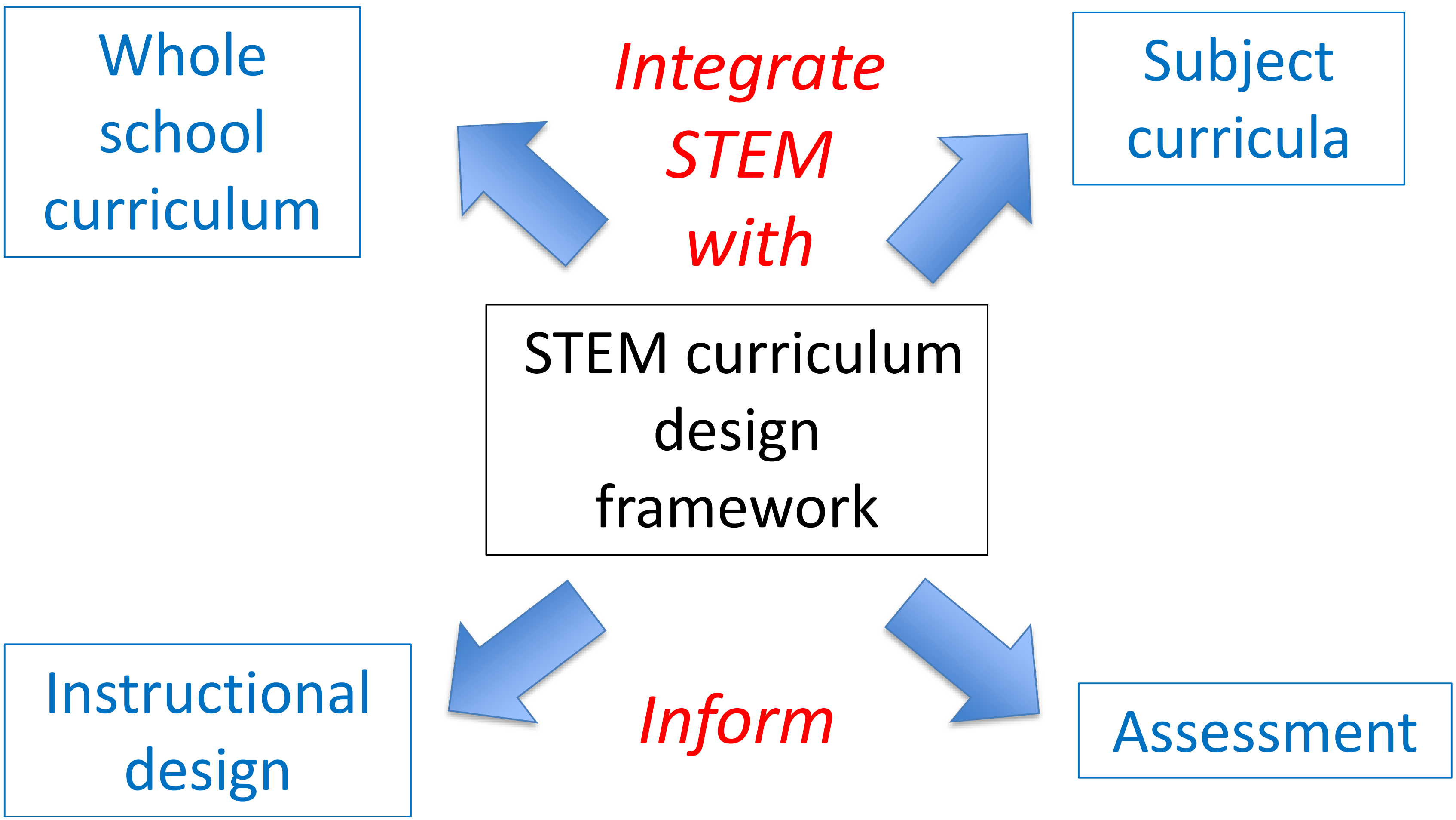
From S e p a r a t I o n
to
Integration

Building STEM curriculum and instructional *‘design’* frameworks

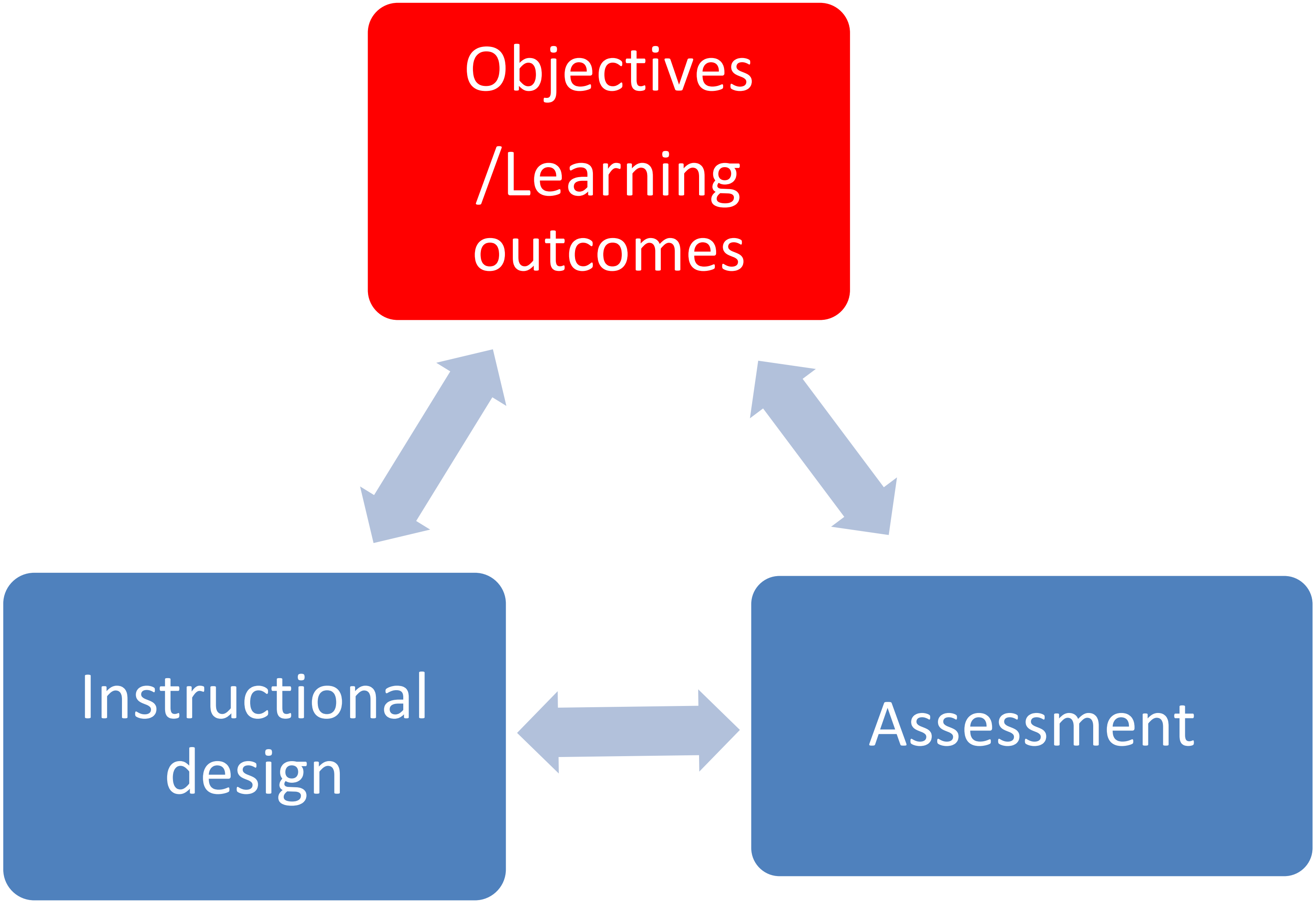
What count as STEM education

STEM Subject curriculum	Integrated STEM curriculum
• Out of context, irrelevant to daily life • Narrow aims – emphasize low-order thinking • Textbook-led, passive learning • Compartmentalization of knowledge • Creativity and innovation under-emphasized	• Contextual, related to daily life • Problem-based • Integrated application of knowledge and skills of different disciplines • Applying technology • Developing higher order thinking (e.g., analyzing and creating)

How could a STEM curriculum design framework help?



Designing a curriculum/activity



Where are we now?

Activity 1

- Read through the aims/expected learning outcomes of the STEM-related subjects provided.
- Identify important learning outcomes related to S/T/E/M.

Connecting STEM subject learning outcomes (I)(Primary)
- A curriculum framework by 'subjects'

Primary	S	T	E	M
General Studies				
Mathematics				
Computer				
Others				

Connecting STEM subject learning outcomes (I)(Secondary) - A curriculum framework by 'subjects'

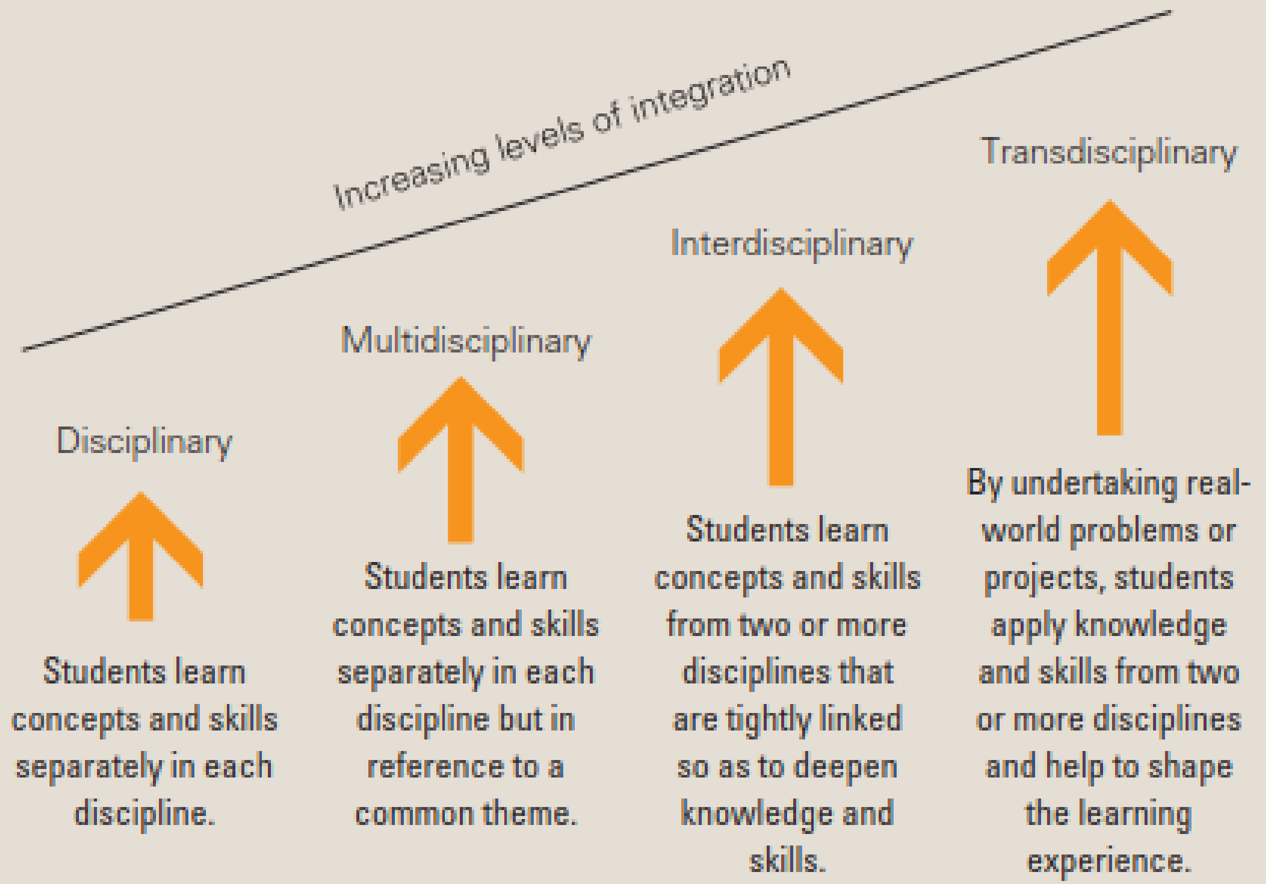
Secondary	S	T	E	M
Science				
Mathematics				
Computer				
Design and technology				

Reflections on Activity 1

- Is it easy to identify the connections between S, T, E and M from the learning outcomes of the STEM-related subjects?
- Which subject(s) show most connections?

The inclined plane of STEM integration

FIGURE 1. The Inclined Plane of STEM Integration



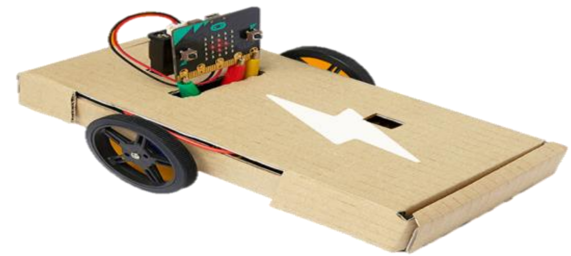
Source: From *STEM Lesson Essentials, Grades 3–8: Integrating Science, Technology, Engineering, and Mathematics* (p. 73), by Jo Anne Vasquez, Cary Sneider, and Michael Comer, 2013. New York: Heinemann. Copyright 2013 by authors. Reprinted with permission.

(Vasquez, 2015)

Activity 2

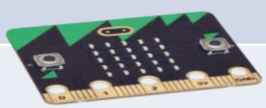
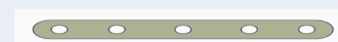
- Study the learning outcomes of the ‘Combat Car’ activity under S, T, E, and M.

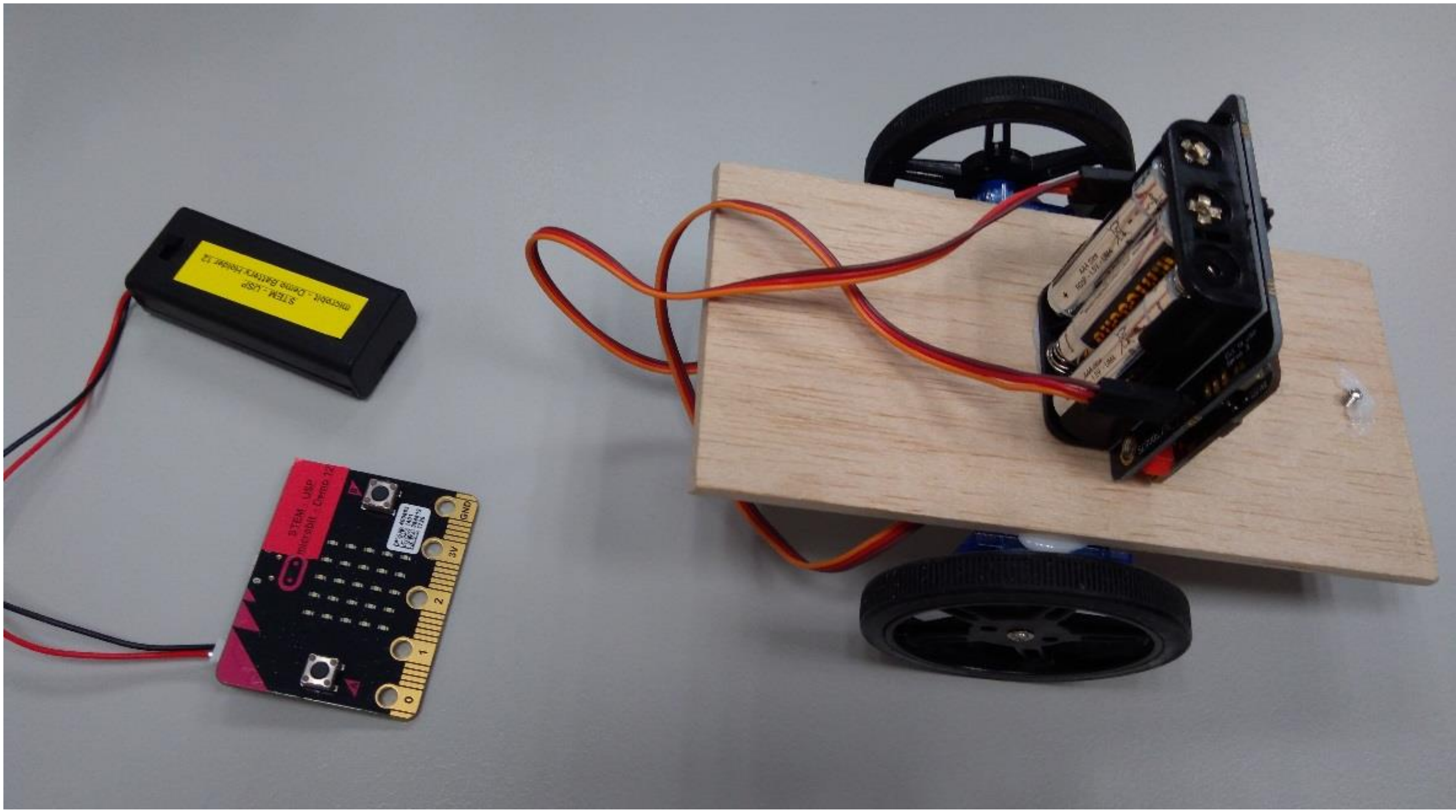
3. 格鬥車所提供的製作素材



Source: 漢華小學

a. 安裝於車上的組件：

組件和用途 	數量	組件和用途 	數量
1.伺服馬達 （Servo Motor） 用途：推動車輪	2	2. 車輪（6cm直徑）	2
3. micro:bit  用途：接收另一塊micro:bit遙控器的信息 	1	4. 伺服板  （servo board） 用途：推動馬達 	1
5. AAA型號電池 用途：供電	3	6. 間隔板 （spacer） （闊度：3mm / 3.5 mm / 4mm ）	1
7. 海綿雙面膠紙、寶貼	1		
		以上第3-7組件必須放於車內，整體重量為	250g
		由於在設計循環的第3步驟中將進行車架的負重測試，故車架最少能負載新增重物1000g，整體重量為	1250g



Source: 汉华小学

'Combat Car' activity

創客活動的STEM元素：

Science 科學

- 探究摩擦力
- 探究能量轉移(電能轉動能)
- 應用科學實驗來探究車速的因素
- 訂定公平測試中的變項
- 闡釋探究過程中所涉及的步驟
- 從數據中得出最佳競賽設計的結論

Technology 科技

- 於MakeCode平台創作簡單的操控程式
- 應用micro:bit內建感應器來改變伺服馬達的角度，藉以控制車子的行駛方向
- 應用藍牙技術讓不同的裝置進行信息交換

Mathematics 數學

- 從數據的趨勢估算重量對摩擦力與車速的影響
- 應用四則運算於科學實驗過程的記錄之中
- 利用合適工具(尺子)、速率計算方法及量度單位(秒)進行量度與數據比較
- 以圖表整理及組織分析的資料

Engineering 工程

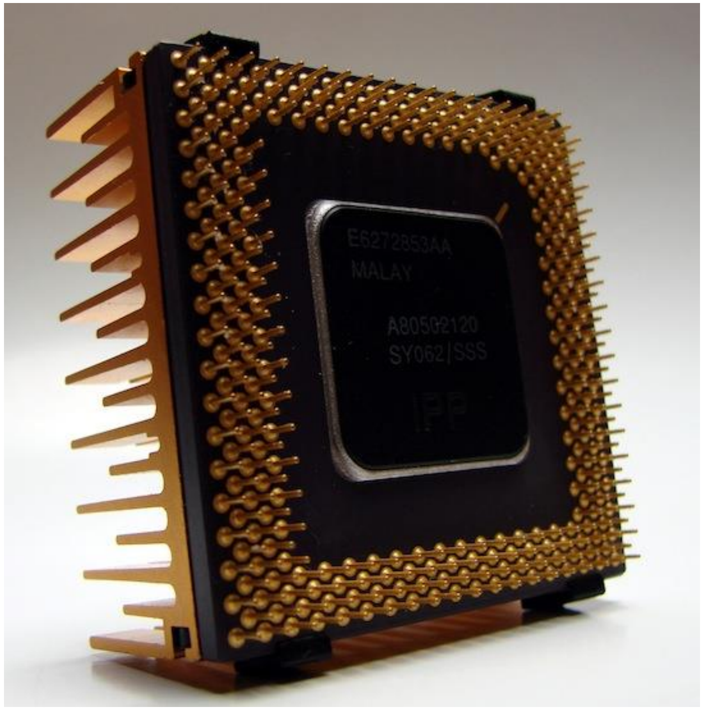
- 應用設計循環理念，發展出設計及改良車身的方案
- 測試設計及評估操控程式對車子行駛效性與穩定性的影響
- 認清設計的限制及優缺點
- 根據任務的限制條件，修改模型設計
- 分析及製作最佳的設計模型

Source: 汉华小学

Reflections

- Is it easier to identify the connections between S, T, E and M from the learning outcomes of this activity compared with Activity 1?
- Why?

Building curriculum design frameworks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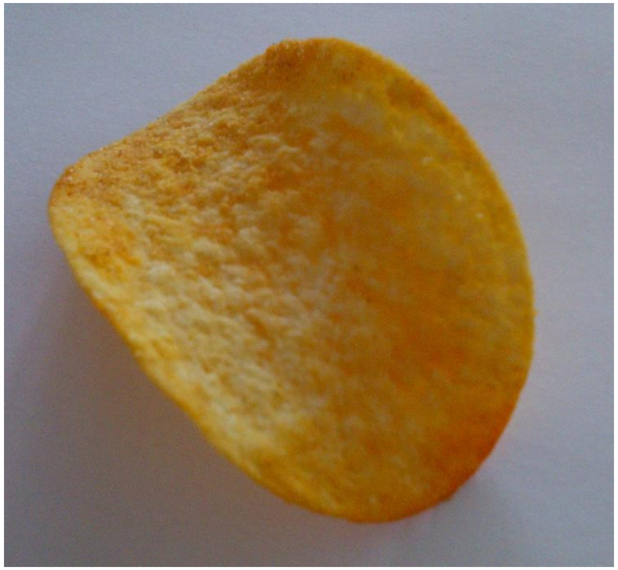
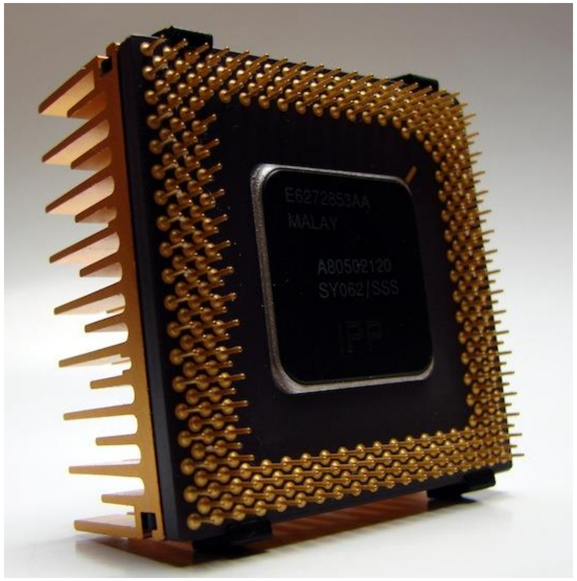
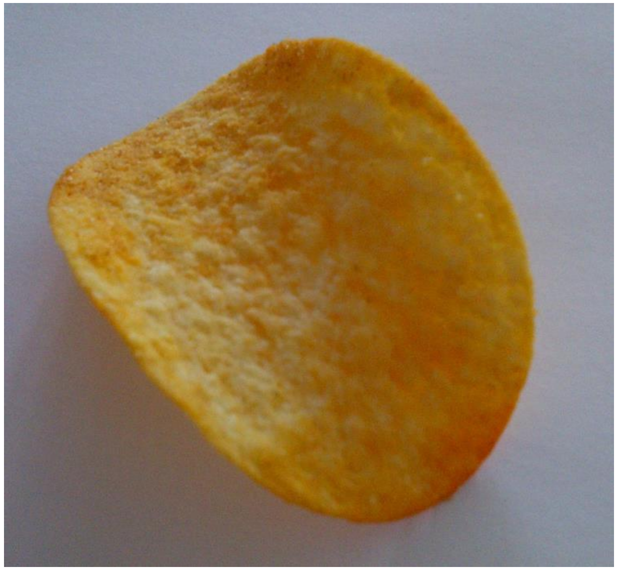
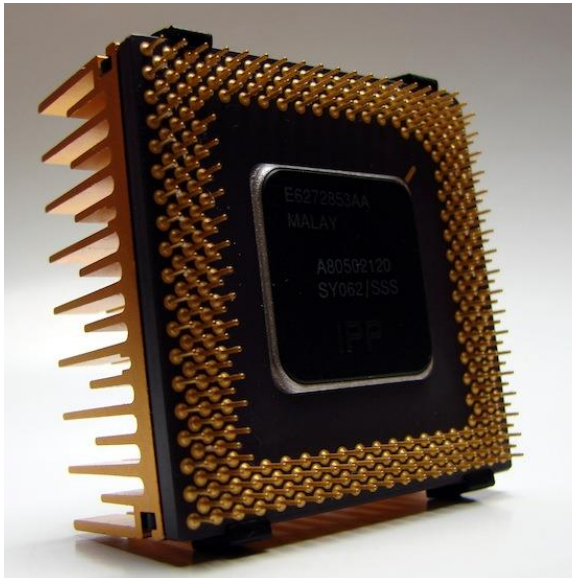
The
"C H I P"
Frameworks





What does ‘CHIP’ stand for?

"C H I P"

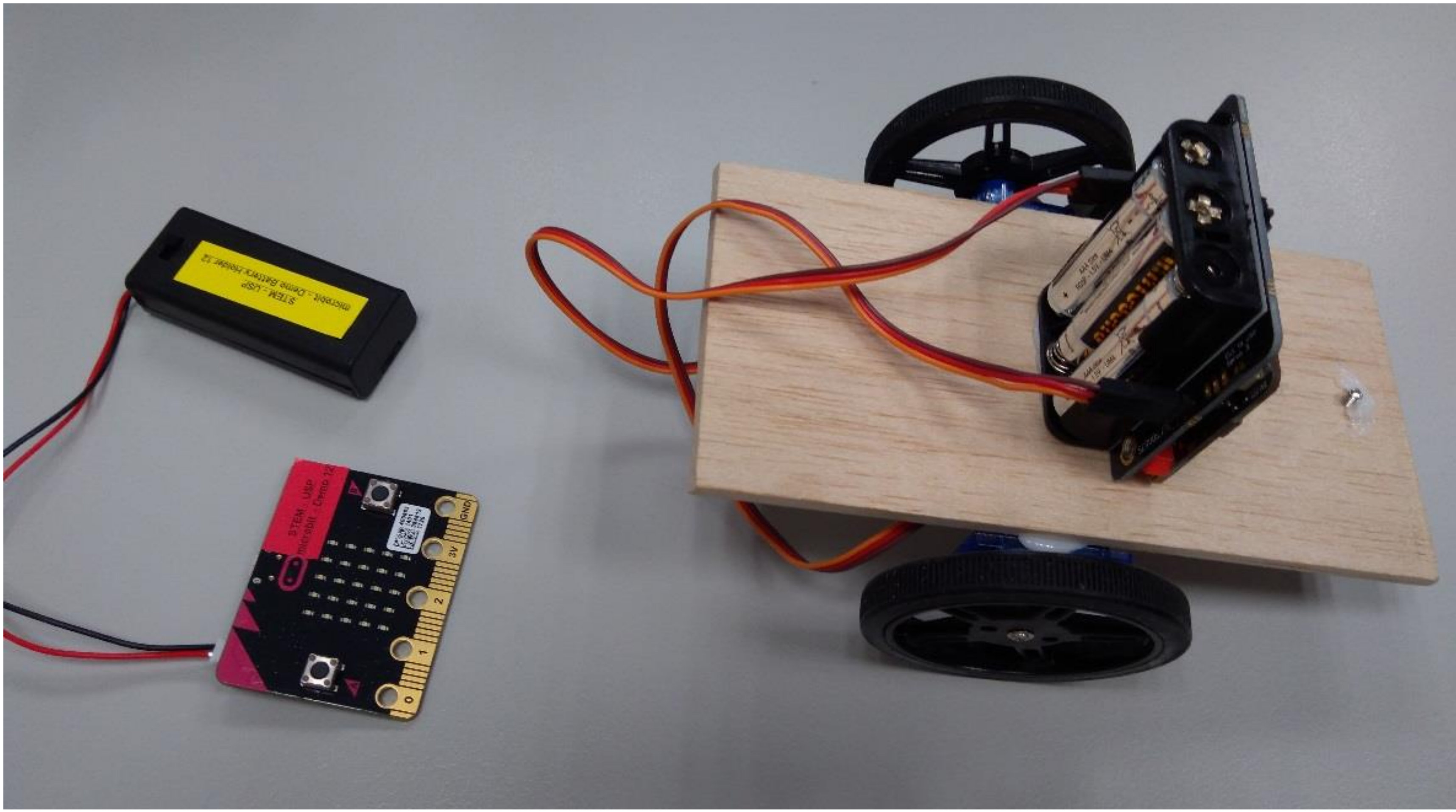
Context

High-order thinking

Integration

Processes

‘Combat Car’



Source: 汉华小学

Contexts for STEM Education

	Personal (Self, family, and peer groups)	**Social** (The community)	**Global** (Life across the world)
Health	Maintenance of health, accidents, nutrition	Control of disease, social transmission, food choices, community health	Epidemics, spread of infectious diseases
Energy efficiency	Personal use of energy, emphasis on conservation and efficiency	Conservation of energy, transition to efficient use and nonfossil fuels	Global consequences, use and conservation of energy
Natural resources	Personal consumption of materials	Maintenance of human populations, quality of life, security, production and distribution of food, energy supply	Renewable and nonrenewable, natural systems, population growth, sustainable use
Environmental quality	Environmentally friendly behavior, use and disposal of materials	Population distribution, disposal of waste, environmental impact, local weather	Biodiversity, ecological sustainability, control of pollution, production, and loss of soil
Hazard mitigation	Natural and human-induced, decisions about housing	Rapid changes (earthquakes, severe weather), slow and progressive changes (coastal erosion, sedimentation), risk assessment	Climate change, impact of modern warfare
Frontiers of science, technology, engineering, mathematics	Interest in science's explanations of natural phenomena, science-based hobbies, sport and leisure, music and personal technology	New materials, devices, and processes, genetic modification, weapons technology, transport	Extinction of species, exploration of space, origin and structure of the universe

Figure 1. Contexts for STEM Education

Note. Adapted from: *Assessing scientific, reading and mathematical literacy: A framework for PISA 2006* (OECD, 2006)

(Bybee, 2010)

‘Combat Car’ activity

Subject Integration

Science 科學

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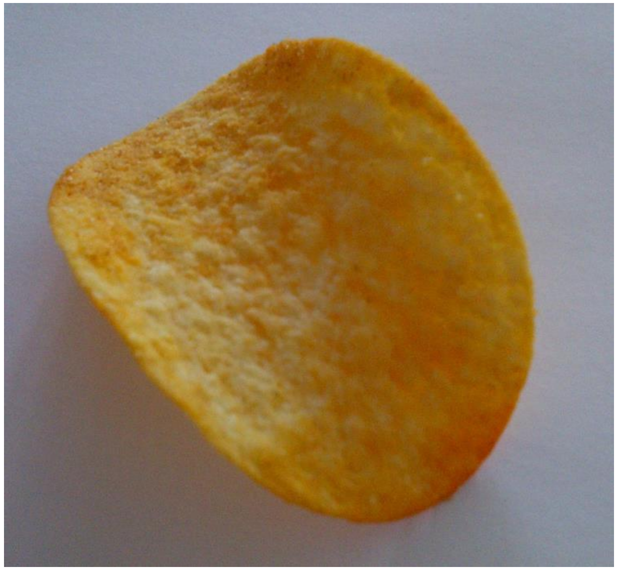
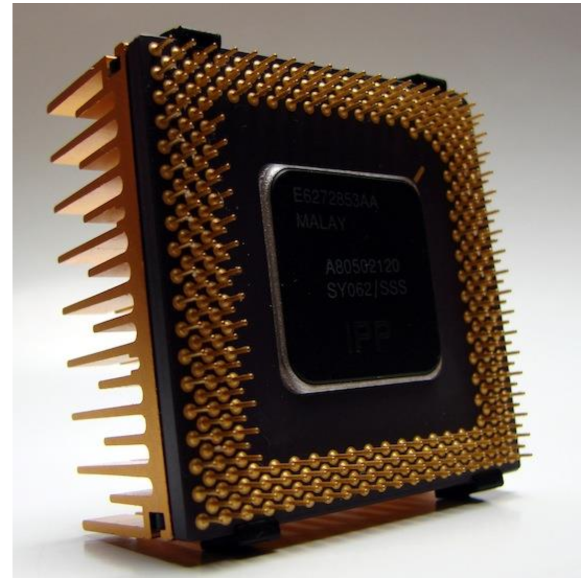
- 分析及製作最佳的設計模型

Source: 汉华小学





“C H I P”

Context✓

High-order thinking ???

Integration✓

Processes???

High-order thinking

Bloom’s taxonomy (1956)
(布鲁姆分类法)

6 levels of cognitive processes:

- Knowledge/Recall (知识/记忆)
- Comprehension(理解)
- Application(应用)
- Analysis (分析) (High-order thinking)
- Synthesis (综合)(High-order thinking)
- Evaluation (评鉴) (High-order thinking)

Revised Bloom's taxonomy
(Anderson and Krathwohl, 2001)

6 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)

Examples of science learning outcomes based on the Revised Bloom taxonomy

- **Name** some common scientific apparatus (Remember)
- **Understand** scientific concepts (Understand)
- **Apply** scientific processes in carrying out investigations (Apply)
- **Identify** patterns from scientific data (Analyze)
- **Evaluate** experimental design and sufficiency of data to support conclusions (Evaluate)
- **Plan** for a scientific investigation (Create)

Quiz (1)
Cognitive processes?

1. Changing from a formula to verbal form of representation (e.g., Newton's Second Law)
2. Classify a vertebrate (脊椎动物) into the one of the known classes of vertebrates (e.g., fish and bird)
3. Explaining the causes of an effect.
4. Making hypotheses (假说)to account for a natural phenomenon.

5. Explaining why a control experiment is set up in a particular way.
6. Setting up a control experiment.
7. Inventing a toy car.
8. Judging whether a technological product meets external criteria.
9. Finding out the relationship between two variables based on experimental data.

10. Applying the laws of trigonometry(三角几何学) to practical situations.
11. Planning for an experiment.

Activity 3

- Classify the expected learning outcomes of the ‘Combat Car’ activity, according to the revised Bloom Taxonomy.

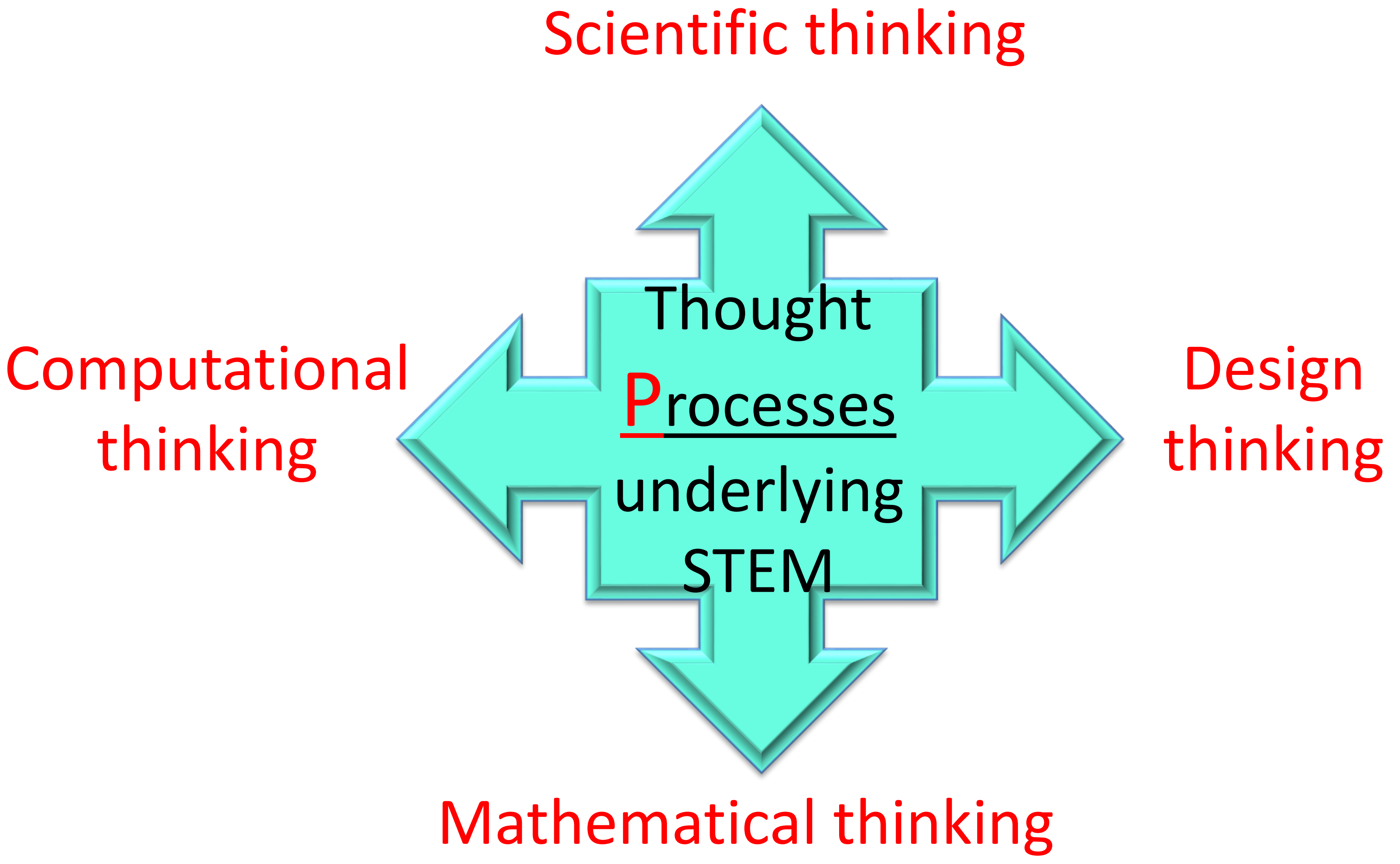
Reflection on Activity 3

1. Which cognitive level has the highest number of learning outcomes?
2. For STEM, which cognitive level(s) do you think are more important?

Processes ?

Knowledge taxonomy – a new dimension to the revised Bloom taxonomy (Anderson and Krathwohl, 2001)

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



Scientific thinking
Computational thinking
Thought Processes underlying STEM
Design thinking
Mathematical thinking

Activity 4

- Classify the learning outcomes of the STEM activity for Activity 2, according to the Knowledge Taxonomy.

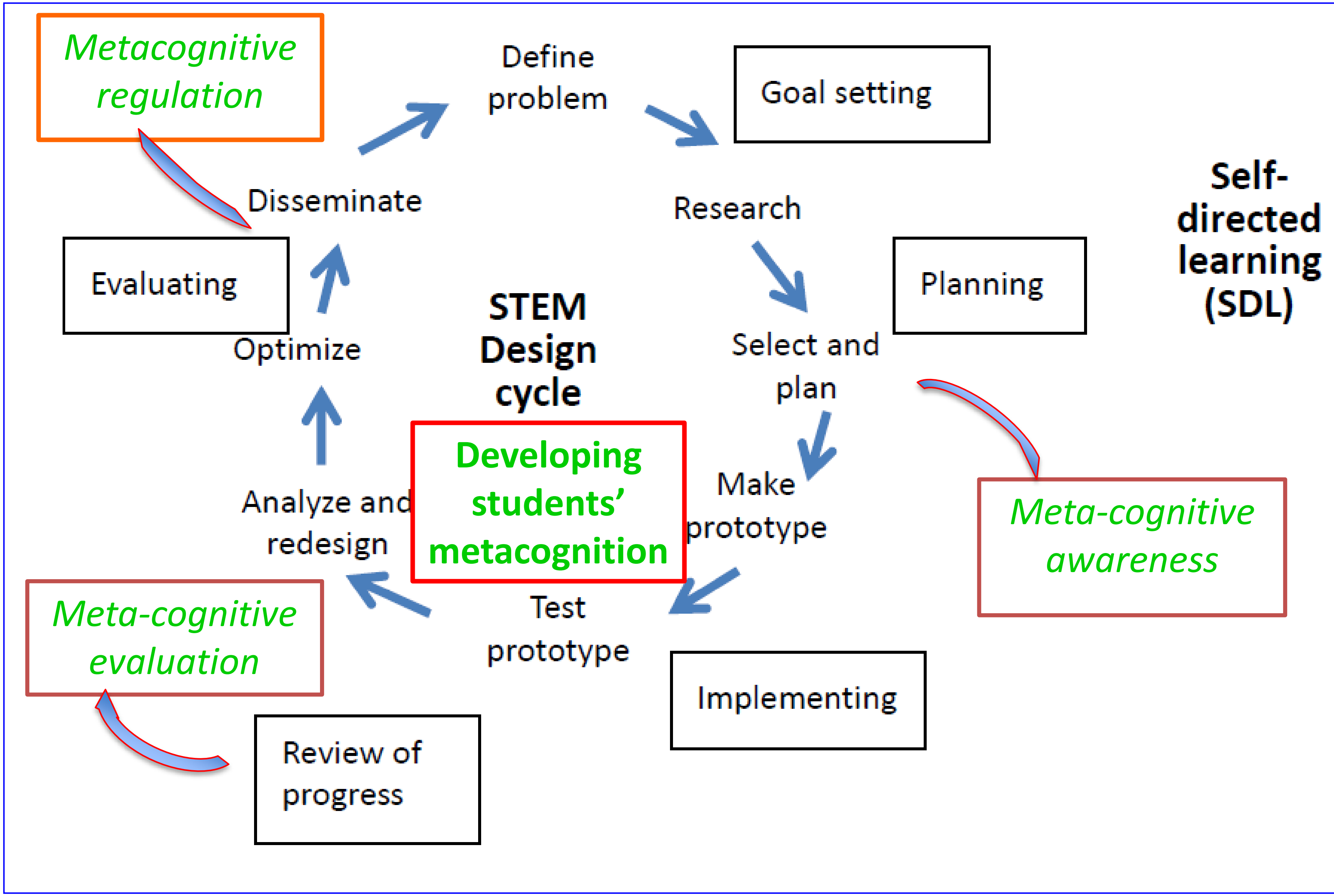
Metacognitive knowledge (後設認知知識)

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 --------> SDL

(Self-directed learning)

Self-directed Learning (自主學習)



Benefits of Bloom’s taxonomy in designing STEM learning outcomes

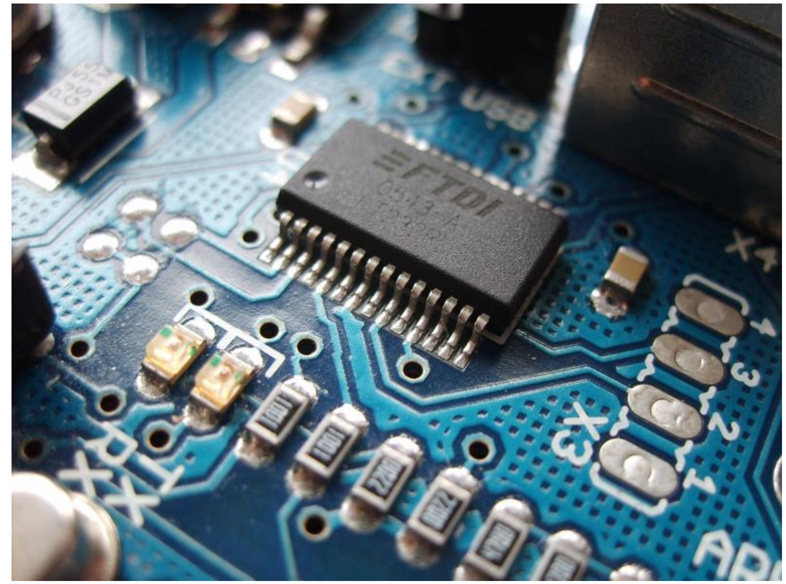
Benefits of designing STEM learning outcomes based on revised Bloom taxonomy

1. Highlight high-order thinking skills in different domains of STEM *education (analyze, evaluate, and create)*
2. Emphasize different dimensions of knowledge (conceptual, procedural, and metacognitive)
3. Link the learning outcomes of different STEM domains at different cognitive levels to reflect the in-depth relationships among S, T, E, and M.
4. Enhance vertical and horizontal integration of learning outcomes within and across STEM domains *(Ensure basic processes, e.g. understanding, are mastered for developing higher-order thinking processes.)*

Other learning outcomes of Integrated STEM education

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



"CHIPS"

- Context✓
- High-order thinking✓
- Integration✓
- Processes✓
- Skills✓

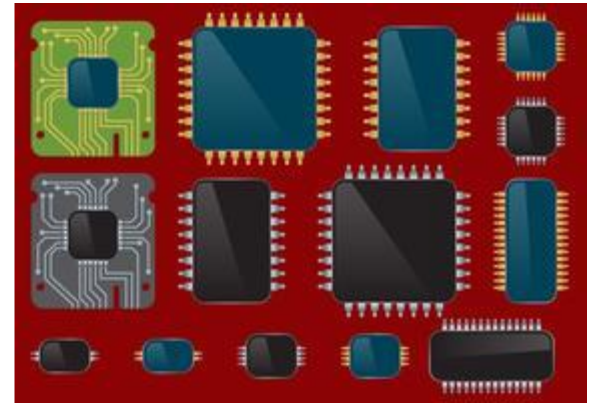
Affective Domain

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 pack of "CHIPS"

Attitudes

Context

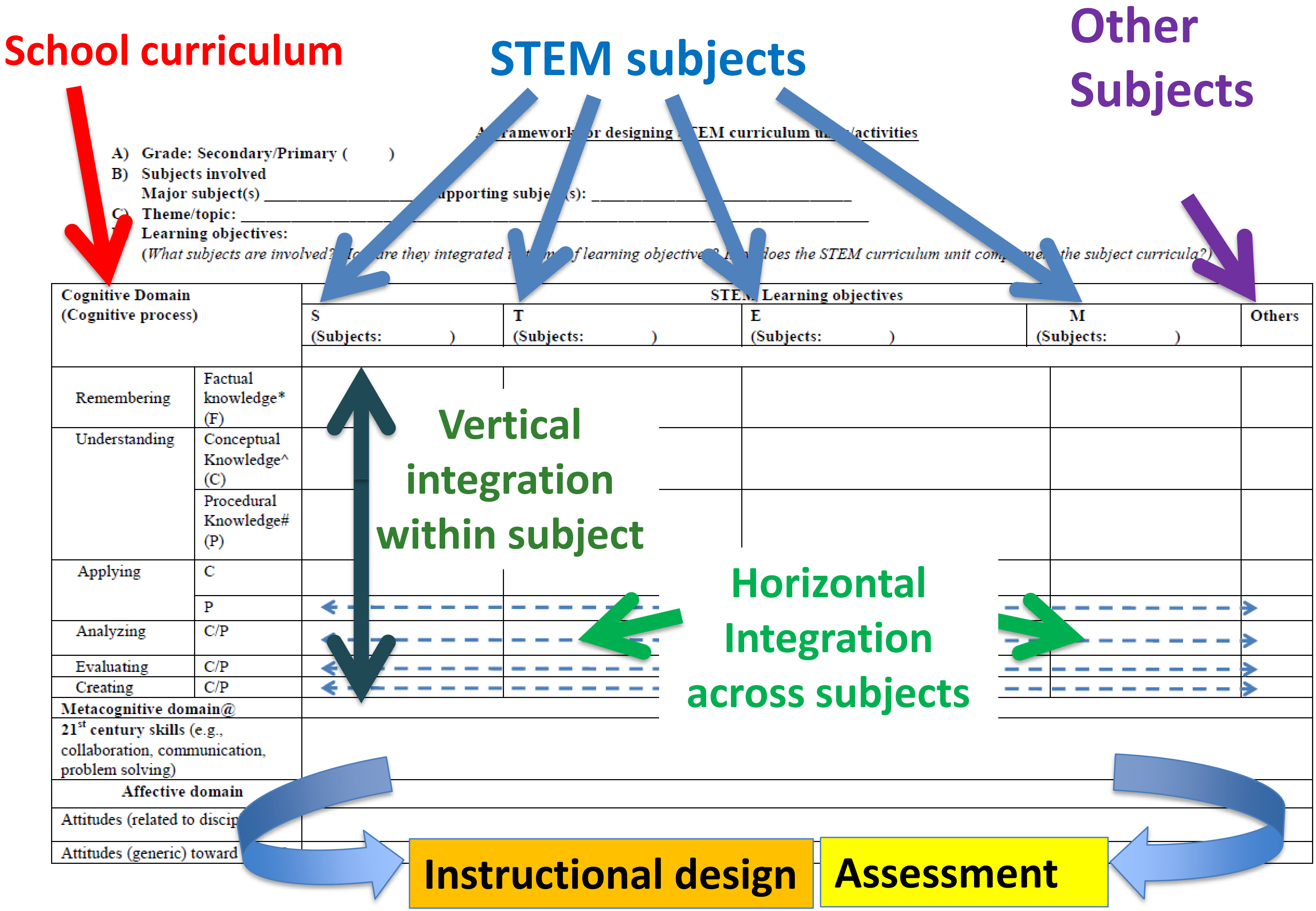
High-order thinking

Integration

Processes

21st **S**kills

A Multi-dimensional Framework for STEM Curriculum Design



From curriculum framework to activity(instructional) design

Two basic approaches to STEM activity design

Inquiry-based approaches:

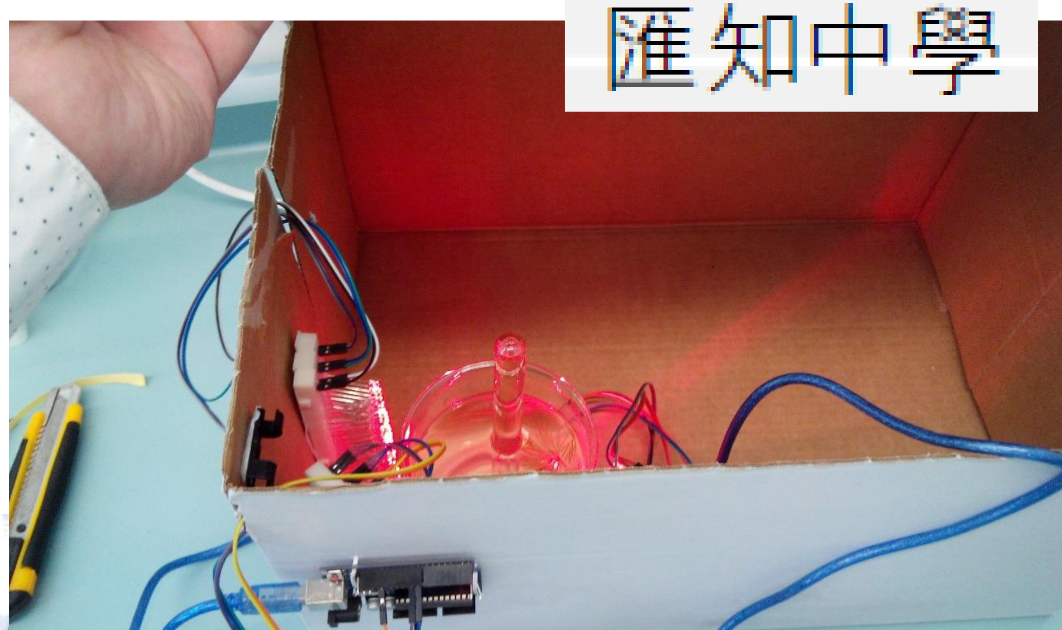
- Technology for scientific practice
- Integrated application of S/T/E/M concepts or processes to scientific inquiry

Design-based approaches:

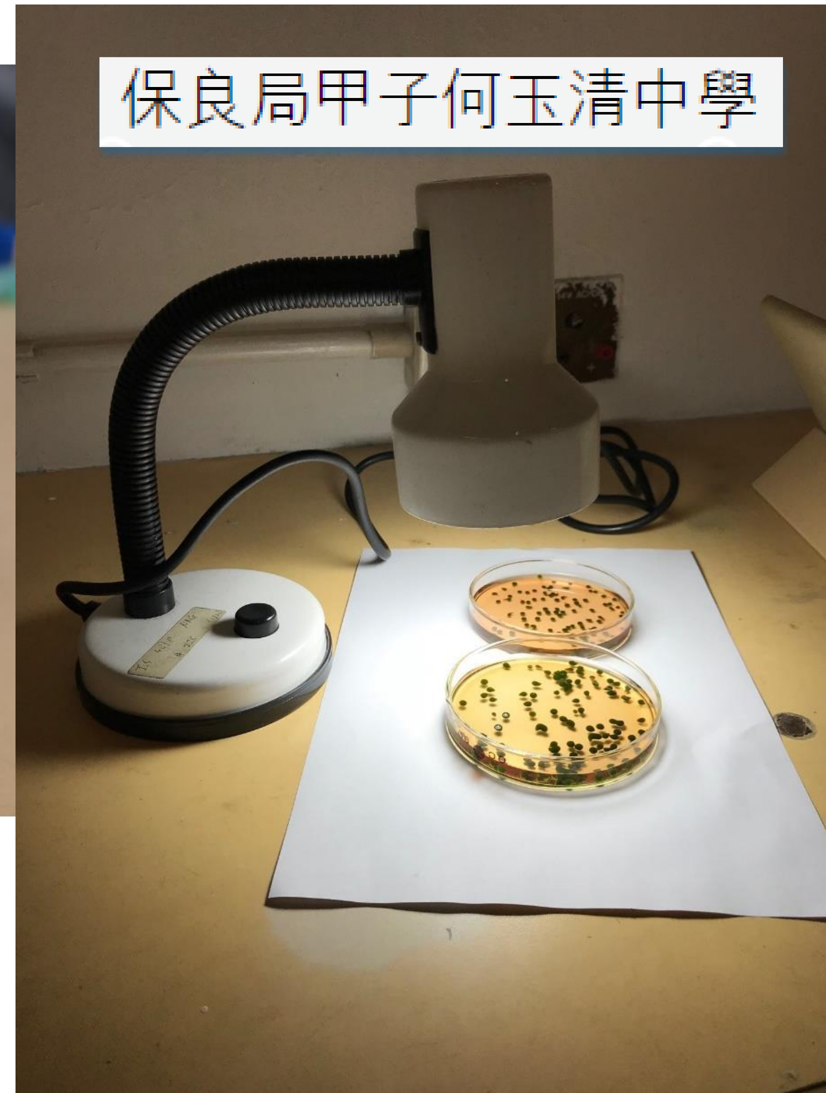
- Technology for engineering practice
- Integration of scientific inquiry/visual art into engineering practice

Technology for scientific practice
(應用科技，調控自變量)

滙知中學



Integrated application of S/T/E/M concepts or processes to scientific inquiry

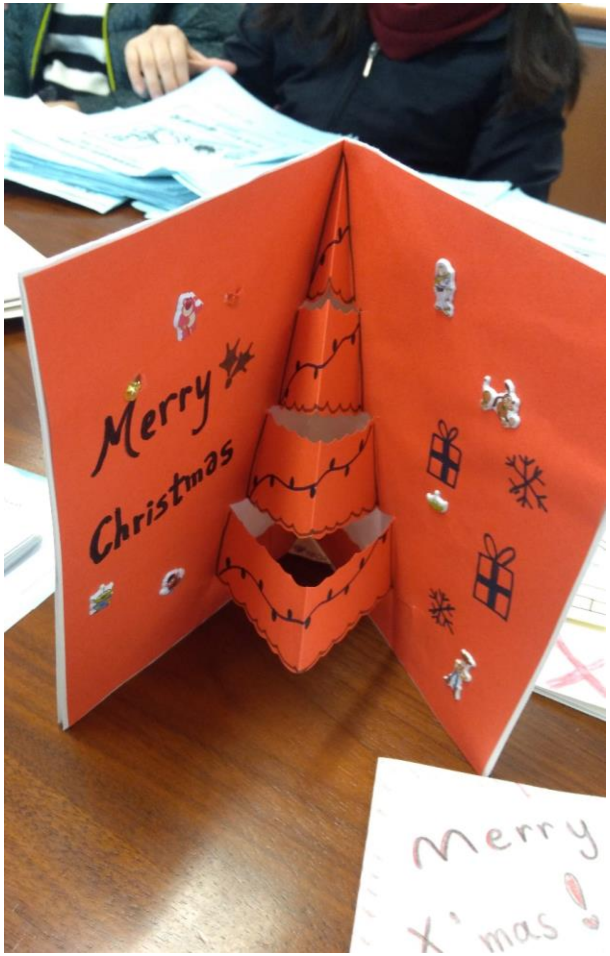


Technology for engineering practice

博愛醫院陳楷紀念中學

Integration of scientific inquiry/visual art into engineering practice

中華基督教會基華小學（九龍塘）



東華三院郭一葦中學

特點：

- 探究科學原理
- 運用科技產品和工具
- 包含設計與工藝/工程
- 融入創意藝術

Translating learning outcomes into activity(instructional) design

A TWO-STEP process

Instructional design

A. Aligning the activity process with the learning outcomes → LEARNING FLOW
B. Designing activity (instructional) plan

Aligning the activity process with the learning outcomes → LEARNING FLOW

Design-based STEM activity (Design cycle)

Engineering design process	**Research**	**Plan**	**Make prototype**	**Test**	**Redesign**

Design-based STEM activity (Design cycle)

M					
E					
T					
S					
STEM domain / **Engineering design process**	**Research**	**Plan**	**Make prototype**	**Test**	**Redesign**

Design-based : Designing instructions (Primary level)

M (Mathematics)					
E (GS, VA)					
T (Computer, Visual art, GS)					
S (General Studies)					
STEM domain / Engineering design process	**Research**	**Plan**	**Make prototype**	**Test**	**Redesign**

Design-based : Designing instructions (Secondary level)

M (Math)					
E (Computer, Design & Technology)					
T (Computer, Design & Technology)					
S (Sciences)					
STEM domain / Engineering design process	**Research**	**Plan**	**Make prototype**	**Test**	**Redesign**

Inquiry-based STEM activity

Inquiry process	**Hypothesize (predict)**	**Plan**	**Conduct**	**Analyze**	**Conclude**

Inquiry-based STEM activity

M					
E					
T					
S					
STEM domain / **inquiry process**	**Hypothesize (predict)**	**Plan**	**Conduct**	**Analyze**	**Conclude**

Inquiry-based: Designing instructions (Primary level)

M (Mathematics)					
E (GS, VA)					
T (Computer, Visual art, GS)					
S (General Studies)					
STEM domain / Inquiry process	**Hypothesize (predict)**	**Plan**	**Conduct**	**Analyze**	**Conclude**

Inquiry-based: Designing instructions (Secondary level)

M (Math)					
E (Computer, Design & Technology)					
T (Computer, Design & Technology)					
S (Sciences)					
STEM domain / Inquiry process	**Hypothesize (predict)**	**Plan**	**Conduct**	**Analyze**	**Conclude**

Activity 5

1. Select a STEM activity (design or inquiry based) that was practiced in your school.
2. Design the learning flow based on the learning outcomes and the approach to STEM integration.

BLUE – Factual knowledge

RED – Conceptual knowledge

GREEN – Procedural knowledge

2. Designing instructional plan

Aspects of instructional design:

- Teaching/learning approaches (e.g., SDL strategies)
- Scaffolding and learning flow
- Learning environment
- Resources
- Grouping
- Record and format of student work
- Dissemination/sharing of students' learning outcomes


Thank
You!