STEM IN MATHS (SIM) SERIES (I): MATHEMATICS AS SCIENCE

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STRUCTURE OF THE TALK

Chapter 1: What is STEM, really? And what kind of education for preparing ourselves to live in the 21st Century?

Chapter 2: What is Mathematics, really? And what is the role of the "M" in STEM?

Chapter 3: **SIM** Spirit – Making sense of mathematics through Transforming the pedagogy in the mathematics classroom

Chapter 4: What can we learn from Archimedes? The wonder of learning Maths through scientific inquiry

Chapter 1

What is STEM, really? And what kind of education for preparing ourselves to live in the 21st Century?

WHAT IS 'M' IN STEM?

STE*Money*
STE*Market*
STE*Mania*

STEM – WHAT? WHY? HOW?

Here comes the STEM
Drop like a pebble
from the cloud
Splash!
And gone?
Drip like the drizzle
from the sky
Whoosh!
And rippled with the breeze?

What kind of impact would STEM have on our education?

EDUCATION FOR 21ST CENTURY

The key advices for future education as offered by Yuval Noah Harari's *21 lessons for the 21st century:*

1. **Education (in terms of schooling) is not preparing our schoolchildren to secure a future job**
2. **The maxim for future education: change is the only constant and learning to learn is of the top priority for our schoolchildren**
3. **Teaching children not programming but reinvention**
4. **Equip the children with mental flexibility through the teaching of 'the four Cs' – critical thinking, communication, collaboration and creativity**

UNDERSTANDING AS A DANGEROUS ADVENTURE

Understanding is an adventure and, like any other adventure, is dangerous….. This implies that it ***affords unique opportunities*** …of contributing…to the broadening of our human ***experiences***, our ***self knowledge***, and our horizon, for everything understanding mediates is mediated along with ourselves.

(Gadamer's *Reason in the Age of Science*, 1979[1981Trans], pp.109-110)

LEARNING TO LEARN AS A HERMENEUTICAL PROCESS

…hermeneutics brings the contribution of the sciences into this context of mutual agreement that links us with the tradition that has come down to us in a unity that is efficacious in our lives, it is not just a repertory of methods…but philosophy (***practical philosophy***)..not only accounts for the procedures applied by science but also gives an account of the questions that are prior to the application of every science

(Gadamer's *Reason in the Age of Science*, 1979[1981Trans], p.137)

DEFINITIONS FROM OXFORD DICTIONARY

- ***Science***: the intellectual and practical activity encompassing the systematic study of the structures and behaviour of the physical and natural world through **observation and experiment**
- ***Technology***: the branch of ***knowledge*** ***(for technological innovation – invent/create, realise, implement)*** dealing with **engineering** or applied **sciences**
- ***Engineering*****:** the branch of **science** and **technology** concerned with the ***design***, building, and use of engines, machines, and structures.
- ***Mathematics***: the **abstract science** of number, quantity, and space, either as abstract concepts, or as applied to other disciplines such as physics and engineering.

THREE LEVELS OF INQUIRY ABOUT STEM

Level 1: Epistemology

How best to teach STEM?

Level 2: Ontology

What STEM is,

How STEM interacts with the real world?

Level 3: Axiology

Why children should learn STEM?

(see Chesky & Wolfmyer's *Philosophy of STEM Education*, 2015)

EXTREMELY BRIEF HISTORY OF STEM

STEM is not a new concept…STEM is not even a new acronym. The idea of content integration was originally explored more than a century ago… to standardize the agrarian school system of the late 1800's…the ***spirit*** of integrated instruction ***in STEM was actually honored in education more in the late 19th century than it is today***…In the early 1990's, the National Science Foundation formally coined the STEM acronym we use today to refer to the *individual* content disciplines of Science, Technology, Engineering, and Mathematics, but without the intent to formally integrate the subjects in schools.

(See Elliott Ostler's *21st Century STEM Education: A Tactical Model for Long-Range Success*, p.29)

STEM CONTENT =STEM EDUCATION?

…a degree in a STEM ***discipline*** would have the option to be highly specialized while a STEM ***education*** degree will require a somewhat broader general **understanding** of the **interrelatedness** of STEM topics…. Math teachers need to understand how the specific principles they teach in their math classes have **relevance**, and are even necessary, to other technical aspects of scientific testing and engineering heuristics.

(See Elliott Ostler's *21st Century STEM Education: A Tactical Model for Long-Range Success*, p.29)

WHAT A ***K-12 STEM EDUCATION*** IS FOR?

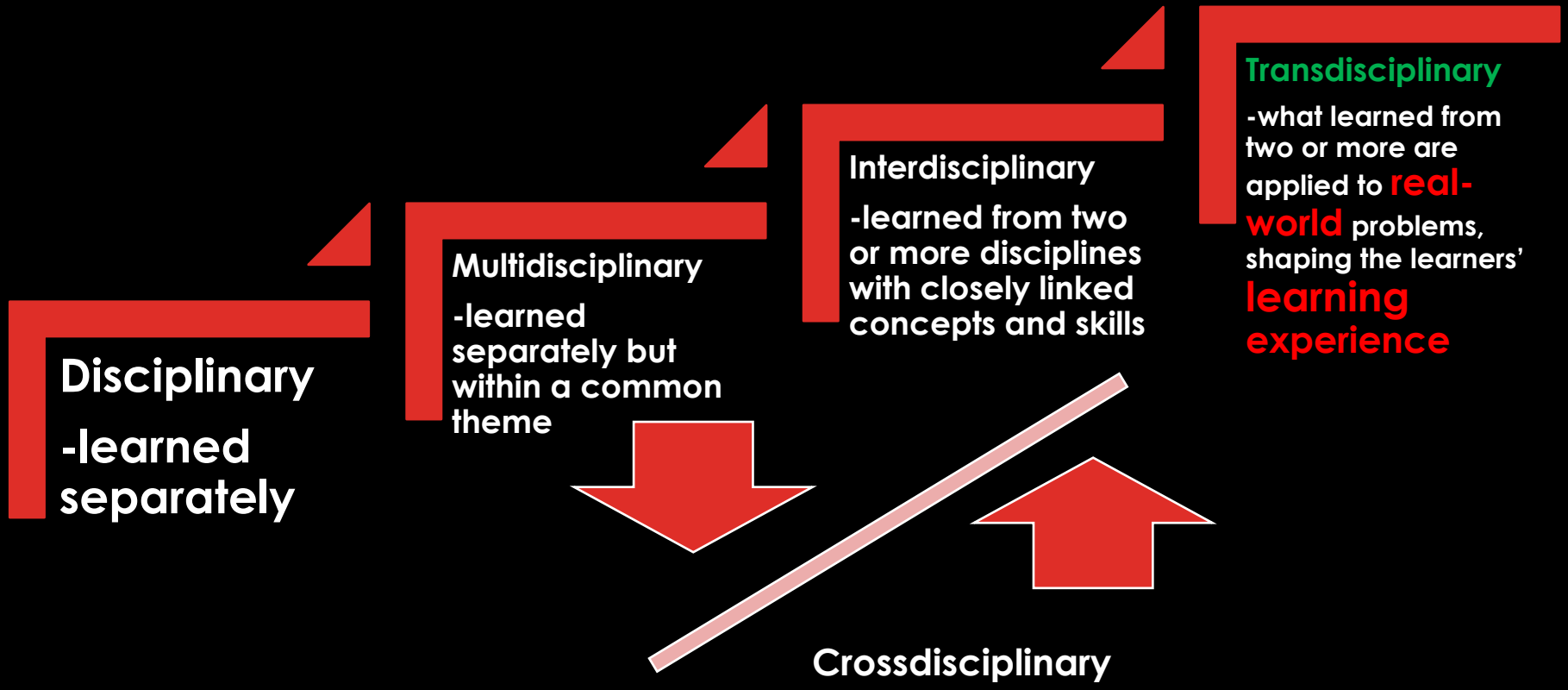
SIX functions of a STEM education:

1. **Problem-solvers**
2. **Innovators**
3. **Inventors**
4. **Self-reliant** (self-motivation, self-confidence, self-regulated or self-directed learning)
5. **Logical thinkers**
6. **Technologically literate**

How would we develop such a ***trans-disciplinary*** STEM curriculum?

(Janice Morrison's *TIES STEM education monograph series, attributes of STEM education*, 2006)

LEVELS OF STEM INTEGRATION



(Adapted from Vasquez et al., *STEM lesson essentials, grades 3-8: integrating science, technology, engineering, and mathematics*, 2013)

HOW TO INTEGRATE?

Of the four STEM areas, "math" is the most clearly defined as a formal subject…. The four STEM fields … have epistemological characteristics that differ markedly. … educators were primarily concerned with making school instruction more relevant to the life experiences of students

(See Dennis Herschbach's *The STEM Initiative: Constraints and Challenges*, pp.109-110)

My response to this: IN TODAY'S CLASSROOM LEARNING OF MATHS, CONCERNS ARE ACADEMIC ACHIEVEMENT RATHER THAN MAKING TEACHING MORE RELEVANT TO LIFE!

WHAT IS STEM, REALLY?

Here I attempt to say what I mean for it:

STEM as converging ***affordances*** that enhance the ***self-awareness*** of learners who need to equip themselves for coping with complexity as arisen from the technological advancement

(Law, *personal communication*, 2018)

MATHS AS THE AFFORDANCE OF AFFORDANCES

Science – **Inquiry** (open-ended)

Technology – **Innovation**

Engineering – **Design** (Creating) and Making (Constructing)

Mathematics – **Vision** for the reasons

(Seeing the problems and envisioning the solutions)

Chapter 2

What is Mathematics, really? And what is the role of the "M" in STEM?

WHAT IS MATHEMATICS?

Mathematics as a study of ***patterns***
(Resnik, 1981)

Mathematics as a study of ***structures***
(Shapiro, 1997)

Mathematics as ***ontology***
(Badiou, 2005)

MATHEMATICS IS ONTOLOGY

If what Alan Badiou argues is correct, mathematics enables us to understand the ontological (about a world or situation) truth and its ***relation to the world around us*** simply because he believes that "mathematics is the only ***discourse*** that can think ontologically"

(see Chesky & Wolfmyer's *Philosophy of STEM Education*, 2015)

MATHEMATICAL LENS

- **Mathematics is the classification and study of all possible patterns.** (Walter Warwick Sawyer, 1955)
- **Mathematics is a broad-ranging field of study in which the properties and interactions of idealized objects are examined.** (Source: Wolfram MathWorld)

Through Mathematics we see ***pattern, order,*** or ***structure.***

WHY MATHS?

be-cause….

What ***cause*** homo sapiens develop mathematics as we know today?

The ***cause***s come from our ***be***-ing as a human

MATHS = SCHOOL MATHS?

WHAT 'X' BELIEVE IN THE SUBJECT MATTER? WHO IS 'X'?

Let's see what John Dewey (*My Pedagogic Creed*, 1897) believe:

- I believe that **the social life of the child** is the basis of concentration, or correlation, in all his training or **growth**.
- I believe…that the true centre of correlation on the school subjects is not science, nor literature, nor history, nor geography, but **the child's own social activities**.
- I believe that **education cannot be unified in the study of science…because apart from human activity, nature itself is not a unity**; nature in itself is a number of diverse objects in space and time, and….is to introduce a ***principle of radiation*** rather than one of concentration.

MATHEMATICS AND LIFE

Without the making of meaning, both mathematics and life can be perceived as an ***absurd*** entity!

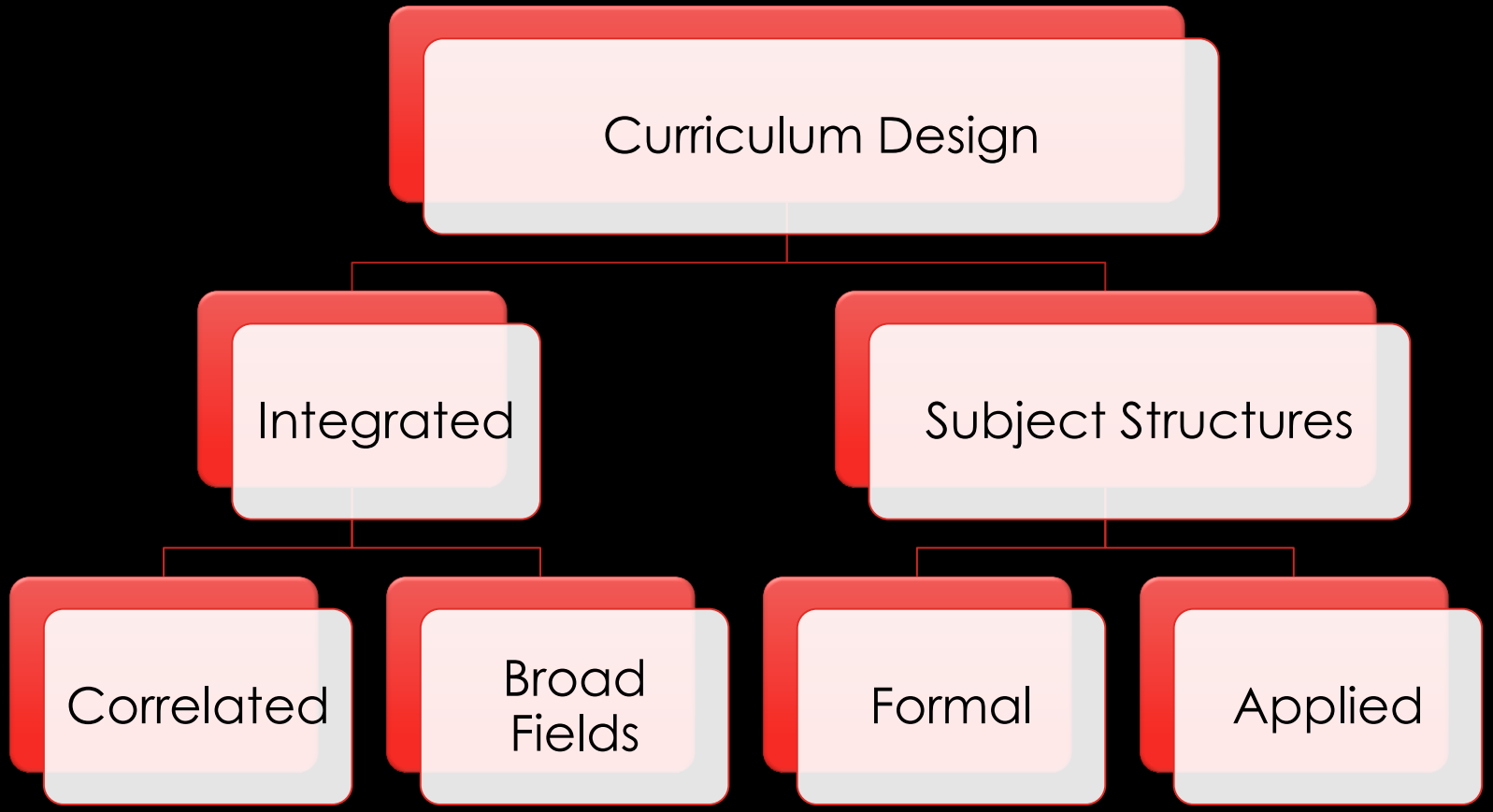
MAKE SENSE OF LIFE THROUGH MATHS

My own endeavour is not just to make sense of maths through our living but also of life itself through maths. I started with *Maths in Daily Life* (1997) and then to MACS (2017) to SIM (2018)

Maths As Common Sense (MACS) Project: Making sense of life through the search of invisible maths in our life experiences (with which hopefully knowing why learn maths)

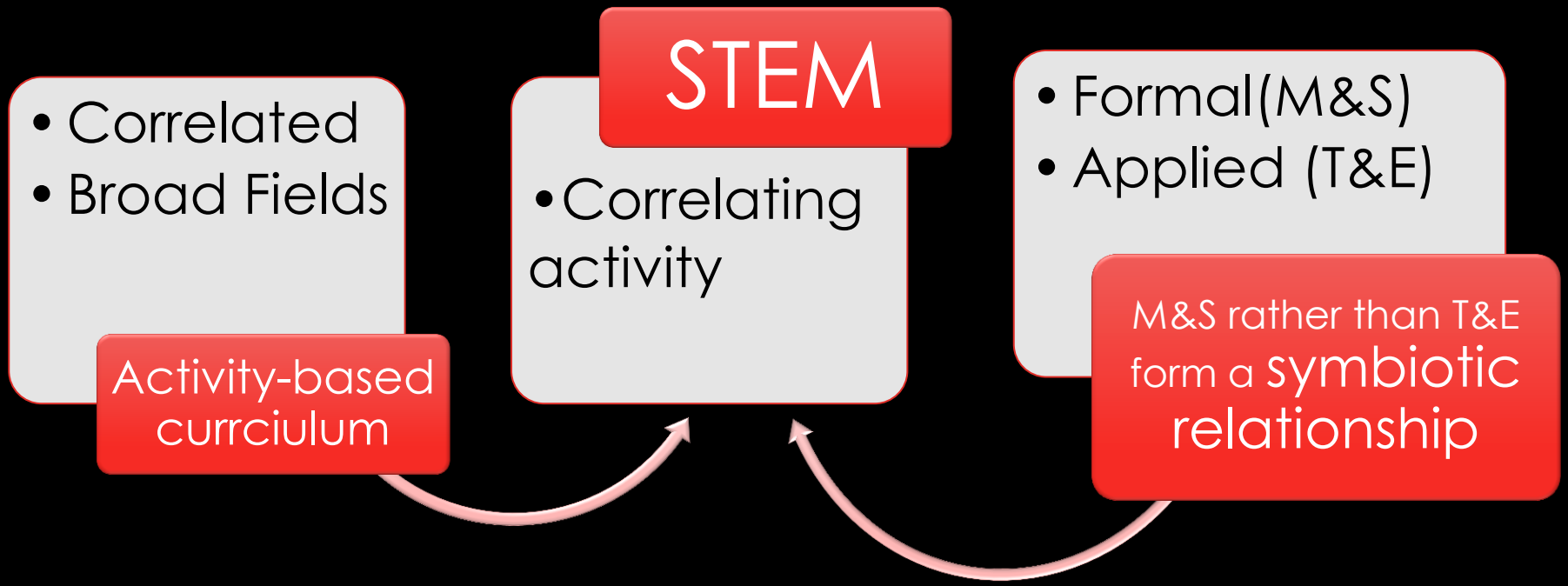
STEM In Maths (SIM) Project: Making sense of learning STEM-related knowledge through a reappraisal of the role of maths in STEM education

CAN '**STEM**' BE A SCHOOL SUBJECT FOR OUR SCHOOLCHILDREN?



(See Herschbach, *The STEM Initiative: Constraints and Challenges*, 2011)

HOW TO DO WITH 'STEM'?



(See Herschbach, *The STEM Initiative: Constraints and Challenges*, 2011)

BROADLY SPEAKING…

"Maths" as an analytical tool (the most formal subject)

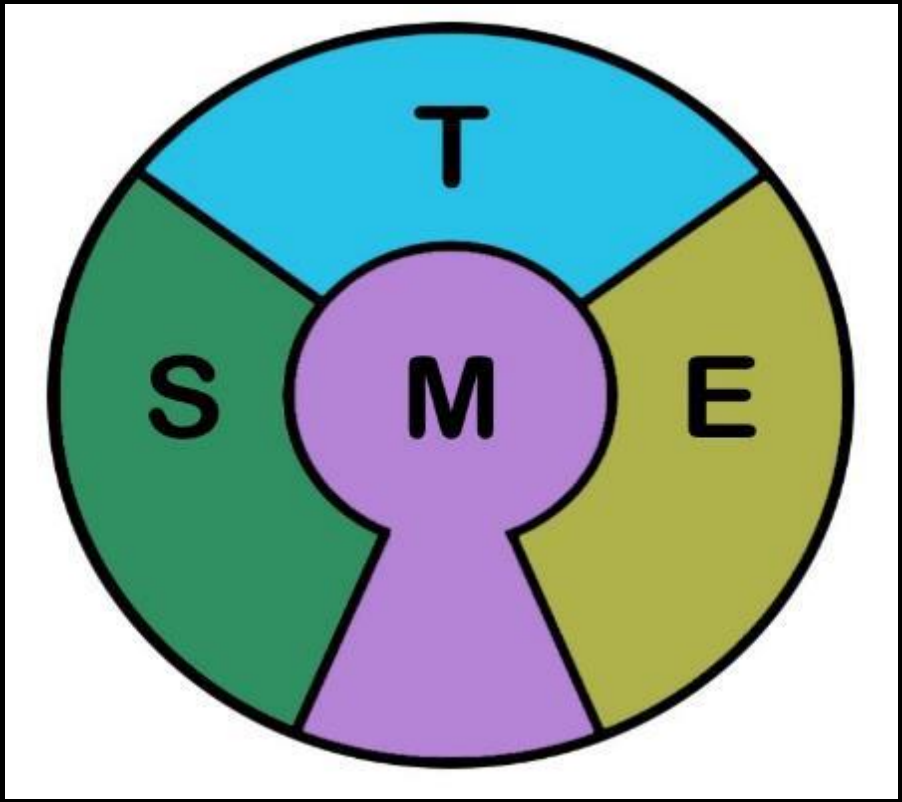
"Science" is to discover and advance knowledge

"Technology" (even broader than science) is just about everything in the designed, man-made world

"Engineering" refers to preparation for specific occupations or to apply from what we learn from maths, science and technology

(See Herschbach, *The STEM Initiative: Constraints and Challenges*, 2011, pp. 108-109)

THE ROLE OF MATHS IN STEM



M
E
T
S

(see Law, *School Mathematics Newsletter*, Issue 21, p. 8)

Chapter 3

SIM Spirit – Making sense of mathematics through Transforming the pedagogy in the mathematics classroom

MATHEMATICS/STEM PEDAGOGIES

- Traditional pedagogy
- **Constructivists pedagogy**
- **Transformative pedagogy**

(see Chesky & Wolfmyer's *Philosophy of STEM Education*, 2015)

WHAT SHOULD WE DO IN MATHS LESSONS

- promoting open-ended problems
- Applying mathematics to actual problems
- encouraging mathematical discourse: "talking" math
- use mathematics to describe the world
- highlighting topics such as geometry and spatial relations
- adopting 'hands-on' and 'minds-on' instructional activities

(Meyer & Meyer's *Teaching Mathematical Thinking through Origami*, 1999)

A NON-STEM MATHEMATICS LESSON

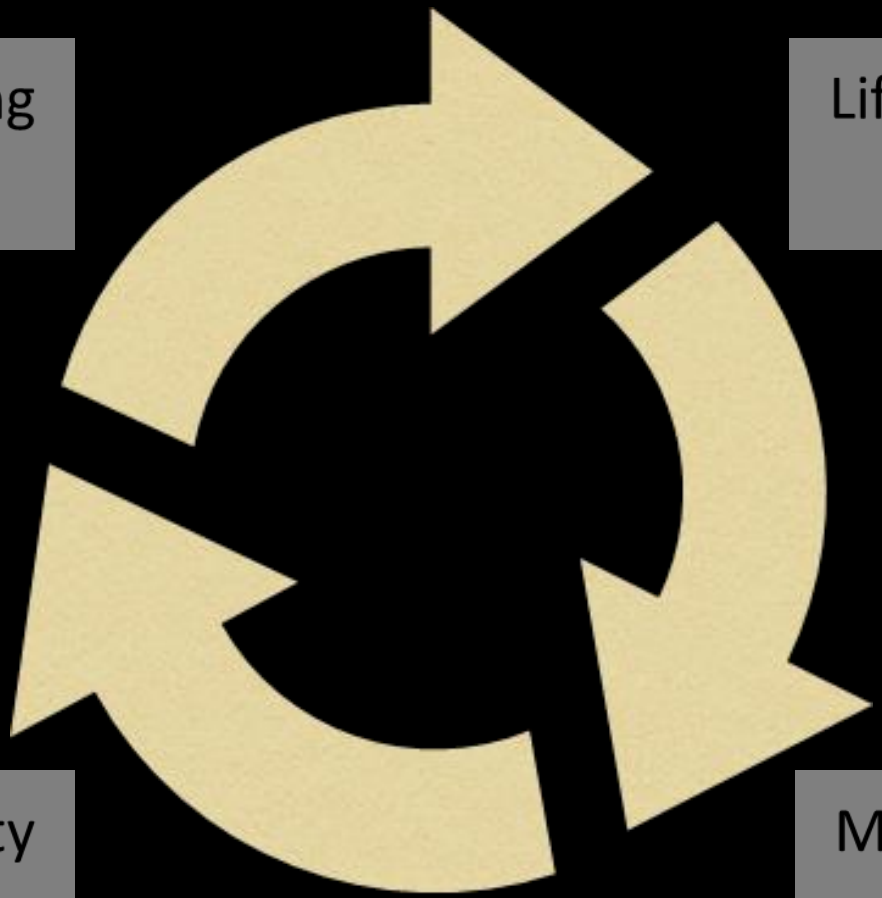
Video:

MATHS TEACHER (Mark Angel Comedy) (Episode 118)

BETWEEN "THINKING" AND "DOING"

Hand-on learning
動手「做」

Life experiencing
活「體驗」



Asking with curiosity
好奇「問」

Mindful Thinking
用心「想」

PAS - DANCING MATHS

Person-Agent-Subject

(Brian Rotman)

HOW TO IMPLEMENT STEM EDUCATION?

- D-Model (Detached)：Buy supporting educational services from the outside of school (借助外界提供支援教育的服務)
- A-Model (Add-in)：Create school-based STEM curriculum (以校本形式設計STEM課程)
- I-Model (Inclusive)：Develop STEM-embedded Subject-based curriculum [以學科本身原有的課程滲入STEM元素（IM:以數學為本；IG:以常識為本）]

‘IM’ MODEL (模式)：STEM-IN-MATHS (SIM) EDUCATION

M mapped with SET Ontology:
{{S},{T},{E},{S,T},{T,E},{S,E},{S,E,T},{Φ}}
(***SET*** as a code for Science, Engineering and Technology)

- IM0：M
- IM1：MS/MT/ME
- IM2：MST/MTE/MSE
- IM3：METS

WHAT AN IM LESSON IS DOING?

- Hand-on activity
- Open-ended inquiry (with the conduct of experiment)
- Dialogic (with space open for innovative thinking)
- Design ideas drawn from real-life experiences
- Extension tasking leading to the follow-up design of project work

Chapter 4

What can we learn from Archimedes? The wonder of learning Maths through scientific inquiry

METS

M: Seeing the inquiry problems through life experiences

(以數學語言理解生活經驗的意識，從而進一步界定探究的問題)

E: Constructing the model design for the identified task

(從問題出發，設計解難所需模型)

T: Exploring for the right tool for the task

(協商探討為解決問題創造所需工具 - 包括電腦軟件的使用)

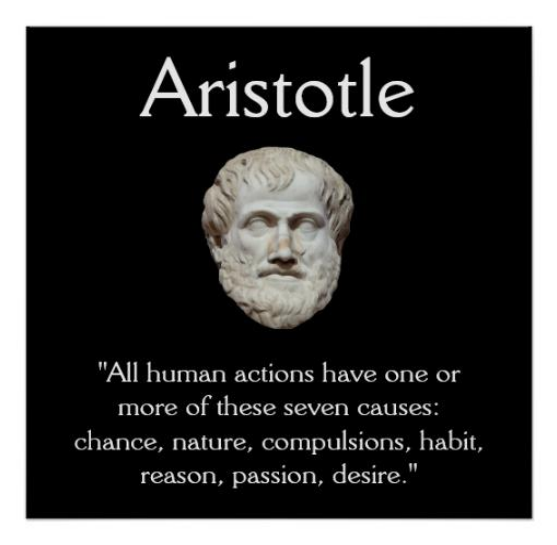
S: Experimenting for the inquiry of phenomenon

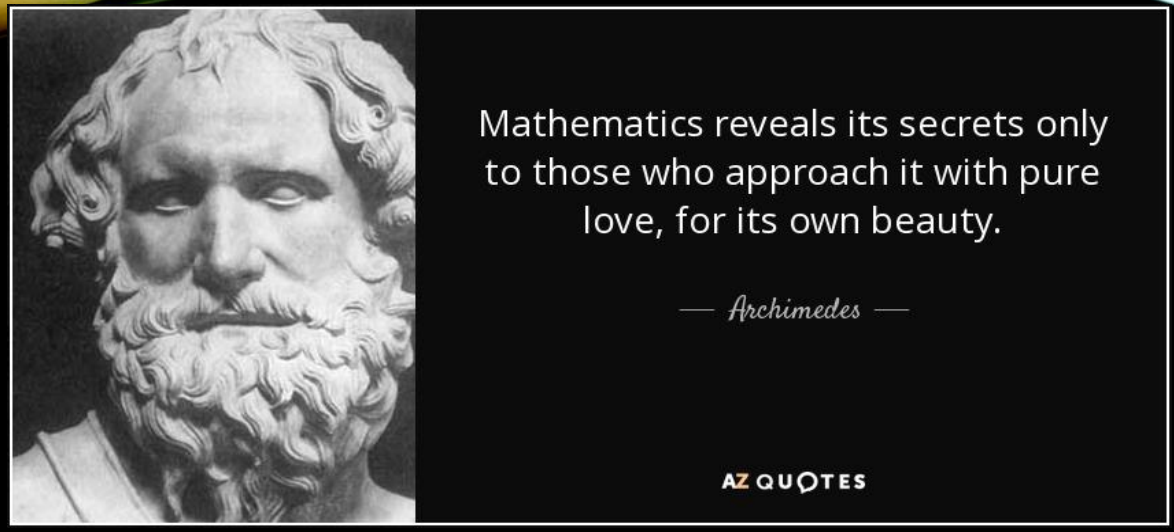
(利用實驗進一步探索相關的自然環境現象)

(see Law, *School Mathematics Newsletter*, Issue 21, p. 9)

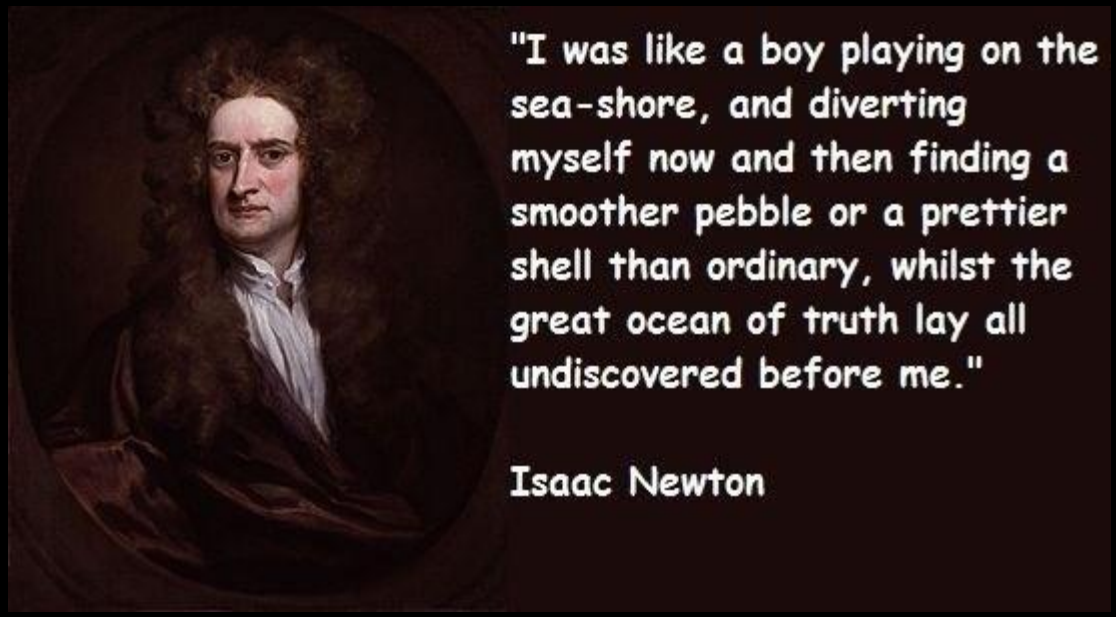
METSICIAN (數創師)

Can you name THREE great METSicians in the history of human civilization?





THE GREAT METSICIANS



Web pictures

ARCHIMEDES (287 - 212 BC) FAMOUS THEOREM

a sphere has two-thirds the volume of its circumscribing cylinder

WHAT IS SCIENCE?

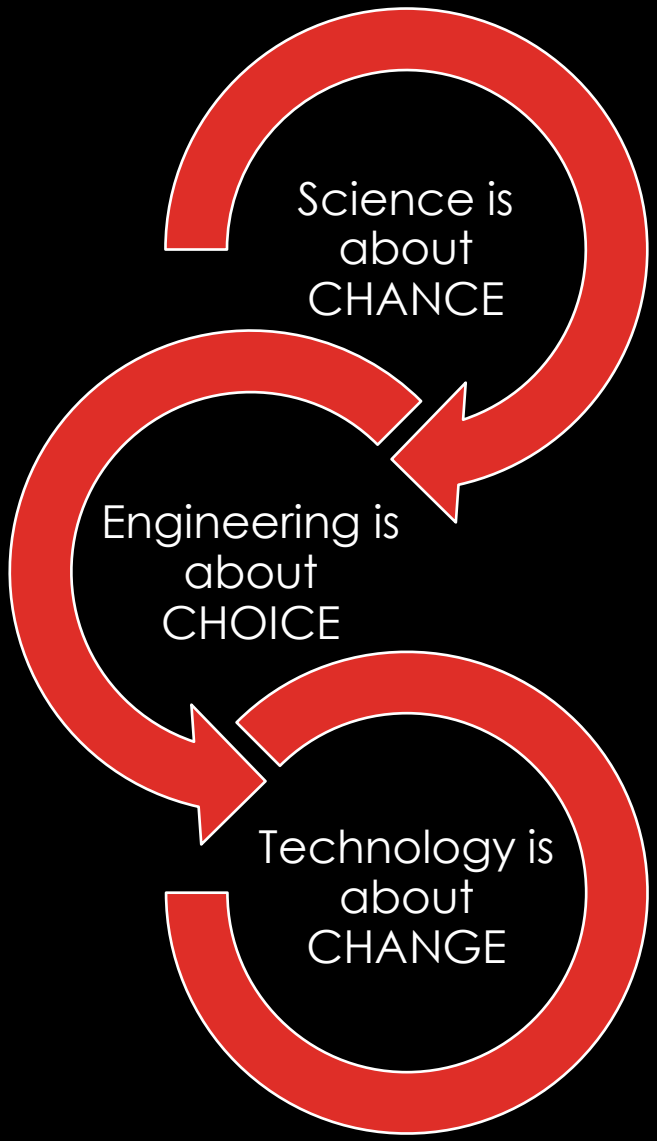
Science may be regarded as providing a series of ***different views of the world***,….. Each of the windows gives an ***equally valid view*** of different aspects ***of the same reality***….The full complexity of reality is far beyond our ability to grasp, but our limited ***understanding*** has given us powers…. The journey is what makes the enterprise fascinating.

(Brian Davies concluded in his book *Science in the Looking Glass: What Do Scientists Really Know?*, 2003, p. 279)

MATHS AS SCIENCE: WONDER AND PUZZLE

Observe the nature
And the world around us
Enlighten ourselves with the wonder
That drives us to endeavour with an inquiry
Think for a cause of what happens
That makes ourselves entangled
With unfinished chains of puzzle
Searching for the invisible trickster
Hidden in unbounded space
Or under our own shadow

CHANCE – CHOICE - CHANGE



THANK YOU!

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