

STEM IN MATHS (SIM) SERIES (II): MATHEMATICS AS ENGINEERING

Law Huk Yuen (羅浩源)

drhylaw@gmail.com

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STEM RHAPSODY

Is this the real life?

(這就是人生嗎?)

Is this just fantasy?

(或者，只是我的幻覺?)

Calculus Rhapsody

MATHS AS ENGINEERING (*MAE*) THREE LEVELS



3 E behind Engineering

WHAT IS ENGINEERING? GENERAL VIEW

Engineering is the *creative application of science, mathematical methods, and empirical evidence to the innovation, design, construction, operation and maintenance of structures, machines, materials, devices, systems, processes, and organizations for the benefit of humankind.*

The term engineering is derived from the Latin *ingenium*, meaning "cleverness" and *ingeniare*, meaning "to contrive, devise".[1]

(Source: Wikipedia)

WHAT IS ENGINEERING? INSIDERS' VIEW

Engineering is the knowledge required, and the process applied, to conceive, **design**, make, build, operate, sustain, recycle or retire, something of significant technical content **for a specific purpose** – a concept, a **model**, a product, a device, a process, a system, a technology.

(See Robert Malpas' *The University of Engineering: A UK Perspective*. The Royal Academy of Engineering, 2000)

ENGINEERING AS A SOCIAL ENDEAVOUR

Engineering is not technology driven, nor should it be.... Our real driver is **social**, because we want to **improve the quality of life** out in the community. ...Engineers... combine science-based technologies with social insight, to improve the quality of life.

(See John Turnbull's *The Context and Nature of Engineering Design, Philosophy of Engineering*, 2010, p.34)

HOW I SEE ENGINEERING

Engineering as

- a **design** (choice of models) with
- a specific **purpose** (what for? Can really improve our quality of life?)
- for particular social **context** (Will what works in X be the same as what works in Y?)

....WHEN WE MEAN TO BUILD

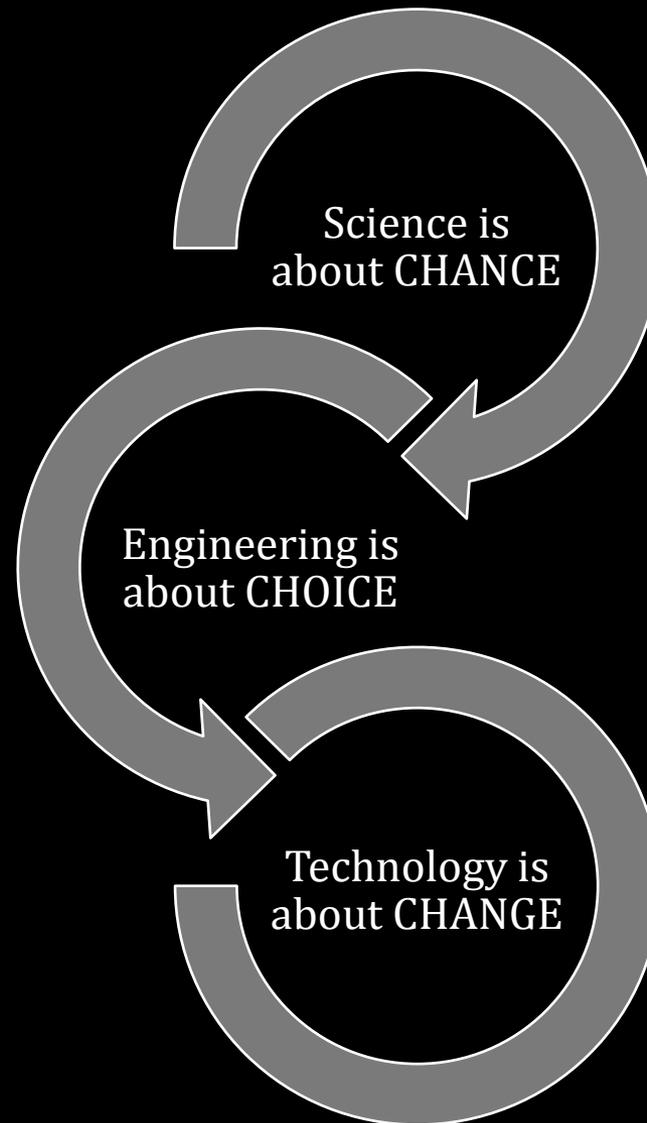
We first survey the plot, then draw the *model*;
And when we see the figure of the house,
Then must we rate the cost of the erection;
Which if we find outweighs ability,
What do we then but draw *anew the model*
In fewer offices, or at last desist
To build at all?

(See Shakespeare's *Henry IV* Part 2)

Design is about interacting with people and thus an art of compromise through iterative modelling

(See Chris Elliott's *Engineering as Synthesis – Doing right Things and Doing Things Right*, *Philosophy of Engineering*, 2010)

CHANCE – CHOICE - CHANGE



SCIENCE OF CONCRETE: WHAT MAKES A LESSON ENGAGING?

Students as ‘bricoleurs’ (a bricoleur is the layman who makes sense out of puttering and hands-on)

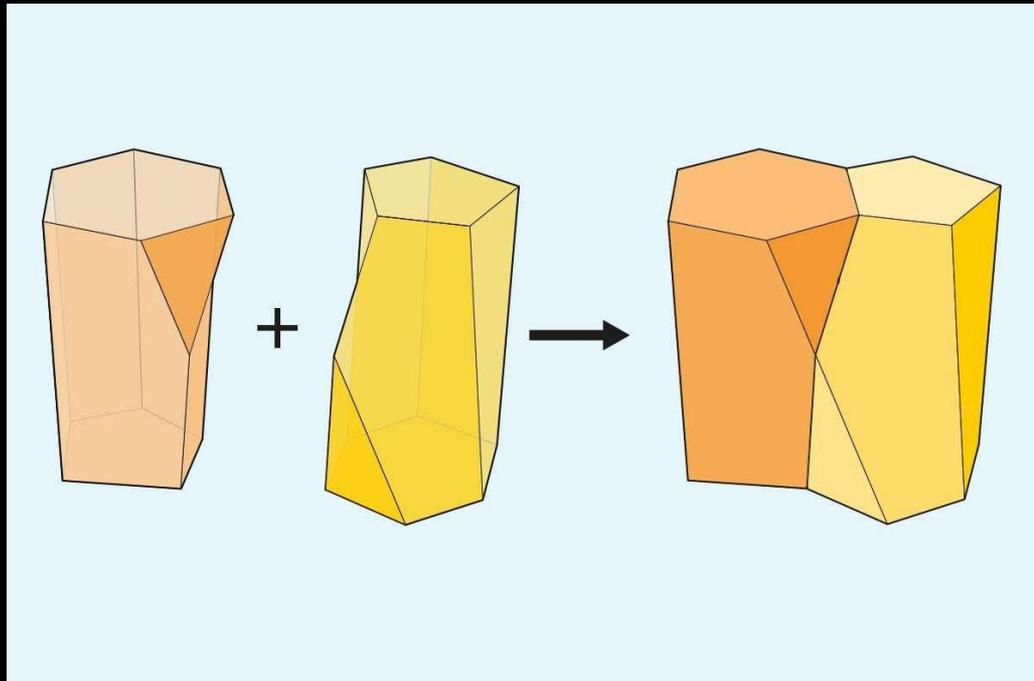
“The ‘bricoleur’ is adept at performing a large number of diverse tasks... His universe of instruments is closed and the rules of his game are always to make do with ‘whatever is at hand’, that is to say with a set of tools and materials which is always finite and is heterogeneous...”

(See Claude Lévi-Strauss’ *The Savage Mind*, p.17)

SCUTOID: THE NEW MODEL

The video:

Welcome the SCUTOID in our Academia - Scientists discovered brand New Geometric shape!



HOW WE FIND THINGS USEFUL OR INTERESTING?

Humans do not learn about or engage with the material world because such “things” are deemed useful. Rather...we find things “useful or interesting because they are first of all known.” In other words, we engage with material as we find it in front of us.

(Michelle Molina adopted the view of Claude Lévi-Strauss in writing up *Introduction: An Ambivalent Philosophy of the Concrete, Rethinking the Human*, 2010, p. 7)

The key is to design a lesson with the task so as to enable the students to engage with material as they find in front of them!

DESIGN AS A COMBINATION OF SCIENCE AND ART

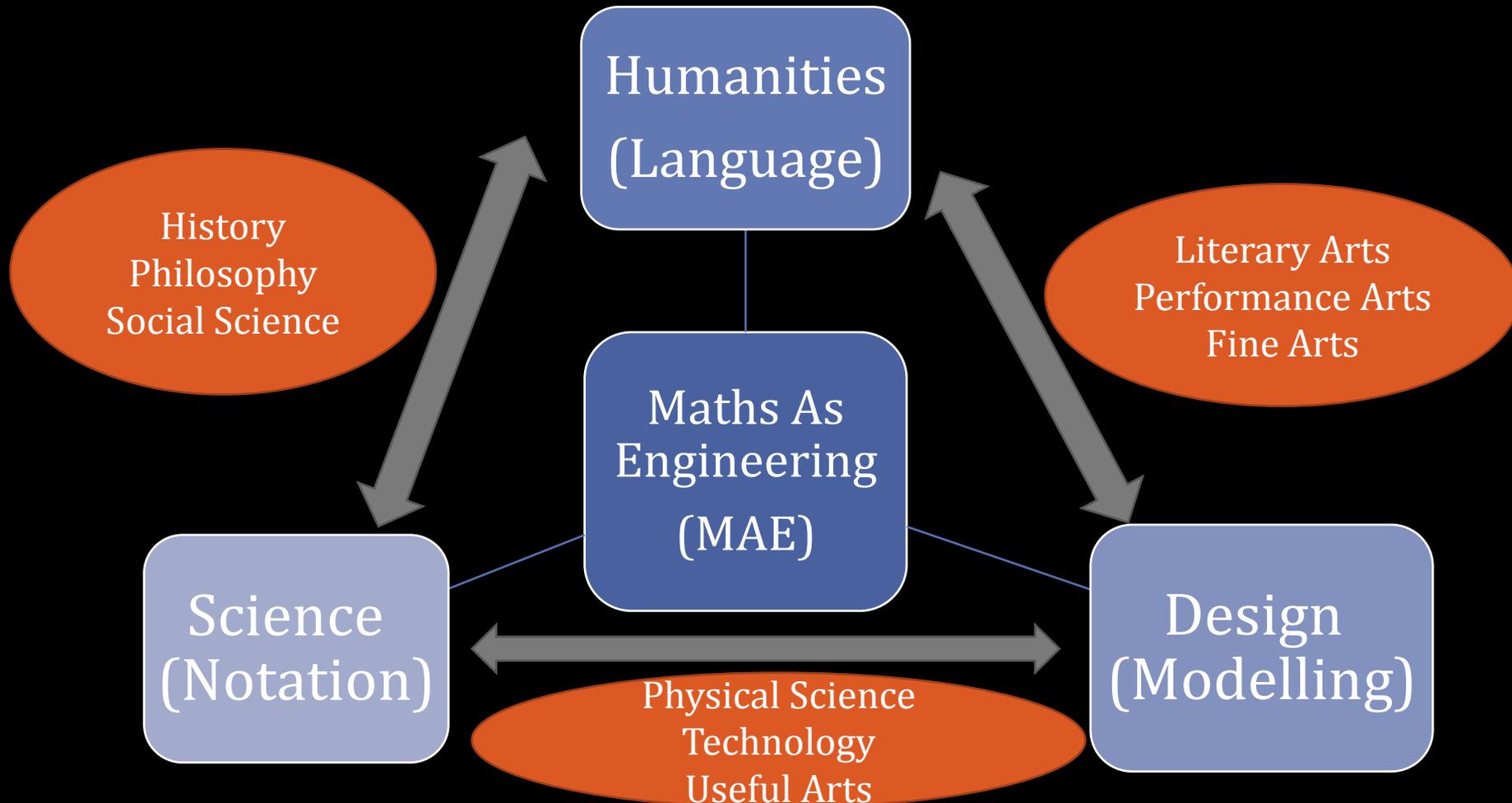
Science is the Differential Calculus of the mind. Art the Integral Calculus; they may be beautiful when apart, but are greatest only when combined.

科學是心靈的微分，詩是心靈的積分，微分與積分分開時各有各的美麗的漣漪，但合起來時，尤能見到壯闊的波瀾 (童元方“閱讀陳之藩” 2012)

-- Sir Ronald Ross

(Quoted in *The Complete Poems of Hugh MacDiarmid 1920-76*, 1978, Vol. 2, [1360])

DESIGN AS THE THIRD CULTURE



(Adapted from Bruce Archer's *Design as a Discipline*, 1979)

A DESIGN EXAMPLE

The purpose:

How can we increase the cleanliness of the toilets?

The particular context: the **male** toilets

The design:

The famous mock fly in the urinals of gents' toilets

(first used at Schiphol Amsterdam airport)

(See Maarten Franssen's *Roles and Rules and the Modelling of Socio- Technical Systems, Philosophy of Engineering*, 2010, p.48)



TRANSFORMING THE WORLD THROUGH ACTIVITY

“.....the way philosophy becomes experience is not through a reflection upon the world, but through human activity that effectively transforms it.”

(Sam Gillespie, *The Mathematics of Novelty: Badiou's Minimalist Metaphysics*, 2008, p.148)

CHOPSTICKS (I): THE LENGTH OPTIMIZATION

The objective: to find the optimum length of the chopstick for the adult

Independent variable is the length of the chopsticks.

Dependent variable is the food-pinching performance.

(See Hsu & Wu's An investigation for determining the optimum length of chopsticks, 1991)

CHOPSTICKS (II): THE LENGTH OPTIMIZATION

The Operational definition of the dependent variable :

The study used a randomized complete block design to evaluate the effects of the length of the chopsticks on the food-serving performance. The “Food Pinching Performance” was determined by counting the number of peanuts picked and placed in a cup (PPPC).

Controlled Variables :Based on the description of the experiment controlled variable are :

- The age of the participants was controlled based on the block design.
- The material of the chopsticks (wood, metal, and so on).
- The type or size of foods they pinch with chopsticks.
- Chopstick lengths : 180, 210, 240, 270, 300, and 330 mm

(See Hsu & Wu's *An investigation for determining the optimum length of chopsticks*, 1991)

ENGAGING WITH TASKS

There is no other decision that teachers make that has a greater impact on students' opportunity to learn and on their perceptions about what mathematics is than the selection or creation of the tasks with which the teacher engages the students in studying mathematics.

(Lappan and Briars 1995, p. 138)

CREATING MEANINGFUL TASKS

Questions for design of meaningful tasks:

- **Does the task lead anywhere?**
- **Does the task lead to model building?**
- **Does the task lead to inquiry and justification?**
- **Does the task involve flexible use of technologies?**
- **Is the task relevant to students?**

(See Romberg and Kaput's "Mathematics Worth Teaching, Mathematics Worth Understanding," in Elizabeth Fennema and Thomas A. Romberg (eds.), *Mathematics Classrooms that Promote Understanding*, 1999)

THE TASK: [MAKEOVER] MEATBALLS BY DAN MEYER

22. *Application* A prep chef has just made two dozen meatballs. Each meatball has a 2-inch diameter. Right now, before the meatballs are added, the sauce is 2 inches from the top of the 14-inch-diameter pot. Will the sauce spill over when the chef adds the meatballs to the pot?



LESSON STORY: THREE ACTS

Dan Meyer (July 13, 2013)

The Problem: Will it overflow?

Act One

1. How many meatballs will it take to overflow?
2. What is a number of meatballs you know is too high?
3. What is a number of meatballs you know is too low?

SEARCH FOR THE DATA

Act Two

4. What information would be useful to know here?



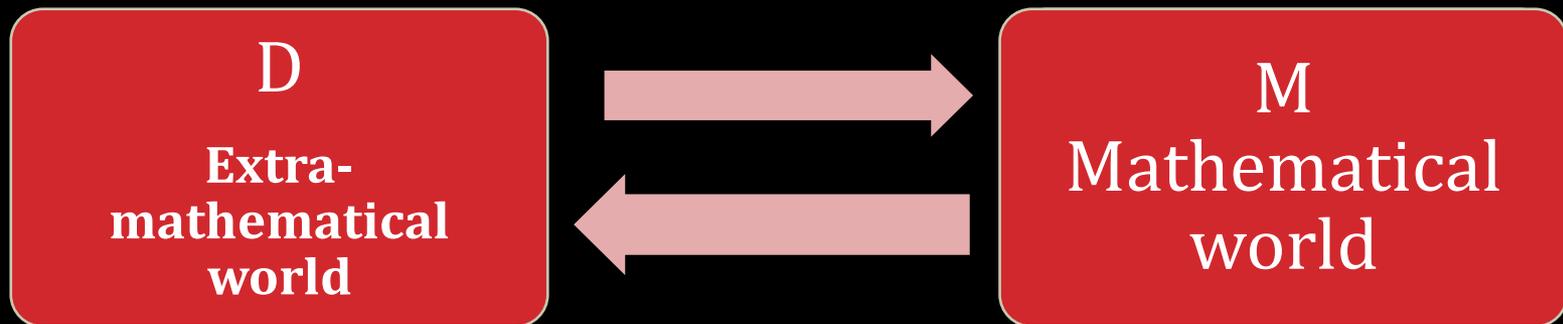
ENDING WITH EXTENSION

Act Three

The video: [meatball](#)

5. The chef adds 50 meatballs to a different pot and it overflows. Determine possible dimensions for that pot and its sauce level.
6. The math worked out to 33 meatballs but the answer was 36. What might account for the difference?
7. The chef wants to combine all 36 meatballs into one meatball. How big will that meatball be? Will it still overflow?

MODELLING CYCLE: MAPPING TWO WORLDS



Source: www.immchallenge.org.au
(Mathematical Modelling 2018)

MODELING PROCESS

- **Identify the problem:** We identify something in the real world we want to know, do, or understand. The result is a question in the real world.
- **Make assumptions and identify variables:** We select “objects” that seem important in the real-world question and identify relations between them. We decide what we will keep and what we will ignore about the objects and their interrelations. The result is an idealized version of the original question.
- **Do the math:** We translate the idealized version into mathematical terms and obtain a mathematical formulation of the idealized questions. This formulation is the model. We do the math to see what insights and results we get.
- **Analyze and assess the solution:** We consider: Does it address the problem? Does it make sense when translated back into the real world? Are the results practical, the answers reasonable, and the consequences acceptable?
- **Iterate:** We iterate the process as needed to refine and extend our model.
- **Implement the model:** For real world, practical applications, we report our results to others and implement the solution.

(Excerpts from GAIMME 2016, pp. 12–13.)

MODELLING MATHS CONCEPTS

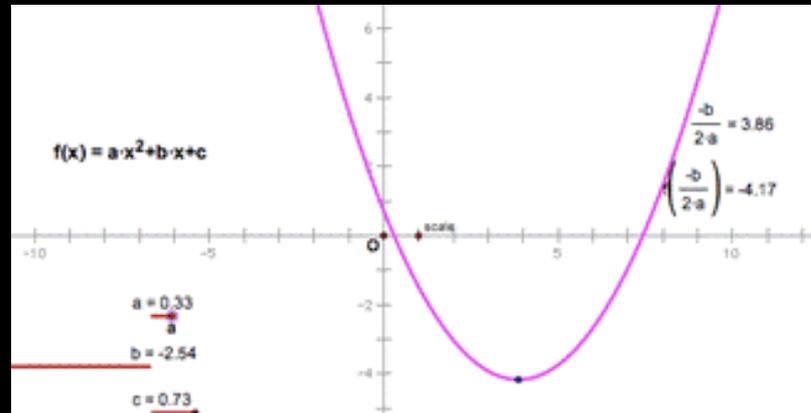
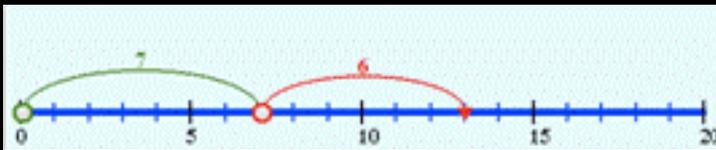
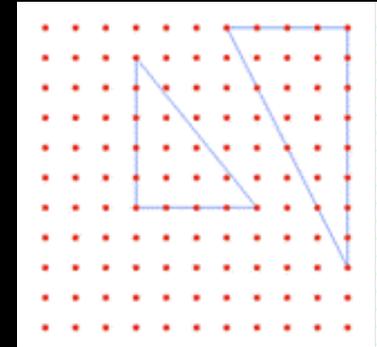
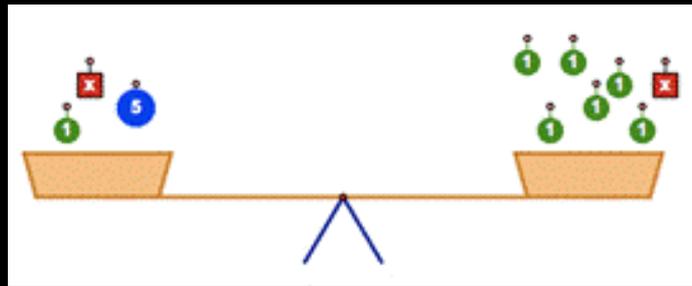
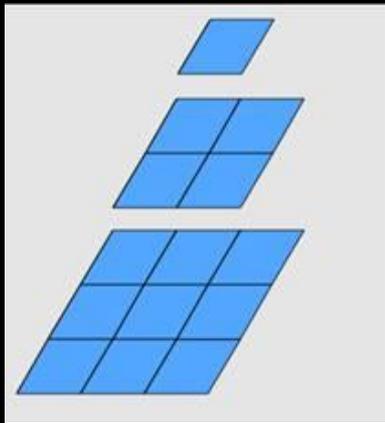
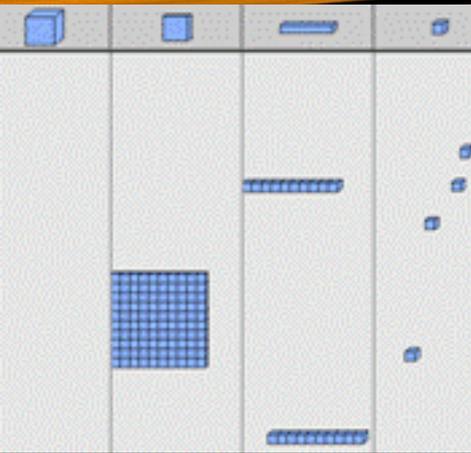


Image sources:

<http://www.learnalberta.ca/content/mewa/html/teaching/models.html>

HSYPERTHERMIA: DANGER FOR CHILDREN LEFT IN HOT CAR

Specify and formulate the mathematical problem

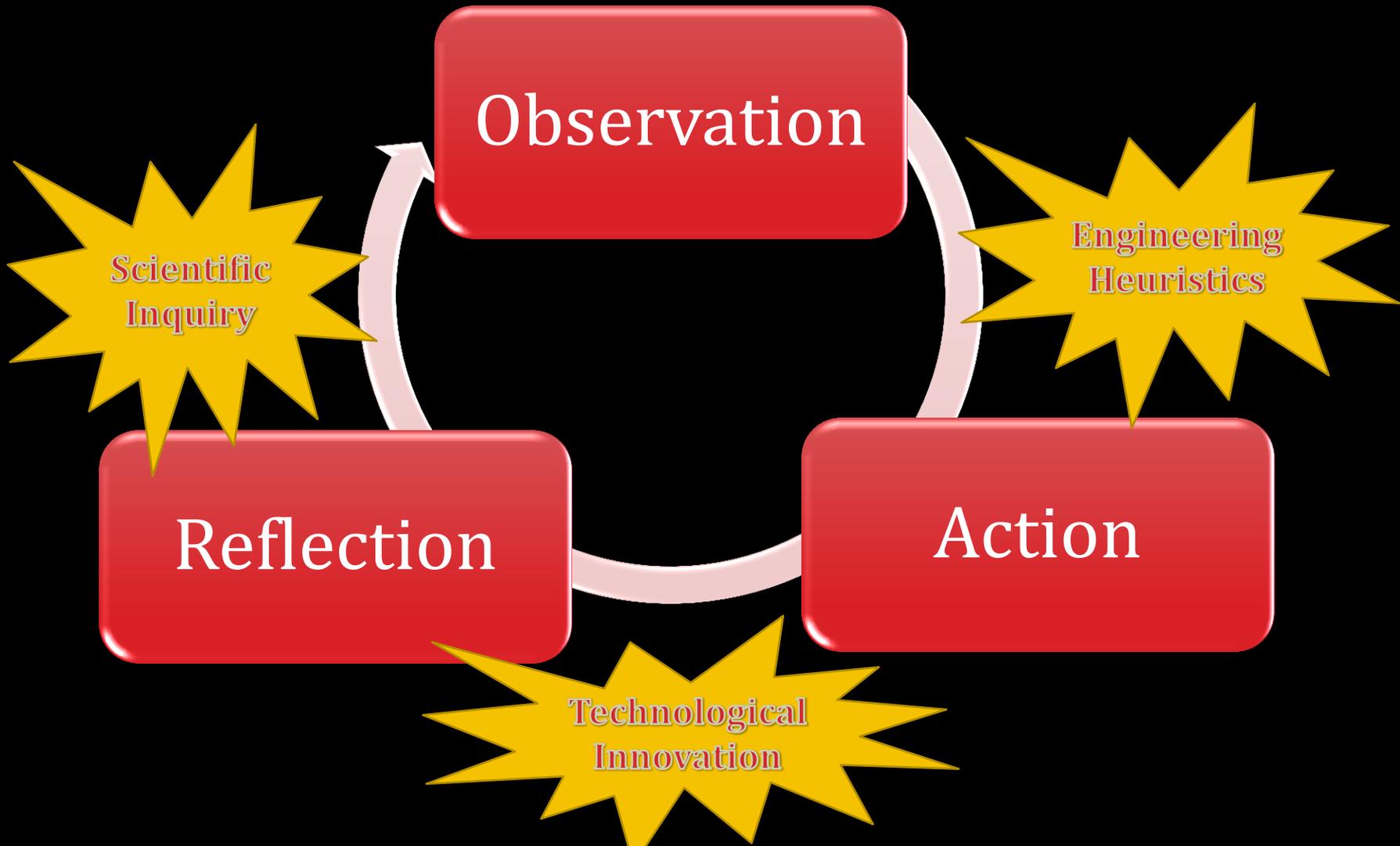
The rate of fluid loss from a body (a cube) depends on (is proportional to) its surface area, S . The amount of fluid in a body depends on (is proportional to) its volume, V . So a critical factor is the surface area/volume ratio of the body.

How would you use a graph to describe the model? (Plot a graph of S/A ratio against the length of side of cube)

Can you conclude that smaller cubes (children) will lose fluid at a greater rate than larger cubes (adults)?

Source: www.immchallenge.org.au
(Mathematical Modelling 2018)

THE ETHICS BEHIND THE PLANNING FOR ACTION





THANK YOU!

drhylaw@gmail.com