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**

**Design Element**

<table>
<thead>
<tr>
<th>Ice block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic bag</td>
</tr>
<tr>
<td>Cover - choose from:</td>
</tr>
<tr>
<td>• silver foil</td>
</tr>
<tr>
<td>• white paper</td>
</tr>
<tr>
<td>• black paper/plastic</td>
</tr>
<tr>
<td>Filler - choose from:</td>
</tr>
<tr>
<td>• polystyrene balls</td>
</tr>
<tr>
<td>• foil pieces</td>
</tr>
<tr>
<td>• white sand</td>
</tr>
<tr>
<td>• black/brown sand</td>
</tr>
<tr>
<td>• shredded paper</td>
</tr>
</tbody>
</table>

**How the design element affects the flow or movement of energy.**
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?

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**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 1](image1.jpg)

Picture 2

![Picture 2](image2.jpg)

Picture 3

![Picture 3](image3.jpg)

Picture 4

![Picture 4](image4.jpg)
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>
<tr>
<th>Outside materials</th>
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</table>

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>
<tr>
<td>Science (and Mathematics) as inquiry</td>
<td>Balloon rockets</td>
</tr>
<tr>
<td></td>
<td>Scary investigations</td>
</tr>
<tr>
<td></td>
<td>Ice block keeper</td>
</tr>
<tr>
<td></td>
<td>Bait bags</td>
</tr>
</tbody>
</table>

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

   HOW THE ICE BLOCK MELTER WORKS!

   1. Solar energy (radiant energy) is converted to thermal energy in the cardboard frame.
   2. Because the cardboard is at a higher temperature than the filler, heat energy is transferred by conduction to and through the filler material. Energy is absorbed by the milk carton.
   3. Heat energy is transferred from the filler to the ice block by conduction, until the temperature of the filler and the ice block equalise.
   4. Because the equilibrium temperature is above the melting point of ice, the ice block melts. It changes from a solid state to a liquid state.
   5. Melting occurs when the transfer of heat energy to the ice block increases the kinetic energy of the water molecules. The increased thermal energy of the water molecules overcomes the attractive forces between the molecules and they move apart and become less ordered. The ordered solid melts into the less ordered liquid.
   6. If the filler material is a poor conductor of heat energy (and therefore a good insulator), heat energy is transferred very slowly through the filler. The temperature difference between the filler and the ice block is not large, and heat energy is transferred only very slowly to the ice block. The ice block melts more slowly.

2. The relevant science concepts

   “About Energy”

   Heat energy is the thermal energy transferred as a result of a temperature difference, both between and within different kinds of matter.

   The atoms which make up matter are held together by the attractive forces between them. Intermolecular forces. At the same time, these atoms are in a constant state of motion or vibration, rather like a constant state of agitation. Because they are moving, they have kinetic energy. The relative strengths of the intermolecular forces (tending to hold the matter particles together) and the vibrational forces (tending to move the particles apart) determine the kind or “state” of the matter. (See About Matter for more on this subject.)

   Matter has thermal energy because of this vibration or random movement of its atoms. The amount of thermal energy depends on both the number of atoms present, and their kinetic energy. If there is a temperature difference between one part of matter and another (or between two kinds of matter in contact), energy is transferred via the collisions of the moving atoms, from the low temperature matter to the high-temperature matter. The energy which is transferred is called heat energy.

   The concept of heat energy is a difficult one and causes many misunderstandings in students. Try to keep these ideas in mind about heat energy:
   - Heat energy is thermal energy in transit. Once this transfer ends (as when the temperature between two objects equalizes) we no longer call it heat. The concept of heat energy is always associated with temperature differences.
   - An object contains thermal energy, not heat energy.
   - Thermal energy is the energy associated with the kinetic energy of atoms in all kinds of matter. (See also About Heat and Temperature for further information on this topic.)

   Energy can be converted from one form to another. Here are some examples of energy conversions:
   - The potential energy contained in a child at the top of the slide is converted to kinetic energy as she moves down the slide.
   - The energy of combustion heat can be converted into mechanical energy as the car moves forward.
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 energies of the water atoms. But the ocean contains a much greater amount of thermal energy because of the vastly greater number 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 can cool 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 to transmit

Let’s return to the concept of “heat energy”: the flow of energy from an object at one temperature to an object at a higher temperature. Just like any other form of energy, we can measure heat energy. If we continue defining heat energy as an energy flow, then, we can measure heat energy as “the amount of energy which flows when there is a temperature difference”.

“About heat and temperature”

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 fungal colonies grow large enough to see—tiny thread-like organisms on the surface, or puffs 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 discoloration 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 nutrients such as sodium and potassium. They enter the soil to be reused quickly by plants.

The microorganisms are the most important players in the process of decomposition. They are not just those that use the chemical reactions within them which are able to break down the large plant molecules, the cellulose and woody tissues of the discarded leaves and twigs. As they begin to dissolve the tough plant tissues, they act like tomato-soya on a pig, making the leaves tastier for the larger soil and litter organisms, like the springtails, round worms, rotifers and larvae and insects. These microorganisms feed on the bacteria and fungi growing on the leaves, and in the process, show up the softer leaf tissue, repackaging it into tiny, spherical fecal pellets.

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

“About decomposition”
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

- Analyse children’s understandings (1)
- Increase knowledge (7)
- Use knowledge (3)
- Use for exams (1)

- 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)
What did students think about the conception reflections?

How useful were they for you?

- Not at all: [Percentage responses]
- Sometimes: [Percentage responses]
- Almost always: [Percentage responses]

How did they affect your confidence for doing science?

- Decreased: [Percentage responses]
- No effect: [Percentage responses]
- Increased: [Percentage responses]

How useful were they for developing knowledge-evaluating skills?

- Not at all: [Percentage responses]
- Sometimes: [Percentage responses]
- Almost always: [Percentage responses]
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.
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Thank you!