Assessment of STEM Integrated Learning

A teacher workshop

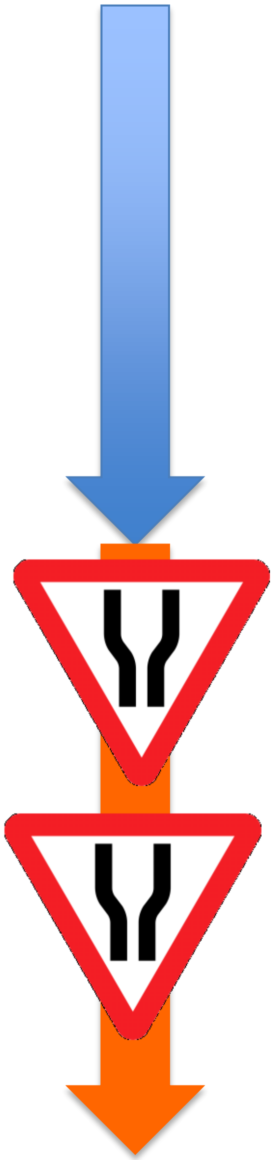
This workshop will discuss….

The Six 'W's of Assessment in STEM:-

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

STEM education:
What have been discussed and what not

Theory/Macro

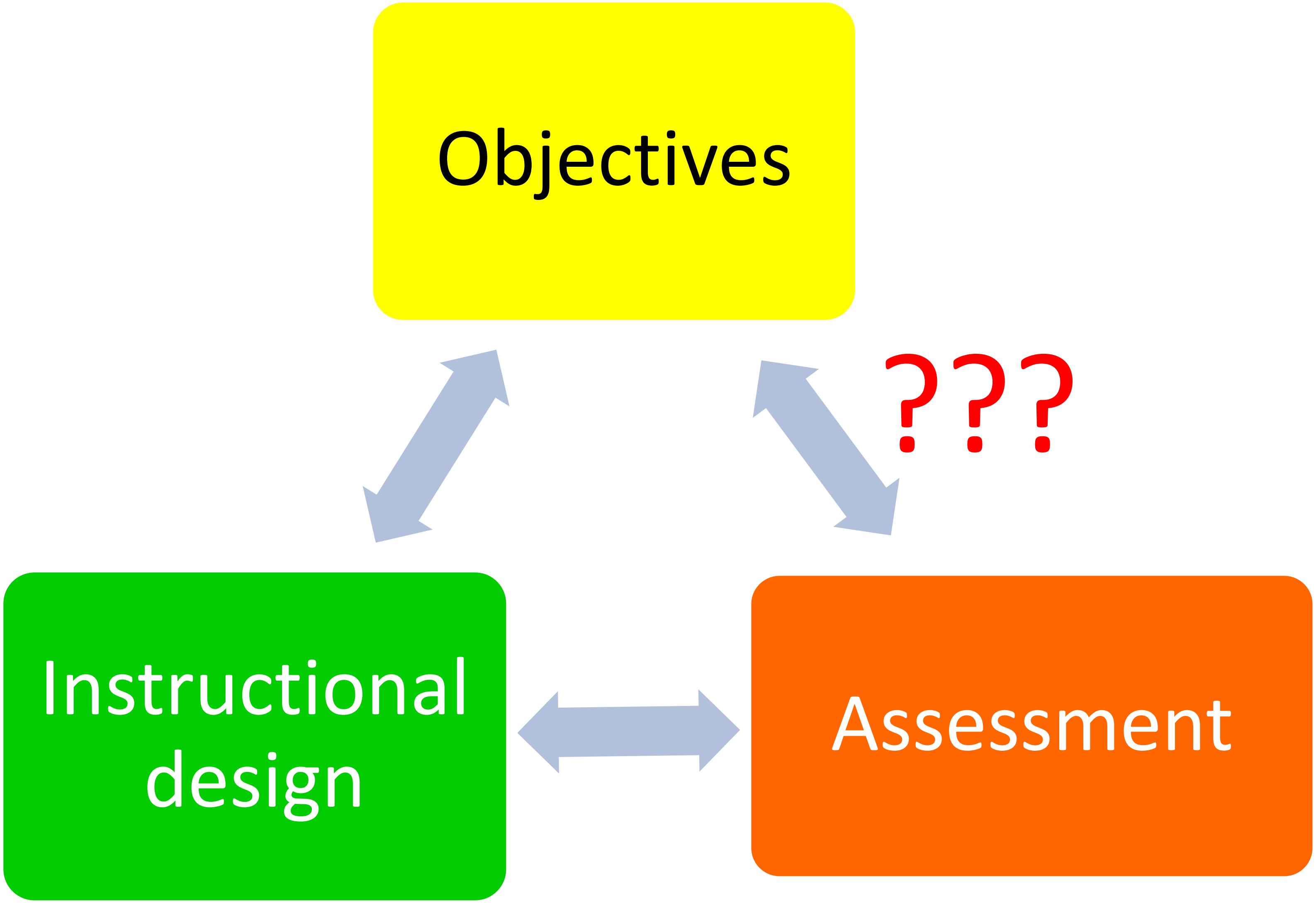


Practice/Micro

- Vision and goals (STEM literacy, 21st century skills)
- Content areas (Robotics, Smart City, 3-D printing, AI)
- Learning approaches (interdisciplinary, inquiry-based, design-based, problem-based, project-based)
- Curriculum organization and interdisciplinary collaboration
- Curriculum design (incl. SDL and assessment)

Assessment in STEM:
1. The ‘Why’?

The curriculum process



Can the existing assessment measures cater to assessment in STEM?

- Context? Authenticity?
- Range of outcomes assessed?
- Low-order thinking or high-order thinking?
- Compartmentalized or Integrated?
- Knowledge or skills?
- Summative or formative?

Assessment - a bottle-neck in STEM education

THREE problems to address:

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 political problem)

2. The ‘What’?

What to assess in integrated STEM

Specifying intended learning outcomes (ILOs)

Activity

- Devise **5 ILOs** that you think are most important for integrated STEM education.

Intended learning outcomes of Integrated STEM education

Emphases of STEM education

1. Integration of knowledge and skills across disciplines (**learning aspect**)
2. Innovative problem solving (**action aspect**)

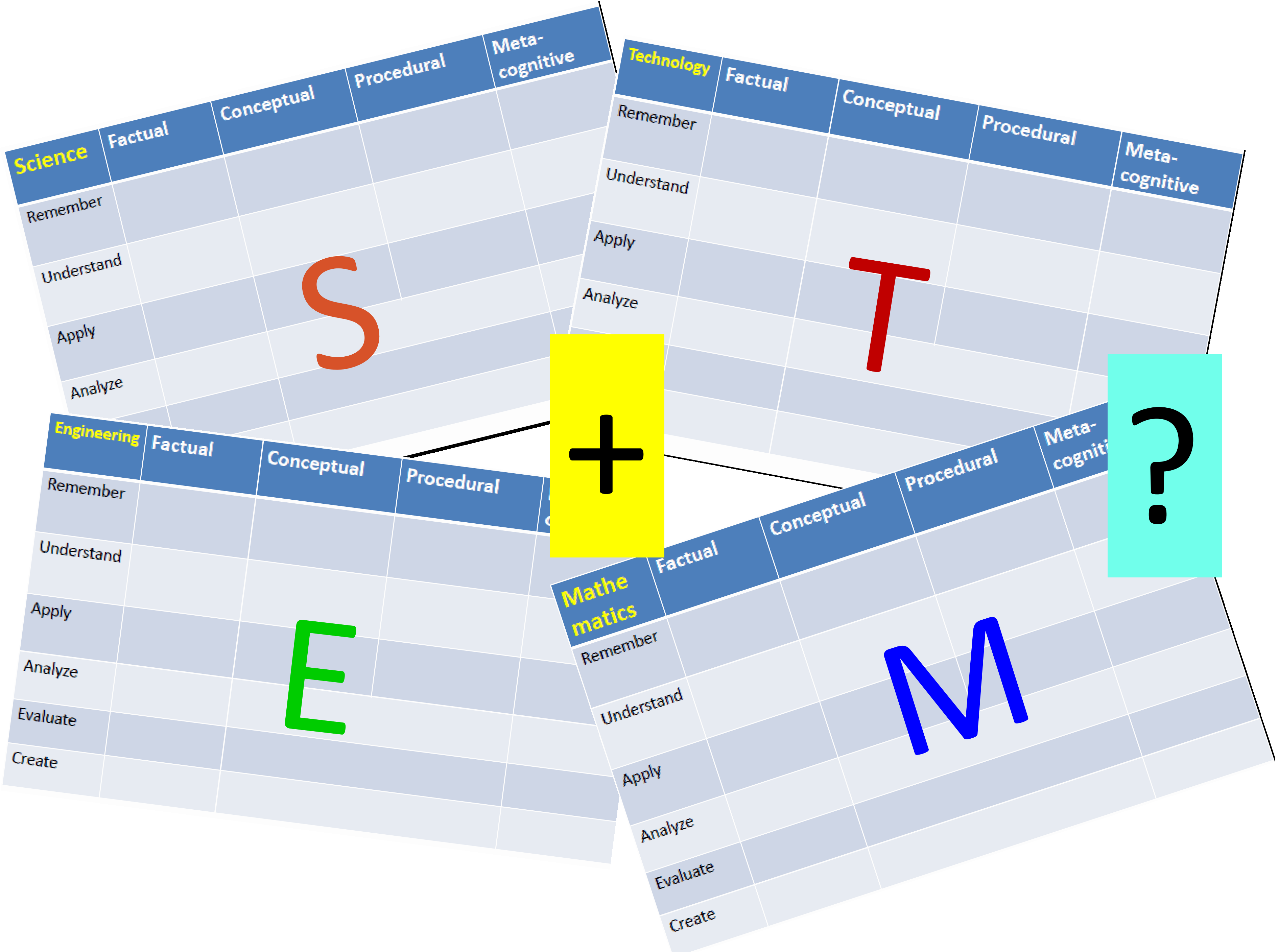
Domains of ILOs

1. Cognitive domain
2. Metacognitive domain
3. 21st century skills
4. Attitudes

1. Cognitive Domain

Revised Bloom's Taxonomy (Anderson, et al 2001)

E.g. Science	Factual	Conceptual	Procedural	Meta-cognitive
Remember	State the laws of levers			
Understand		Understand how levers provide leverage		
Apply			Apply the law of the lever in calculating the effort needed to raise a load	
Analyze		Analyze the data from an experiment to deduce the law of the lever		
Evaluate		Evaluate the sufficiency of the data to reach the conclusion		
Create		Plan for an investigation into the law of the lever		


Science
Factual
Conceptual
Procedural
Meta-cognitive
Remember
Understand
Apply
Analyze
S
Technology
Factual
Conceptual
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Meta-cognitive
Remember
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+
Engineering
Factual
Conceptual
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Understand
Apply
Analyze
Evaluate
Create
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Mathematics
Factual
Conceptual
Procedural
Remember
Understand
Apply
Analyze
Evaluate
Create
M
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Emphases of integrated STEM education
(1) High-order thinking

	Factual	Conceptual	Procedural	Metacognitive
Remember				
Understand				
Apply				
Analyze				
Evaluate				
Create				

Higher-order thinking

Emphasis of integrated STEM education
(2) Hands-on, minds-on

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

Emphasis of integrated STEM education
(3) Self-directed learning & PBL

	Factual	Conceptual	Procedural	Metacognitive
Remember				
Understand				
Apply				
Analyze				
Evaluate				
Create				

Self-directed learning & Problem-based learning

2. Metacognitive Domain (後設認知知識)

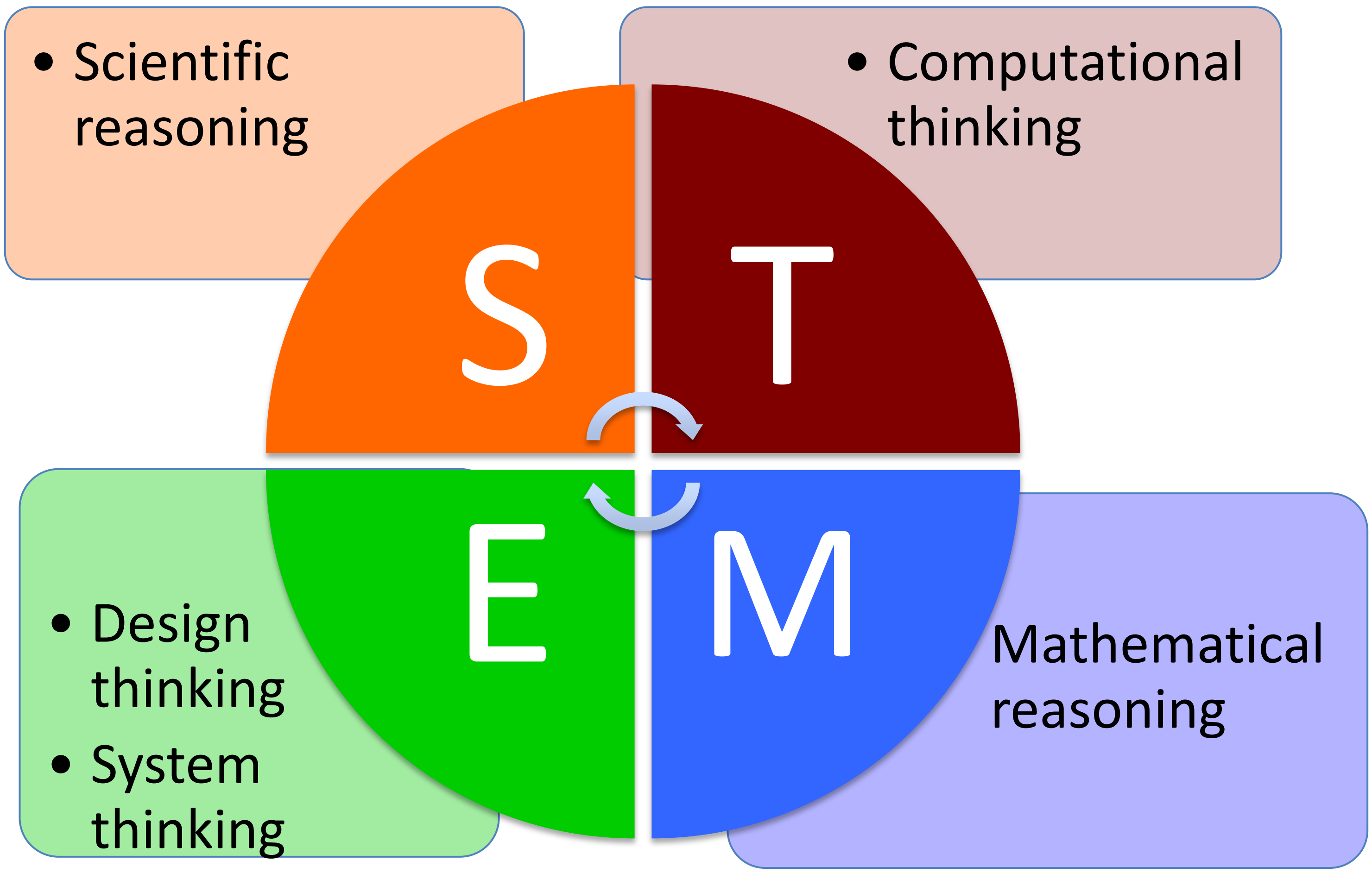
1. Understanding strategies for learning, thinking and problem solving
2. Understanding strategies for performing different cognitive tasks
3. Awareness of one's strengths, weaknesses and abilities in applying those strategies

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

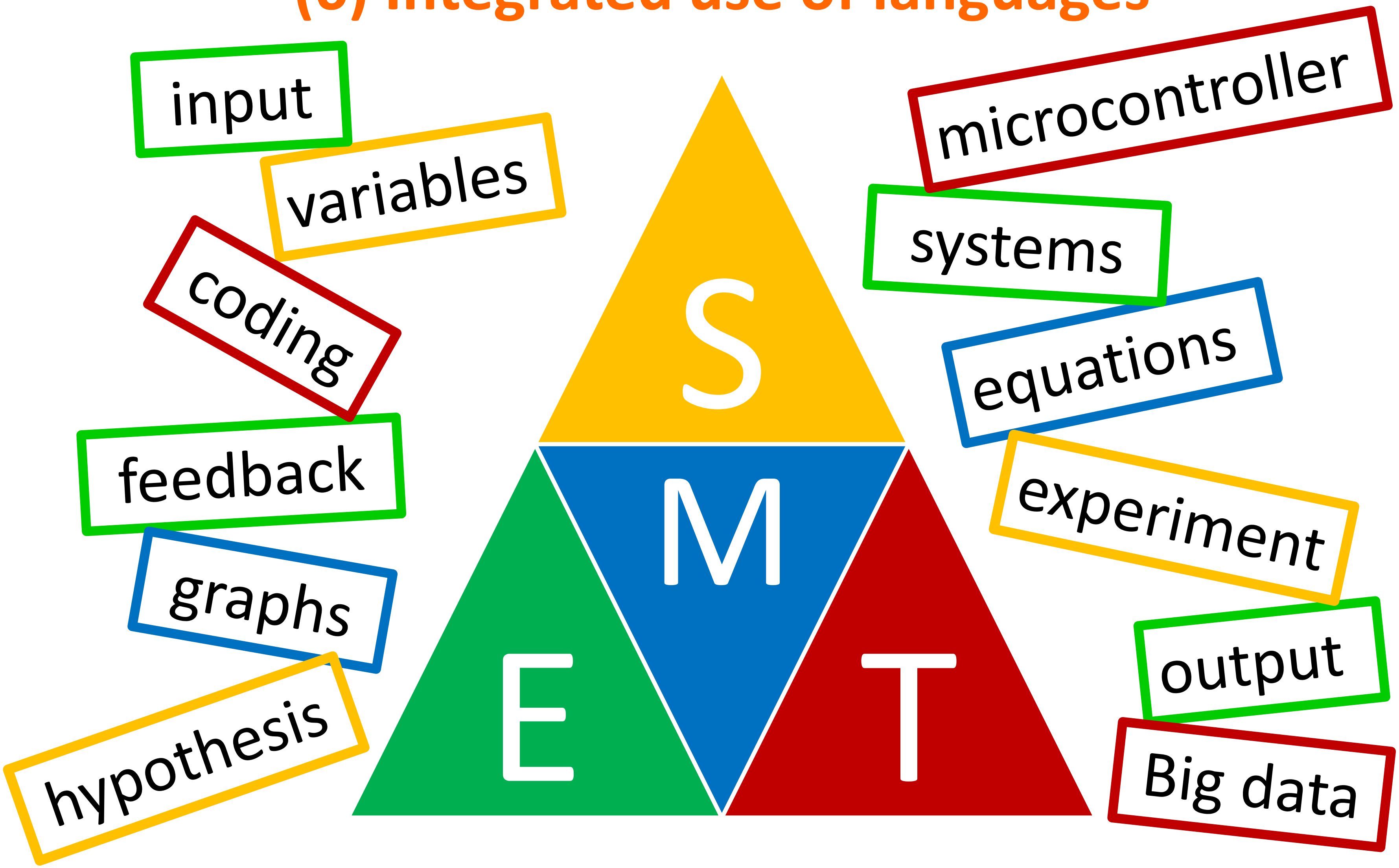
Emphasis of integrated STEM education
(4) Integration of knowledge

	Factual	Conceptual	Procedural
Remember			
Understand			
Apply		**E (& S, T, M)**: Applying science, mathematics and engineering concepts and processes to solving a problem	**T (& S, E)**: Using technology devices or processes (including ICT) to collect and analyze data, or to make artifacts
Analyze		**S (& M):** Interpreting relationships from experimental data in mathematical terms	
Evaluate		**E (& S):** Determining whether a solution could meet a certain set of criteria and constraints with due consideration to the sufficiency of data to support the conclusion	
Create		**E (& S, T, M)**: Designing and planning a solution to solve a problem by integrating multi-disciplinary knowledge	

Emphasis of integrated STEM education (5) Integration of reasoning



Emphasis of integrated STEM education
(6) Integrated use of languages



3. 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

4. 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

Activity

- Add 5 more ILOs to your list to make a total of **10** STEM ILOs that you think are most important

3. The ‘Where’?

Sources of evidence

- Where could you obtain evidences of student achievement?

Activity

- List as many ***sources of evidence*** as possible for assessing STEM learning outcomes

4. The ‘When’?

Formative or Summative?

During the learning process - Formative assessment

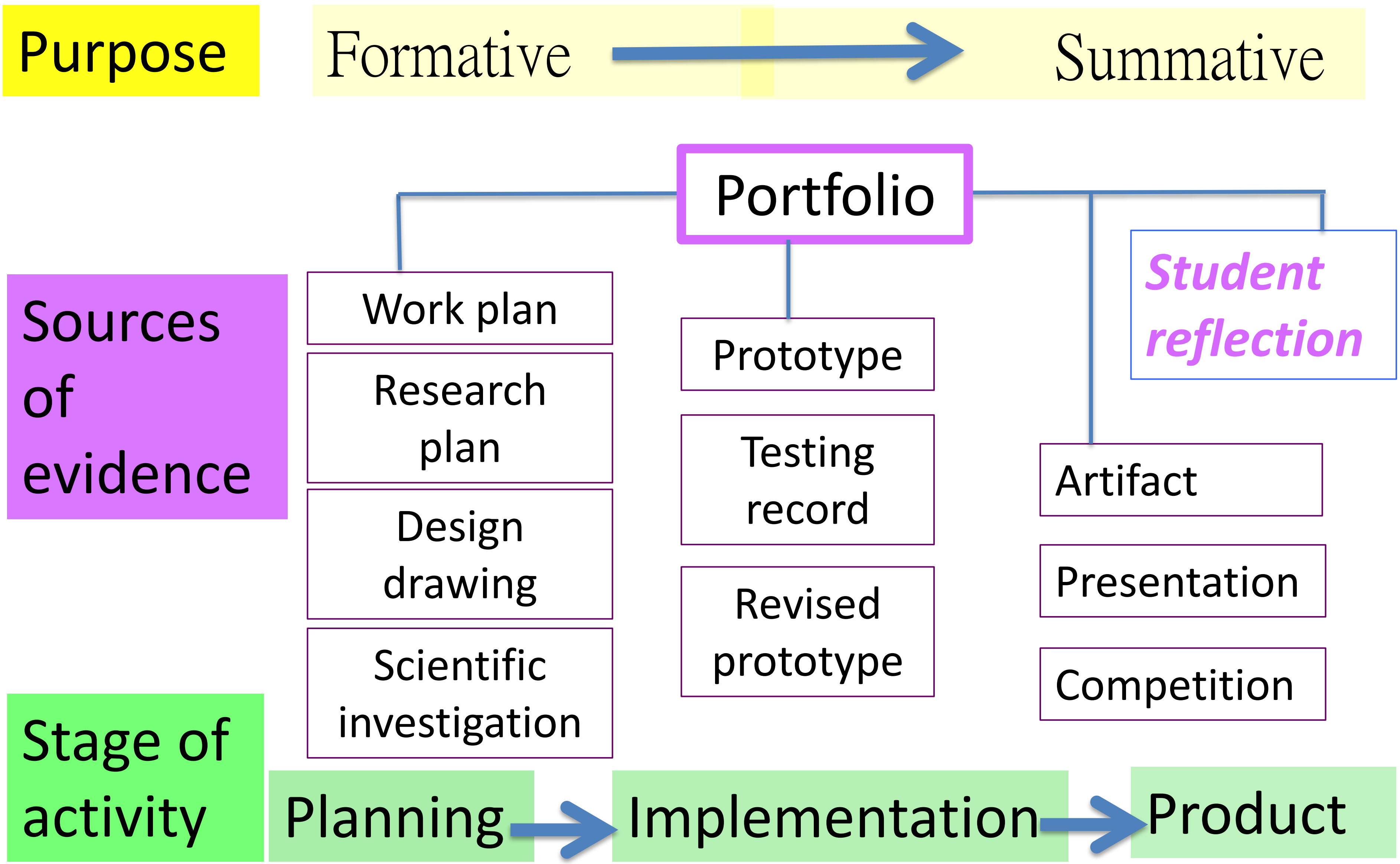
After the learning process - Summative assessment

Activity

- What are the sources of evidence that are useful for:
  - formative purpose?
  - summative purpose?
- Re-arrange your sources of evidence in chronological order

*Add additional sources to your list as you see fit

Summing up


Purpose
Formative
Summative
Portfolio
Sources of evidence
Work plan
Research plan
Design drawing
Scientific investigation
Prototype
Testing record
Revised prototype
Student reflection
Artifact
Presentation
Competition
Stage of activity
Planning
Implementation
Product

Next:

Matching ILOs with sources of evidence.

Activity A

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 (Diameter = 7cm; Height = 12cm)
  - Reusable
- Constraint:
  - Can only use simple materials available in a stationery store or a supermarket

Draw your design in the form of an annotated diagram illustrating the scientific principles of your design, and the dimensions with calculation shown.

Discussion

1. What ILOs could be assessed based on the design drawing?

   (Check from your list of ILOs)

2. What are the limitations of design drawing as evidence of learning?

Activity A ILOs assessed (Suggestions)

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

Activity B

Assessing products/Artifacts

1. Examine the TWO problem scenarios and artifacts provided.
2. What ILOs could be assessed based on artifacts produced by students?

   (Check from your list of ILOs)
3. What are the limitations of artifact as evidence of learning?

Activity B ILOs assessed (Suggestions)

1. Understanding and application of science/engineering conceptual knowledge (e.g., levers, feedback system)
2. Understanding and application of scientific/technological procedural knowledge (e.g., fair test, coding)
3. Problem solving
4. Hands-on/crafts/IT skills
5. Creativity

Activity C

Assessing process (Student portfolio as evidence)

1. Examine the **<u>TWO e-portfolios</u>** shown.
2. What do they tell you about student achievement?
3. What ILOs could be assessed based on student portfolios?

   (Check from your list of ILOs)

1. What are the limitations of portfolios as evidence of learning?

Activity C ILOs assessed (Suggestions)

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

Activity D

In your table, match all your sources of evidence with your learning outcomes.

Discussion

- Which source(s) of evidence are **most** widely applicable to measuring learning outcomes?
- Which source(s) of evidence are **least** widely applicable to measuring learning outcomes?
- Which source(s) of evidence are most useful for measuring **cognitive outcomes**?
- Which source(s) of evidence are most useful for measuring **meta-cognitive outcomes**?
- Which source(s) of evidence are most useful for measuring **21st century skills**?
- Which source(s) of evidence are most useful for measuring **attitudes**?

5. The 'How'?

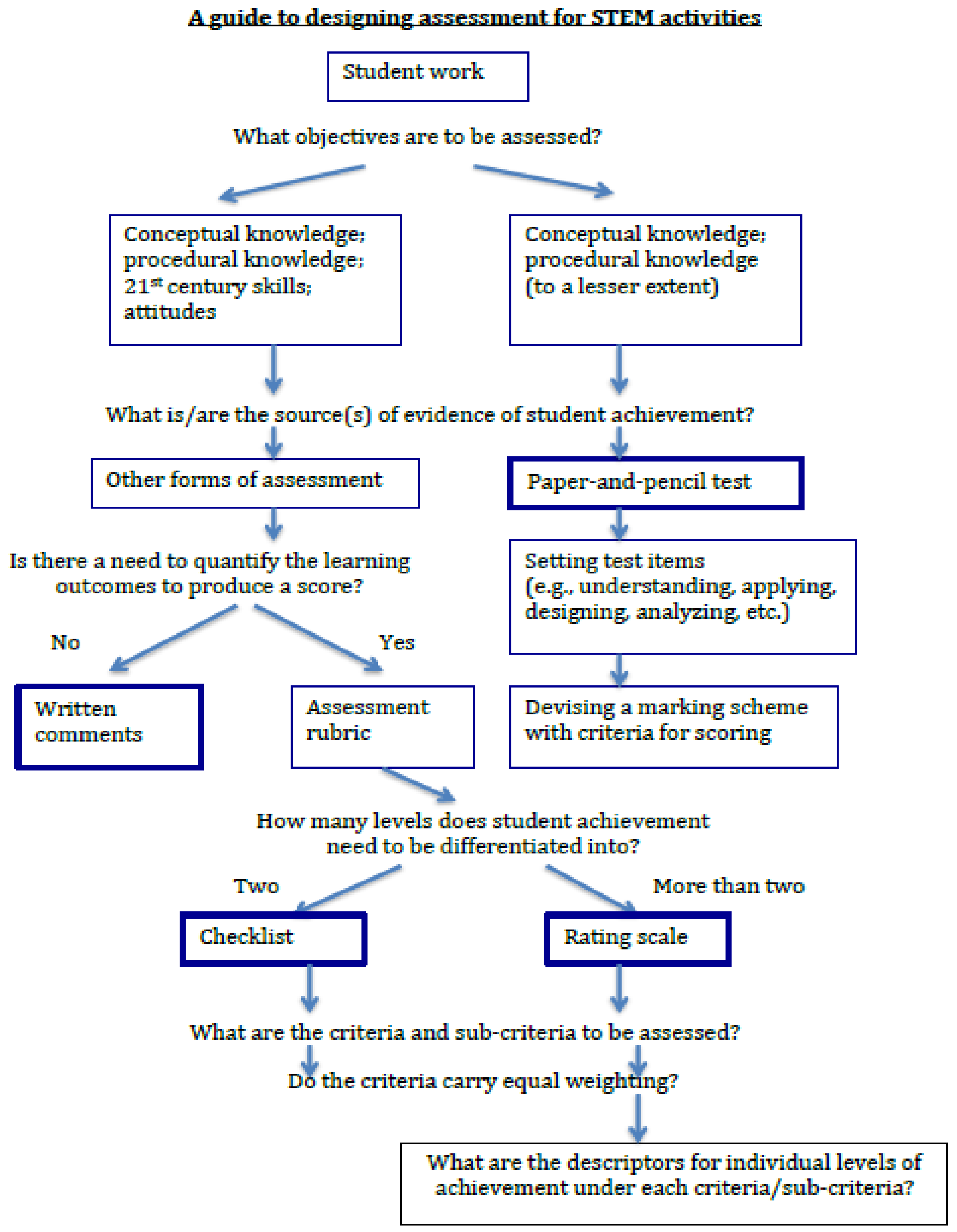
Judging performance/achievement

1. Modes of assessment (= sources of evidence)
2. Assessment criteria (= ILOs)
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
Student work
What objectives are to be assessed?
Conceptual knowledge; procedural knowledge; 21st century skills; attitudes
Conceptual knowledge; procedural knowledge (to a lesser extent)
What is/are the source(s) of evidence of student achievement?
Other forms of assessment
Paper-and-pencil test
Is there a need to quantify the learning outcomes to produce a score?
No
Yes
Setting test items (e.g., understanding, applying, designing, analyzing, etc.)
Written comments
Assessment rubric
Devising a marking scheme with criteria for scoring
How many levels does student achievement need to be differentiated into?
Two
More than two
Checklist
Rating scale
What are the criteria and sub-criteria to be assessed?
Do the criteria carry equal weighting?
What are the descriptors for individual levels of achievement under each criteria/sub-criteria?

Designing assessment rubric

(Suggested steps)

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

E.g. Criterion: Problem-solving skills

Sub-criteria	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.

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
- Relate to level of assistance rendered by others (teachers/parents)

Activity

Pick one of the following ILOs and break it down into sub-criteria:-

1. Creativity
2. Collaboration with peer
3. Collecting information (Researching)
4. Students’ self-reflection on learning

Set the levels and descriptors for one of your sub-criteria.

- Exchange your rubric with another group and talk about what they have produced.

Scoring

Activity

Scoring your design drawing using an assessment rubric

- Swap your design (coke package) with another group and assess the design using the assessment rubric provided

Reflection on scoring using assessment rubric

1. Is your assessment/scoring reliable and valid?
2. What are the limitations or potential risks in using assessment rubrics for scoring?
3. How to further improve assessment using rubric?

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)*

Activity

- What ILOs can best be assessed through self and peer assessment?
- Modes of self/peer assessment (e.g. Google form on SDL)

Discussion

- What are the advantages and disadvantages of self and peer assessment?
- How to make full use of these two assessment measures?

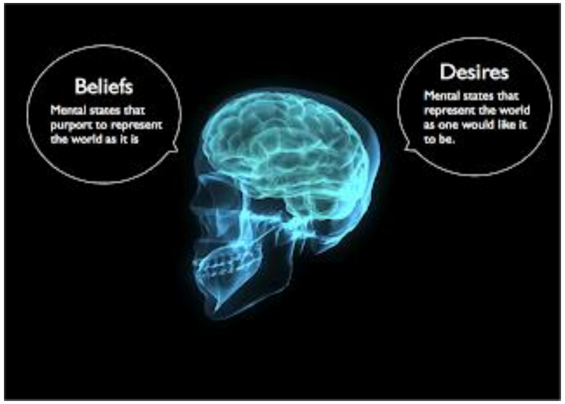
Paradigm shift in assessment

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.



Reflection

- Please take a fresh look at your group's BIG assessment table.
- **What changes would you like to make to your table after this workshop?**

- 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 to stimulate your thinking !**

STEM Education

A **golden opportunity** to reform school assessment

OR

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

???


THANK
YOU