RECOGNISING AND UNDERSTANDING STUDENT MODEL-BASED REASONING IN SCIENCE: METHODOLOGICAL DECISIONS AND CHALLENGES

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RESEARCH QUESTIONS

- **What roles do models of different types play in student reasoning about the tasks?**
- What levels (of complexity, sophistication) of reasoning can be distinguished in students' interactions?
- What kind of interactions (e.g. student-student) promote or hinder reasoning at higher levels?
- In what ways do the tasks and materials provided facilitate or constrain students from engaging in reasoning at higher levels?

Methodological Focus:
The development of an analytical framework to capture and represent reasoning in both science and mathematics, and further to identify model-based reasoning.

REASONING

- Reasoning as **systemic logical applications and mental procedures** (TIMSS, 2007)
- Reasoning as **argumentation** (Driver, Newton& Osborne 2000; Simone, Erduran and Osborne, 2002; Kelly et al., 1998; Yackel, 2004; Krummheuer, 2007)
- Scientific reasoning (SR) as **thinking skills** involved in inquiry, experimentation, evidence evaluation, inference and argumentation that are done in the service of conceptual change or scientific understanding (Zimmerman, 2005).

MODELS AND MODEL-BASED REASONING IN SCIENCE

- Modeling and model-based reasoning have been recognized as **signature practices in sciences** regardless of domains or specialisations (Giere, 1988; Nersessian, 2008).
- Models are recognised as **a bridge** between scientific theory and the world-as-experienced (reality) (Tiberghien, 1994; Gilbert, 2004).
- Models are **forms of argument** that are mobilised to support socially grounded claims about the nature of physical reality (Lehrer, Shauble and Lucas, 2008; Lehrer and Schauble, 2010).
- At its basic level, a model is **an analogy** that varies in its complexity, ranging from literal similarity to pure relational structure (Lehrer, Shauble and Lucas, 2008).

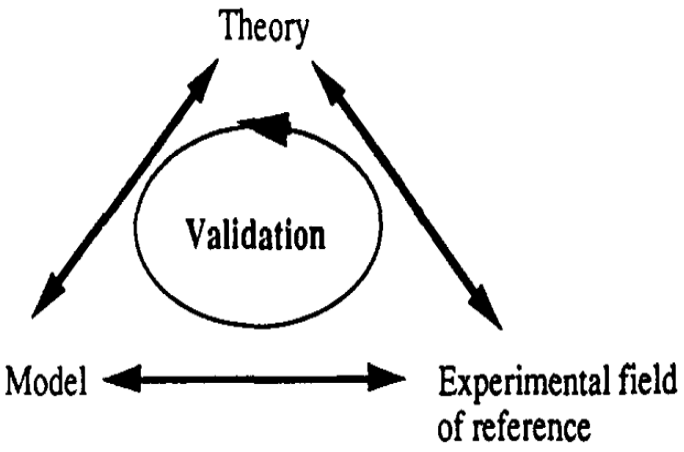


Figure 2. Levels of the analysis grid based on modeling.

(Tiberghien, 1994)

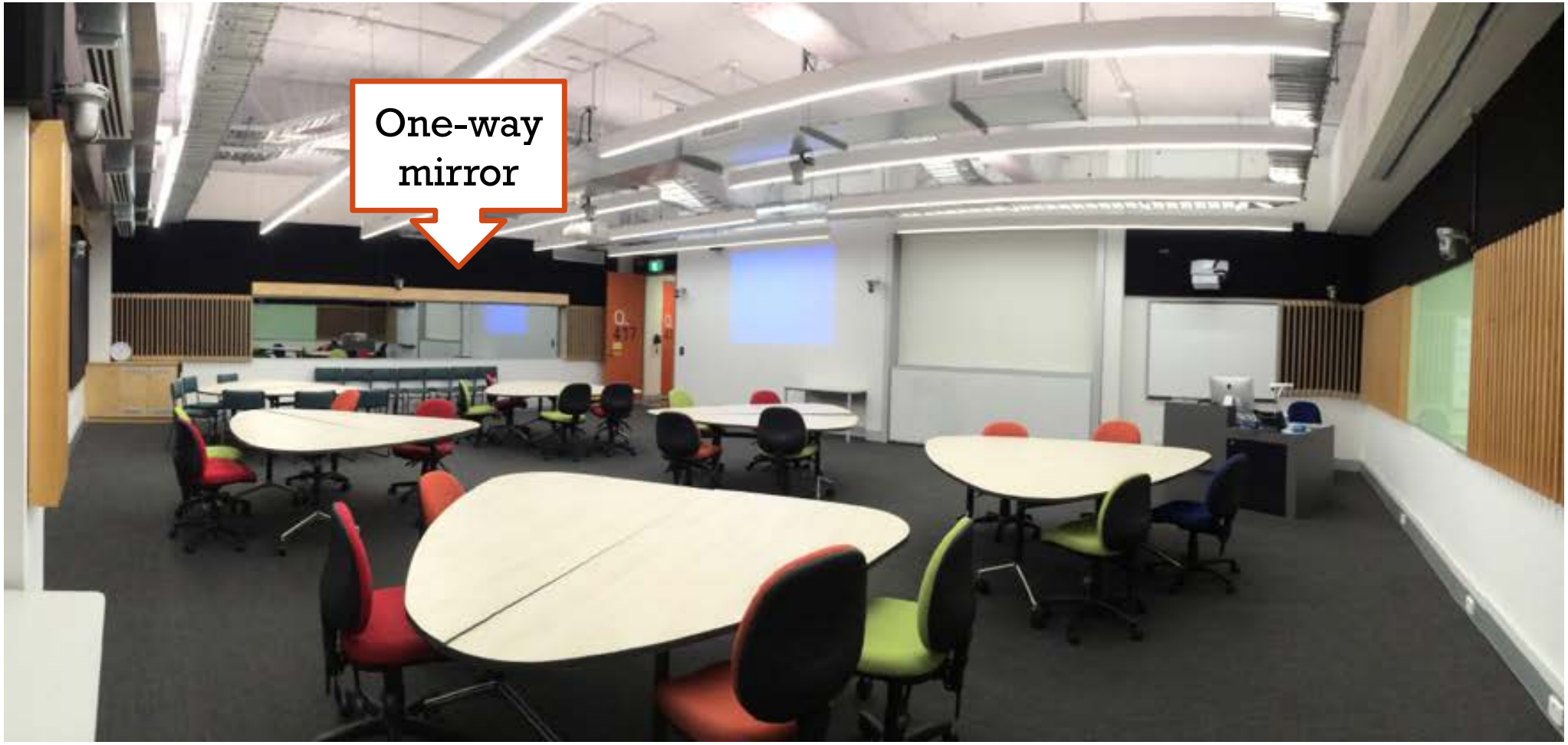
FORMS OF MODELING (LEHRER AND SHAUBLE, 2000)

- **Physical models***:* "like models of solar systems or elbows, are microcosms of systems that draw heavily on children's intuitions about resemblance to sustain the relationship between the world being modelled and the model itself" (p. 41).
- **Representational models**: "like maps, diagrams, and related forms of display notations, are often based at first on overt resemblance. However, extended work with them typically fosters children's understanding of the need to establish conventions that make explicit the relationship between the model and the world" (p. 41; see also Lehrer, Jacobson, Kemeny, & Strom, 1999).
- **Syntactic Models**: "exchange resemblance for analogy. In a syntactic model, the epistemological claim is that one system functions much like another" (p. 43).
- **Hypothetical-Deductive Models**: "move beyond the realm of describing the observable. These models embody unseen hypothetical entities that interact to produce emergent behaviour" (p. 43).

STUDY DESIGN

- **Two single sessions** in a specially designed learning classroom (Science of Learning Research Classroom) at the University of Melbourne with 10 wall and ceiling mounted video cameras with zoom and tilt capacity, and eight radio microphones, controlled from a room with visual access.
- Session plans consistent with the **Year 5/6 curriculum** at the school were developed and negotiated with the teachers who took their own class (24 students) for one hour.
- Single sessions were conducted for the topics of: **physical and chemical change** (science), painted cube (problem solving task in mathematics).

SCIENCE OF LEARNING RESEARCH CLASSROOM



Key:

Cameras (x 10):

Radio mics (x18):

Filming target (students):

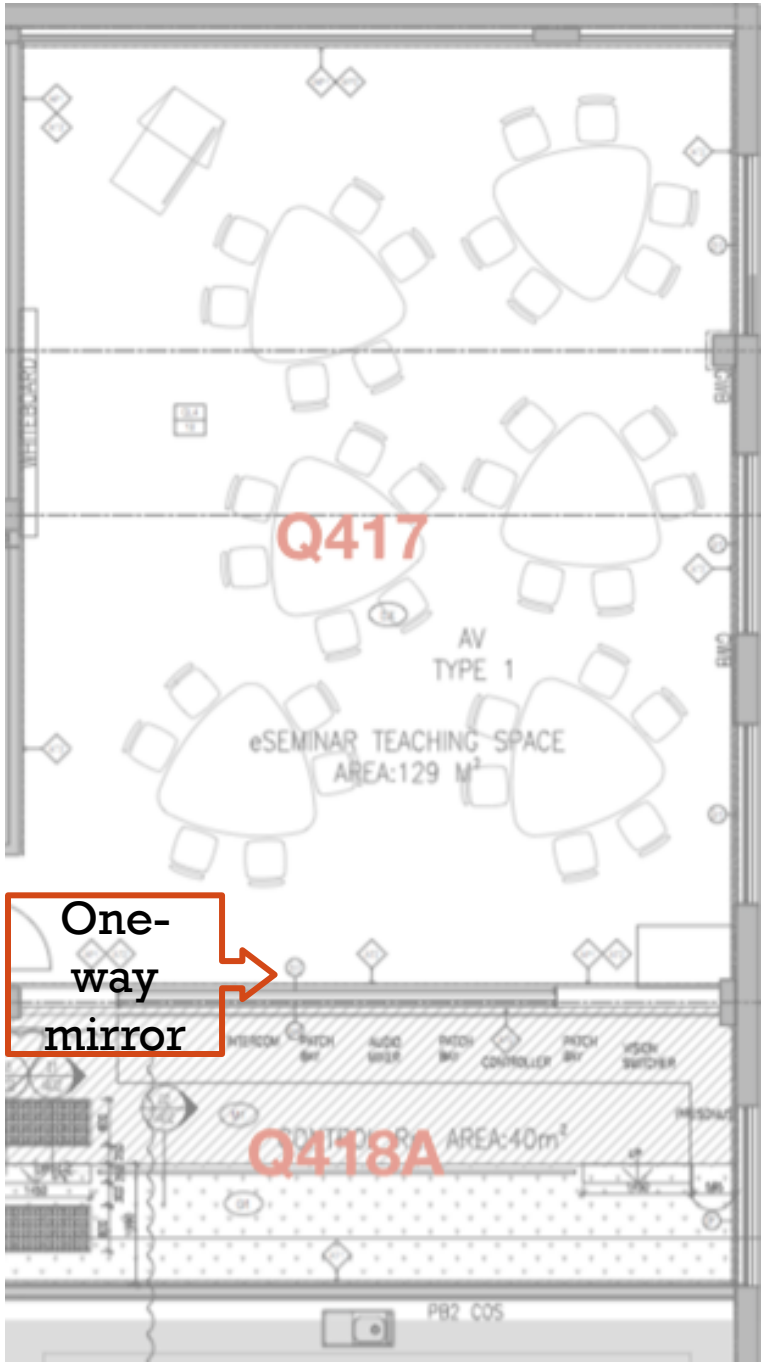
Filming target (teacher):

Students (x26):

Teacher:

Researchers:

Technicians:



Science of Learning Research Classroom Q417

Control Room Q418A

VIDEO DATA – MULTIPLE PERSPECTIVES

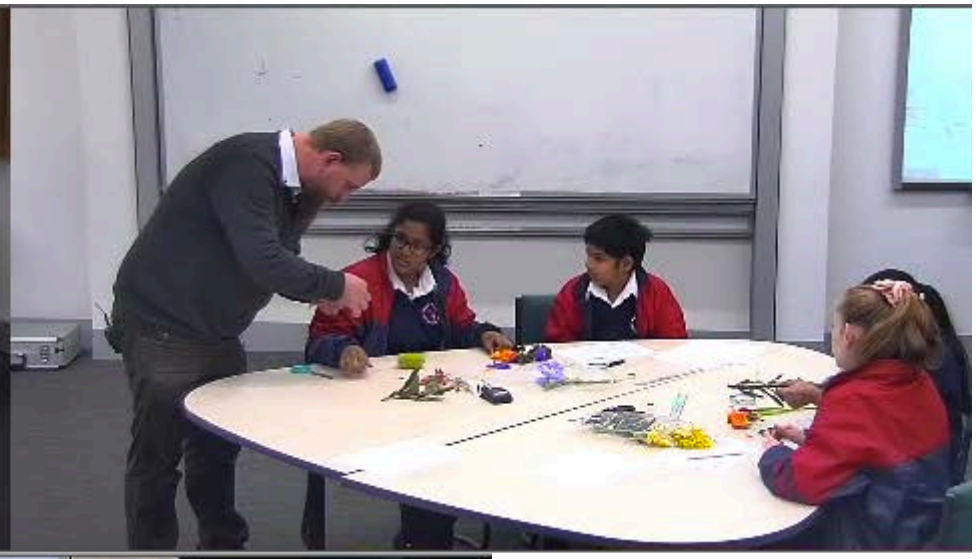


Table camera (front on)

Teacher camera (front on)

Table camera (top down)

SLRC SCIENCE SESSION

- Introducing the tasks: teacher demonstration
- Investigation 1: Physical Change (dissolving of icing sugar in vinegar) – pairs of students
- Investigation 2: Chemical Change (bicarb and vinegar acid-base reaction) – pairs of students
- Whole Class Sharing

Physical and Chemical Change

Team Member's names: _____

Investigation 1: Icing Sugar and Vinegar

What do you need?	What do you predict will happen?	What do you observe?	Can you explain what happened?
• One balloon • One bottle with 50 ml white vinegar • One funnel • One container with 5 grams of icing sugar • Playdough • Toothpicks • Whiteboard • Whiteboard markers **What are you going to do?** 1. Open one bottle, smell the vinegar (carefully). 2. Add the icing sugar into the balloon using the funnel. 3. Place the balloon on top of the bottle (Do not tip the icing sugar into the bottle, see picture below)  4. Before tipping the icing sugar from the balloon into the vinegar, *make a prediction of what will happen in the 2nd column (on the right).* 5. Now tip the icing sugar from the balloon into the bottle. 6. Observe what happens to the icing sugar when it is added to the vinegar before shaking the bottle. *Write down your observations in the 3rd column.* 7. Shake the bottle gently for 30 seconds. 8. Observe what happens inside the bottle and what happens to the balloon. *Write down your observations in the 3rd column.* 9. Feel the bottle and let the bottle sit for a while until no further changes happening. *Write down your observations in the 3rd column.* 10. Open the bottle, smell the liquid. *Write down your observations in the 3rd column.*	You may write down or draw your predictions.	Write down as many observations as you can (including what you can see, smell, or feel).	Imagine if you have a magnifying glass that can be zoomed in millions of times, what you might be able to see? 1. Make some annotated drawings OR construct models using playdough and toothpicks to show what you might be able to see using such a magnifying glass: 1) before adding icing sugar 2) just after adding icing sugar 3) after shaking for 30 seconds 4) after a while, when nothing seems to happen anymore. *Please use the whiteboard and markers for drawings.* 2. Can you use the drawings/models to explain some of your observations in the 3rd column?

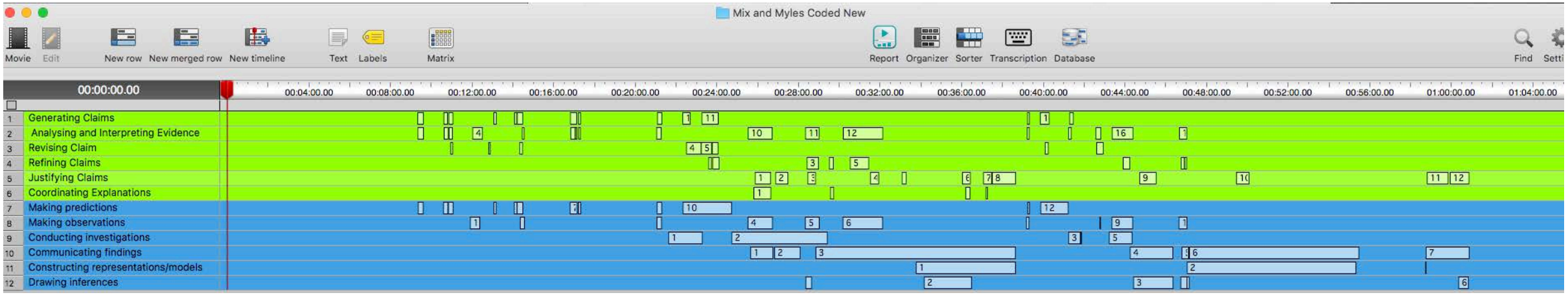
Investigation 2: Baking Soda (Bicarb) and Vinegar

What do you need?	What do you predict will happen?	What did you observe?	Can you explain what happened?
• One balloon • One bottle with 50 ml white vinegar • One funnel • One container with 5 grams of baking soda (bicarb) • Playdough • Toothpicks • Whiteboard • Whiteboard markers **What are you going to do?** 1. Open the second bottle, smell the vinegar (carefully). 2. Add the baking soda (bicarb) into the balloon using the funnel 3. Place the balloon on top of the bottle (Do not tip the baking soda into the bottle, see picture below)  4. Before tipping the baking soda from the balloon into the vinegar, *make a prediction of what will happen in the 2nd column (on the right).* 5. Tip the baking soda from the balloon into the bottle. 6. Observe what happens inside the bottle and what happens to the balloon. *Write down your observations in the 3rd column.* 7. Feel the bottle and let the bottle sit for a while until no further changes happening. *Write down your observations in the 3rd column.* 8. Open the bottle, smell the liquid. *Write down your observations in the 3rd column.*	You may write down or draw your predictions.	Write down as many observations as you can (including what you can see, smell, or feel).	Imagine if you have a magnifying glass that can be zoomed in millions of times, what you might be able to see? 1. Make some annotated drawings OR construct models using playdough and toothpicks to show what you might be able to see using such a magnifying glass: 1) before adding baking soda 2) just after adding baking soda 3) after a while, when nothing seems to happen anymore. *Please use the whiteboard and markers for drawings.* 2. Can you use the drawings/models to explain some of your observations in the 3rd column?

IDENTIFYING AND ANALYSING REASONING

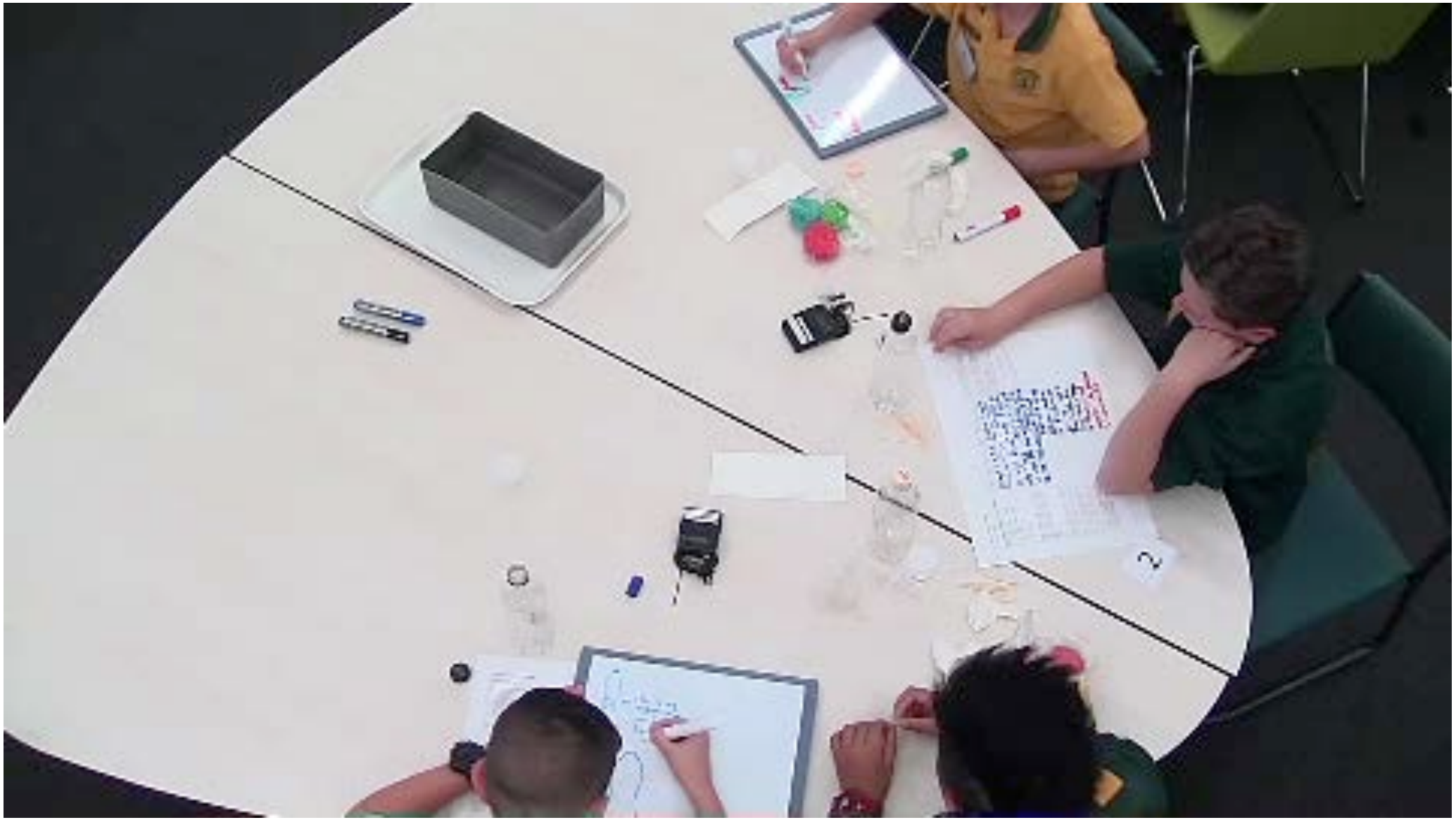
- Argumentation
  - Generating Claims
  - Analysing and Interpreting Evidence
  - Revising Claims
  - Justifying Claims
  - Coordinating Explanations
  - Reaching Concensus
  - Generalising
- Phases of Scientific Inquiry
  - Making predictions
  - Conducting investigations
  - Making observations
  - Drawing inferences
  - Constructing representations/models
  - Communicating findings
- Forms of Modeling (Lehrer & Schauble, 2000)
  - Physical Models
  - Representational Models
  - Syntactic Models
  - Hypothetical-Deductive Models

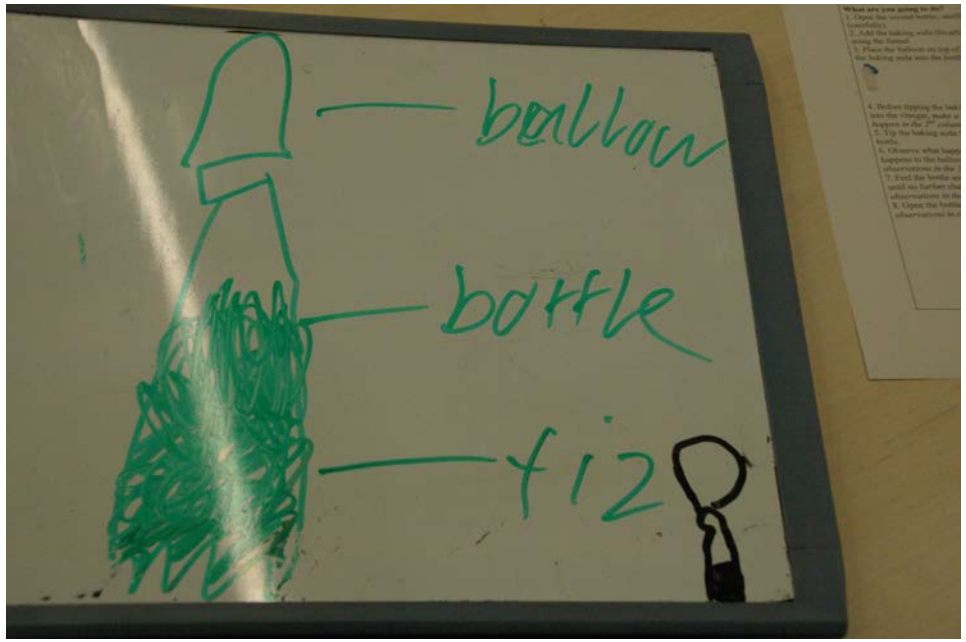
APPLYING THE CODES TO ONE PAIR OF STUDENTS IN THE SCIENCE SESSION

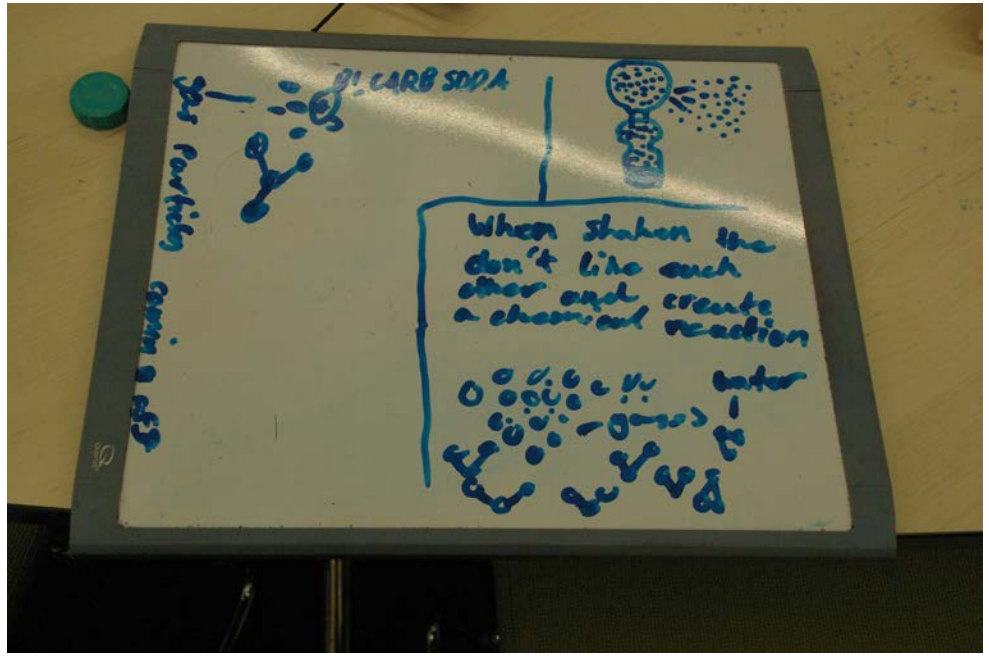


Representing and Modeling Icing Sugar Dissolving

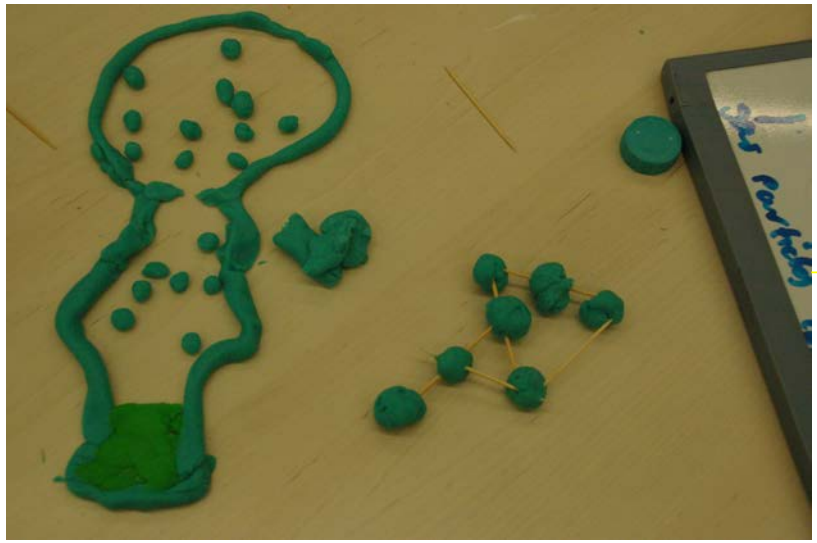
Explaining Icing Sugar Dissolving

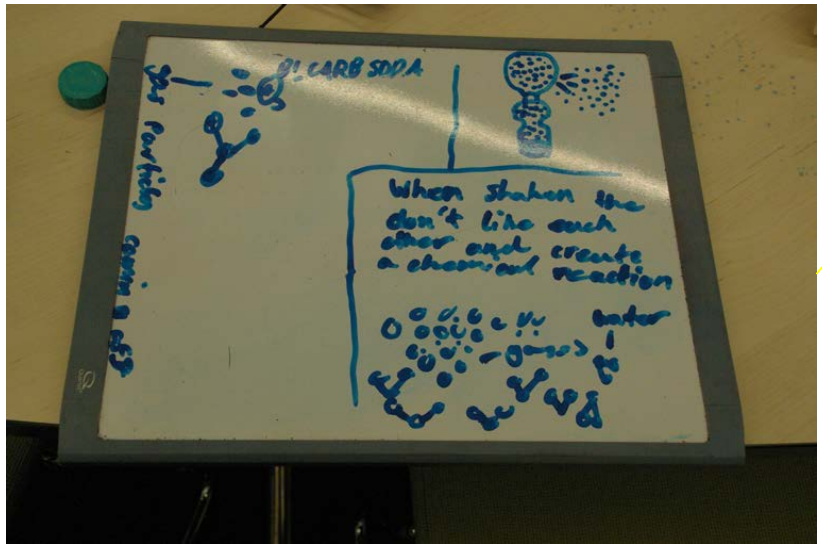






Representing bicarb and vinegar reaction





Explaining bicarb and vinegar reaction

DISCUSSION: METHODOLOGICAL CHALLENGES

- Describing "reasoning" using the same set of language and terminologies across two subject areas: science and mathematics
- Representing "reasoning" through coding: grain size and time scale. And what did we leave out during this process? E.g. the embodied tacit doing?
- Identifying what constitute "a model" and the roles of the models in reasoning for science and mathematics
- In what ways and in what circumstances generalisation can be made in relation to the levels of reasoning and modeling identified?

FOLLOW PROJECT UPDATES ON:

www.researchgate.net/project/model-based-reasoning-in-science-and-mathematics