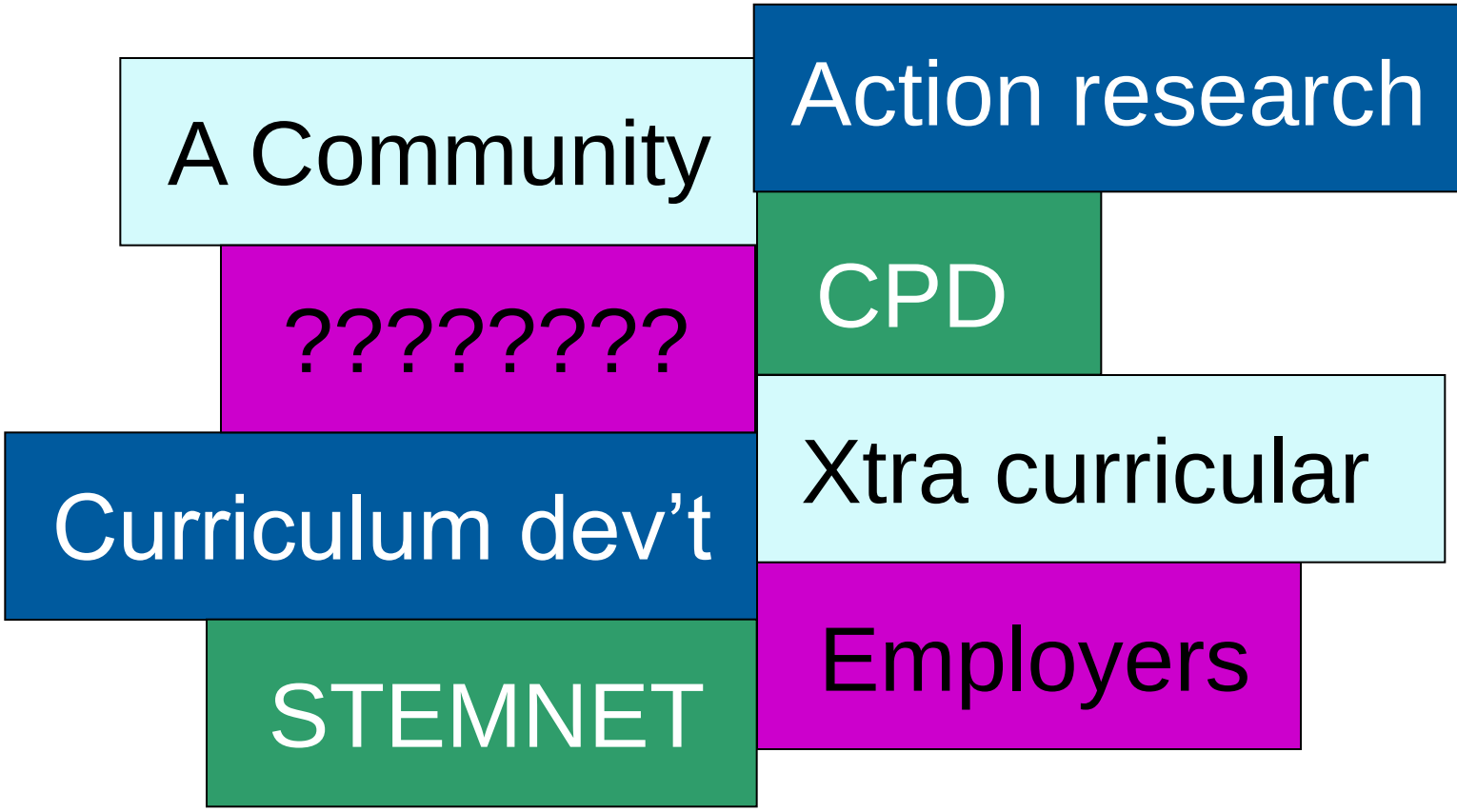
Reframing, analysing, practising in different contexts

Deep exploration of the engineering problem-solving cycle

Project-based learning, thinking routines

[What we'll be doing]

Thinking like an Engineer Project



Thinking like an Engineer

Welcome to the Thinking like an Engineer page of the Expansive Education Network. Here you will find specific resources to support your cluster, upcoming events and the contact details of other schools in the cluster.

Events:

Launch - 10th December, Winchester Science Centre

Resources

Action Research Case Studies

STEM Resources

Project Contacts:

eedNET at Winchester University: For support with emerging AR questions, projects and research
Dr. Janet Hanson: janet.hanson@winchester.ac.uk

Advanced search...

Search: Found: 3

Name	Organization	Membership
Avery, Philip	Bohunt School	Secondary
Green, Gary	Bohunt School	Secondary
Hoad, Laura	Bohunt School	Secondary

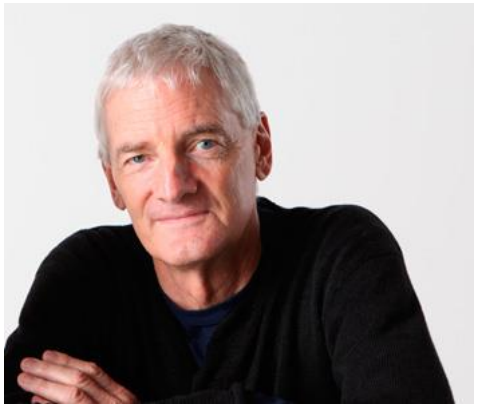
ROYAL ACADEMY OF ENGINEERING

WINCHESTER SCIENCE CENTRE AND PLANETARIUM

Dr Rhys Morgan
Director of Engineering & Education
Launch and Overview

Royal Academy of Engineering

The UK's national Academy for Engineering


ROYAL ACADEMY OF ENGINEERING

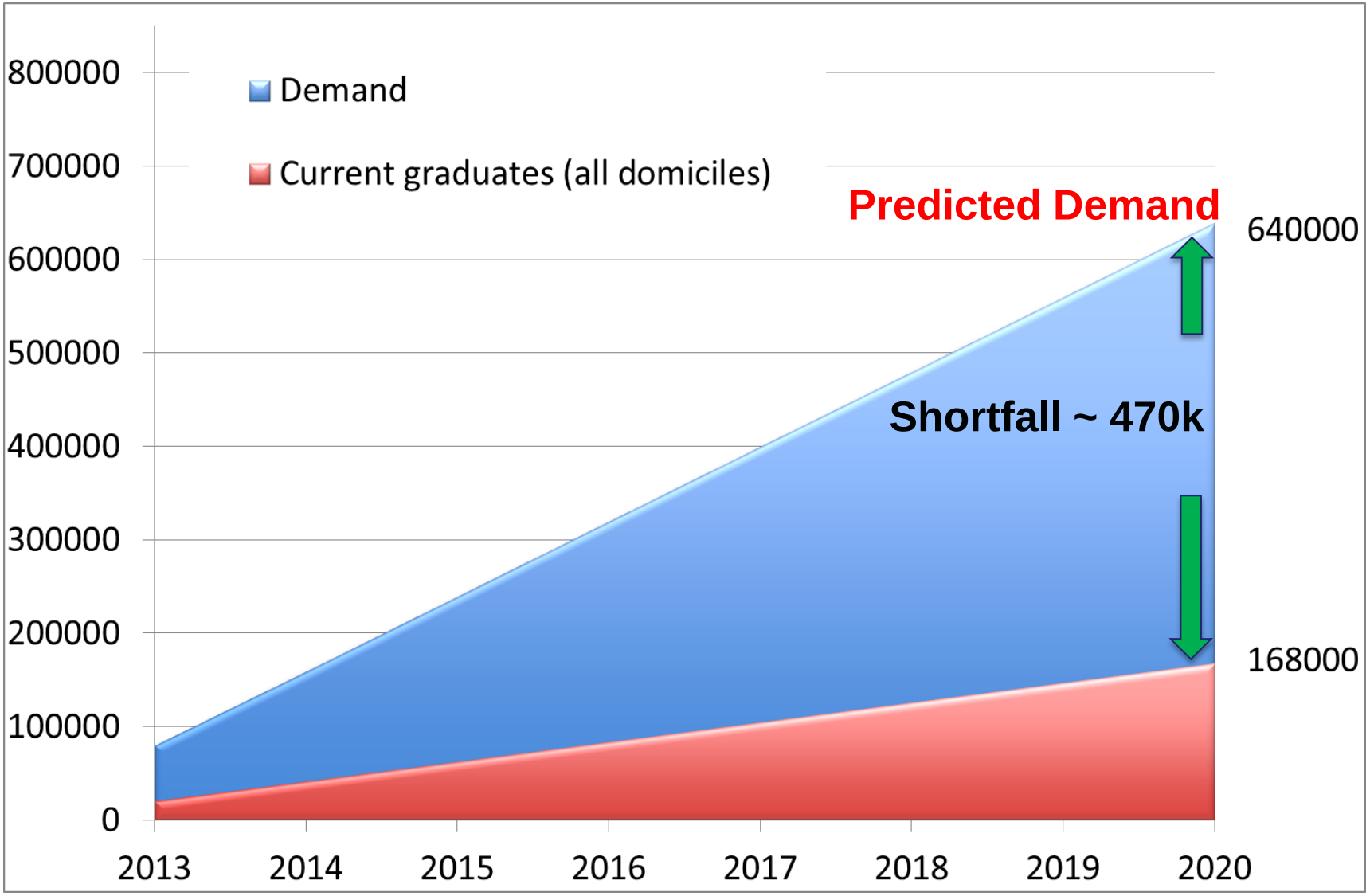
Engineering is Everywhere!

“Engineers build the world around us. They use science to solve problems”

Nina and the neurons, BBC CBeebies

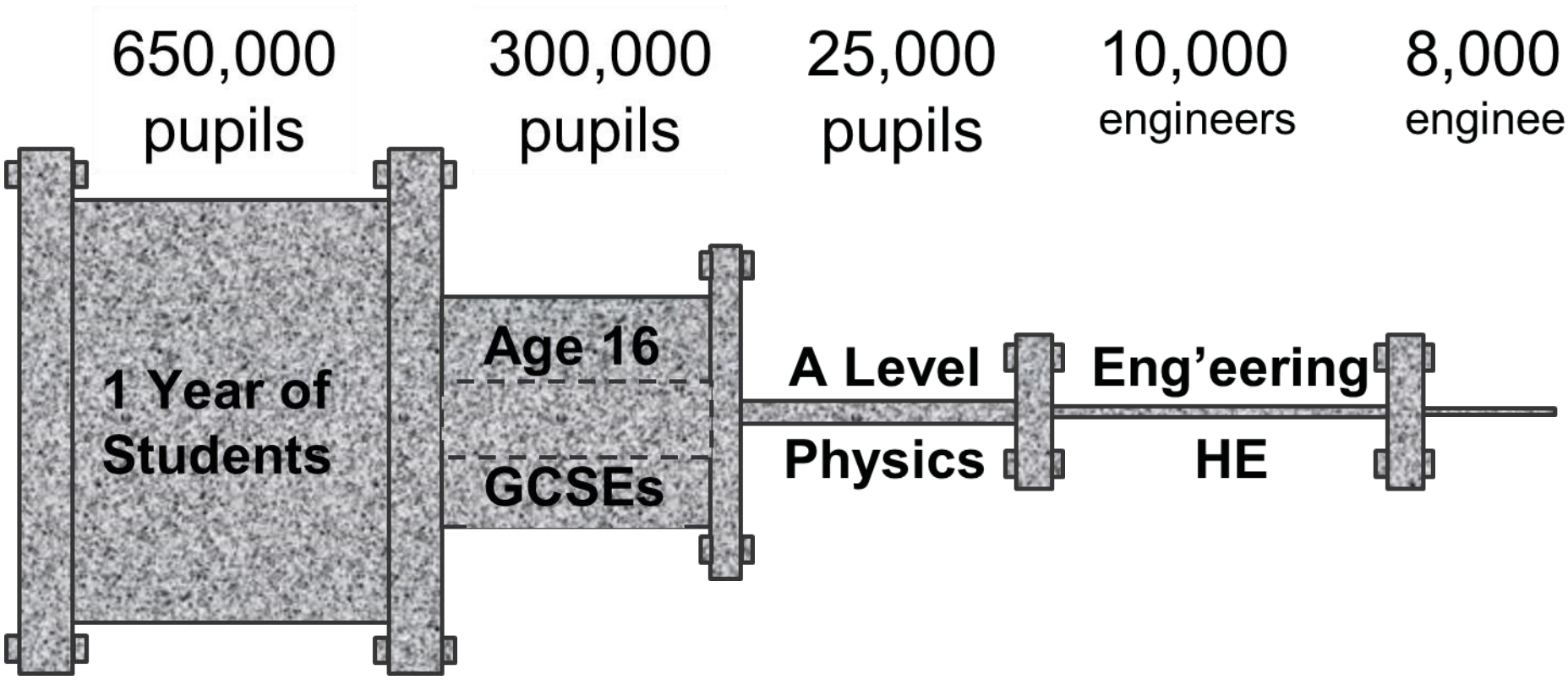
ROYAL ACADEMY OF ENGINEERING

Future demand for engineers



ROYAL ACADEMY OF ENGINEERING

UK engineering skills pipeline




WELBECK
Tomorrow's Engineers
STEMNET
Science, Technology, Engineering and Mathematics Network

STEM EDUCATION STAKEHOLDER MAP

UKRC / WISE
AFBE - UK
Generating Genius
WES

Diversity organisations

LMS
JMC
MEI
IMA and others

Mathematics community

Science Discovery Centres
Techniquest
Science Museum
Royal Observatory

STEM teacher support
Design and Technology Assoc (DATA)
Assoc of Science Educators (ASE)
NAACE (ICT subject assoc)
Computing at School

NCETM
National STEM Centre
Science Learning Centres (regional)
SSAT
Teach First
Teaching Leaders
National Space Academy

Prominent STEM funders
Salters Institute
NESTA
Gatsby Foundation
Wellcome Trust
Nuffield Foundation
Lloyds Register
Ogden Trust
BITC
Sutton Trust
ERA Foundation
1851 Commission
Reece Foundation
Others
Livery Companies

STEM Activities
Big Bang Fair
STEM Directories
Bloodhound
Arkwright
Industrial Cadets

SCHOOLS
FE & Skills
Higher Education

Baker-Dearing
AoC
UUK

EMPLOYERS

Education institutions
London Knowledge Lab

Coderdojo
TWSU
Apps for Good
Code club
Stemettes

EDT
Smallpeice
Young Engineers
Primary Engineer
Tomorrow's Engineers

STEMNET
Education and Employers Taskforce
EBPs
CODING CLUBS

Royal Academy of Engineering
The Engineering Profession
Engineering Council, Engineering UK
36 Engineering Institutions (IET, IMechE, ICE…)
Non licenced engineering institutions (IMI…)
FEANI, SEFI

Science community
Royal Society
Royal Institution
Royal Soc Chemistry
Soc of Biology
Inst of Physics
Science Council
Others… e.g Royal Astronomical, Royal Geological, etc.

Awarding bodies
AQA
Edexcel
OCR
WJEC
EAL
City and Guilds

5-19 education
DFE
OFQUAL
OFSTED
TDA / TA

HE, FE & skills
BIS
National Careers Service
National Apprenticeship Service
HEFCE / HEFCW
ETF

Sector Skills Councils (SEMTA, COGENT, E-Skills…)
UKCES

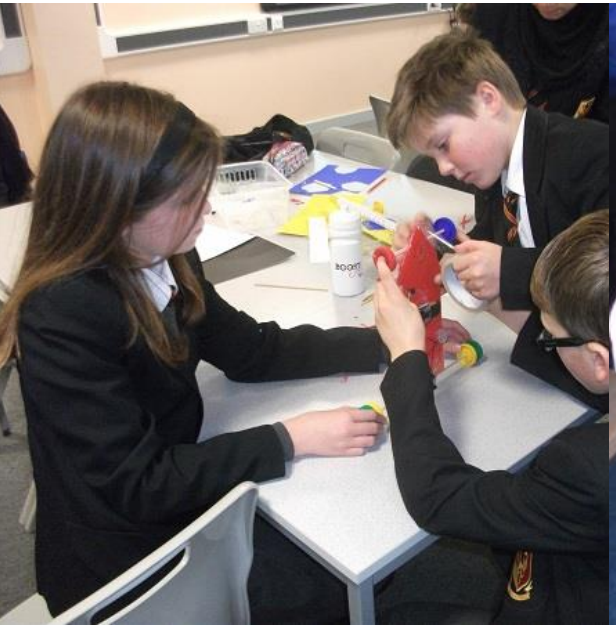
STEM policy bodies
E4E
EPC
ACME
NCUB
SCORE
CASE
UKforCE
CBI
NextGen.Skills
EEF

This is an indicative landscape.
rhys.morgan@raeng.org.uk (Dec 2014)

Education programmes

Schools

- Connecting STEM teachers - National Teachers Network
- Regional projects: South London, Swansea, Barrow-in-Furness, Stoke-on-Trent



Education programmes

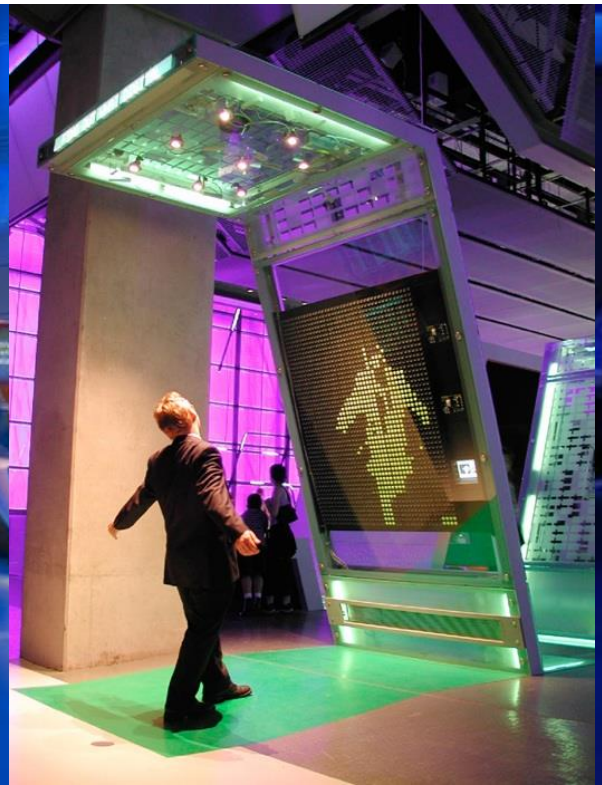
Schools

- Curriculum resource material development

ROYAL ACADEMY OF ENGINEERING

Engineer your future!

- 3 year interactive exhibition at the Science Museum
- Supported by industry and BIS
- Drawing on the Academy's *Thinking like an Engineer* report


Philip Avery
Director of Learning & Strategy, Bohunt Education Trust
Why Engineering Habits of Mind at Bohunt School?

BOHUNT

BOHUNT

"We first make our habits, and then our habits make us."

BOHUNT

How are we doing at Bohunt?

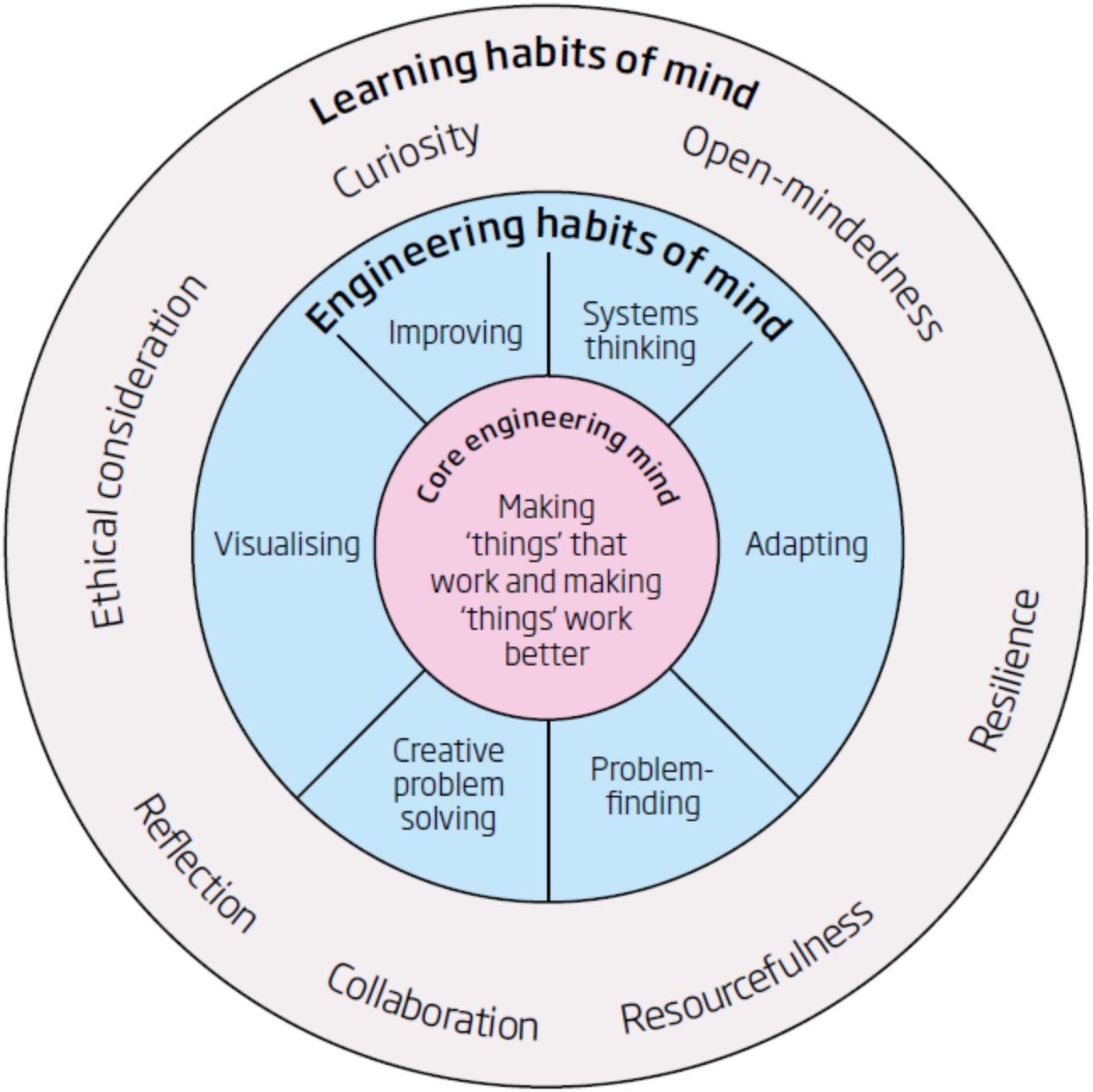
- **Attainment**: 87% 5A*-C inc E&M, 1033 VA
- **Skills**: Immersion Language Teaching, iPad Band, Apps for Good
- **Ambition**: School's success, Growth Mindset, Chimp Paradox, Outdoor Programme, STEM Festival

BOHUNT

Attitudes and Interpersonal Skills

- STEM Curriculum:
  - Freedom as non-examined
  - Career focused and challenging as working in partnership with industry
  - Rigorous due to the structures put in place
- Advantages:
  - Experienced by all
  - Integration with Industry
  - Sustained focus

BOHUNT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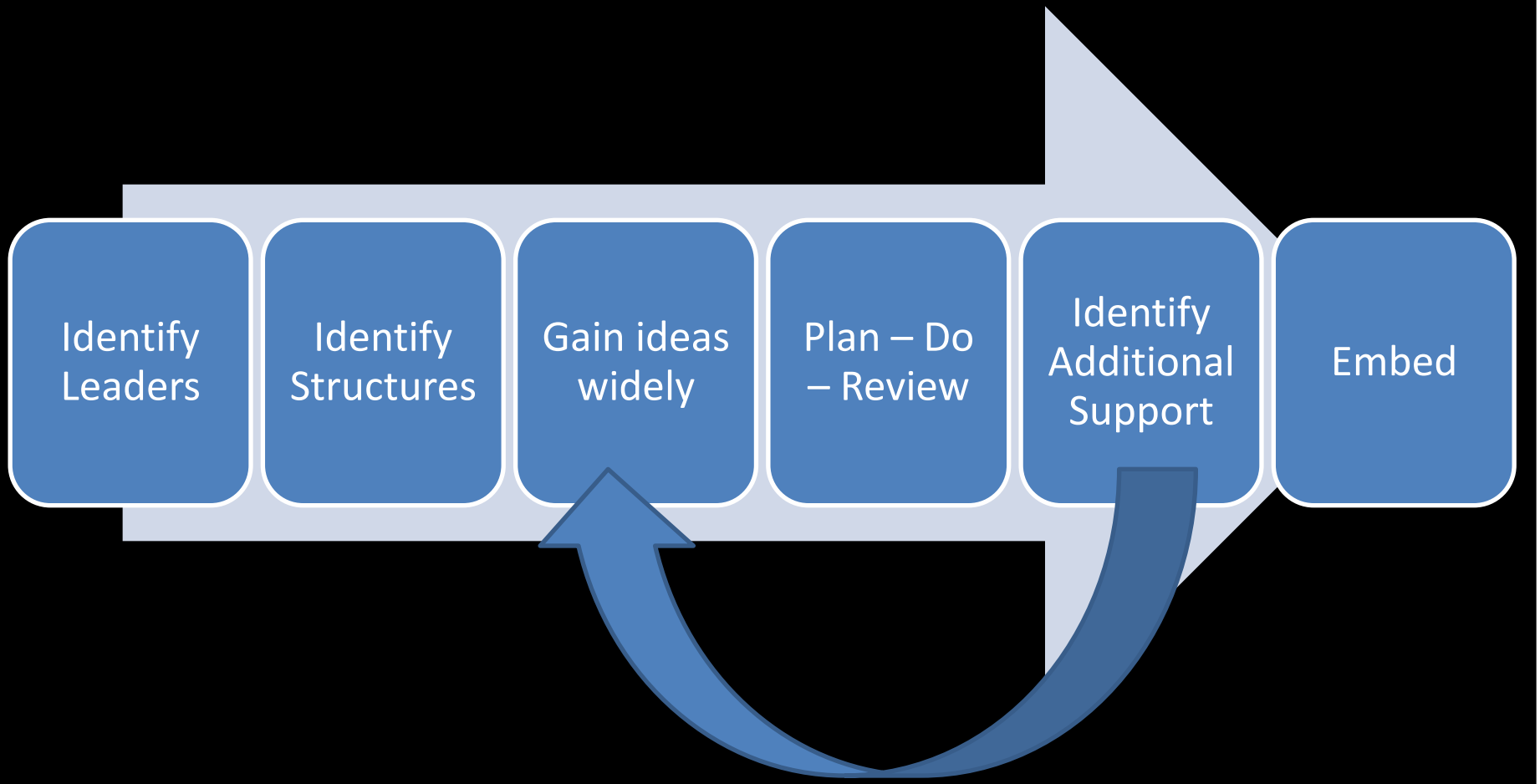
BOHUNT

Professional Development

- Change Teams
  - Every member of staff has 2 additional frees
  - 1 goes to Change Team work
  - 1 goes to Collaborative Learning Cluster work

- Collaborative Learning Clusters
  - 5 staff working together
  - Co-planning, observation, reflection
  - To answer a big question

BOHUNT


Identify Leaders
Identify Structures
Gain ideas widely
Plan – Do – Review
Identify Additional Support
Embed

BOHUNT

Engaging AND Effective
Trial & Improvement
Self-Discovery (play game and fix bugs)
DIRT marking (reflective analysis)
Challenge Based Learning
Guided Learning
Problem Solving
Competitive teamwork
Real life application
Assessment for Learning
Visualising
Problem finding
Questioning to establish CPS
Unexpected
Appropriate visual methods/aids
Creative coding
Here's the answer, what was the question?
Write your own questions
2D to 3D

BOHUNT
WORTHING

BOHUNT

EXPANSIVE EDUCATION NETWORK

www.raeng.org.uk/thinkinglikeanengineer

www.expansiveeducation.net

www.winchester.ac.uk/realworldlearning