Chapter 08
Auxiliary Tools and Applications for Scientific Inquiry

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Chapter 08
Auxiliary Tools and Applications for Scientific Inquiry

- Section 01 Auxiliary Tools and Applications for “Observing and identifying”.
- Section 02 Auxiliary Tools and Applications for “Planning and executing”.
- Section 03 Auxiliary Tools and Applications for “Analyzing and finding”.
- Section 04 Auxiliary Tools and Applications for “Discussing and communicating”.
- Section 05 Afterword.

Inquiry ability

- Thinking Ability (t)
  1. Imagination and creativity (i)
  2. Reasoning and argumentation (r)
  3. Critical thinking (c)
  4. Modeling (m)
- Problem-Solving (p)
  1. Observing and identifying (o)
  2. Planning and executing (e)
  3. Analyzing and finding (a)
  4. Discussing and communicating (c)

Imagination and creativity(i)

- ti-II-1
  Students can observe the patterns of daily life phenomena and use their imagination and curiosity for understanding and describe natural environment phenomena under the teacher's guidance.
- ti-III-1
  Students can use their curiosity to notice differences in the patterns of everyday phenomena due to certain changes. Students are also able to imagine what might happen based on known scientific knowledge and the scientific method in order to perceive different methods, and complete different activity tasks.

Reasoning and argumentation(r)

- tr-II-1
  Students can know that there are reasons for the results of natural phenomena observed and recorded, and can state their ideas based on acquired knowledge.
- tr-III-1
  Students can connect the natural phenomena that they and others have observed and recorded with acquired knowledge. And they can detect each other's relationships, present perceptions and know there are differences with others.

Critical thinking(c)

- tc-II-1
  Students can easily distinguish or classify the observed natural science phenomena.
- tc-III-1
  Students can make simple records and classify the data or information collected. Moreover, they can think about the correctness of information and identify and differences between information and facts from others based on what they have learned.

Modeling(m)

- tm-II-1
  Students can understand simple conceptual models through observing the relationships in natural phenomena, and connect them with real life experiences.

- tm-III-1
  Students can explore the relationships in natural phenomena, establish simple conceptual models, and understand the existence of different models through the process of questioning, observation, and experimentation.

Observing and identifying(o)

- po-II-1
  Students can make observations from daily experiences, learning activities, and the natural environment, and then they are able to become aware of problems.
- po -II-2
  Students can ask questions based on observation, data collection, reading, thinking, and discussion.
- po-III-1
  Students are aware of problems from learning activities, daily experiences and technology applications, the natural environment, books, and online media.
- po -III-2
  Students can preliminarily identify problems that are suitable for scientific inquiry and can propose appropriate problems for scientific inquiry based on observation, data collection, reading, thinking, and discussion.

Planning and executing(e)

- pe-II-1
  Students can understand the possible effects of a change in one factor and predict the approximate outcome of the activity.
- pe-II-2
  Students can correctly and safely operate items, devices, scientific equipment, and use chemicals suitable for their learning stage. And they can observe and record the experimental process.
- pe-III-1
  Students can understand the meaning of independent and dependent variables. They can predict the possible effects of changes and perform the appropriate number of experimental operations. Under the guidance or instructions of the teacher or textbook, students can understand the plan of inquiry, and plan simple inquiry activities according to the characteristics of the problem and resources (such as equipment).
- pe-III-2
  Students can correctly, safely operate objects, equipment, technology equipment, and resources appropriate for this learning stage. Students can perform objective qualitative observation or record measured data in detail.

Analyzing and finding(a)

- pa-II-1
  Students can organize existing information or data by using simple classification, charting, etc.
- pa-II-2
  Students can use the information or data they receive to generate explanations, get answers, and solve problems. And they can compare their own inquiry results with others (e.g., from a teacher) and check if the results are similar or not.
- pa-III-1
  Students can use simple ways, such as analyzing and comparing, creating charts and tables, and using simple mathematics to organize existing information or data.
- pa-III-2
  Students can use the information or data they receive to generate explanations, discover new knowledge, learn about cause and effect, solve problems, or discover new problems. And they can compare their own inquiry results with others (e.g., from classmates) and check if the findings are similar or not.

Discussing and communicating(c)

- pc-II-1
  Students can listen attentively to their classmates' reports, ask questions or make comments. And they can conduct a review of the method, process or outcome of the inquiry.
- pc-II-2
  Students can use the simple forms of speaking, writing, or drawing to express the process and findings of inquiry.
- pc-III-1
  Students can understand a classmate's report, ask reasonable questions or express opinions. And they can also check the alignments among the "research questions," "method of inquiry," "gathered evidence," and "findings of inquiry" and evaluate and identify the strengths and weaknesses.
- pc-III-2
  Students can express the process of inquiry, discovery, and results using the simple forms of orals, texts, or images (for example, photography or video), drawings or objects, scientific terms, mathematical formulas or models.

Four Key Points of Problem-Solving

1. Observing and identifying
2. Planning and executing
3. Analyzing and finding
4. Discussing and communicating

Section 01
Auxiliary Tools and Applications for “Observing and identifying”.

Types of student problems:

- Noun Definition Problems
- Phenomenon Explanation Problems
- Inquiry Questions

Section 01 Auxiliary Tools and Applications for “Observing and identifying”

- Take “Timing Tools” for example:
- Teacher prompts the use of physical tools and poses questions. Introduce a timing tool (such as an electronic watch, stopwatch, or smartphone timer) and ask the students what kind of time it can be used to measure.
- Use thinking tools to stimulate students to generate scientific inquiry questions.
  Utilize thinking aids to help students think based on observation and life experiences, thereby generating more relevant scientific inquiry questions.

Section 01 Auxiliary Tools and Applications for “Observing and identifying”

- Use thinking aids (such as sticky notes, whiteboards, or digital software) to stimulate ideas for scientific exploration.
- Use thinking aids (such as sticky notes, shared document files, or presentation software) to assist students in organizing their thoughts.
- For example, students can write their ideas on sticky notes and then engage in group or whole-class discussions, categorization, or summarization by reattaching the sticky notes under appropriate category headings.

Section 01 Auxiliary Tools and Applications for “Observing and identifying”.

- Use thinking aids (such as sticky notes, shared document files, presentation files, or concept mapping software) to help students organize their thoughts.
- The teacher can use digital tools such as shared document files, presentation software, or concept mapping software to input and display information on the classroom projection screen (as shown in Figure 8-2), and then facilitate the process of moving and categorizing the ideas.

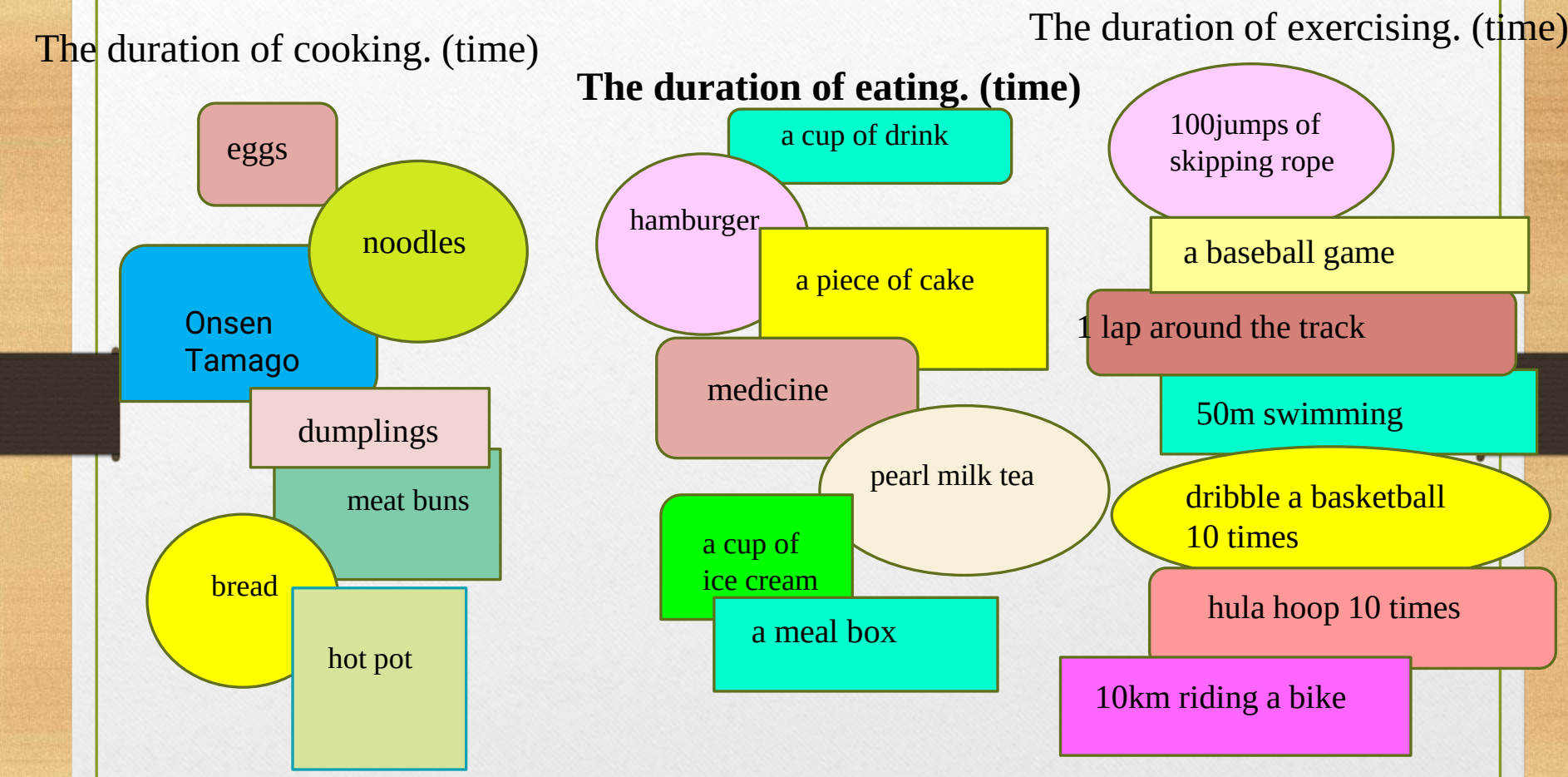

Figure 8-2
Concept or mind map software as a thinking tool for categorizing and summarizing student questions.

Section 01 Auxiliary Tools and Applications for “Observing and identifying”.

- Using thinking tools such as sticky notes, shared documents, slide presentations, or concept mapping software to assist students in generating questions through comparative and divergent thinking.
- For example, based on the previously mentioned topic of "measuring time," after comparing and engaging in divergent thinking, students can generate several investigable questions (see Figure 8-3).
- For instance, when students are unsure how to formulate questions, they can use a mind map to engage in divergent thinking about variables or factors to be investigated. Then, scaffolding can be provided through sentence completion to guide students towards convergent thinking. The example of investigating convex lenses, as shown in Figure 8-4, illustrates this process.

Think about this and share your idea with everyone.

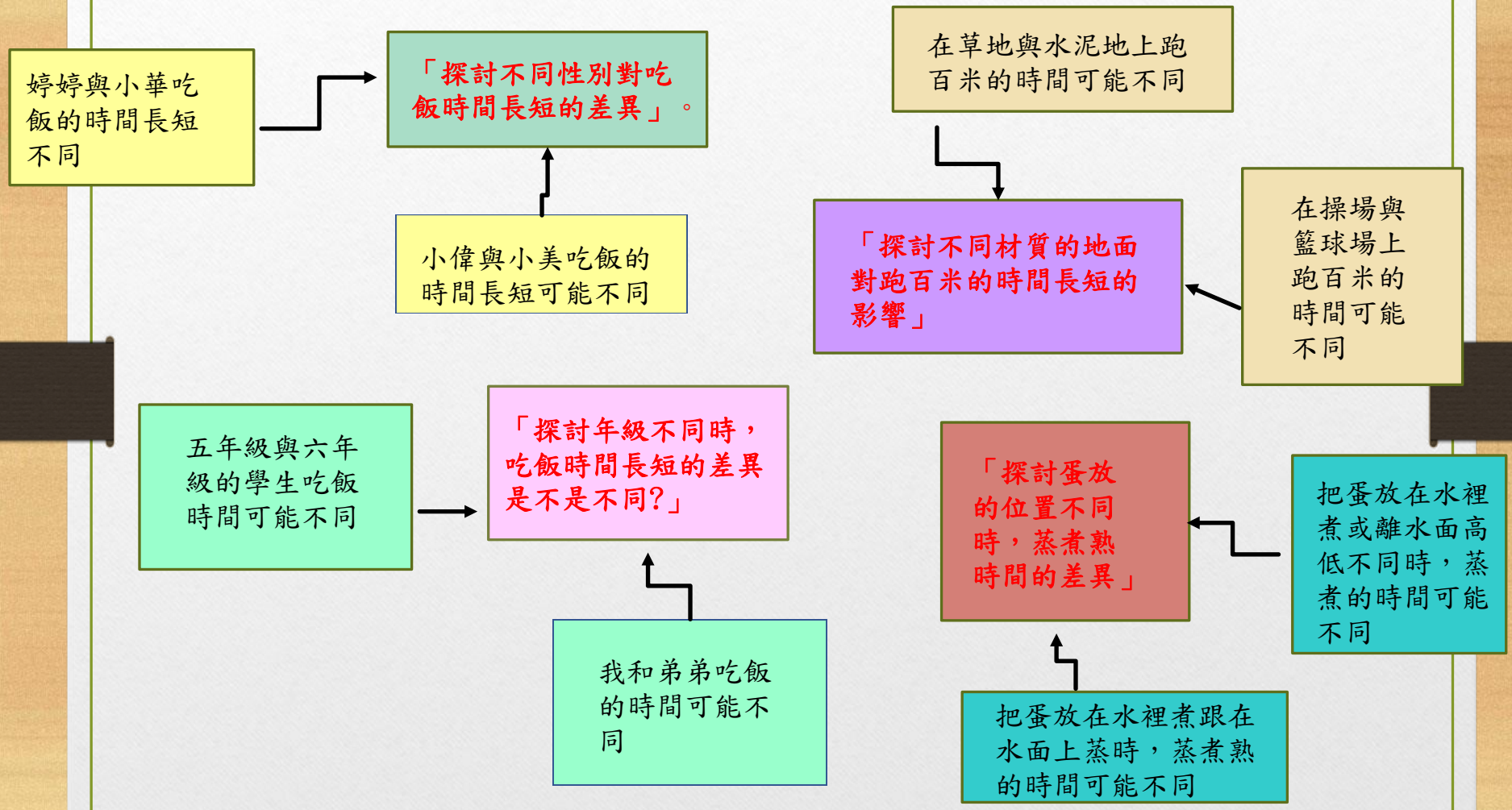

Figure 8-3: Thinking Tools (Concept or Mind Mapping Software)

Example of a “Convex Lens Mind Map” Obtained through Teacher-Student Discussion

- "Convex Lens Mind Map" Obtained through Teacher-Guided Student Discussion
- If students are unable to formulate or describe the problem they want to investigate, the teacher can provide the assistance of a "Fill in the Blanks" tool for students to fill in the missing information.
- The form of the convergent thinking aid for the relationship between independent and dependent variables is as follows:
  - I want to investigate: Will the change in factor (A) affect the change in factor (B)?
  - For example: Will the thickness of a convex lens affect the distance of the image formation?
- It can be further refined as: How does the thickness of a convex lens affect the distance of the image formation?

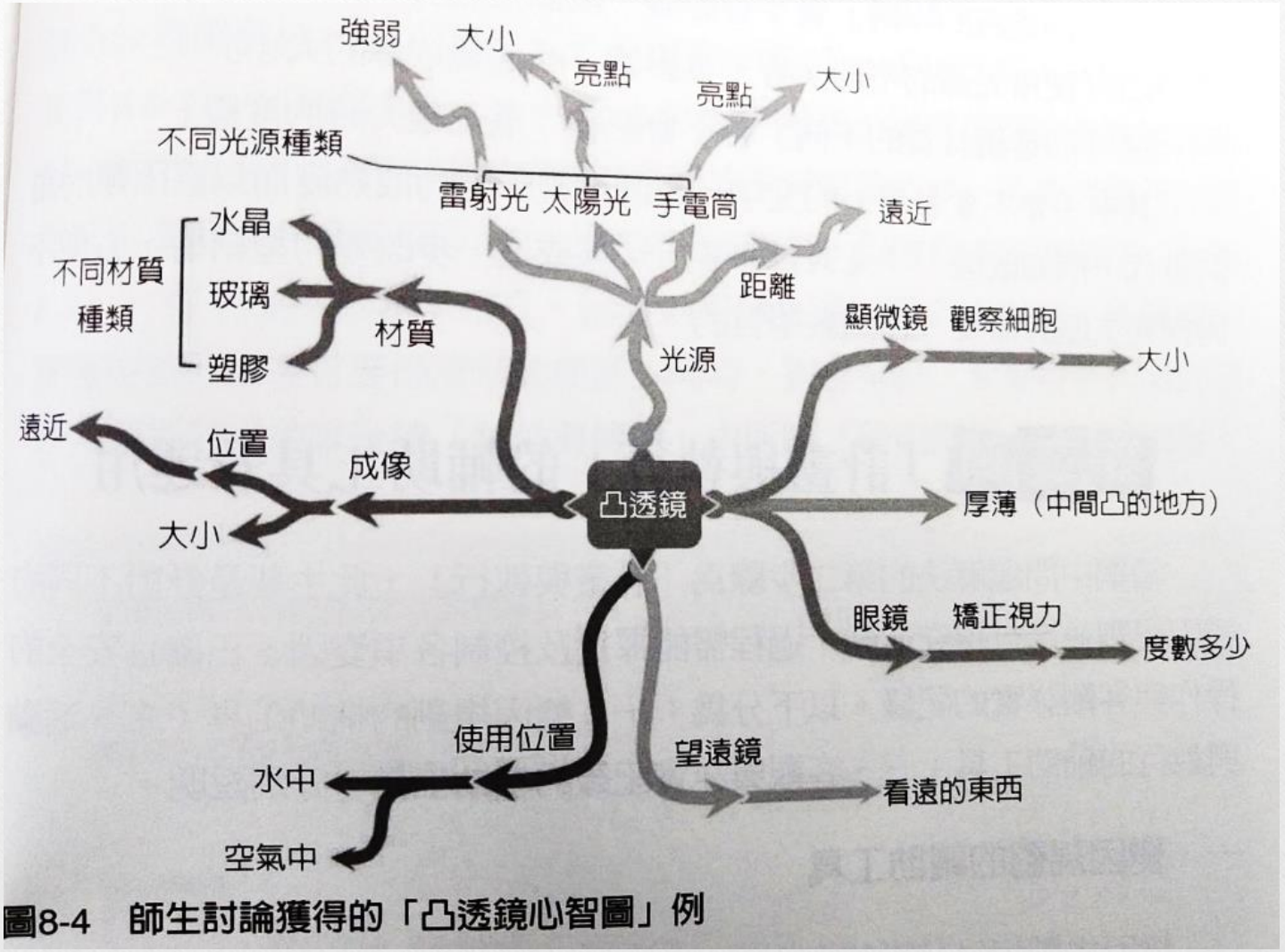

圖8-4　師生討論獲得的「凸透鏡心智圖」例

Section 02
Auxiliary Tools and Applications for “Planning and executing”.

- Auxiliary tools for planning variables.
- Auxiliary tools for planning and executing.

Section 02 Auxiliary Tools and Applications for “Planning and executing”

- Auxiliary tools for planning variables.
- Generate a list of potential influencing factors (variables) through divergent thinking.
- For example, "Identify factors that may affect the cooking time of eggs based on life experiences."
- Students may suggest: intensity of heat, amount of water, covering the pot or not, presence of wind, and so on.

Section 02 Auxiliary Tools and Applications for “Planning and executing”

- Evaluate the importance of factors (variables) and make judgments through convergent thinking.
- Analytic Hierarchy Process (AHP): This method involves pairwise comparisons to establish importance ranking. For example, if A is considered more important than B, and B is considered more important than C, then the conclusion is A > B > C.
- Group Brainstorming: Utilize sticky notes or the aforementioned software to have students write down the influencing factors. Then, facilitate group or class discussions to categorize the factors and determine their importance order within each category, as shown in Figure 8-5.

What factors influence the speed at which eggs float when cooked?
(In order of importance)
Which factors are you investigating?
Which factors are you trying to keep as similar as possible?

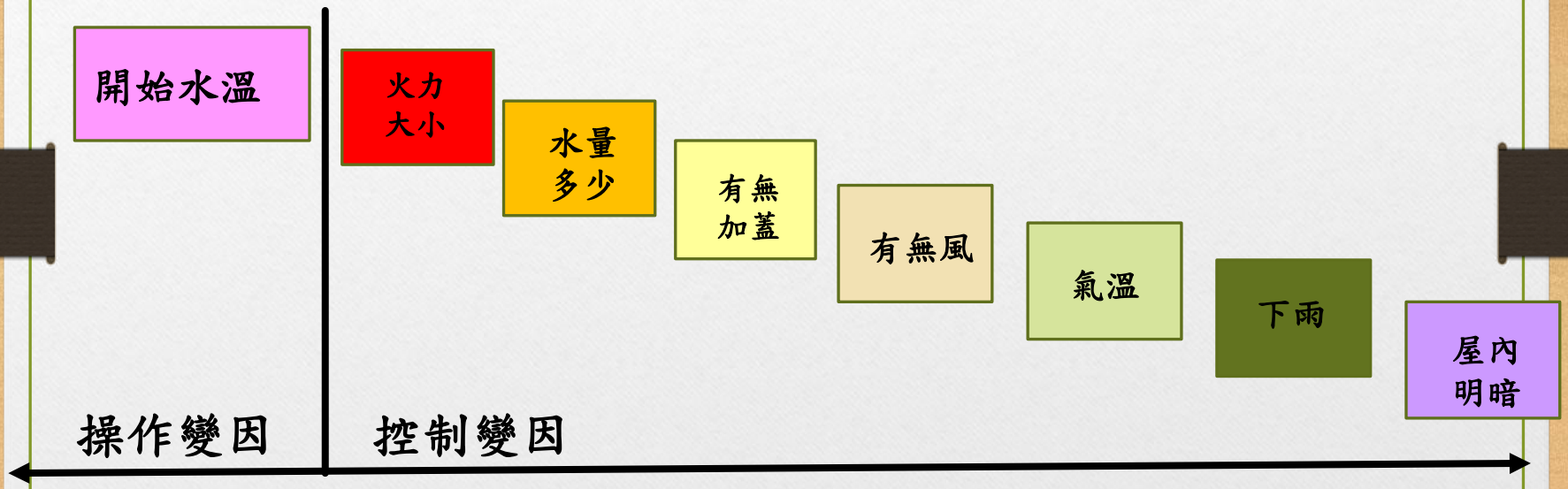

Figure 8-5: Convergent Evaluation of the Importance and Determination of Factors (Auxiliary Tools for Variables)

Section 02 Auxiliary Tools and Applications for “Planning and executing”

- Auxiliary tools for planning and executing.
- Selection of Planning and Execution Strategies: Prioritizing by Importance, Priority, or Feasibility.
- Selection or Substitution of Tools and Materials for Planning and Execution Assistance.
  - For example, in conducting experiments related to convex lenses, previous imaging experiments used candles or LED lights as objects to observe lens imaging. However, this may not be easily relatable for students. In this exploratory activity, any object from daily life or an image on a mobile phone screen can be used as the experimental object, producing an image through the lens.

Figure 8-6 Lens Imaging Example - Hand

Section 02 Auxiliary Tools and Applications for “Planning and executing”

- Auxiliary Tools for Objective and Detailed Recording
- Elementary school students can record their findings through illustrations, written descriptions, or tables.
- If a student measures that water does not boil at 100 degrees Celsius, should the student modify their answer?

Section 03 Auxiliary Tools and Applications for “Analyzing and finding”.

- Auxiliary tools for analyzing.
- Auxiliary tools for finding.

Section 03 Auxiliary Tools and Applications for “Analyzing and finding”.

- Auxiliary tools for analyzing.
- For second-stage students, they focus on using classification to create charts, organizing existing information or data, and so on. For upper-grade students, they focus on further comparing results and using simple mathematical methods.
- Guiding elementary school students to create charts in three steps:

1. Extract common factors as column names to form a record table.
2. Simplify the table by extracting common units.
3. Extract fixed value columns.

Extract common factors as column names to form a record table, using the Wheel Axis Experiment Record (Table 8-1).

Force	Radius of axis	Radius of wheel	Weight of object
5gw	2cm	4cm	2.5gw
10gw	2cm	4cm	5.0gw
15gw	2cm	4cm	7.5gw

Extract common units to simplify the table, using the Wheel Axis Experiment Record (Table 8-2).

Force (gw)	Radius of axis (cm)	Radius of wheel (cm)	Weight of object (gw)
5	2	4	2.5
10	2	4	5.0
15	2	4	7.5

Delete the columns of constant values (i.e., controlled variables).

- The radius of axis is 2 cm.
- The radius of wheel is 4 cm.

Force(gw)	Weight of object(gw)
5	**2.5**
10	**5.0**
15	**7.5**

Section 03 Auxiliary Tools and Applications for “Analyzing and finding”.

- Auxiliary tools for finding.

	A	B	C
1	欄位	A1	A2
2		軸半徑2公分	輪半徑4公分
3			
4	B1	2	2
5		施力(公克重)	物體重量(公克重)
6	B2	5	2.5
7	B3	10	5.0
8	B4	15	7.5
9			
10			

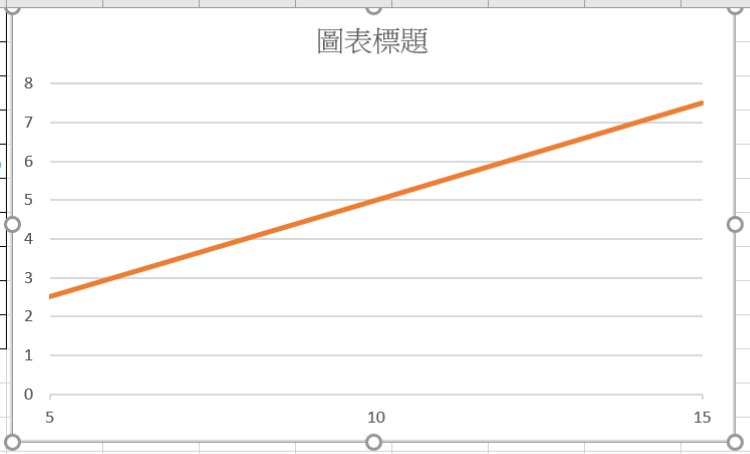

Figure 8-7: Creating Charts or Performing Mathematical Calculations Using Excel

Section 04
Auxiliary Tools and Applications for "Discussing and communicating".

- Auxiliary tools for discussing.
- Auxiliary tools for communicating.

Auxiliary Tools for Discussing.

- 主張（Claim, C）：自己的看法
- 證據（Data, D）：觀察到或學過，可用以證明自己看法的事實資料
- 理由（Warrant, W，即論述）：使證據能夠連結主張的原因或道理
- 支持理論（Backing, B，即原理）：支持自己看法的邏輯或科學知識
- 反例（Rebuttal, R）：例外的狀況

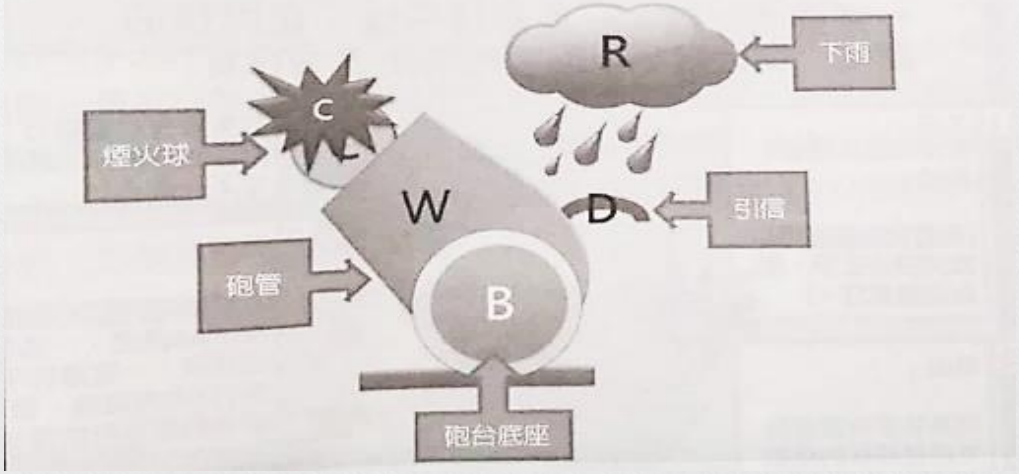

圖8-8「大砲圖像」的論證教學模型(引自盧玉玲，2017)

Auxiliary Tools for Discussing.

- Toulmin’s argumentation model
- Data: Is the obtained data valid? Does the data have clear and credible sources?
- Warrant: Is the process of inferring from the data correct?
- Backing: Are there any other pieces of evidence supporting this inference?
- Qualifier: Based on the previous description, can a reasonable claim be formulated? Is the claim proposed based on the data and the process of inference reasonable?
- Rebuttal: Does this claim need to be qualified with conditions to avoid being refuted by others?
- Claim: If the claim is reasonable and not easily refutable, then accept the current proposition.

Does a crumpled piece of paper fall faster to the ground?

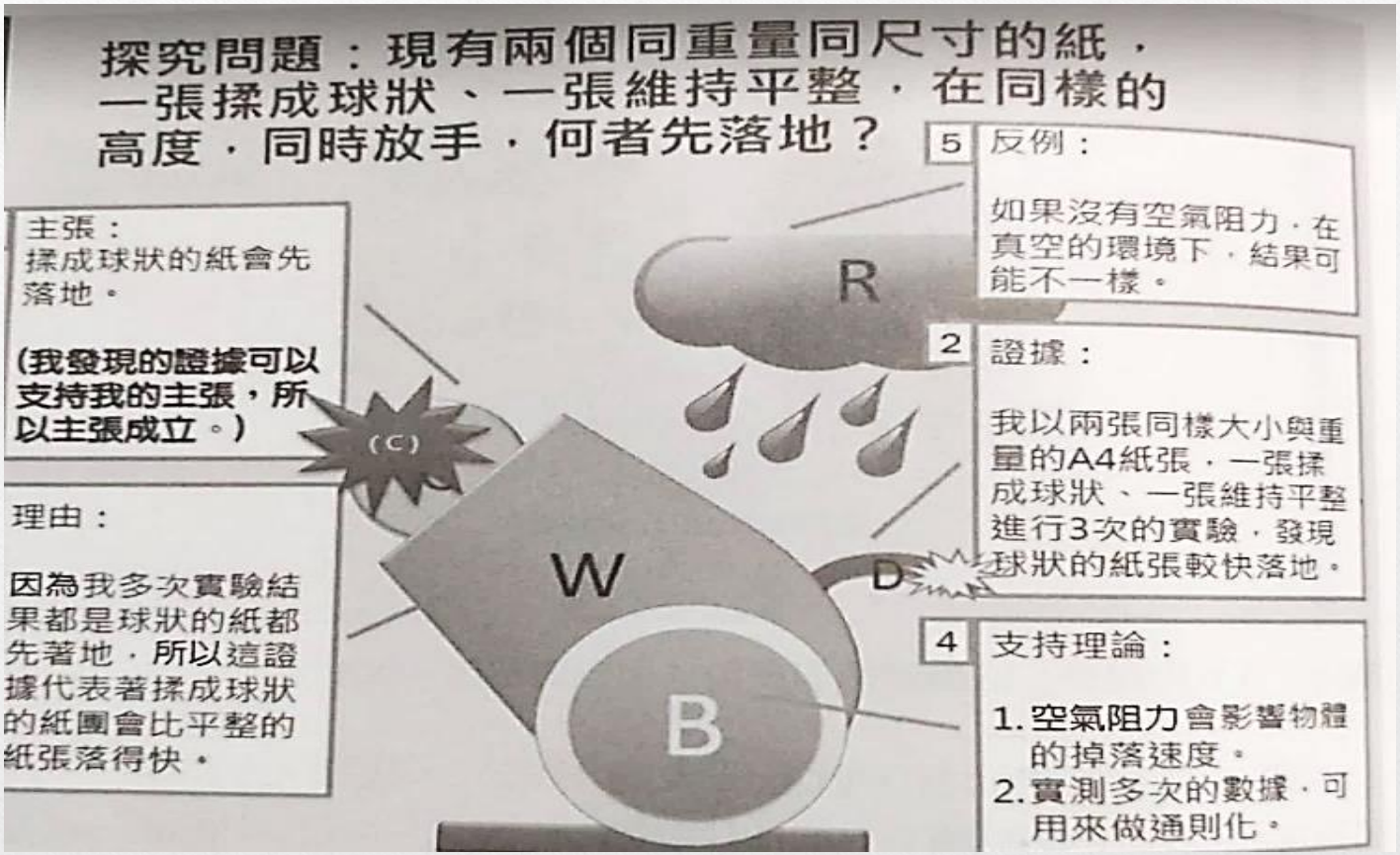

圖8-9 「大砲論證模型」的運用例:揉成一團的紙較快掉地?

Auxiliary Tools for Communicating

- "Communication" is the sharing of the inquiry process and results.
- For second-stage students, teachers mainly cultivate their ability to use "simple forms of oral language, writing, or drawings."
- For third-stage students, teachers further develop more diverse communication skills, such as posters, models, 3D books, oral presentations, videos, written descriptions with illustrations, drawings or physical objects, scientific terms, mathematical formulas, etc.

Section 05 Afterword

By utilizing the tools of scientific inquiry effectively, scientific investigation activities can become more contextualized and engaging, aligning with student-centered learning. It expands the dimensions of students' thinking and cultivates the habit and ability to think scientifically.

Homework

1. Please choose a tool or experimental materials from everyday life as a starting point for teaching and develop it into a scientific inquiry teaching activity.
2. Please apply at least one software tool to assist you in conducting instructional activities for answering natural science questions in your class.