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Exposing Inadequate Knowledge Frameworks While Building Learner Confidence? Strange, but Successful, Bedfellows

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Exposing inadequate knowledge frameworks while building learner confidence?
Strange, but successful, bedfellows!

Adrianne Kinnear
My aim today: To describe students’ perceptions of strategies designed to improve metacognitive processes within science learning.

The students were trainee primary teachers.
The challenge is a global one: Trainee primary teachers can exhibit

- restricted science experiences
- poor science knowledge
- low learner confidence
- negative attitudes to the discipline
- entrenched alternative conceptions

and often “don’t know what they don’t know.”

This suite of characteristics can affect the quantity and quality of their science teaching.
The challenges were also local:

The teaching unit

- was the only science content unit in the degree program
- required integration of mathematics content as well as science
- was a single semester unit (3 hours over 12 weeks)
- involved over 200 diverse students
- was one of the first units the students encountered.
The ice block keeper - a sample activity:

**Aim of the workshop:**
To design the “best” ice block keeper from the materials provided, and test the effectiveness of your design.
By working mathematically and scientifically, you will:
- use your current knowledge about materials, heat and energy flows to design an ice block keeper;
- review the concepts of a ‘control’ in an investigation
- review some simple mathematics concepts (e.g. percentage change) to describe the investigation outcomes;
- use mathematical and scientific reasoning to explain the investigation outcomes, evaluating your own knowledge frameworks in the process.

**Our ice block keeper and how it works**

<table>
<thead>
<tr>
<th>Design Element</th>
<th>How the design element affects the flow or movement of energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover - choose from:</td>
<td></td>
</tr>
<tr>
<td>- silver foil</td>
<td></td>
</tr>
<tr>
<td>- white paper</td>
<td></td>
</tr>
<tr>
<td>- black paper/plastic</td>
<td></td>
</tr>
<tr>
<td>Filler - choose from:</td>
<td></td>
</tr>
<tr>
<td>- polystyrene balls</td>
<td></td>
</tr>
<tr>
<td>- foil pieces</td>
<td></td>
</tr>
<tr>
<td>- white sand</td>
<td></td>
</tr>
<tr>
<td>- black/brown sand</td>
<td></td>
</tr>
<tr>
<td>- shredded paper</td>
<td></td>
</tr>
</tbody>
</table>
Other sample activities:

**Investigating heat and temperature**

All these objects are have been sitting in the laboratory at about 23°C all

- Trophy
- Blanket
- Saucepan
- Hammer
- Bottle

Would you predict their temperatures to be the same or different?

Explain why you think this:

How could you determine if your prediction was correct?

**Investigating decomposition**

**WHAT IS HAPPENING TO THE LEMON?**

Here are four pictures of a lemon in varying stages of decay. For each step in the process describe:
- what you think is happening to the lemon;
- the interactions responsible for these changes;
- why the matter in the lemon is decreasing.

Picture 1

Picture 2

Picture 3

Picture 4
Students’ designs were diverse:

<table>
<thead>
<tr>
<th>Outside materials</th>
<th>Filler materials</th>
<th>Orientation</th>
<th>% mass remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Air</td>
<td>Upright</td>
<td>25.9%</td>
</tr>
<tr>
<td>silver foil</td>
<td>silver foil &amp; wet black sand</td>
<td>upright</td>
<td>53.4%</td>
</tr>
<tr>
<td>white paper &amp; foil</td>
<td>poly balls</td>
<td>upright</td>
<td>81.8%</td>
</tr>
<tr>
<td>white paper</td>
<td>wet sand, foil and poly balls</td>
<td>upright</td>
<td>1.0%</td>
</tr>
<tr>
<td>white paper</td>
<td>poly balls and shredded paper</td>
<td>on side</td>
<td>85%</td>
</tr>
<tr>
<td>silver soil</td>
<td>dry white sand and poly balls</td>
<td>upright</td>
<td>5.0%</td>
</tr>
</tbody>
</table>
Cognitive dissonance was powerful:

<table>
<thead>
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Worse than the control!
Alternative understandings were revealed:

- “Foil inside insulates the ice block …”
- “White paper over the foil outside to keep the direct sunlight off the foil …
- “Damp sand keeps the inside cool.”
- “Dry white sand attracts the least amount of heat.”
- “Sand acts as an insulator … fact that it is wet helps in cooling and taking the heat energy away from the ice block.”
Underlying course principles:

- Enjoyable, supportive and positive learning environment.
- Constructivist approaches.
- Involves collaborative group discussion.
- Improves (at least not decrease) learner confidence.
- Relevant science experiences.
- Authentic science experiences.

Most importantly …
... the course needed to provide opportunities for reflection on, and evaluation of, the students’ own conceptual frameworks in science.
# Course content was a vehicle:

<table>
<thead>
<tr>
<th>What the lecturer saw!</th>
<th>What the students saw (initially)!</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy in physical systems</td>
<td>Solar energy</td>
</tr>
<tr>
<td>Energy in chemical systems</td>
<td>Solutions &amp; crystals</td>
</tr>
<tr>
<td>Energy in biological systems</td>
<td>Animals of the soil &amp; leaf litter</td>
</tr>
</tbody>
</table>
| Science (and Mathematics) as inquiry | Balloon rockets  
|                                      | Scary investigations  
|                                      | Ice block keeper  
|                                      | Bait bags |

Metacognition at work

Conception Reflections
Conception reflections:

- were post-activity strategies to capitalise on the students’ findings and the cognitive dissonance
- were very structured to show an explicit process
- were done individually and out-of-class.

They were organised as follows …
Conception reflections:

- relied on scaffolded content resources

1. The science behind the activity

2. The relevant science concepts
**Other sample activities:**

### Investigating heat and temperature

The ocean at a local beach and a glass of water both have a temperature of 20°C, reflecting similar average kinetic energy of the water atoms. But the ocean contains a much greater amount of thermal energy because of the vastly greater numbers of vibrating water atoms in the ocean compared with the glass of water! So the temperature of a substance is quite independent of the thermal energy it contains.

Temperature does measure the amount of kinetic energy in the atoms of an object. When you stand in the sun, some of the radiant energy (containing many forms of electromagnetic radiation) is absorbed at the skin surface, and is transformed into thermal energy, increasing the movement (kinetic energy) of the atoms in your skin tissue. This is reflected by an increase in skin temperature. Of course, your body temperature will not increase because the body will counteract the increase in skin temperature by dilating the skin blood vessels and by producing a film of moisture which cools the skin surface by evaporation.

There is an important conclusion to all this. *Temperature* and *Heat* are very different concepts and should not be confused with one another, nor taken to be the same thing. We can verify that heat and temperature are different by considering two containers of water, one holding twice as much water as the other.

**Heat energy** is thermal energy that can be transferred from one object to another, resulting in an increase in temperature. For example, a 250ml beaker of water is heated to 10°C and is then poured into a 10ml beaker of water, which was at 20°C. The total amount of heat energy transferred is determined by the temperature of the water at the point of contact (10°C). The final temperature of the water in the 10ml beaker is 15°C. The heat energy transferred is the difference between the initial temperature (20°C) and the final temperature (15°C). The heat energy transferred is 5°C.

### Investigating decomposition

The decomposition process begins with the growth of colonies of very tiny organisms, microorganisms on the surfaces of the fallen leaves. (Fungi) can begin growing on some leaves before they even leave the tree. Sometimes the fungal colonies grow large enough to see— as tiny threads over the surface, or puff of cotton-wool-like mould (just like the mould which grows on old food in the fridge!). The bacteria are too tiny to see with the naked eye, even when they form larger colonies. But we can “see” them by the discoloured patches on the leaf surface, and we can “smell” them. The earthy smell of freshly turned soil is due to a particular kind of bacteria which lives in and among the soil and litter.

During these early stages of decomposition, rain washes out the more soluble materials such as sodium and potassium. They enter the soil to be used quickly by plants.

The microorganisms are the most important players in the process of decomposition. They are the only ones that have the chemical reactions within them which are able to break down the large plant molecules, the cellulose and woody tissue of the discarded leaves and twigs. As they begin to dissolve the tough plant tissue, they act like tomato sauce on a plate, making the leaves tastier for the larger soil and litter organisms, like the springtails, round worms, millipedes, insect larvae and mites. These microorganisms feed on the bacteria and fungi growing on the leaves, and in the process, chew up the fallen leaf tissue, repackaging it into tiny, spherical fecal pellets.

In the process of decomposition, larvae are broken down chemically by bacteria and fungi (see the dissection in picture 2) and physically by the chewing of minibeasts (picture 3).

The micro-animals, which are very diverse and abundant, are the litter scavengers. They also act as tiny vehicles for bacteria and fungi, distributing them through the litter. Over time, these populations of micro-animals attract micro-predators such as larger insects, pseudoscorpions, spiders and small centipedes. In this way, complete food chains develop within the litter layers and the upper soil surface.
Conception reflections:

- directed students in evaluating their knowledge against the expert’s (scientist’s) view.

Conception Reflection

Most people have understandings about science and mathematics which are different from those of discipline experts. These understandings are formed by trying to make sense of experiences and knowledge coming at us from diverse kinds of sources - our own day-to-day experiences, our previous education, reading, television, and conversations with teachers and friends. We call these different understandings alternative knowledge frameworks. Alternative knowledge frameworks can be very resistant to change, and if they are very different from the correct scientific and mathematical frameworks, they can impede learning.

As a teacher, you will need to be able to identify children’s alternative knowledge frameworks. To do this, you will first need to be able to evaluate your own, and then have the knowledge and tools to be able to ensure they are accurate.

The reflection strategies throughout this unit are designed to help you develop the ability to evaluate your own science and mathematics knowledge, and assess for yourself where you need additional or correct information. Having this ability will help you become an independent learner and a confident and better teacher of science and mathematics to children.

Compare your explanation for the ice-block keeper with the scientific one provided and describe how well your explanation compares with it. You can use the following questions as headings to help you evaluate your own knowledge frameworks against the scientific ones (some students have found that a table like the one on the next page is useful to make the comparisons):

- What aspects of your explanation are similar or identical to the scientific one? (This comparison will help you identify where your understandings are sound scientifically).
- What aspects of your explanation do not seem to match those of the scientist?
- What parts of your explanation lack detail or are missing entirely?
- Are scientific terms being used differently in the two explanations?
- Are there aspects of the scientific explanation which you do not fully understand or are different from what you believe?
Evaluation of the strategies:

What were the students’ perceptions and attitudes?

Did I achieve that ‘first-step’ awareness without decreasing the confidence?

Pre- and post-course attitudes survey (Likert)
  • Confidence in doing science
  • Personal usefulness of science
  • (Enjoyment of school science)

Post-course Questionnaire
  • Specific course strategies
    • Scale data
    • Qualitative data

Student workbooks
  • Reflections on knowledge
  • Degree of metacognition
Were science attitudes affected?

• An attitudes survey was administered, 1st and 11th weeks of the semester.
• There were no negative effects found.

• After the unit, more students felt confident about:
  – succeeding in science
  – their knowledge for teaching science to children
  – doing science with children.

• After the unit, more students considered they would use science in their daily lives.
What did the students think about the unit?

How useful has it been for acquiring new knowledge?

How has it affected your confidence for doing science?

How has it affected your attitudes towards learning science?
Were the conception reflections understood?

What do you think these activities were designed to achieve?

- Well understood
- Unable to tell from response
- Misunderstood
- No answer or don't know

Distinguish between our own ideas and fact (19)
Reflect on abilities and knowledge (18)
Analyse our own understandings (14)
Highlight misconceptions (11)
See how previous knowledge influences understanding (10)
Challenge thinking (6)

Analyse children’s understandings (1)
Increase knowledge (7)
Use knowledge (3)
Use for exams (1)
What did students think about the conception reflections?

How useful were they for you?

- Not at all: 10%
- Sometimes: 50%
- Almost always: 30%

How did they affect your confidence for doing science?

- Decreased: 5%
- No effect: 30%
- Increased: 65%

How useful were they for developing knowledge-evaluating skills?

- Not at all: 10%
- Sometimes: 40%
- Almost always: 50%
What did students think about the conception reflections?

8%: were the most useful activities (cf 71% for science activities)

4%: were the least useful activities (cf 28% of maths activities)

7%: were the least enjoyable activities (cf 32% for maths activities) (Only one student scored them as the most enjoyable activity)

19%: were the most challenging (cf 47% for ice block keeper)

22%: provided the most useful learning outcomes (cf 27% understanding)
Improvements:

- Vary the process to minimise repetition.
- Provide more time for feedback and discussion of conception reflections the following week.
- Provide exemplars of reflections and assignment projects.
Conclusions & limitations:

• The strategies can be successful, provided
  – the learning environment is supportive and positive
  – sufficient suitable resources are provided
  – challenges to understandings are embedded in collaborative and enjoyable hands-on activities.
  – the unit is not driven by a content-approach.

• Time and class size are constant limitations on what can be achieved (particularly for ‘reflecting on the reflections!’).

• Identifying tutors with sufficient pedagogical understanding is a significant issue.
References:


The course resources mentioned in this presentation are available as pdf files. Adrianne Kinnear: a.kinnear@ecu.edu.au

Thank you!