Science (S1-3) Teacher Network

Enhancing Science Learning through Quality Design of Diagnostic Tasks and Key Practical Tasks

Teacher Training Material

Prepared by Science Education Section
Innovation Technology Education Division
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Science (S1-3) Curriculum Support Materials
Enhancing Science Learning through Quality Design of
Diagnostic Tasks and Key Practical Tasks

Background

A meaningful science learning environment that sparks curiosity, develops problem-solving skills, and strengthens scientific literacy is essential for engaging students and nurturing their scientific inquiry skills. To this end, teachers need well-designed diagnostic tasks and key practical tasks that purposefully guide students through effective classroom discourse and hands-on practicals. Quality diagnostic tasks help teachers uncover students' prior knowledge and misconceptions, enabling focused learning support. Key practical tasks, on the other hand, allow students to apply scientific knowledge and inquiry skills to solve authentic science problems. These purposefully designed learning tasks offer students opportunities to construct evidence-based arguments, collaborate with peers, and refine practical skills through experiments. By adopting suitable learning and teaching strategies that reveal students' scientific thinking and promote meaningful scientific discourse, teachers can play a key role in supporting the systematic development of students' scientific inquiry skills.

In light of the above, the Science Education Section of the Education Bureau has launched the Science (S1-3) Teacher Network in 2025 to support science teachers in designing quality learning tasks which could be adapted for science lessons, and in developing effective learning and teaching strategies for Science (S1-3). This resource package is a summary of some of the reference materials developed within the Network. The resource package consists of two parts:

- L&T material I: Enhancing Lesson Effectiveness through Diagnostic Tasks
- L&T material II: Using AI to Develop Skill-Based Questions for Key Practical Tasks (KPTs)

The learning and teaching materials in this resource package are for reference only, teachers may adapt the activities to suit the needs and interests of their students.

L&T material I: Enhancing Lesson Effectiveness through Diagnostic Tasks

Objectives

(a) Use specific question formats (e.g., two-tier multiple-choice questions) to gain potentially deeper insights into student understanding, enabling a more detailed evaluation of scientific arguments and the identification of misconceptions.

(b) Implement responsive teaching strategies by using "Talk moves" to guide effective classroom discussions, analyse diagnostic data to address misconceptions, and strategically structure subsequent lesson activities based on student understanding.

Part A: The Challenge with Simple Multiple-Choice (MC) Questions

Simple MC questions can reveal **what** students know, but the questions can be limited in showing **how** students are thinking.

Example Question

Question	Options
Dolphins live in the ocean and have fins. Which group of vertebrates do dolphins belong to?	(A) Fish (B) Mammal (C) Reptile (D) Amphibian

Note:

Simple MC questions are suitable for checking students' understanding on definite scientific knowledge. However, the answering format in simple MC questions may not always provide deep diagnostic insight, potentially hindering the identification of students' learning gaps. Teachers may need to put in extra effort to uncover the reasons why students are unable to make a correct response (e.g., misunderstandings, misconceptions, or ineffective processes). Unless purposefully designed, simple MC questions may be difficult for teachers to use for enhancing students' engagement.

Part B: Two-Tier Multiple-Choice Questions

Two-Tier MC questions can be used to diagnose the student's Claim and chosen Evidence, serving as an initial step to reveal students' thinking.

Example Question

Tier	Component	Question	Example Options
Tier 1 (Claim)	**What** students know	Which group of vertebrates do dolphins belong to?	(A) Fish (B) Mammal
Tier 2 (Evidence)	**Why** students think that	Which statement best supports your answer?	(A) Dolphins live in the water and have fins. (B) Dolphins breathe air with lungs and feed milk to their young. (C) Dolphins have body shapes that help them swim fast. (D) Dolphins are warm-blooded and live in groups.

Benefits and Analysis of Two-Tier Responses

Analysing the combination of selections allows for inferences about a student's understanding and potential misconceptions.

Student Selection (Tier 1 / Tier 2)	Possible inference about Student Understanding
B / B (✓ Claim / ✓ Evidence)	This student may be able to identify the key traits of a mammal (air-breathing, feed milk to its young) that distinguish it from a fish.
B / A (✓ Claim /✗ Evidence)	One possible interpretation is that the student has memorized the fact that "dolphins are mammals" but believes the defining characteristics are related to habitat.
A / C (✗ Claim /✗ Evidence)	The student may be focusing on easily visible physical traits (e.g., body shape) rather than key biological characteristics.

Part C: Fostering Inquiry with "Talk Moves"

The results from a two-tier MC question can be used to for discussing and building scientific reasoning. Teachers, acting as facilitators, can use the "Talk moves" to guide the class discussion.

Purpose	Talk Move	Example Dialogue
1. Help individual students share, expand, and clarify their own thinking.	**"Say More"** Encourages students to elaborate on their initial concept.	"I see you claimed that dolphins are fish based on the body shape. Can you say more about your reasoning?"
	"So, Are You Saying...?" Verify or clarify a student's reasoning by repeating or summarising their explanation.	"Let me clarify your reasoning. Are you saying that the most important scientific rule for classification is an animal's body shape?"
2. Support the development of students' deeper reasoning.	**"Challenge"** Prompting students with a conflicting idea or a counter-example.	"I want everyone to turn and talk to your partner for one minute. Here's the question: 'What is the problem with using body shape or habitat as the primary evidence for classification?'"
3. Promote attentive listening among students.	**"Who Can Rephrase or Repeat?"** Encourages students to restate or summarise the concepts presented by their peers.	"After talking with your partner, has your thinking shifted? Before you share your own idea, what new evidence did your partner bring up?"
4. Analyse a peer's statement and explain their agreement or disagreement using reasoned judgement.	**"Agree/Disagree and Why?"** Encourages students to evaluate a classmate's comment using their own logic and justify whether they agree or disagree.	"Do you agree or disagree that this evidence is misleading? Why?"

Remarks for teachers

- Remember that the teaching goal is not only to identify misconceptions but also to create a discourse for students to revise their thinking.
- If the whole class is asked a challenge question and is met with silence, avoid giving the answer immediately. Instead, teachers may ask students to discuss the challenge with a partner for a short period of time (e.g., 30 seconds).
- Regularly reflect on what worked and adapt talk move approaches to achieve optimal engagement.

Part D: Actionable Steps for the Next Lesson

- **Review the Assessment:** Identify one Simple MC question that could be improved.
- **Convert the Question:** Convert that one question into a two-tier MC question to better diagnose student thinking.
- **Plan the Talk:** When using the question, prepare one or two "Talk moves" in advance to discuss the results with the class.

Template: An example two-tier MC question is available for teachers' reference.

Step 1: Use a device to scan the QR code;

Step 2: Log in to a personal Google account;

Step 3: Click the "USE TEMPLATE" button in the top right corner.

L&T material II: Using AI to Develop Skill-Based Questions for Key Practical Tasks (KPTs)

Objectives

(a) Use AI for efficient resource design by applying a 3-step framework to generate skill-based questions for Key Practical Tasks (KPTs).

(b) Create adaptive learning materials by using AI to align KPT worksheets with specific scientific inquiry skills and diverse student ability levels.

Part A: Teaching Principles for KPTs

Some important remarks for implementing KPTs:

- Completion of the core KPTs is required by the Science (S1-3) curriculum. Teachers may adopt a variety of ways to conduct KPTs in science lessons. For example, teachers may consider conduct two related KPTs in either a single or separate practical sessions.

- Teachers may adopt various formats to facilitate students to keep proper records for their learning through KPTs. The record keeping could be done can using a dedicated practical notebook or organising into a series of practical worksheets.

- Teachers should set questions for the KPTs targeting scientific inquiry skills; teachers should select or curate questions that are of suitable difficulty having regard to students' ability and interests.

Part B: A Practical 3-Step Framework for Designing Skill-Based Questions with AI

As a demonstration, teachers can use AI tools through the following structured process to generate questions for the following KPT in Unit 8, 'Atomic World' of the Updated Science (Secondary 1-3) Curriculum Framework, 2025:

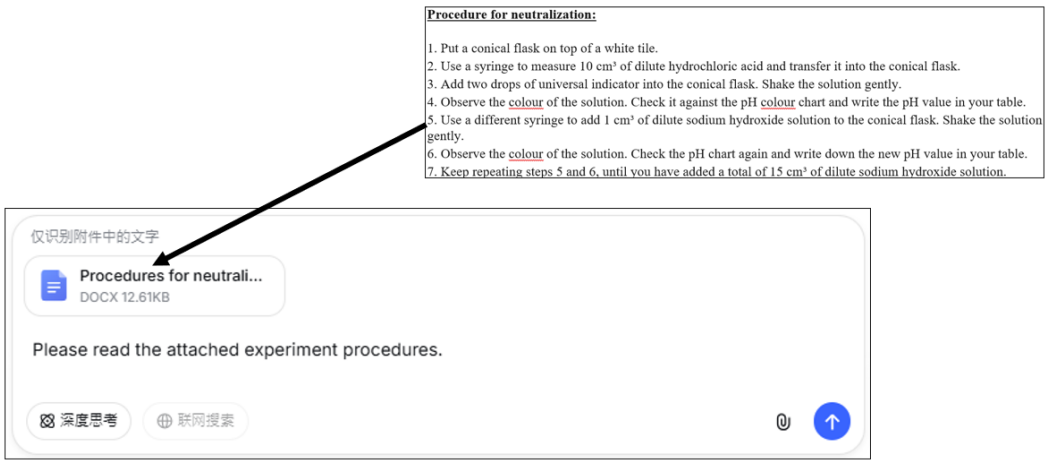
"Investigate the observable changes (e.g., in temperature, pH value, or the colour of pH paper/acid-alkali indicator) when an acid is mixed with an alkali."

Step 1: Provide the Experiment Context and Procedure

Giving the AI a clear context about the KPT (e.g., copy and paste the detailed procedure of the KPT).

AI Prompt: "Please read the attached experiment procedures."

Demonstration:

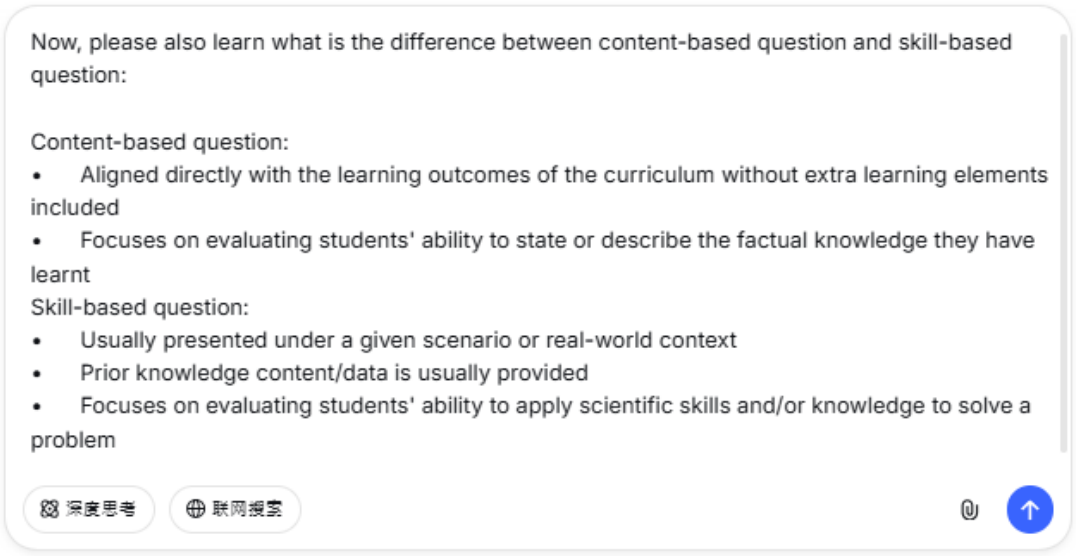


Step 2: Explain the Difference Between Content-Based and Skill-Based Questions

Explain the distinction between content-based and skill-based questions to the AI. The full prompt for this step is provided in **Appendix 1** for teachers to copy and use.

AI Prompt: "Now, please also learn what is the difference between content-based question and skill-based question."

Demonstration:

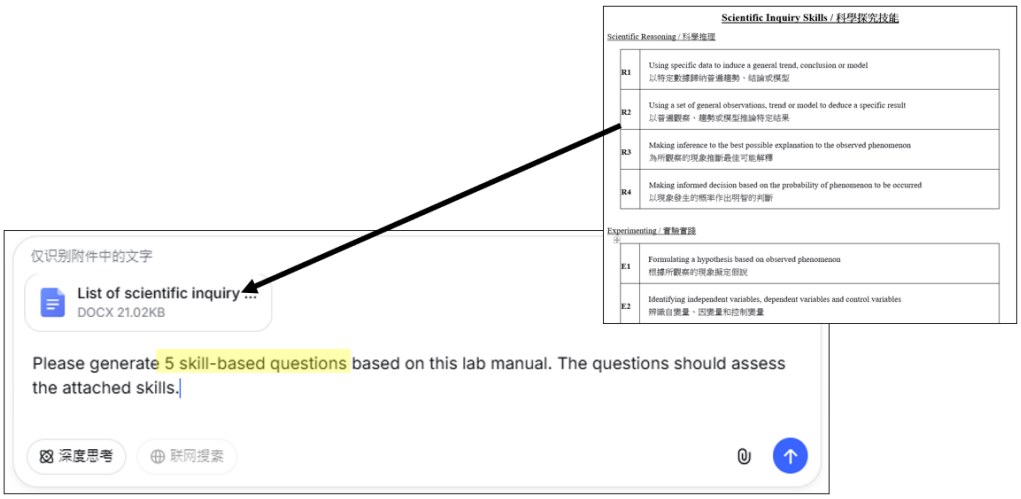


Step 3: Provide the Scientific Inquiry Skills List

Provide the complete scientific inquiry skills list from the Updated Science (Secondary 1 to 3) Curriculum Framework (**Appendix 2)** and instruct the AI to generate questions targeting these specific skills.

AI Prompt: "Please generate 5 skill-based questions based on this lab manual. The questions should assess the attached skills."

Demonstration:



Following the 3-step process for the specified KPT, the AI can generate a variety of skill-based questions. One sample output is provided below.

Demonstration:

1. Skills: D2 (Using tables and graphs for data analysis) & R1 (Using specific data to induce a general trend)

Question: A student performed the experiment and recorded the pH after each addition of sodium hydroxide.

Total Volume of NaOH Added (cm^3)	0	2	4	6
pH	2	2	3	4

Plot a graph of pH (y-axis) against the total volume of sodium hydroxide added (x-axis). Describe the overall trend shown by your graph. At approximately which volume of NaOH does the most significant change in pH occur, and what does this indicate about the reaction?

Remarks for teachers

Consider the following criteria when choosing a range of potential questions generated by the AI.

Criterion	Key Questions to Consider
1. Alignment with Scientific Inquiry Skills	Does the question accurately assess the intended scientific inquiry skills?
2. Appropriate Difficulty	Is the cognitive demand of the question suitable for the students' current ability level?
3. Practicality	Can the question be implemented within the lesson's time constraints?
4. Relevance and Engagement	Is the question interesting and does it connect to real-world contexts or students' daily life experiences?

Part C: Extending AI Use: Towards Adaptive Learning (適性化學習)

After generating skill-based questions, AI can be applied to a further step: creating scaffolded learning materials to support adaptive learning. One of the advantages of providing multiple sets of learning materials of various difficulties is allow teachers to cater to the varying ability levels within a classroom, providing appropriate support and challenge for all students.

Generate Differentiated Learning Materials Using AI

Teachers can instruct the AI using the following structured prompt:

"Please design two lab manuals for adaptive learning activity – one easier and one more difficult. Also, provide a marking scheme for both. All questions must assess the scientific inquiry skills from the list I provided."

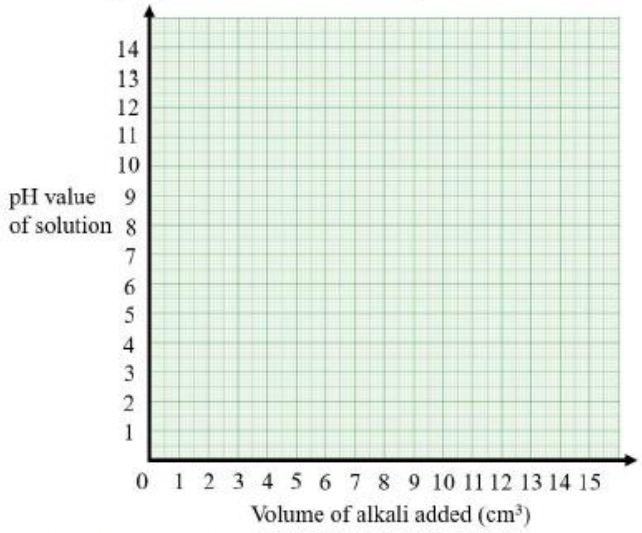
The following are two examples (version 1 and 2), both generated using a structured AI prompt and subsequently refined to serve for adaptive learning:

(Version 1)

Discussion:

1. **[D2 - Using Graphs for Data Analysis] (3 marks)**
   A graph paper is provided below.
   a) Plot your data from the table onto the graph. (2 marks)
   b) Draw a smooth curve of best fit through your points. (1 mark)

Change of pH value of the solution against the volume of alkali added



2. **[R1 - Inducing a General Trend] (2 marks)**
   Look at the curve you drew. Describe the general trend of how the pH changes as more dilute sodium hydroxide is added. (2 marks)

_____

3. **[R2 - Deducing the Neutral Point] (2 marks)**
   a) Using your graph, determine the volume of dilute sodium hydroxide added when the solution became neutral (pH 7). (1 mark)

_____

   b) How can you tell this from your graph? (1 mark)

_____

4. **[E2 - Understanding Variables] (2 marks)**
   Why was it important to use a different syringe for adding dilute sodium hydroxide? (2 marks)

_____

_____

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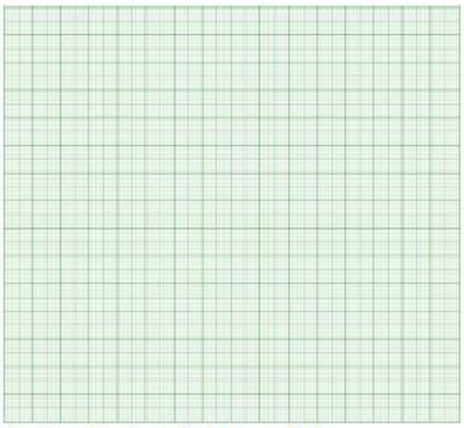
(Version 2)

Discussion:

1. **[D2 - Using Graphs for Data Analysis] (3 marks)**
   Plot the pH value of solution against volume of alkali added in the following graph paper. (3 marks)



2. **[R3 - Making Inference to the Best Explanation] (2 marks)**
   From your graph, determine the most precise volume of dilute sodium hydroxide needed to neutralize the acid. Justify your choice by describing the feature of the graph you used. (2 marks)

3. **[R1 - Inducing a General Trend] (2 marks)**
   Describe the relationship between the volume of alkali added and the pH. During which volume interval was the change in pH the most rapid? (2 marks)

4. **[E7 & R3 - Reliability and Inference] (3 marks)**
   If a student used the same syringe for both the acid and the base:
   a) How would this affect the **reliability** of their results? (1 mark)

   b) Infer whether their measured volume of dilute sodium hydroxide would be higher or lower than the true value. Justify your inference. (2 marks)

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Appendix 1

Difference Between Content-Based and Skill-Based Questions

Content-based question:

- Aligned directly with the learning outcomes of the curriculum without extra learning elements included
- Focuses on evaluating students' ability to state or describe the factual knowledge they have learnt

Skill-based question:

- Usually presented under a given scenario or real-world context
- Prior knowledge content/data is usually provided
- Focuses on evaluating students' ability to apply scientific skills and/or knowledge to solve a problem

Appendix 2

Scientific Inquiry Skills / 科學探究技能

Scientific Reasoning / 科學推理

R1	Using specific data to induce a general trend, conclusion or model 以特定數據歸納普遍趨勢、結論或模型
R2	Using a set of general observations, trend or model to deduce a specific result 以普遍觀察、趨勢或模型推論特定結果
R3	Making inference to the best possible explanation to the observed phenomenon 為所觀察的現象推斷最佳可能解釋
R4	Making informed decision based on the probability of phenomenon to be occurred 以現象發生的概率作出明智的判斷

Experimenting / 實驗實踐

E1	Formulating a hypothesis based on observed phenomenon 根據所觀察的現象擬定假說
E2	Identifying independent variables, dependent variables and control variables 辨識自變量、因變量和控制變量
E3	Making qualitative observations and quantitative measurements 進行定性觀察與定量量度
E4	Commenting accuracy and precision in a scientific measurement 評論科學量度中的準確度與精密度
E5	Setting up a controlled experiment to minimise confounding factors to identify causation 設定對照實驗以減低干擾因素對辨識因果關係的影響

E6	Choosing from alternative experimental methods or improving the method for a scientific investigation 從不同的實驗設計進行選擇或改良科學探究方法
E7	Commenting the reliability of a scientific measurement or a scientific investigation 評論科學量度或科學探究的可靠性

Data Processing / 數據處理

D1	Using scientific notation, significant figures and ratio for expressing and comparing scientific data 運用科學記數法、有效數字和比，以表達和比較科學數據
D2	Using tables and graphs for data analysis 運用表格和圖像作數據分析
D3	Using scientific formula for scientific inference 運用科學公式作科學推斷
D4	Identifying outliers and handling data from repeated measurements to assess the uncertainty incurred 找出異常值和處理重複量度所得數據，以評估所涉及的不確定性