Conducting Science Investigations

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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 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

is
- learner-centered
- inquiry-based
- research-based
- decongested
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)

STE Literacy Skills
Component 2: Content and Connections

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 Material
- Properties & Structure
- Changes
- Interactions

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

Science Content (G1-10)
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

<table>
<thead>
<tr>
<th>Way</th>
<th>Discovery</th>
<th>Scientist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial and error</td>
<td>Tungsten filament</td>
<td>Edison</td>
</tr>
<tr>
<td>By accident</td>
<td>Rubber</td>
<td>Goodyear</td>
</tr>
<tr>
<td>Intuition</td>
<td>King’s problem</td>
<td>Archimedes</td>
</tr>
<tr>
<td>Intuition</td>
<td>Relationship between matter and energy</td>
<td>Einstein</td>
</tr>
<tr>
<td>Chance or</td>
<td>Synthetic dye</td>
<td>Perkins</td>
</tr>
<tr>
<td>Serendipity</td>
<td>Posts-it notepads</td>
<td>3M</td>
</tr>
<tr>
<td>Experimental method</td>
<td>****************************</td>
<td>******</td>
</tr>
</tbody>
</table>

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 hypothesized 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

<table>
<thead>
<tr>
<th>Sample</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pico</em></td>
<td>Test for the elements Na, K, Ca &amp; Mg</td>
</tr>
<tr>
<td><em>Kalabaw</em></td>
<td>Test for the elements Na, K, Ca &amp; Mg</td>
</tr>
<tr>
<td><em>Indian mango</em></td>
<td>Test for the elements Na, K, Ca &amp; Mg</td>
</tr>
</tbody>
</table>

**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
<table>
<thead>
<tr>
<th>Processes used</th>
<th>What students do</th>
<th>What scientists or researches do</th>
</tr>
</thead>
<tbody>
<tr>
<td>observe</td>
<td>Use the senses aided by technology</td>
<td>Use senses aided by more sophisticated technology</td>
</tr>
<tr>
<td>experiment</td>
<td>Change something; Watch what happens</td>
<td>Manipulate and control variables</td>
</tr>
<tr>
<td>collaborate</td>
<td>Work with others in class</td>
<td>Other scientists and researchers</td>
</tr>
<tr>
<td>record</td>
<td>Write in notebooks; journals</td>
<td>Field notes, data sheets, print outs</td>
</tr>
<tr>
<td>measure</td>
<td>Use lab equipment</td>
<td>Scientific instruments</td>
</tr>
<tr>
<td>sort/classify</td>
<td>Color, size, shape, mass</td>
<td>Classification keys; field guides</td>
</tr>
<tr>
<td>compare</td>
<td>Biggest, farthest</td>
<td>Changes over time; changes in condition</td>
</tr>
<tr>
<td>analyze</td>
<td>How, what why it happens</td>
<td>Data analysis</td>
</tr>
<tr>
<td>evaluate</td>
<td>Evidence good enough?</td>
<td>Peer review</td>
</tr>
<tr>
<td>share</td>
<td>Tell others</td>
<td>Scientific conferences and paper</td>
</tr>
</tbody>
</table>
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.
New knowledge in science is produced by creative acts of the imagination allied with the methods of scientific inquiry.

There is a single method for doing science.
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)

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structured (Guided Discovery)</td>
<td>The problem is given; the procedure is given step by step</td>
</tr>
<tr>
<td>Semi-Structured</td>
<td>The problem is given; the procedure is designed by students</td>
</tr>
<tr>
<td>Unstructured (Open-ended)</td>
<td>Students identify the problem, formulate hypothesis and design the procedure to test the hypothesis</td>
</tr>
</tbody>
</table>
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 an 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

<table>
<thead>
<tr>
<th>Criteria</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
<td>Purpose is not identified</td>
<td>Purpose is somewhat vague</td>
<td>Purpose is identified</td>
<td>Purpose is identified</td>
<td>Purpose is clearly identified</td>
</tr>
<tr>
<td></td>
<td>Relevant variables are not described</td>
<td>Relevant variables are not described</td>
<td>Relevant variables are described</td>
<td>Relevant variables are described</td>
<td>Relevant variables are described</td>
</tr>
<tr>
<td><strong>Hypothesis</strong></td>
<td>Predicted results and hypothesized</td>
<td>Predicted results and hypothesized</td>
<td>Predicted results and hypothesized</td>
<td>Predicted results and hypothesized</td>
<td>Predicted results and hypothesized</td>
</tr>
<tr>
<td></td>
<td>relationship between variables is not</td>
<td>relationship between variables are</td>
<td>relationship between variables stated</td>
<td>relationship between variables stated</td>
<td>relationship between variables stated</td>
</tr>
<tr>
<td></td>
<td>stated</td>
<td>unclear</td>
<td>are reasonable</td>
<td>are reasonable</td>
<td>clearly stated and reasonable</td>
</tr>
<tr>
<td>Criteria</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------------------------------------------------</td>
<td>------------------------------------------------------------------</td>
<td>------------------------------------------------------------------</td>
<td>------------------------------------------------------------------</td>
<td>------------------------------------------------------------------</td>
</tr>
<tr>
<td>Materials</td>
<td>There is no list of necessary lab materials</td>
<td>Most lab materials included</td>
<td>All necessary lab materials included but not listed in any particular order</td>
<td>All necessary lab materials included and listed</td>
<td>All necessary lab materials included and listed in an organized manner</td>
</tr>
<tr>
<td>Procedure</td>
<td>Procedures are not listed</td>
<td>Procedures are listed but not in clear steps</td>
<td>Procedures are listed in clear steps but not numbered and/or in complete sentences</td>
<td>Procedures are listed in clear steps Each step is numbered and in a complete sentence</td>
<td>Procedures are listed in clear steps Each step is numbered and in a complete sentence Diagrams are included to describe the set-up</td>
</tr>
<tr>
<td>Analysis</td>
<td>Trends/patterns are not analyzed</td>
<td>Trends/patterns are not analyzed</td>
<td>Trends/patterns are logically analyzed for the most part Questions are answered in complete sentences</td>
<td>Trends/patterns are logically analyzed</td>
<td>Trends/patterns are logically analyzed Questions are answered thoroughly and in complete sentences</td>
</tr>
<tr>
<td></td>
<td>Questions are not answered</td>
<td>Analysis is inconsistent</td>
<td>Analysis is general</td>
<td>Analysis is thoughtful</td>
<td>Analysis is insightful</td>
</tr>
<tr>
<td>Criteria</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Error Analysis</td>
<td>There is no discussion of experimental errors</td>
<td>Some experimental errors are identified</td>
<td>Experimental errors and their effects are discussed</td>
<td>Experimental errors are determined Their effects are discussed</td>
<td>Experimental errors are determined Their effect and ways to reduce errors are discussed</td>
</tr>
<tr>
<td>Conclusion</td>
<td>No conclusion was included or shows little effort and reflection on the lab</td>
<td>A statement of the results is incomplete with little reflection on the lab</td>
<td>A statement of the results of the lab indicates whether results support the hypothesis</td>
<td>Accurate statement of the results of the lab indicates whether results support the hypothesis</td>
<td>Accurate statement of the results of lab indicates whether results support hypothesis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Possible sources of error and what was learned from the lab discussed</td>
</tr>
</tbody>
</table>
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 describe 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.
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.