Assessment of STEM Integrated Learning

A teacher workshop

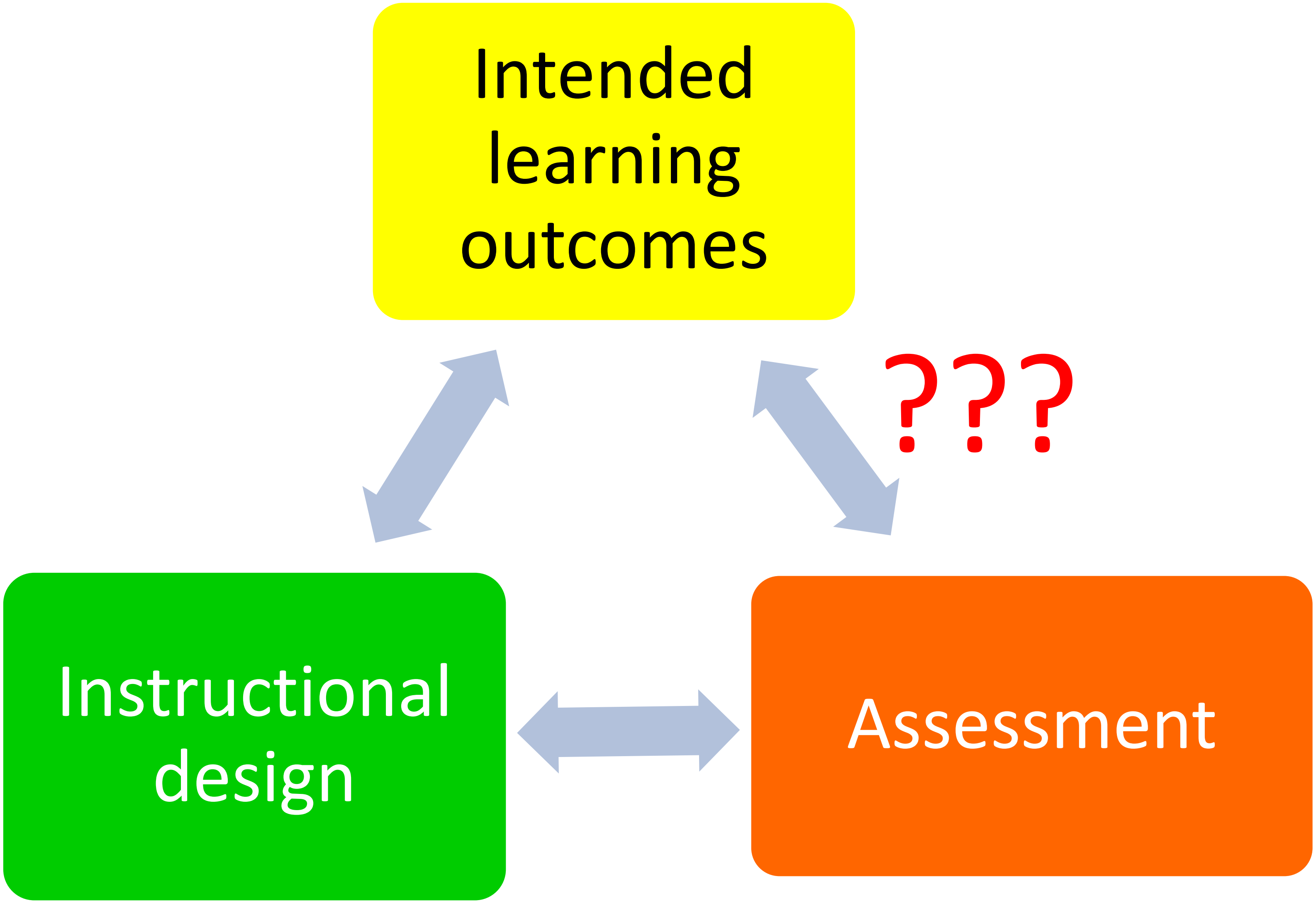
This workshop will discuss….

The Six ‘W’s of Assessment in STEM:-

1. **Why?**
2. **What?**
3. **Where?**
4. **When?**
5. **How?**
6. **Who?**

Assessment in STEM:
1. The ‘Why’?

The curriculum process
(A feedback loop)



Can the existing assessment measures cater to assessment in STEM?

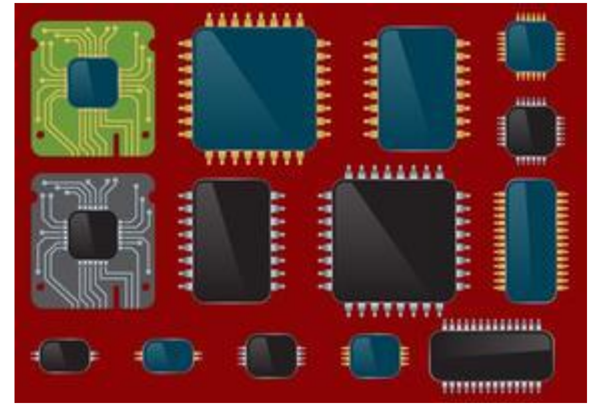
- Context?
- Range of outcomes assessed?
  - Low-order thinking or high-order thinking?
  - Concepts? Processes?
  - 21^{st} century skills?
- Compartmentalized or Integrated?
- Summative or formative?

Assessment in STEM education- THREE crucial considerations

1. What are the intended learning outcomes (ILOs) to be assessed? (A curriculum problem)
2. How to develop valid assessment measures? (A professional problem)
3. How to integrate STEM assessment into the current school assessment and reporting system? (A professional/political problem)

2. The ‘What’?

What to assess in integrated STEM



A pack of "CHIPS"

- **A**ttitudes
- **C**ontext
- **H**igh-order thinking
- **I**ntegration
- **P**rocesses
- 21st **S**kills

Domains of Intended learning outcomes (ILOs) of Integrated STEM education

1. Cognitive domain
   - cognitive processes/levels
   - Knowledge types
2. Metacognitive domain
3. 21st century skills domain
4. Affective domain

Setting Intended Learning Outcomes in the Cognitive Domain - *TWO* Dimensions

Revised Bloom's taxonomy (Cognitive Domain)

Anderson and Krathwohl (2001)

Dimension 1:

Knowledge taxonomy

1. Factual knowledge
2. Conceptual knowledge *(Knowledge about ‘what’ and ‘why’)*
3. Procedural knowledge *(Knowledge about ‘how’ – including understanding of procedures and implementing procedures by applying different thought processes)*
4. Metacognitive knowledge

Metacognitive Domain
(後設認知知識)

1. Understanding strategies for learning, thinking and problem solving
2. Understanding strategies for performing different cognitive tasks
3. Awareness of one's strengths, weaknesses and abilities in applying those strategies

*** Metacognitive knowledge is the basis of self-directed learning.*

Dimension 2:
Taxonomy of cognitive processes

SIX levels of cognitive processes:

- Remember (記憶)
- Understand (理解)
- Apply (應用)
- Analyze (分析) *(High-order thinking)*
- Evaluate (評鑑) *(High-order thinking)*
- Create (創造) *(High-order thinking)*

2-D matrix
‘Knowledge Type’ Vs ‘Cognitive Level’

	Factual	Conceptual	Procedural	Metacognitive
Remember				
Understand				
Apply				
Analyze				
Evaluate				
Create				

Examples of science learning outcomes based on the Revised Bloom taxonomy

Knowledge type? Cognitive process/level?

1. **Name** some common scientific apparatus
2. **Understand** scientific concepts
3. **Apply** scientific processes in carrying out investigations
4. **Identify** patterns from scientific data
5. **Evaluate** experimental design and sufficiency of data to support conclusions
6. **Plan** for a scientific investigation

Examples of science learning outcomes based on the Revised Bloom taxonomy

- **Name** some common scientific apparatus (Remember factual knowledge)
- **Understand** scientific concepts (Understand conceptual knowledge)
- **Apply** laboratory techniques in carrying out investigations (Apply procedural knowledge)
- **Identify** patterns from scientific data (Analyze, PK)
- **Evaluate** experimental design and sufficiency of data to support conclusions (Evaluate, PK)
- **Plan** for a scientific investigation (Create, CK/PK)

Emphases of ILOs in STEM
(1) High-order thinking

	Factual	Conceptual	Procedural	Metacognitive
Remember				
Understand				
Apply				
Analyze				
Evaluate				
Create				

Higher-order thinking

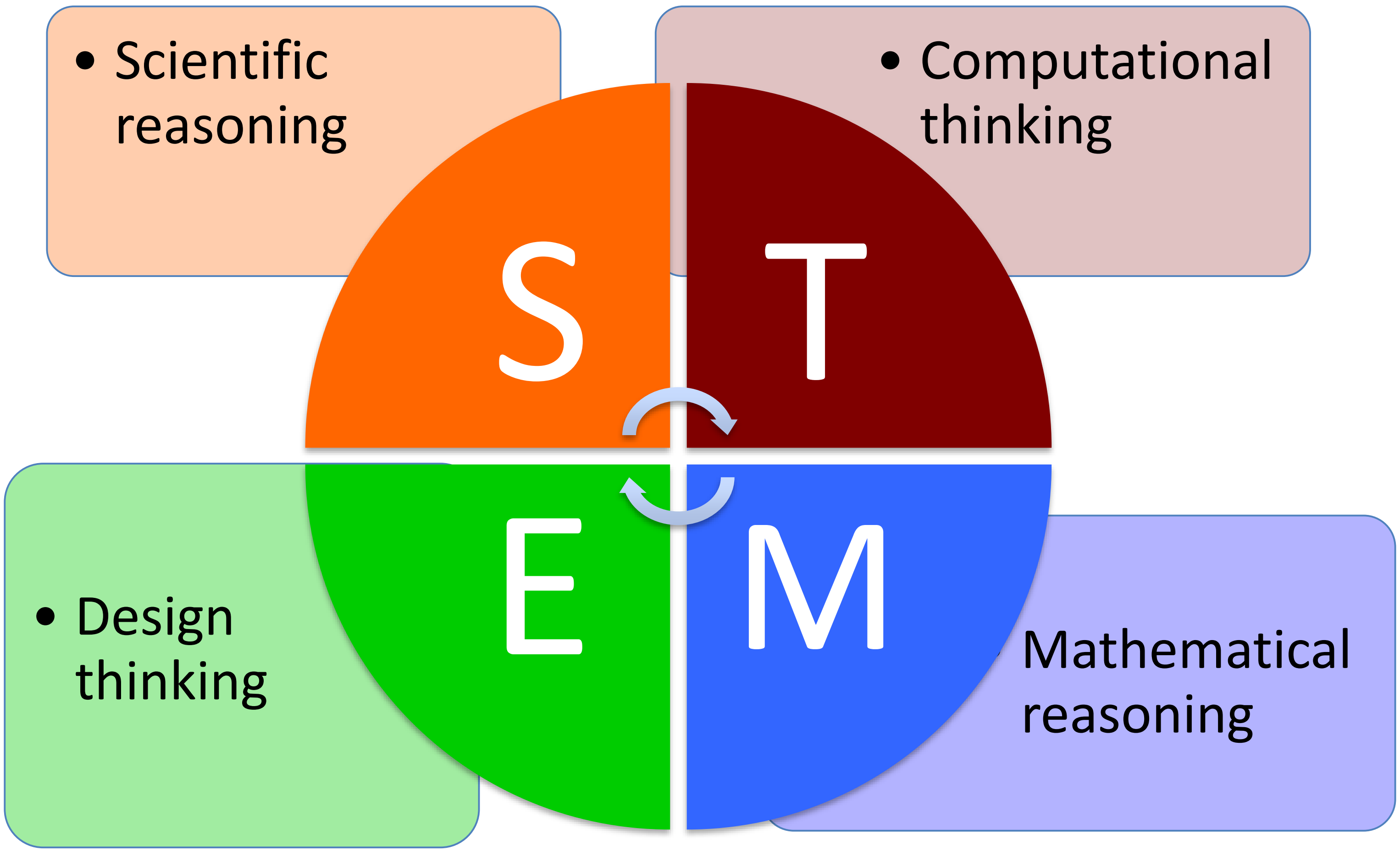
Emphases of Intended Learning Outcomes
(2) Procedural knowledge

	Factual	Conceptual	Procedural	Metacognitive
Remember				
Understand				
Apply			Hands-on, minds-on experience and skills	
Analyze				
Evaluate				
Create				

Examples of learning outcomes for STEM

E.g. Science	Conceptual	Procedural
Remember	Name the laws discovered by Mendel about heredity	State the characteristics of a fair test
Understand	Understand how levers provide leverage	Explain why a control experiment is needed in a fair test
Apply	Apply the concept of air pressure in explaining how the hand-wash bottle works	Connecting a closed circuit with two LEDs and a buzzer
Analyze	Identify the causes of the increase in plastic wastes	Analyze data from a fair test to find out the effect of one variable on another
Evaluate	Evaluate the explanatory power of a theory	Evaluate the effectiveness of a product against external criteria
Create	Generate a theory based on evidence	Plan for an investigation into the effect of light colour on plant growth/ Design a product to solve a societal problem

Reasoning/Thought processes underlying conceptual and procedural knowledge in STEM



Emphases of Intended Learning Outcomes
(3) Self-directed learning & PBL

	Factual	Conceptual	Procedural	Metacognitive
Remember				
Understand				
Apply				
Analyze				
Evaluate				
Create				

Self-directed learning & Problem-based learning

Emphases of Intended Learning Outcomes
(4) 21st century skills

- Communicating information, ideas, designs/solutions and arguments
- Critical reasoning and argumentation
- Collaborating with peers
- Problem solving
- Creativity and innovativeness
- Self-learning, self-monitoring, self-reflecting and self-regulating

Emphases of Intended Learning Outcomes
(5) Affective Domain

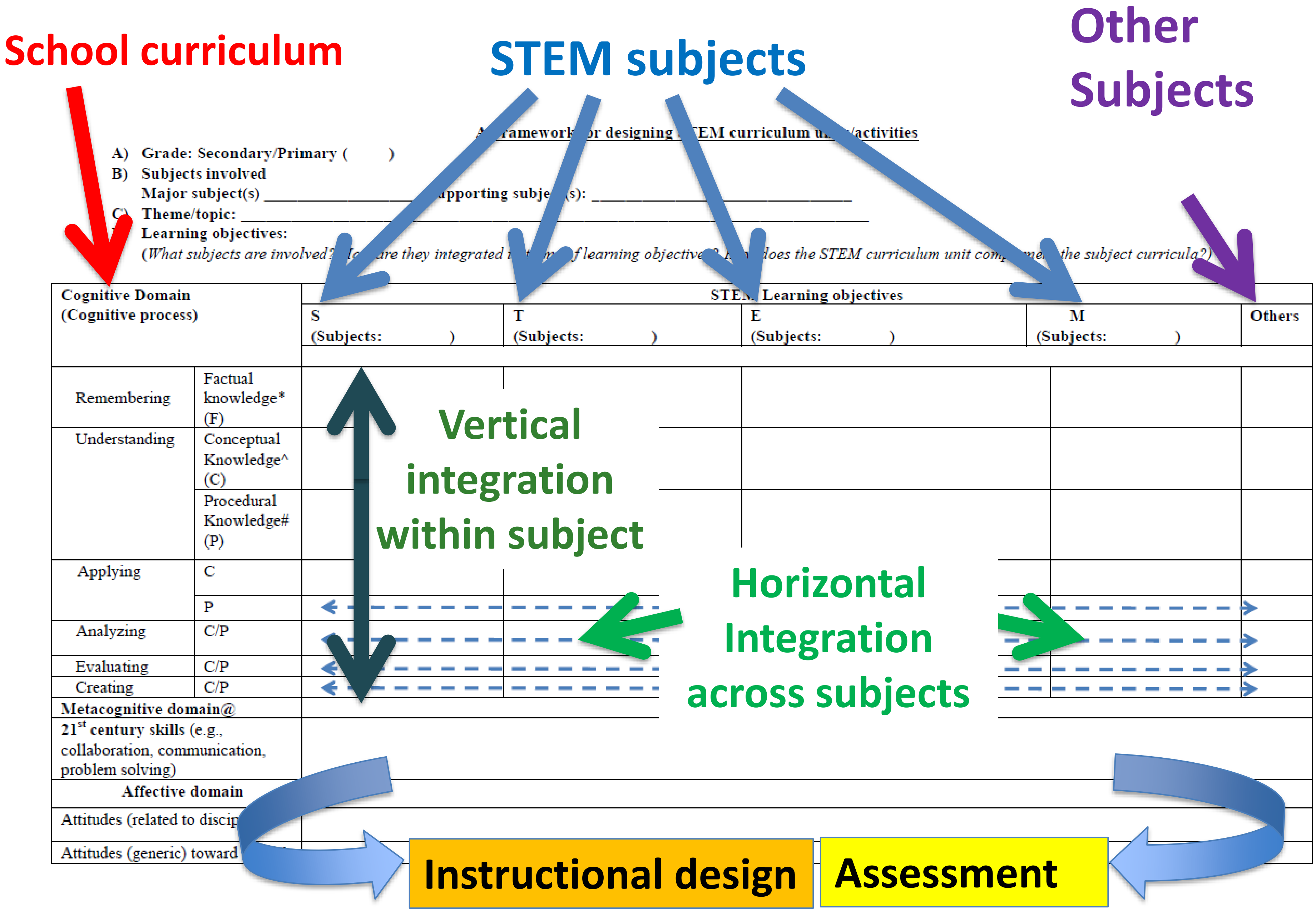
Attitudes (related to disciplines)

- Objective, able to tolerate ambiguity or uncertainty, curiosity, honesty, striving for optimization, open-minded, willing to take risks, being precise and reflective

Attitudes toward STEM

- Interest, willingness to participate, valuing, persevering, self-confidence, feeling satisfied

A Multi-dimensional Framework for STEM Curriculum Design



3. The ‘Where’?

Sources of evidence

- Where could you obtain evidence of student achievement?

Activity 1

- List as many ***sources of evidence*** as possible for assessing STEM learning outcomes
- What do different sources of evidence tell you about student performance ???

Activity 1: Some sources of evidence

- Work plan
- Prototype
- Research plan
- Student reflection
- Design drawing
- Scientific investigation
- Artifact
- Competition
- Revised prototype
- Testing record
- Presentation

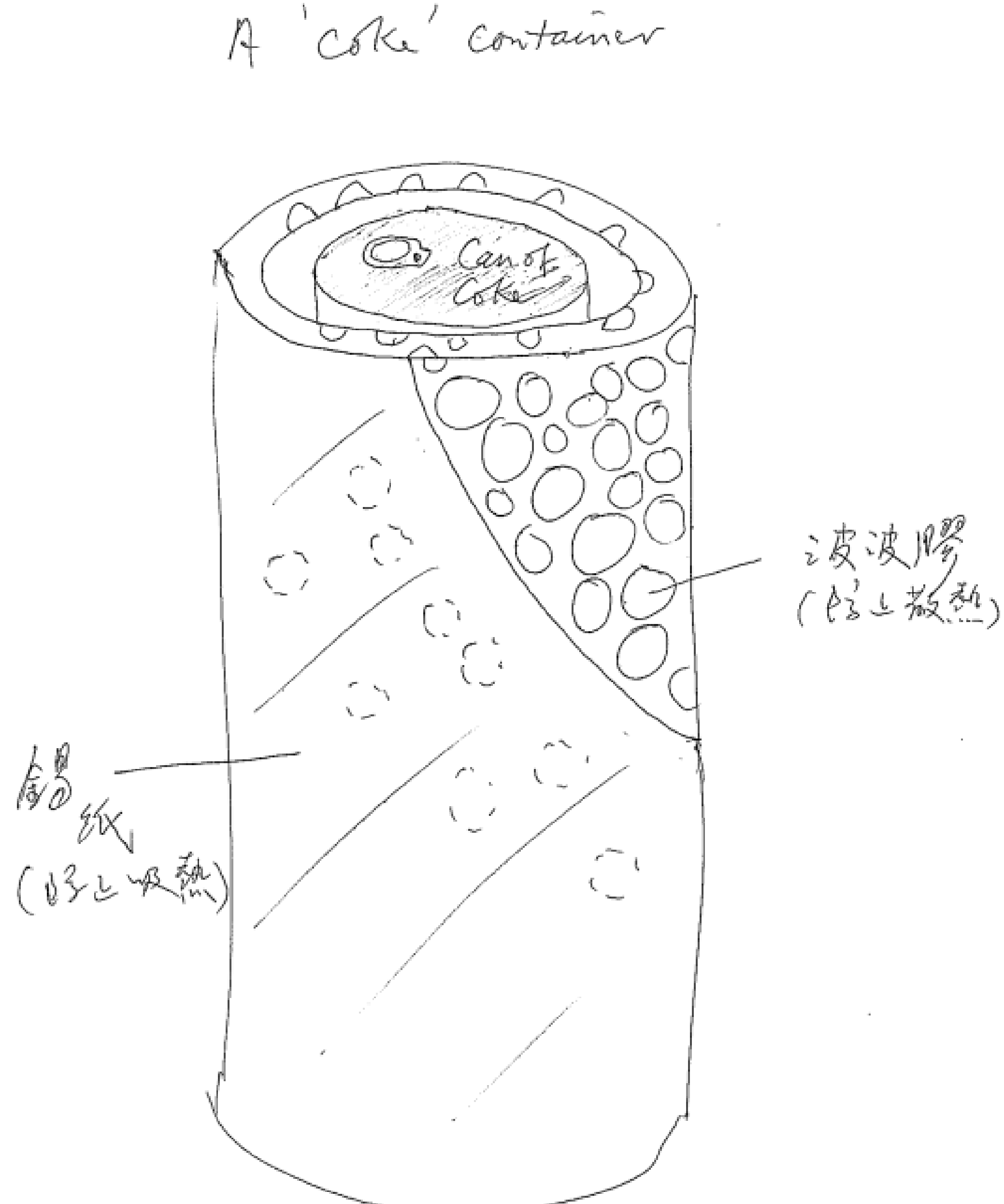
Activity 2 - Assessing designs

Design a small container that can keep a can of coke ($330\ cm^3$) cold after it was taken out from the fridge.

- Criteria for your design:
  - Only a gain of 10^oC is allowed after half an hour.
  - The volume of the container is no more than double that of the coke can
  - Reusable
- Constraint:
  - Low cost, use materials available in a stationery store or a supermarket

Draw your design in the form of an annotated diagram illustrating details and explanations of the design.

A sample of student’s design drawing



Discussion

1. What features are included and what are missing in the design drawing?
2. What ILOs could be assessed based on the design drawing?
3. What are the limitations of design drawing as evidence of learning?

Activity 2 - Assessing designs

(Suggested ILOs to be assessed)

1. Understanding and application of scientific concepts
2. Understanding and applying mathematical concepts and skills
3. Problem solving skill
4. Creativity
5. Skills for making design drawing
6. Written communication skills

Activity 3

Assessing products/artifacts

1. Examine the STEM product provided
2. What ILOs could be assessed based on the artifact produced?
3. What are the limitations of artifacts as evidence of learning?

Activity 3

Assessing products/artifacts
(Suggested ILOs to be assessed)

1. Understanding and application of procedural knowledge (S, T, E and M)
2. Effectiveness in meeting criteria
3. Stability
4. Problem solving
5. Hands-on/crafts/IT skills
6. Creativity

4. The ‘When’?

Formative or Summative?

During the learning process - Formative assessment

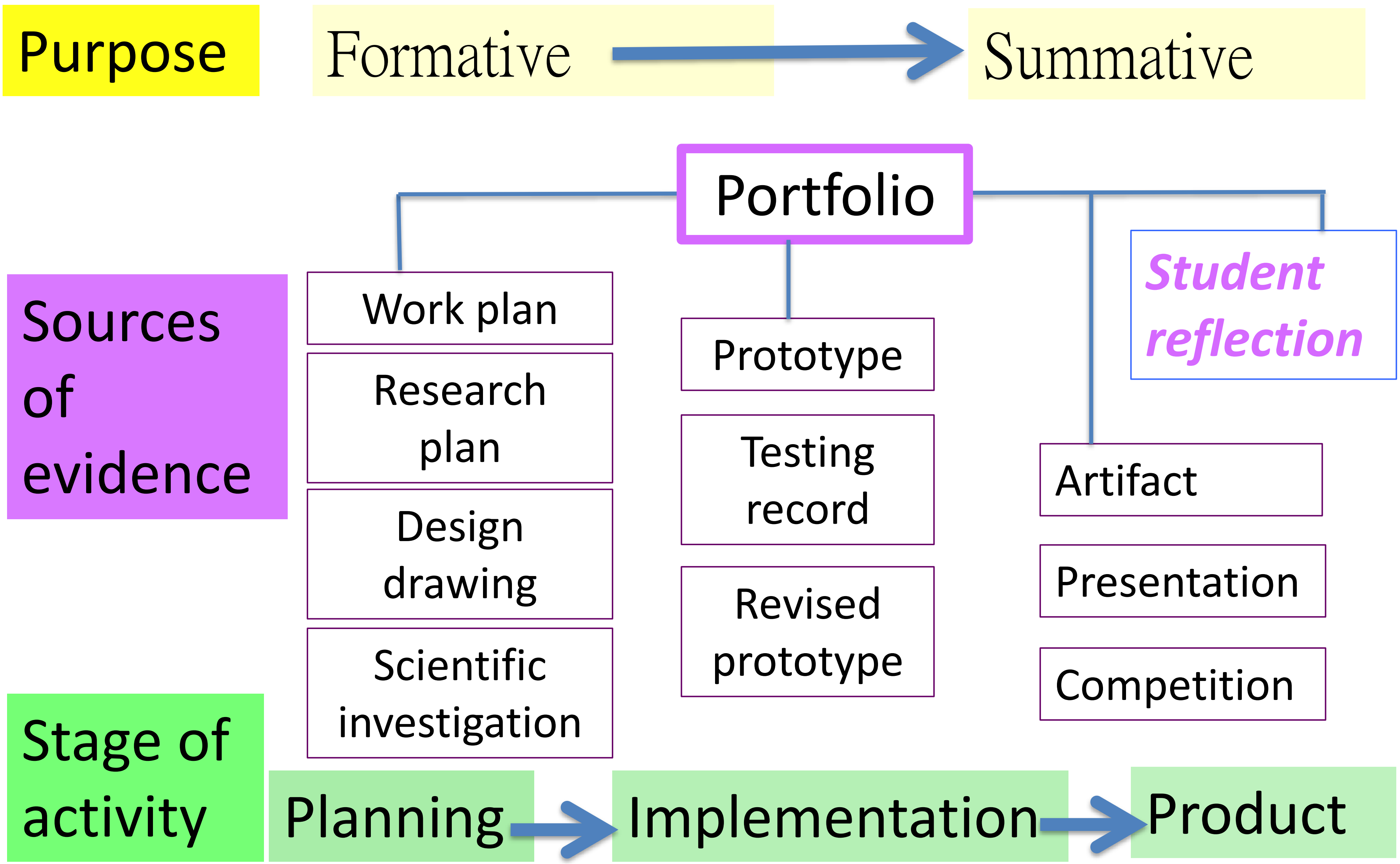
After the learning process - Summative assessment

Activity 4

1. What are the sources of evidence that are useful for:
   - formative purpose?
   - summative purpose?
2. Arrange your sources of evidence in chronological order on the A3 table provided

*Add additional sources of evidence as you see fit

Activity 4: Sources of evidence aligned with the assessment process



Activity 5

Assessing the learning process
(Student portfolios as sources of evidence)

1. Examine **TWO student e-portfolios.**
2. What do they tell you about student achievement?
3. What ILOs could be assessed based on student portfolios?
4. What are the limitations of portfolios as evidence of learning?

Activity 5 - Assessing e-portfolio

(Suggested ILOs to be assessed)

1. Information search/research skills
2. Problem solving (planning)
   - Generating alternative solutions
   - Generating hypotheses (if investigations required)
   - Breaking down the tasks into sub-tasks and sequencing them appropriately
3. Problem solving (implementation)
   - Testing/experimentation
   - Trouble-shooting
   - optimization

Activity 5 - Assessing e-portfolio

(Suggested ILOs to be assessed)(Cont'd)

4. Hands-on/crafts/IT skills (including use of tools/instruments)
5. Collaboration
6. Communication
7. Critical reasoning
8. Attitudes

5. The ‘How’?

Judging performance/achievement

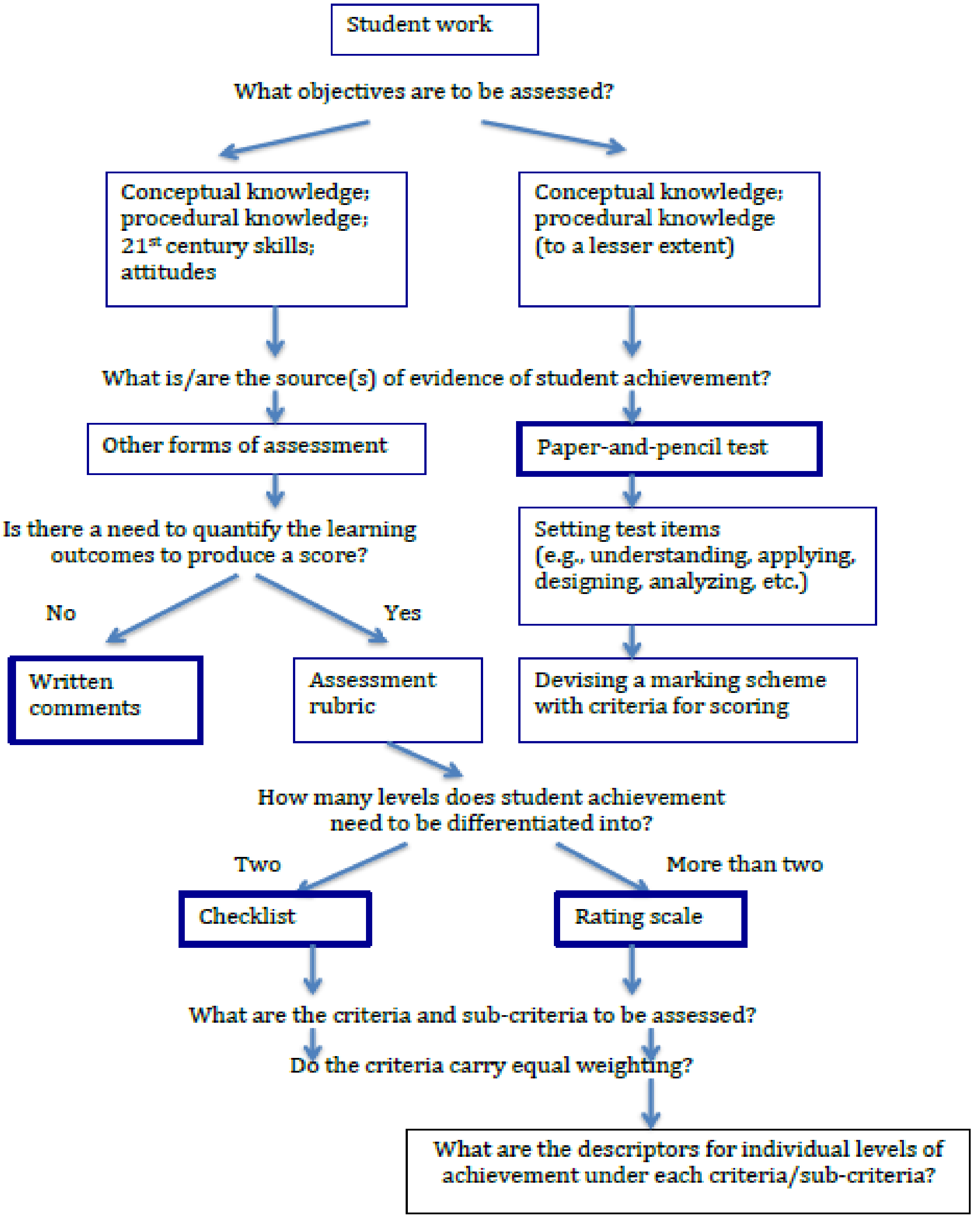
1. Modes of assessment (= Sources of evidence)
2. Assessment criteria (= Expected learning outcomes)
3. Levels of achievement

   Purposes:-

   – recording achievement
   – differentiating abilities
   – indicating progression
   – Providing feedback

A road map for choosing and designing assessment measures

A guide to designing assessment for STEM activities



Designing assessment rubric
(Suggested steps)

1. Deciding on the assessment criteria (from ILOs)
2. Defining the criteria operationally **(sub-criteria)**
3. Deciding on the number of attainment levels **(for differentiation and progression)**
4. Naming the attainment levels
5. Deciding whether descriptors for individual levels are needed
6. Setting descriptors

Format of assessment rubric (1)
(for *differentiation* within the same grade)

Level of Attainment / Criteria	Excellent	Good	Fair	Poor
Criterion 1				
Sub-criterion (a)	Performance descriptor	Performance descriptor	Performance descriptor	Performance descriptor
Sub-criterion (b)				
Criterion 2				
Criterion 3				

Format of assessment rubric (2)
(for *defining progression* across grades)

Level of Attainment / Criteria	Grade 6	Grade 5	Grade 4	Grade 1-3
Criterion 1				
Sub-criterion (a)	Performance descriptor	Performance descriptor	Performance descriptor	Performance descriptor
Sub-criterion (b)				
Criterion 2				
Criterion 3				

Activity 6 - Designing rubric (1)

Design a rubric for assessing problem-solving skills

- Break it down into TWO sub-criteria
- Set the levels and descriptors for each of the sub-criteria.

Activity 6 - Designing rubric

E.g. Criterion: Problem-solving skills

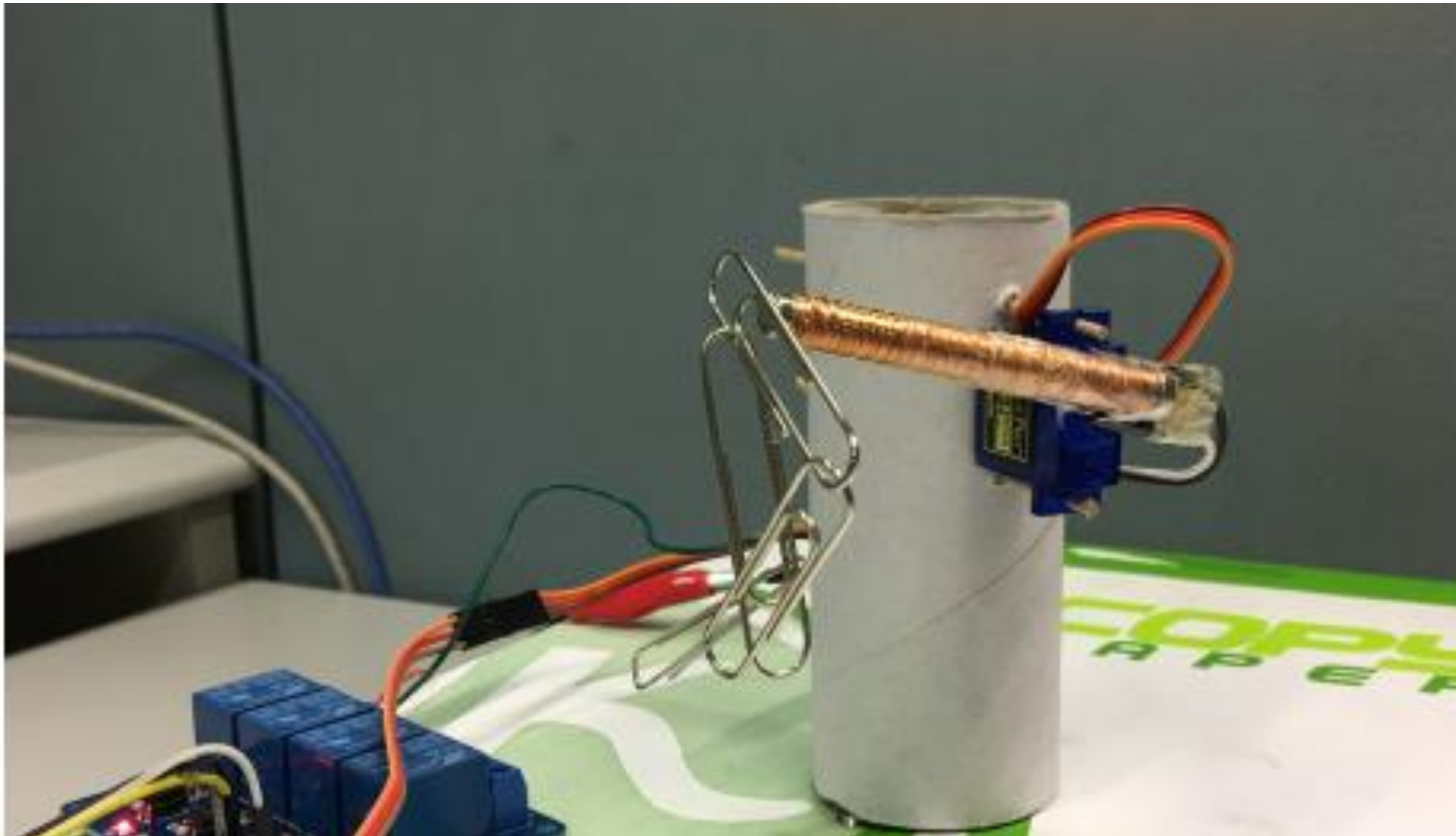
Sub-criterion	High	Middle	Low
Problem analysis	Sequence the sub-tasks	Divide problem into sub-tasks	Take problem as a single task
Considering alternative solutions	Develop criteria for differentia-ting alternative solutions	Develop alternative solutions	Consider only a single solution as if there is a only a single answer to the problem.

Activity 7 - Designing rubric (2)

Design a rubric for assessing engineering design skills

- Select an artifact from your collection
- Break *"engineering design skills"* down into sub-criteria
- Set the levels and descriptors for each of the sub-criteria.

E.g. An automated electromagnet



Activity 7 - Designing rubric (2)

A rubric for assessing engineering skills

評估項目	評估標準	
了解問題的挑戰	‧ 不理解電磁鐵起重機的原理及功用，只模仿別人或現有的設計	‧ 掌握問題的要求及電磁鐵起重機的功用，並清楚設計上的限制
研究	‧ 繞過研究階段而直接製作電磁鐵起重機	‧ 進行全面的研究，包括研究工業用的起重機的設計，以及對電磁效變因進行有系統探究及公平測試
構想意念	‧ 只能提出表面化的意念	‧ 從多方面考慮電磁鐵起重機在設計上的要求，能詳細考慮各組件在操作上的協調
表達意念	‧ 只表達了電磁鐵起重機的基本意念，忽略了細節部分（如組件的協調、操作上可能出現的問題），可行性不大	‧ 能具體地表達設計意念，設計的細節部分亦經過深思熟慮，以增加製成品可行性
製作方法	‧ 不懂運用編程，以控制機械或電磁鐵部份的操作	‧ 有效進行編程，亦能根據科學探究所得到的結果製作電磁鐵組件
解難	‧ 未能識別、分析或解決製作上遇到的難題	‧ 能聚焦於製作上所遇到的難題，提出解決方法
進行測試	‧ 未能按設計要求進行測試	‧ 能對設計的每一項要求作嚴謹的測試
反覆修訂	‧ 未能有系統地根據回饋改良設計，或只完成單一輪設計	‧ 根據測試的數據及他人的回饋，加入新理念，改良原來的設計
對活動過程進行反思	‧ 單憑直覺進行設計，缺乏自我監察力，對過程及製成品缺乏反思	‧ 由始至終都能不斷反思及監察設計策略的成效，如自律地按時間表完成工序、運用客觀數據作檢討及改良
製作質量	‧ 未能滿足設計要求，各組件的運作未能互相配合及協調，結構欠穩	‧ 能滿足設計要求，運作暢順，可靠性高，結構穩定，能重複多次使用

初學水平 1 2 3 4 5 專業水平

圖十三：有關工程設計及製作方面的評估項目及評分標準

Hints for designing level descriptors

- Use ‘absolute’ descriptors (illustrated with evidences)
- Use relative descriptors (in case where absolute descriptors are not obtainable)
- Relate to frequency/occurrence of performance indicators
- Relate to level of assistance rendered by others (teachers/parents)

Scoring – points to note

- Assign weighting to each criterion
- Assign a score range for individual attainment levels

Scoring using assessment rubric

Level of Attainment / Criteria	Excellent (9-10)	Good (7-8)	Fair (4-6)	Poor (0-3)
Criterion 1 (50%)				
Sub-criterion (a)	Performance descriptor	Performance descriptor	Performance descriptor	Performance descriptor
Sub-criterion (b)				
Criterion 2 (30%)				
Criterion 3 (20%)				

Reflection on scoring using assessment rubric

1. Do you think the assessment rubric is reliable and valid for assessing students’ performance in STEM?
2. What are the limitations or potential risks in using assessment rubrics for scoring?
3. How to further improve reliability and validity using assessment rubrics?

6. The ‘Who’?

Who could be the assessor?

1. *Teacher*
2. *Self*
3. *Peer (within or outside the student group)*
4. *Others (e.g., parents, judges)*

Discussion

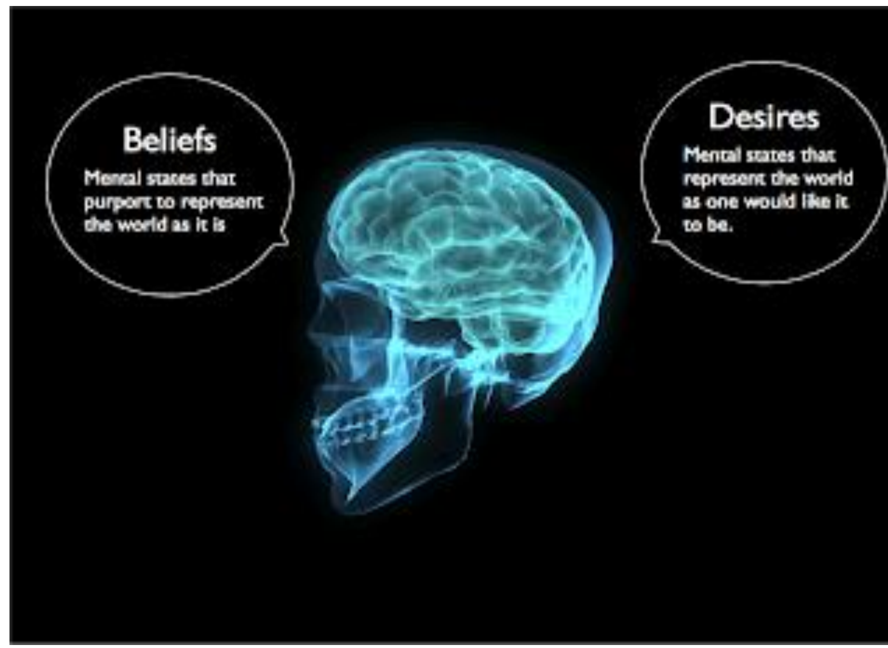
1. What ILOs can best be assessed through self and peer assessment?
2. Modes of self/peer assessment
3. What are the advantages and disadvantages of self and peer assessment?
4. How to make full use of these two assessment measures?

Paradigm shift in assessment for STEM

1. Assess a wider range of intended learning outcomes
2. Make assessment more meaningful and valid
3. Shift emphasis from summative to formative assessment
4. Move from singular to multiple assessment modes
5. Make assessment criteria and levels of performance more transparent
6. Put onto students the responsibility for learning and achieving
7. Focus on progression of attainment (across ability levels, grades and key learning stages)

Final words about assessment

- Make as much evidence of your students' achievement as ***'accessible'***, and ***'assessable'*** as possible.



- No universally applicable assessment practice !
- Need to tailor to your own needs and your students' and school's needs !
- **This workshop is to present to you various possibilities!**

STEM Education

A **golden opportunity** to reform school assessment

OR

Another initiative to be **stifled** by the prevailing school assessment system

???


THANK
YOU

Suggested solutions for activities