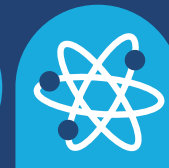Teaching Engineering

Engineering Habits of Mind

& Pre-engineering Thinking

Ways of teaching Engineering

Engineering is a broad subject, with many different definitions. The Royal Academy of Engineering have suggested that education should focus on developing "**Engineering Habits of Mind**" as the desired outcomes of engineering education.

For younger learners, some researchers have presented a wider range of behaviours, described as "**pre-engineering thinking**". This document describes how the Let's Do Engineering resources and activities map onto the concepts of engineering habits of mind and pre-engineering thinking.

Engineering Habits of Mind

What are the Engineering Habits of Mind?

Creative problem-solving

Systems-thinking

Problem-finding

Improving

Engineering Habits of Mind

Adapting

Visualising

Creative problem-solving

Generating ideas and solutions by applying techniques from different traditions, critiquing, giving and receiving feedback, seeing engineering as a 'team sport'.

SUB HABIT 01
Generating ideas
Comes up with suggestions in a range of situations.

SUB HABIT 02
Working in team
Has good people skills to enable idea and activity sharing; good at giving and receiving critique/feedback.

Systems-thinking

Seeing connections between things, seeking out patterns, seeing whole systems and their parts and how they connect, recognising interdependencies, synthesising.

SUB HABIT 01
Connecting
Looks for links, connections, relationships; working across boundaries.

SUB HABIT 02
Pattern-making
Uses metaphors, formulae, images etc. To find pattern.

Problem-finding

Deciding what the actual question is, finding out if solutions already exist by clarifying needs, checking existing solutions, investigating contexts, verifying, thinking strategically.

SUB HABIT 01
Checking and clarifying
Questions apparent solutions methodically and reflectively.

SUB HABIT 02
Investigating
Has a questioning, curious and, where appropriate, sceptical attitude.

Adapting

Making something designed for one purpose suitable for another purpose, by converting, modifying, transforming, adjusting, changing, reshaping, re-designing, testing, analysing, reflecting, rethinking.

SUB HABIT 01
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.

SUB HABIT 02
Deliberate practising
Disciplined; able to work at the hard parts.

Improving

Making things better by experimenting, designing, sketching, guessing, conjecturing, thought-experimenting, prototyping.

SUB HABIT 01
Experimenting
Makes small tests or changes; sketching, drafting, guessing, prototyping.

SUB HABIT 02
Evaluating
Making honest and accurate judgments about 'how it's going'; comfortable with words and numbers as descriptors of progress.

Content: Royal Academy of Engineering: 'Learning to be an Engineer. Implications for the education system'

Visualising

Seeing the end product, being able to move from abstract ideas to concrete, manipulating materials, mentally rehearing practical design solutions.

SUB HABIT 01
Thinking out loud
Puts 3d ideas into words as they become pictures or rehearses possible lines of thought or action.

SUB HABIT 02
Model-making
Moves between abstract and concrete, making models to capture ideas.

Developing Engineering Habits of Mind through activities

The table below shows how the Let's do Engineering activities fit within the Engineering Habits of Mind.

Our activities introducing all engineers, e.g. films, Trumps game, activity book, posters and the Engineer Song, are all excellent ways to explore the EHoM of problem finding - what are the different problems these engineers are working on?

Other activities and resources can be grouped into themes or topics; by covering all activities within a theme all EHoM can be experienced. Themes include Space, Climate Change, Health, Robots and Drones, Materials and Flight.

Activity	Theme	Engineering Habits of Mind					
		Systems thinking	Adapting	Problem finding	Creative problem solving	Visualising	Improving
The Engineer Song	Covers all engineers and all themes	–	–	✓	–	–	–
Top Trumps	Covers all engineers and all themes	–	–	✓	–	–	–
Activity book	Covers all engineers and all themes	–	–	✓	✓	✓	–
Films - engineer interviews	Covers all engineers and all themes	–	–	✓	–	–	–
Engineer posters	Covers all engineers and allthemes	–	–	✓	–	–	–
Engineering design cycle posters	Covers all engineers and all themes	✓	–	✓	✓	✓	✓
Build a rocket	Space	Flight	✓	✓	–	✓	✓	✓

Activity	Theme	Engineering Habits of Mind					
		Systems thinking	Adapting	Problem finding	Creative problem solving	Visualising	Improving
Hula hooping and orbits	Space | Flight	-	✓	-	-	-	✓
Build a wind turbine	Climate change	✓	✓	-	✓	✓	✓
Scarf throwing and plate spinning	Climate change	-	✓	-	-	-	✓
Make a blood model	Health	-	-	✓	-	✓	-
Build a noisemaker	Health | Robots and drones | Flight	✓	✓	✓	✓	✓	✓
Acoustic engineering songs	Health | Robots and drones | Flight	-	✓	-	✓	-	-
Stencilling microchips	Materials	-	✓	-	✓	✓	✓
Build your own water filter	Health	✓	✓	-	✓	✓	✓
Elsie the Engineer	Introducing engineering	✓	-	✓	✓	✓	✓
Introducing engineering (Diane)	Introducing engineering	-	-	-	✓	✓	-
Introducing engineering (Doug)	Introducing engineering	✓	-	-	-	✓	-
Simon Says and do coding	Robots and drones | Health	✓	✓	✓	✓	✓	✓
Exploring materials	Materials	✓	-	-	-	✓	-
Painting with natural dyes	Climate change | Health	-	✓	✓	✓	-	✓
Famous structures around the world	Climate change	✓	-	-	-	-	-
Structures and balancing	Climate change	✓	✓	-	✓	-	-
Water clean up game	Health	✓	-	✓	-	-	-
Space junk tidy up	Flight | Space	✓	✓	✓	✓	✓	✓

Activity	Theme	Engineering Habits of Mind					
		Systems thinking	Adapting	Problem finding	Creative problem solving	Visualising	Improving
Hula hooping and orbits	Flight | Space	-	✓	-	-	-	✓
Build a tower/exploring foundations	Materials	-	✓	✓	✓	✓	✓
Computer vision game	Robots and drones	✓	-	-	-	✓	-
Juggling	Robots and drones	-	✓	-	-	-	✓
Build a solar oven	Climate change	-	✓	✓	✓	✓	✓
Mission to Mars	Robots and drones | Space	-	-	-	-	✓	-
Space rover design - app and craft	Robots and drones | Space	✓	✓	✓	✓	✓	✓
Build your own spectroscope	Robots and drones | Space	✓	✓	-	-	✓	✓
Aeroplane model making	Flight	✓	✓	✓	✓	✓	✓
Amy Johnson songs	Flight	-	-	-	-	✓	-
Coral Drama	Materials | Health	-	-	-	-	✓	-
Coral strength testing	Materials | Health	-	-	-	-	✓	-
Comics	All	-	-	✓	-	-	-

To learn more about the EHoM there are two reports by the Royal Academy of Engineering: 'Thinking like an engineer. Implications for the education system' and 'Learning to be an Engineer. Implications for the education system'.

Both can be accessed by the links below.

Pre-Engineering thinking

Below are the pre-engineering behaviours along with definitions and examples. Zachary Gold, and co-authors, developed the full list, which can be found as Table 1 **here** and is reproduced with permission below.

Communicating goals

Expressing a desired end to achieve a purpose

"I want to put this block on top"
"Let's build a castle"

Following patterns and prototypes

Representing ideas verbally or in structural models

"This tractor is just like the one mom drives at home"

Problem-solving

Verbally identifying problems or suggesting solutions

"This will not work, it's too big"
"This square block will hold it"

Creative and innovative action

Trying a new or innovative approach or idea

Leaning two long blocks together to make a teepee

Solution testing/ evaluating design

Testing and evaluating how a structure functions

Rolling a ball to test if a ramp works
"The floor is stable"

Construction

Collecting and building actions

Stacking or placing blocks, collecting or organizing blocks

Logical and mathematical words

Using math vocabulary or if-then statements

Taller, near, above, square, counting, inside, around
"If we use the square block, then we can close the tunnel"

Explaining how things are built/work

Explaining why or how something is built or works

"Let's put the block this way to hold the door on"

Technical vocabulary

Using specialized STEM words

Gear, balance, stability, satellite, ramp, engine, factory, robot

Note: The Preschool Engineering Play Behaviors (P-EBP) observation instrument is copyrighted and not to be used in research or for other educational purposes without permission of the author (Gold et al., 2017).

Abbreviation: STEM, science, technology, engineering, and mathematics.

Developing Pre-Engineering thinking with activities

The table below shows how the Let's do Engineering activities fit within the Pre-Engineering behaviours.

All activities offer the chance to practice STEM words and nine of our engineering challenges cover all aspects of pre-engineering thinking, e.g. Build a rocket, Build a wind turbine, Build your own water filter, Structures and balancing, Space junk tidy up, Build a tower, Build a solar oven, Space Rover design and Aeroplane model making.

Other activities and resources can be grouped into themes or topics; by covering all activities within a theme all types of pre-engineering thinking can be worked on. Themes include Space, Climate Change, Health, Robots and Drones, Materials and Flight.

Let's do Engineering Activity	Theme	Pre-engineering thinking behaviours								
		Communicating goals	Construction	Problem-solving	Creative action	Explaining	Following patterns	Solution testing evaluation	Logical/maths words	STEM words
The Engineer Song	Covers all engineers and all themes	–	–	–	–	✓	–	–	–	✓
Top Trumps	Covers all engineers and all themes	–	–	–	–	–	–	–	–	✓
Activity book	Covers all engineers and all themes	–	–	–	–	✓	–	–	–	✓
Films - engineer interviews	Covers all engineers and all themes	–	–	–	–	✓	–	–	–	✓

Let's do Engineering Activity	Theme	Pre-engineering thinking behaviours								
		Communicating goals	Construction	Problem-solving	Creative action	Explaining	Following patterns	Solution testing evaluation	Logical/maths words	STEM words
Engineer posters	Covers all engineers and all themes	–	–	–	–	✓	–	–	–	✓
Engineering design cycle posters	Covers all engineers and all themes	–	–	–	–	✓	–	–	–	✓
Build a rocket	Space | Flight	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hula hooping and orbits	Space | Flight	–	–	–	✓	✓	–	–	–	✓
Build a wind turbine	Climate change	✓	✓	✓	✓	✓	✓	✓	✓	✓
Scarf throwing and plate spinning	Climate change	✓	✓	–	✓	✓	✓	–	–	✓
Make a blood model	Health	–	–	–	–	✓	–	–	–	✓
Build a noisemaker	Health | Robots and drones | Flight	✓	✓	✓	✓	✓	–	✓	–	✓
Acoustic engineering songs	Health | Robots and drones | Flight	–	–	✓	✓	✓	✓	✓	✓	✓
Stencilling microchips	Materials	–	–	✓	✓	✓	✓	✓	–	✓
Build your own water filter	Health	✓	✓	✓	✓	✓	✓	✓	✓	✓
Elsie the Engineer	Introducing engineering	–	–	✓	✓	✓	✓	✓	✓	✓
Introducing engineering (Diane)	Introducing engineering	–	–	✓	✓	✓	–	✓	–	✓

Let's do Engineering Activity	Theme	Pre-engineering thinking behaviours								
		Communicating goals	Construction	Problem-solving	Creative action	Explaining	Following patterns	Solution testing evaluation	Logical/maths words	STEM words
Introducing engineering (Doug)	Introducing engineering	✓	✓	–	–	✓	–	–	✓	✓
Simon Says and do coding	Robots and drones | Health	–	–	✓	✓	✓	✓	✓	✓	✓
Exploring materials	Materials	–	–	–	–	✓	✓	–	✓	✓
Painting with natural dyes	Climate change | Health	–	–	✓	✓	✓	✓	✓	✓	✓
Famous structures around the world	Climate change	–	–	–	–	–	✓	–	✓	✓
Structures and balancing	Climate change	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water clean up game	Health	–	–	–	–	✓	✓	–	–	✓
Space junk tidy up	Flight | Space	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hula hooping and orbits	Flight | Space	–	–	–	✓	✓	–	–	–	✓
Build a tower/exploring foundations	Materials	✓	✓	✓	✓	✓	✓	✓	✓	✓
Computer vision game	Robots and drones	–	–	–	–	✓	✓	–	–	✓
Juggling	Robots and drones	–	–	–	✓	✓	–	–	–	✓
Build a solar oven	Climate change	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mission to Mars	Robots and drones | Space	–	–	–	–	✓	✓	–	–	✓

Let's do Engineering Activity	Theme	Pre-engineering thinking behaviours								
		Communicating goals	Construction	Problem-solving	Creative action	Explaining	Following patterns	Solution testing evaluation	Logical/maths words	STEM words
Space rover design - app and craft	Robots and drones | Space	✓	✓	✓	✓	✓	✓	✓	✓	✓
Build your own spectroscope	Robots and drones | Space	✓	✓	-	-	✓	✓	-	✓	✓
Aeroplane model making	Flight	✓	✓	✓	✓	✓	✓	✓	✓	✓
Amy Johnson songs	Flight	-	-	-	-	-	-	-	-	✓
Coral drama	Materials | Health	-	-	-	-	✓	-	-	-	✓
Coral strength testing	Materials | Health	✓	✓	-	-	✓	-	-	✓	✓
Comics	All	-	-	-	-	✓	-	-	-	✓