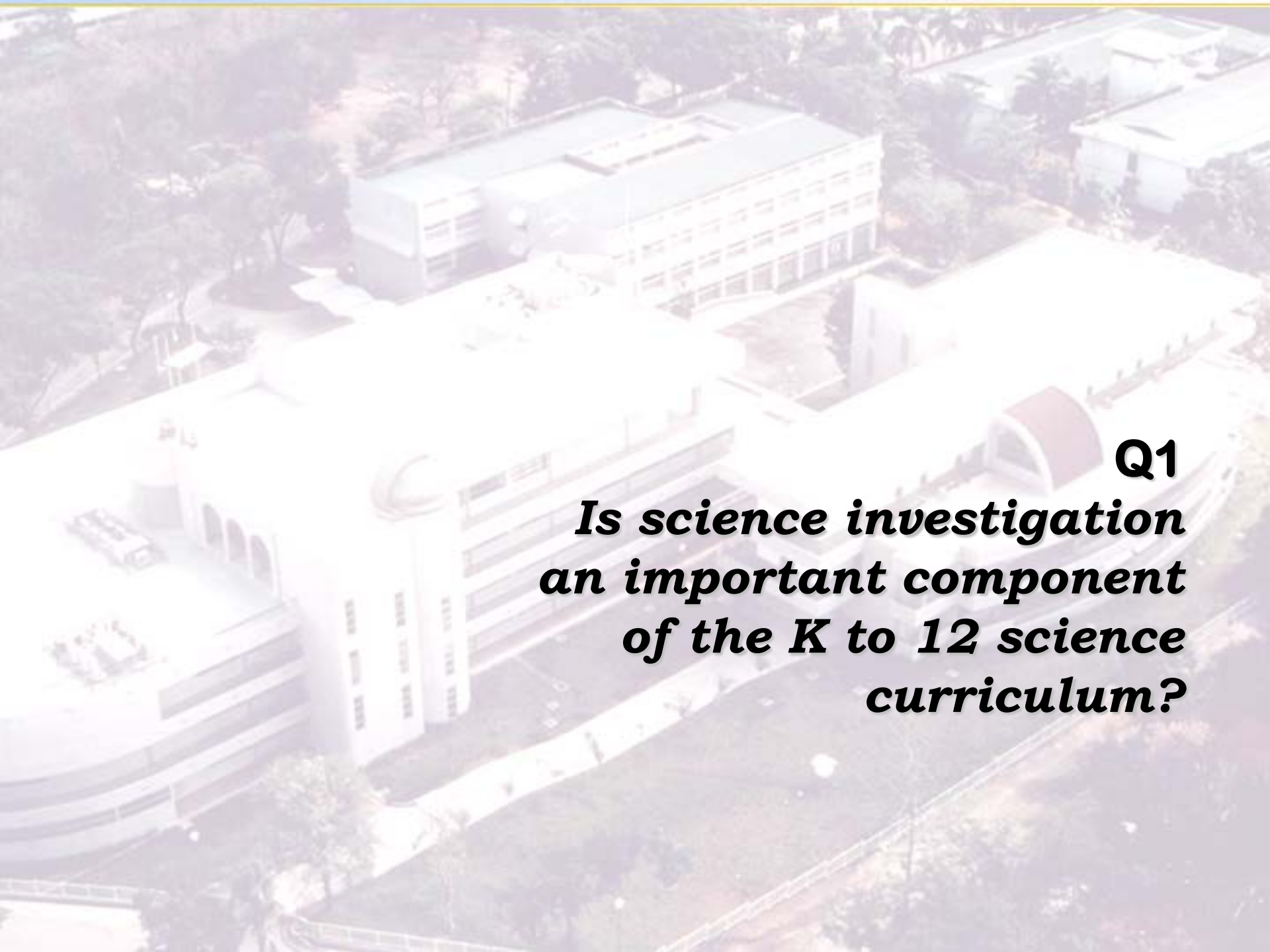
Conducting Science Investigations

Merle C. Tan, PhD
National Institute for Science and Mathematics Education Development
University of the Philippines
merle.tan06@gmail.com

Some Questions about Science Investigations

1. ***Is science investigation an important component of the K to 12 science curriculum?***
2. ***What processes used by scientist in solving problems can be used by students when doing science investigation?***
3. ***How can we develop students' investigation skills?***
4. ***What are some deficiencies in students' investigations?***



Q1

Is science investigation an important component of the K to 12 science curriculum?

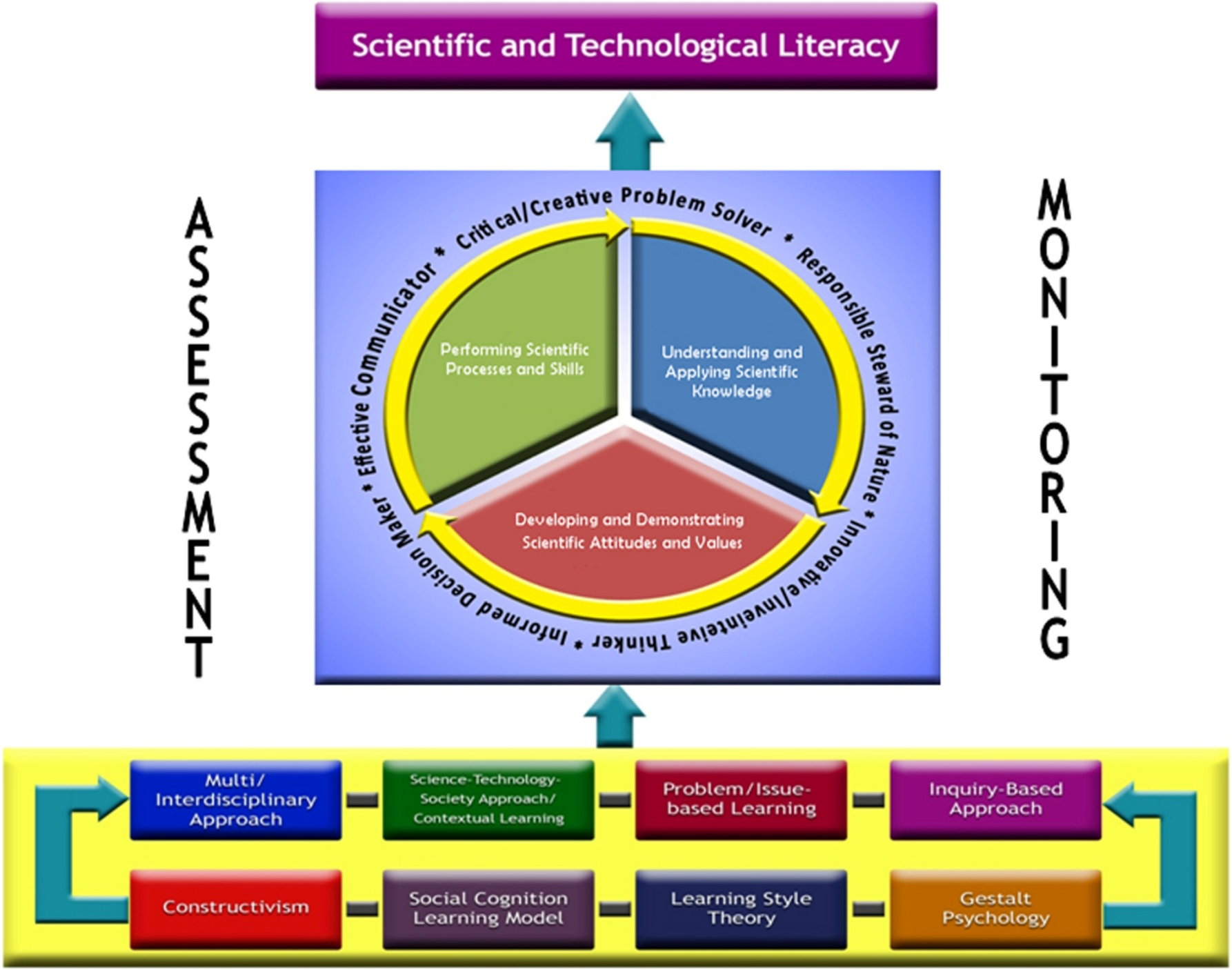
Science in the K to 12 Curriculum

is

- learner-centered
- inquiry-based
- research-based
- decongested

shows

- the place of science and technology in everyday activities
- the link between science and technology, including indigenous technology
- integration/connections within science and across disciplines, including Math
- how science content and processes are intertwined
- spiral progression


Scientific and Technological Literacy
ASSESSMENT
MONITORING
Critical/Creative Problem Solver * Responsible Steward of Nature * Innovative/Inventive Thinker * Informed Decision Maker * Effective Communicator
Performing Scientific Processes and Skills
Understanding and Applying Scientific Knowledge
Developing and Demonstrating Scientific Attitudes and Values
Multi/ Interdisciplinary Approach
Science-Technology-Society Approach/ Contextual Learning
Problem/Issue-based Learning
Inquiry-Based Approach
Constructivism
Social Cognition Learning Model
Learning Style Theory
Gestalt Psychology

Component 1: Scientific Inquiry Skills

Basic Science Processes

Observing
Asking questions
Measuring
Classifying
Inferring
Finding patterns
Predicting
Communicating

Integrated Skills

Formulating hypothesis
Fair testing
- Identifying variables
- Controlling variables

Collecting and organizing data
Interpreting data
Making conclusions

Higher Order Thinking Skills

Critical thinking
Creative thinking
Problem solving
Decision making

(Real-life context)

Scientific Inquiry Skills

STE Literacy Skills

Component 2: Content and Connections

Science Content (G1-10)

Living Things & Their Environment
Characteristics
Structure and Function
Processes
Interactions

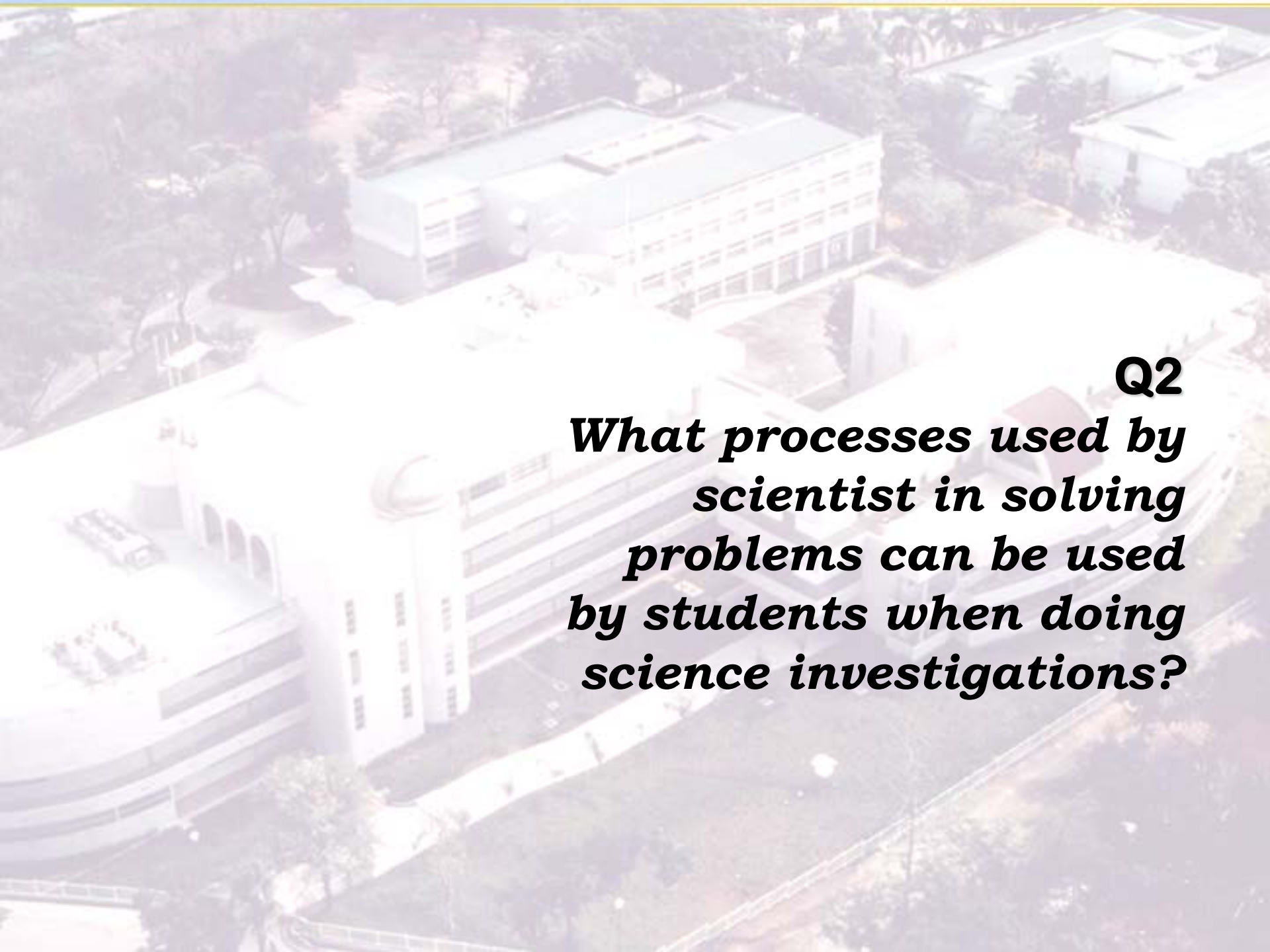
Force, Motion & Energy
Movement
Effects of Force
Forms of Energy and Transformation

Matter
Diversity of Materia
Properties & Structure
Changes
Interactions

Earth and Space
Surroundings: Land, Water, Air,
Weather and Climate
Solar system

Component 3: Scientific Attitudes and Values

- Intellectual honesty
- Objectivity
- Perseverance
- Active listening
- Assuming responsibility
- Taking initiative
- Independent learning
- Analyzing and evaluating information, procedures, and claims
- Making decisions based on sound judgment and logical reasoning



Q2

What processes used by scientist in solving problems can be used by students when doing science investigations?

Different Ways to Solve Problems

Way	Discovery	Scientist
Trial and error	Tungsten filament	Edison
By accident	Rubber	Goodyear
	King's problem	Archimedes
Intuition	Relationship between matter and energy	Einstein
Chance or Serendipity	Synthetic dye	Perkins
	Posts-it notepads	3M
Experimental method	**********	**********

A great number of scientists use the experimental method to search for answers.

Discovery of Argon in 1895

by
Sir William Ramsay
Nobel Prize in Chemistry of Argon &
Family of Nobel Gases, 1904

Lord Rayleigh
Nobel Prize in Physics of Argon, 1904

Rayleigh was
investigating nitrogen
using more than
one method
to make measurements
of the same quantity
(of nitrogen).
He wanted to make sure
that he is measuring
what he thinks
he is measuring.

Rayleigh
noticed
small differences
between methods
because
of the
high precision
of his
Instruments.

He persistently
tracked down
a small
but real anomaly
in those
measurements.

Rayleigh was a physicist; he consulted experts (e.g., Ramsay, a chemist) outside his discipline to help explain his anomalous results.

Rayleigh and Ramsay conducted a series of tests to characterize the new gas, physically and chemically.

Rayleigh and Ramsay eventually realized that the anomaly was due to a previously unknown but relatively plentiful component of the atmosphere, an inert monoatomic inert gas

Rayleigh recognized that claiming the newly-discovered gas, an element, was controversial.

At that time, there was no place for argon in the periodic table which had become established for 25 years.

They evaluated new findings in the context of existing knowledge.

They know that if there were apparent contradictions, the new conclusion will be greeted with skepticism.

Ramsay hypothesize that

if the periodic law and the discovery of a new inert gas are both correct,

then there must be a family of such elements!

Subsequent researches enabled Ramsay to discover other members of the inert gas family.

Sample Student Investigation

Comparing the Metal Elements in the Leaves of Different Mango Varieties

Problems

1. Are the metal elements sodium, potassium, calcium, and magnesium found in mango leaves?
2. Are the metal elements present in the leaves of one variety of mangoes the same as those in other varieties?
3. Is there any difference in the kind of metal elements found in young and adult leaves of the same variety of mango?

Hypotheses

1. Magnesium, calcium, sodium, and potassium are found in mango leaves.
2. The metal elements present in the leaves of one variety of mangoes are the same as those in other varieties.
3. There is no difference in the kind of metal elements found in young and adult leaves of the same mango variety.

Experimental Design

Sample	Treatment
Pico	Test for the elements Na, K, Ca & Mg
Kalabaw	Test for the elements Na, K, Ca & Mg
Indian mango	Test for the elements Na, K, Ca & Mg

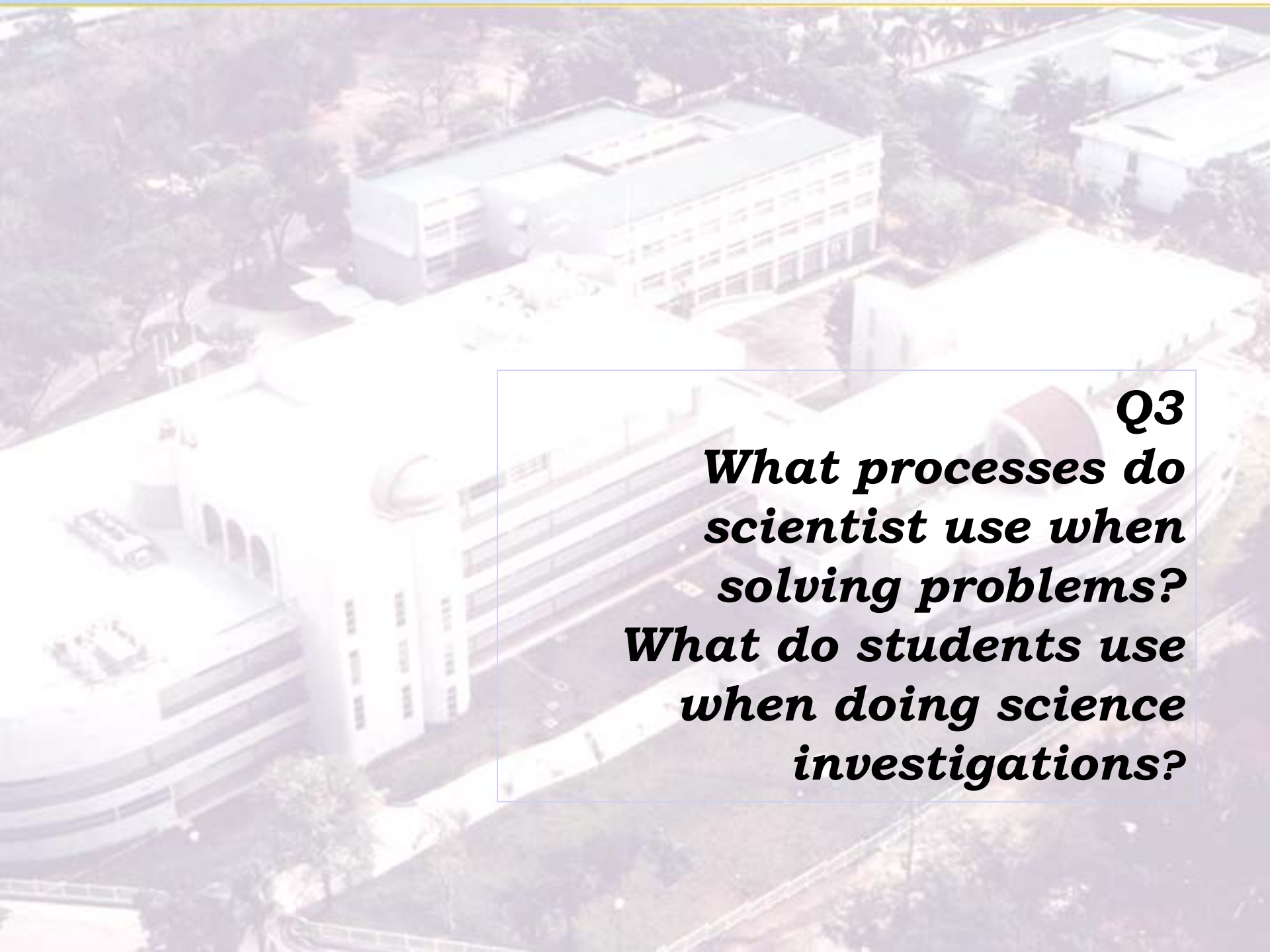
Independent variable: variety of mango
Dependent variable: kind of metal element present
Control variables: maturity of leaves, mass of sample, procedure for determination

Essential Components of a Science Investigation (Experimental Method)

- **Problem** (P): specific question to be answered
- **Hypothesis** (H): a prediction about the relationship between the variables that can be tested.
- **Independent variable** (IV): the variable that is purposefully changed by the experimenter
- **Dependent variable**: the variable that responds to the change or manipulation
- **Constants**: all factors that remain the same and have a fixed value

Essential Components of a Science Investigation (Cont'd)

- **Control**: the standard for comparing experimental effects
- **Repeated trials**: the number of experimental repetitions, objects, or organisms tested at each level of the independent variable
- **Experimental design diagram**: a diagram that summarizes the IV, DV, C, control, number of repeated trials , experimental title, and hypothesis.



Q3

What processes do scientist use when solving problems? What do students use when doing science investigations?

Scientific inquiry is used by scientists to make empirical observations and develop evidence-based explanations of the natural world.

Inquiry immerses students in conducting scientific investigations in familiar and meaningful contexts.

Both scientists and student researchers hers are doing inquiry because they are …

- engage in scientifically-oriented questions
- give priority to evidence in responding to questions
- formulates explanations from evidence
- connect explanations to scientific knowledge
- communicates and justifies explanations

What Scientists and Students Do When They Conduct Science Investigations?

Processes used	What students do	What scientists or researches do
observe	Use the senses aided by technology	Use senses aided by more sophisticated technology
experiment	Change something; Watch what happens	Manipulate and control variables
collaborate	Work with others in class	Other scientists and researchers
record	Write in notebooks; journals	Field notes, data sheets, print outs
measure	Use lab equipment	Scientific instruments
sort/classify	Color, size, shape, mass	Classification keys; field guides
compare	Biggest, farthest	Changes over time; changes in condition
analyze	How, what why it happens	Data analysis
evaluate	Evidence good enough?	Peer review
share	Tell others	Scientific conferences and paper

Changes in Paradigm

Traditional Model

- The scientific method is a step-by-step process.

- The method must be planned out in advance of the inquiry.

Contemporary Model

- The traditional scientific method is simply one possible guide for inquiry

- Scientists can adjust their method of inquiry in the middle of an investigation and still obtain valid results.

Traditional Model

- There is a single method for doing science.

Contemporary Model

- New knowledge in science is produced by creative acts of the imagination allied with the methods of scientific inquiry.

Q3

How Can We Develop Students' Investigations Skills

Activity 1: Analysis of a Research Abstract

Students are given an abstract.

They identify the essential components of an investigation based on questions;

Problem, hypothesis, rationale, experimental design, results of the experiment, conclusion, recommendation

Activity 2: Integrate science investigation in teaching (not just for competition)

Strategies	Description
Structured (Guided Discovery)	The problem is given; the procedure is given step by step
Semi-Structured	The problem is given; the procedure is designed by students
Unstructured (Open-ended)	Students identify the problem, formulate hypothesis and design the procedure to test the hypothesis

Structured Investigation

Which are acids and bases from amongst a given set of materials?

Semi-structured Investigation

What happens or when an acid (vinegar) is mixed with a base (baking soda)?

Unstructured Investigation

Launch a rocket using the product of the reaction between and acid and base as fuel.

Structured Investigation

How much water can a polymer (e.g., sodium polyacrylate) hold?

Semi-structured Investigation

What are possible uses of sodium polyacrylate?

Unstructured Investigation

Determine which diaper brand can hold the most water.

Other Topics for Semi and Unstructured Investigations

- The Degree of Pollution of (…) in Terms of Total Solids
- Investigation of the Effect of Household Wastes on the Dissolved Oxygen in (….)
- The Effects of Acid Rain on Plants
- Comparative Study of the Ripening Effect of Different Farm Products on Banana
- Determination of the Contribution of Tricycles to the Particulate Pollution in (…)
- Comparative Study of Properties of Soaps Made from Different Fats and Oils

Activity 3: Lessons from Award Winning Researches

- Students study some projects of Filipino ISEF Winners
- They are expected to arrive at the following observations: Investigations ….

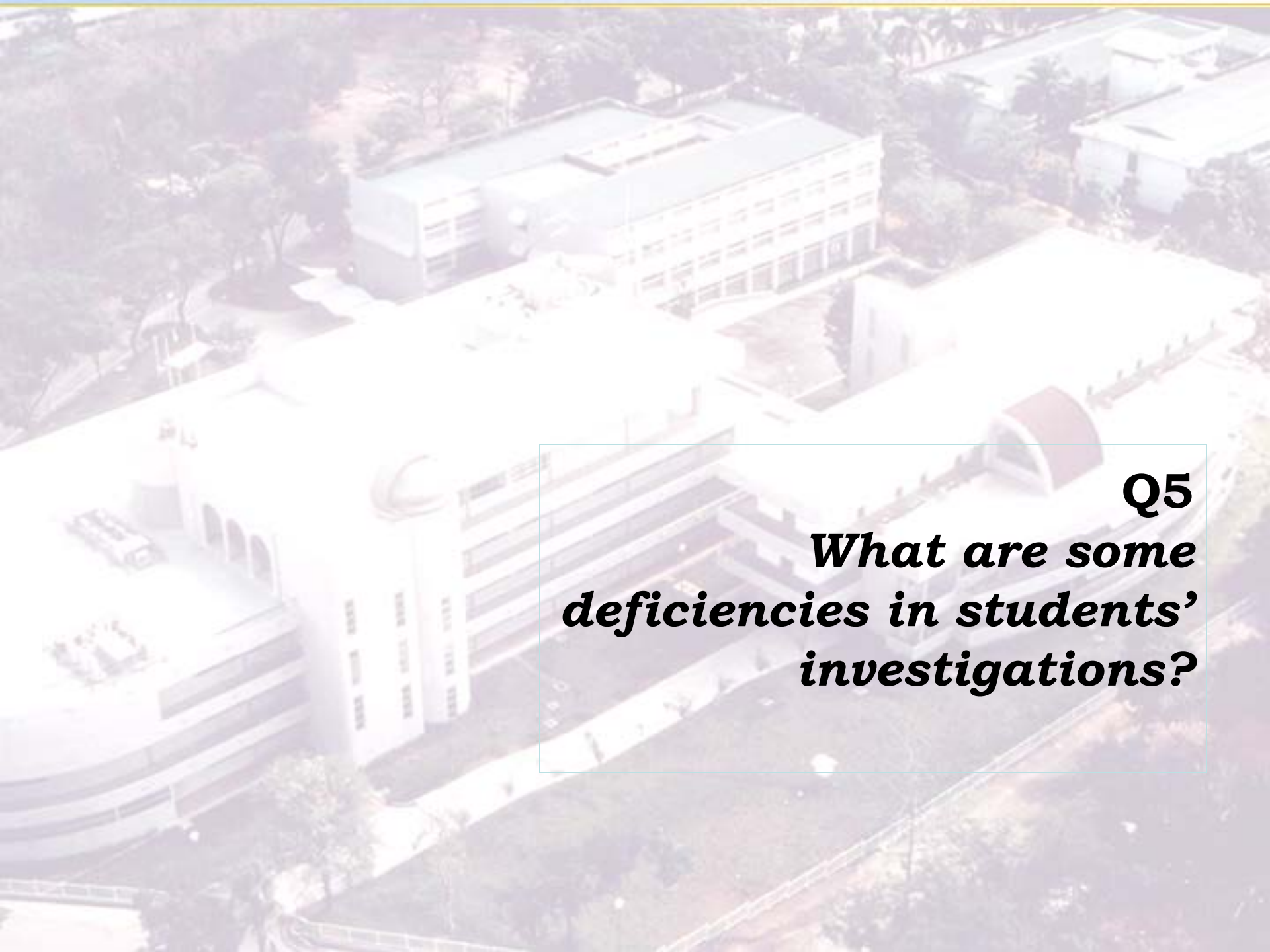
  - ✓ Follow the process of scientific inquiry
  - ✓ Are based on real-life problems
  - ✓ Enable students to perform independently, all procedures as outlined, with teacher guidance
  - ✓ Involved science experts as advisers or consultants
  - ✓ Had proper documentations of data collected
  - ✓ Complied with laws and regulations in use of/ handling chemicals and biological specimens

Activity 4:
Assessing an SIP- Developing and Using a Rubric)

Criteria	1	2	3	4	5
Purpose	Purpose is not identified Relevant variables are not described	Purpose is somewhat vague Relevant variables are not described	Purpose is identified Relevant variables are described in somewhat unclear manner	Purpose is identified Relevant variables are described	Purpose is clearly identified Relevant variables are described
Hypo thesis	Predicted results and hypothesized relationship between variables is not stated	Predicted results and hypothesized relationship between variables are unclear	Predicted results and hypothesized relationship between variables stated are reasonable	Predicted results and hypothesized relationship between variables stated	Predicted results and hypothesized relationship between variables clearly stated and reasonable

Criteria	1	2	3	4	5
Materials	There is no list of necessary lab materials	Most lab materials included	All necessary lab materials included but not listed in any particular order	All necessary lab materials included and listed	All necessary lab materials included and listed in an organized manner
Procedure	Procedures are not listed	Procedures are listed but not in clear steps	Procedures are listed in clear steps but not numbered and/or in complete sentences	Procedures are listed in clear steps Each step is numbered and in a complete sentence	Procedures are listed in clear steps Each step is numbered and in a complete sentence Diagrams are included to describe the set-up
Analysis	Trends/ patterns are not analyzed Questions are not answered Analysis is not relevant	Trends/ patterns are not analyzed Answers to questions are incomplete Analysis is inconsistent	Trends/patterns are logically analyzed for the most part Questions are answered in complete sentences Analysis is general	Trends/patterns are logically analyzed Questions are answered in complete sentences Analysis is thoughtful	Trends/patterns are logically analyzed Questions are answered thoroughly and in complete sentences Analysis is insightful

Criteria	1	2	3	4	5
Error Analysis	There is no discussion of experimental errors	Some experimental errors are identified	Experimental errors and their effects are discussed	Experimental errors are determined Their effects are discussed	Experimental errors are determined Their effect and ways to reduce errors are discussed
Conclusion	No conclusion was included or shows little effort and reflection on the lab	A statement of the results is incomplete with little reflection on the lab	A statement of the results of the lab indicates whether results support the hypothesis	Accurate statement of the results of the lab indicates whether results support the hypothesis Possible sources of error identified	Accurate statement of the results of lab indicates whether results support hypothesis Possible sources of error and what was learned from the lab discussed



Q5

What are some deficiencies in students' investigations?

Stating a Problem

- Some are specific, others are implied or stated in general terms.
- Some studies have three or more problems; these require longer time to finish.
- All problems are predetermined; no questions come up based on observations while conducting the experiments.

Hypothesis/Hypotheses

- **Some researchers do not attempt to guess or predict the results in a descriptive study.**

- **In cases where the hypothesis is stated, it is not appropriate to the research question.**
- **The scientific basis (rationale) for the hypothesis is not stated.**

Related Literature

- **Some information presented are not needed in the study.**
- **Related studies are not fully utilized in the design of the experiment.**
- **Related studies are not used to support or negate findings.**

Design of the Study

- Some procedures are not appropriate to the research problem.
- Others include extra methods not related to the problem.
- Many studies do not described the design in enough detail to be replicated.
- There is lack of awareness of related variables or lack of control. IV and DV are not identified. Some sample size or number of trials are inadequate.
- Some do not report the schedule of the study.

Presentation of Results

- Some data are not organized logically.
- Some do not use graphs where they would have been appropriate.
- Some data analysis are inadequate.
- Students are unable to extract significant findings.

Analysis of Data and Discussion

- **Some discussions have no reference to the research problem.**
- **Some conclusions are either overly cautious or are not justified based on results.**
- **The errors and biases of study are not recognized**

Recommendations

- **Many recommendations are not based on the results of the study**
- **Some recommendations are procedures that were not done in the current study.**

EXTRA CHALLENGE!

Our task as teachers and/or science club advisers is to help move our students

From I know to

I KNOW HOW TO KNOW through Scientific inquiry