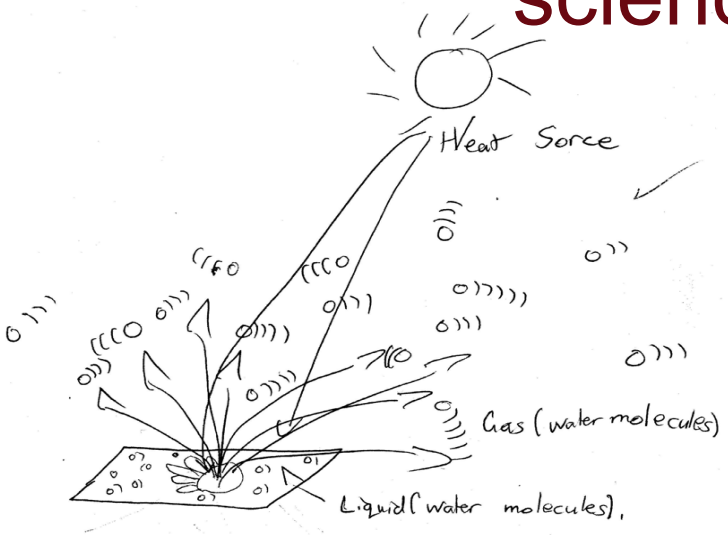
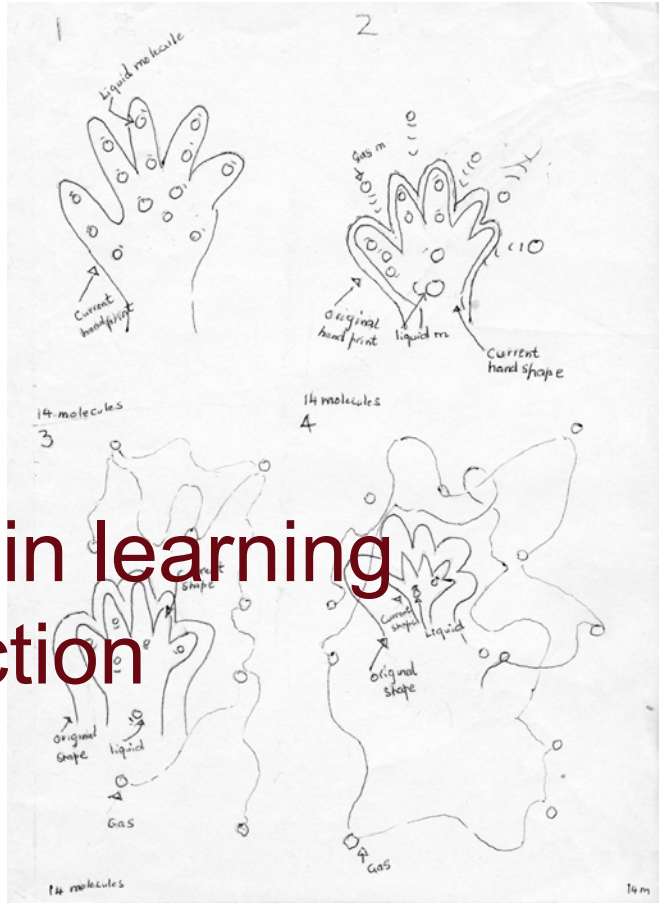
The role of representation in learning science: an introduction



Russell Tytler



Concepts associated with animals in the schoolground

Animals in the schoolground:

- What big ideas would be covered?
- How would we support students to understand them?

The Victorian curriculum

- F-2: Living things have a variety of external features and live in different places where their basic needs, including food, water and shelter, are met
- 3-4: Living things can be grouped on the basis of observable features and can be distinguished from non-living things
- 5-6: Living things have structural features and adaptations that help them to survive in their environment

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Representations

- Representations play a fundamental role in the teaching and learning of science.
- A representation is something that explains some aspect of nature. They can take many different forms or modes.
- Representations are the means by which we understand, and communicate our science understandings.

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- A representation is something that explains some aspect of nature. They can take many different forms or modes.
- Representations are the means by which we understand, and communicate our science understandings.
- *What different representations do we use in science both in terms of what we use to teach but also to understand?*

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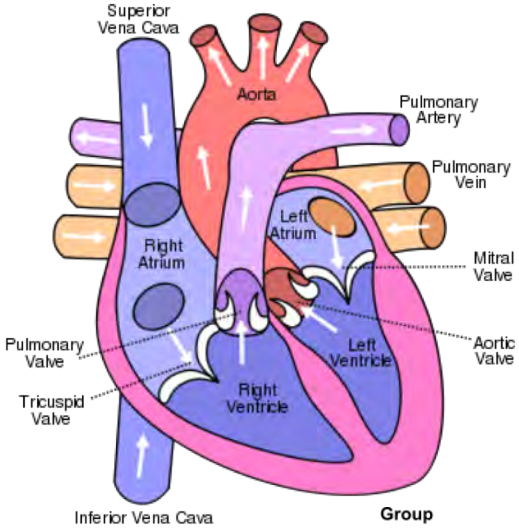
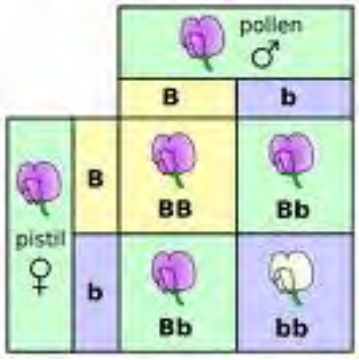
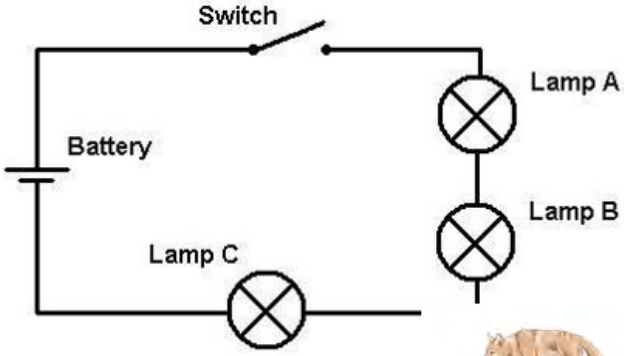


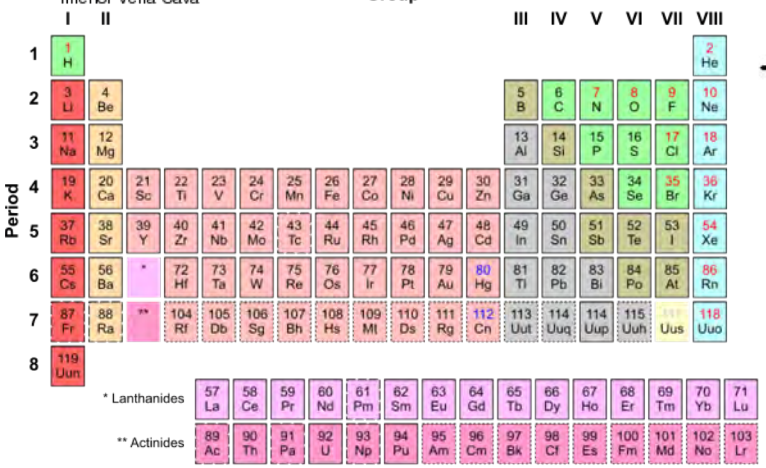
coefficients

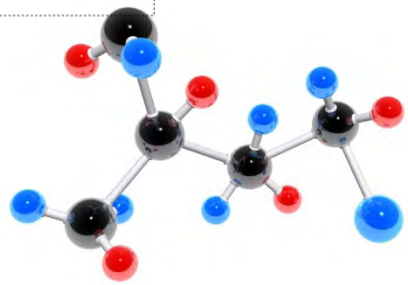
$$2H_2 + O_2 \rightarrow 2H_2O$$

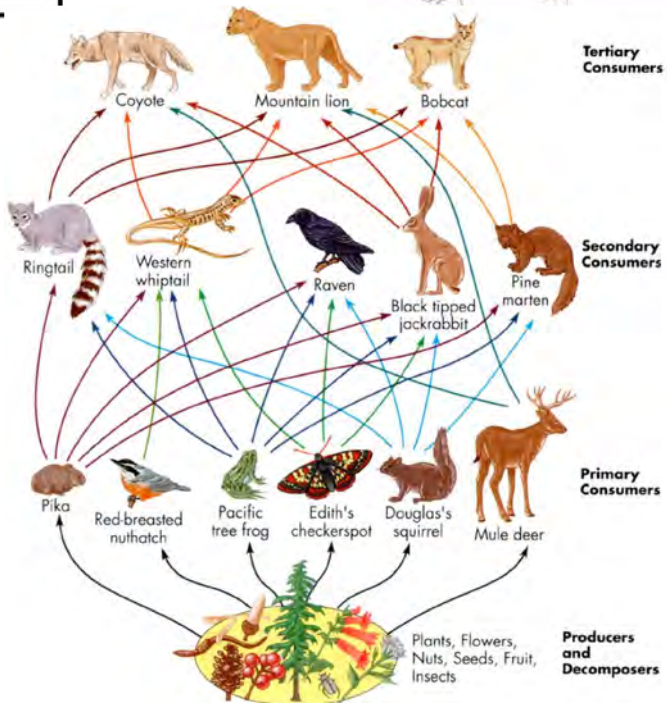
reactants *products*







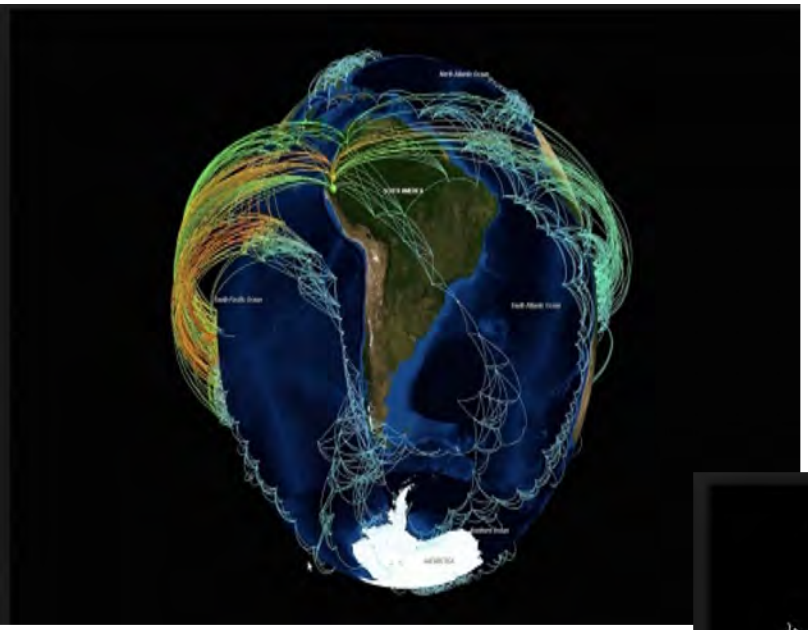




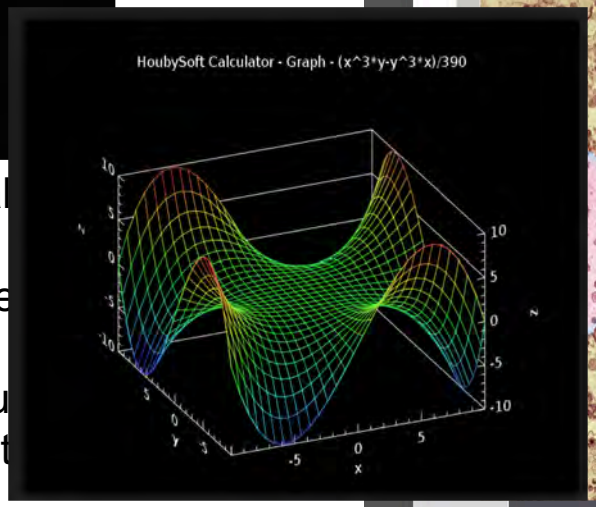
Diversity in living things

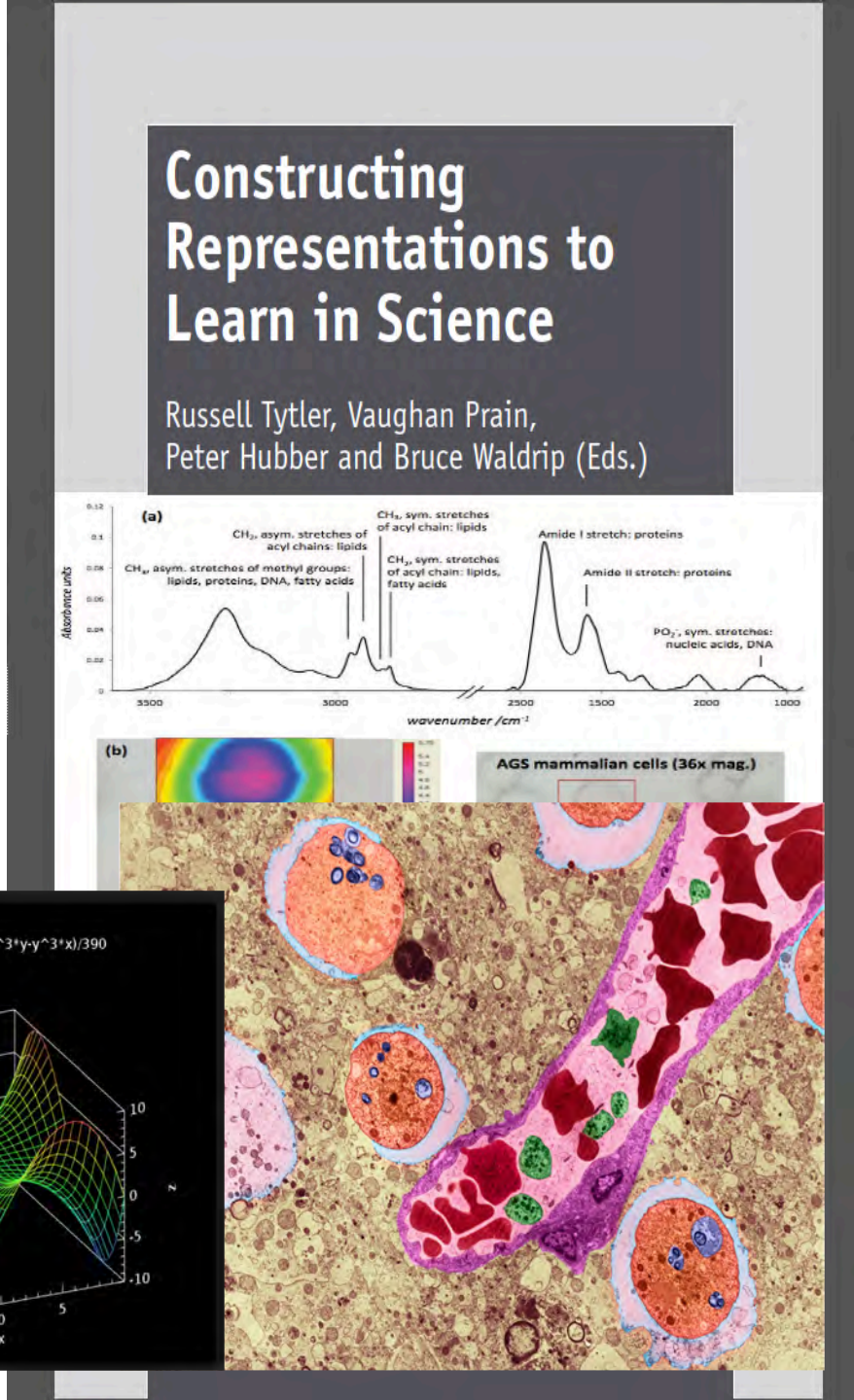
- What does it mean to understand a concept like ‘diversity of living things’, scientifically?
- Using the whiteboards, generate a range of representations that you associate with the concept of diversity.

Scientific discovery is driven by the invention of new representational and material practices



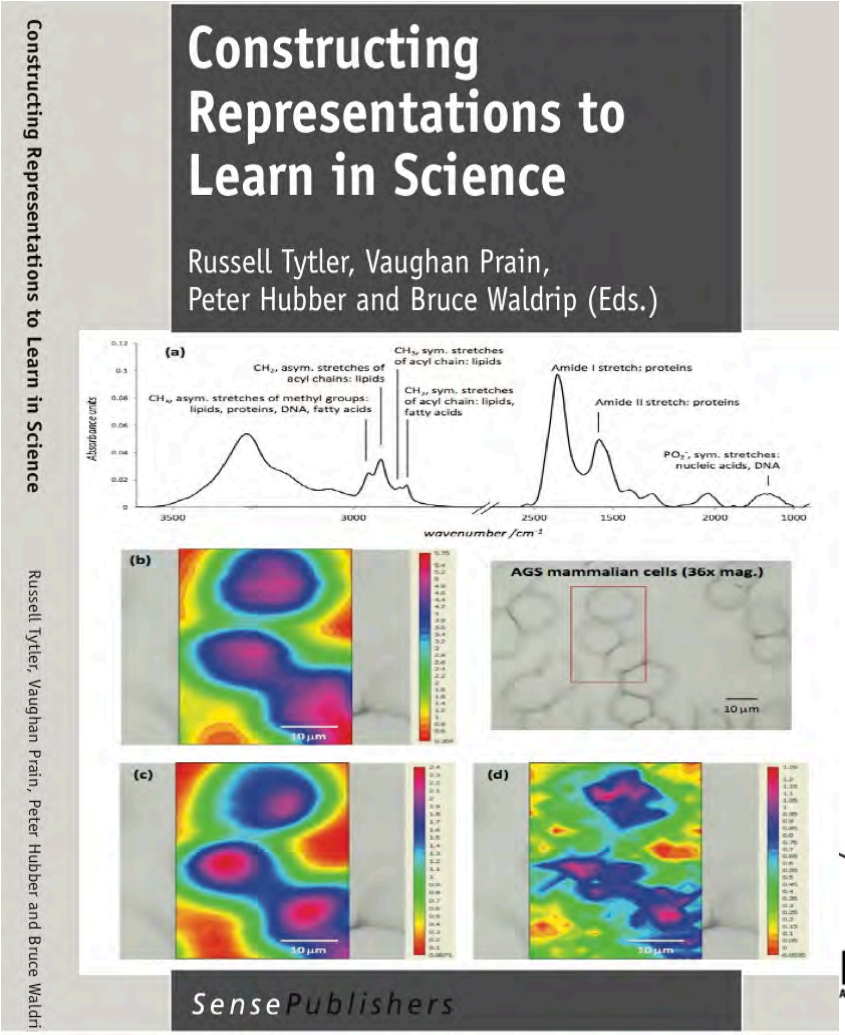
Climate network visualization reveal
the backbone structure of strong
statistical interrelations (links) betwe
surface air temperature time series
(nodes) all over the globe with featu
including the tropical Walker circulat
and surface





Multi Modal representations

- Representational tools are crucial resources for speculating, reasoning, contesting and justifying explanations, knowledge building, and communicating.
- In the ‘Role of representation in learning science’ (RiLS) study we used video, interview and student workbook data from an upper primary school classroom unit on animals to explore
  a. how the multimodal representations of science support a range of reasoning processes central to knowledge building in science, and
  b. the centrality of representations in student learning



Animals in the school ground

1. Exploration of biotic and abiotic features of a school ground environment, including representing animal populations, habitat, in a variety of ways, and
2. Studies of an invertebrate using digital microscopes, internet searching, modeling of its movement

- The key features included
  - a focus on the concepts of habitat, diversity, animal structure and function and the adaptive purposes of behaviour
  - an explicit focus on representations and the use of multimodal representations,
  - students generating their own representations and using these to explore ideas, and
  - students asking questions, exploring and investigating.

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Unit sequence part A: Animal diversity

- Pre test.
- Introduction to the school environment – identification of habitats to study: a) what animals are found in the school ground habitats? b) what characteristics do the animals have that enable them to survive?
- Students undertake a preliminary investigation of their habitat.
- The idea of scientifically studying a habitat is introduced, and the need to develop quantitative data through sampling, measurement and representation.

MALCOLM: What sorts of things you might want to record? Temperature, what was the weather like, humidity. … Can we find out at what depth these creatures are living? Whether they interact with each other? Are there any predators? What else?

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- Students explore their habitat, counting animals and recording a range of environmental conditions.
- Direct teaching concerning diversity and classification
- Students develop and display posters representing an account of their habitat, and present preliminary ideas about how the animals and plants interact.

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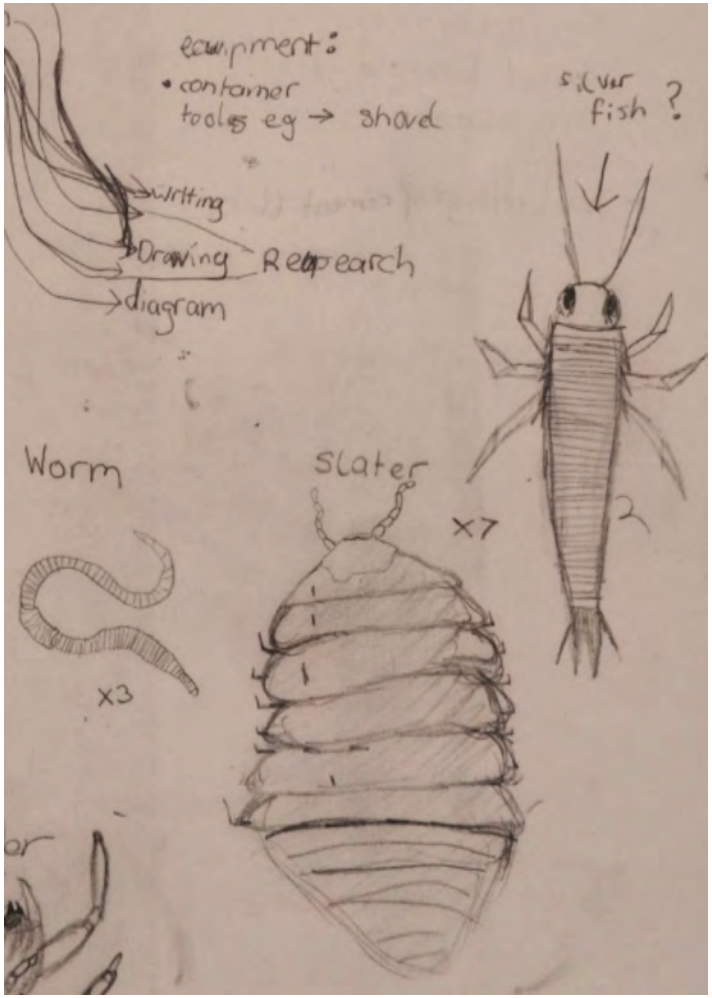
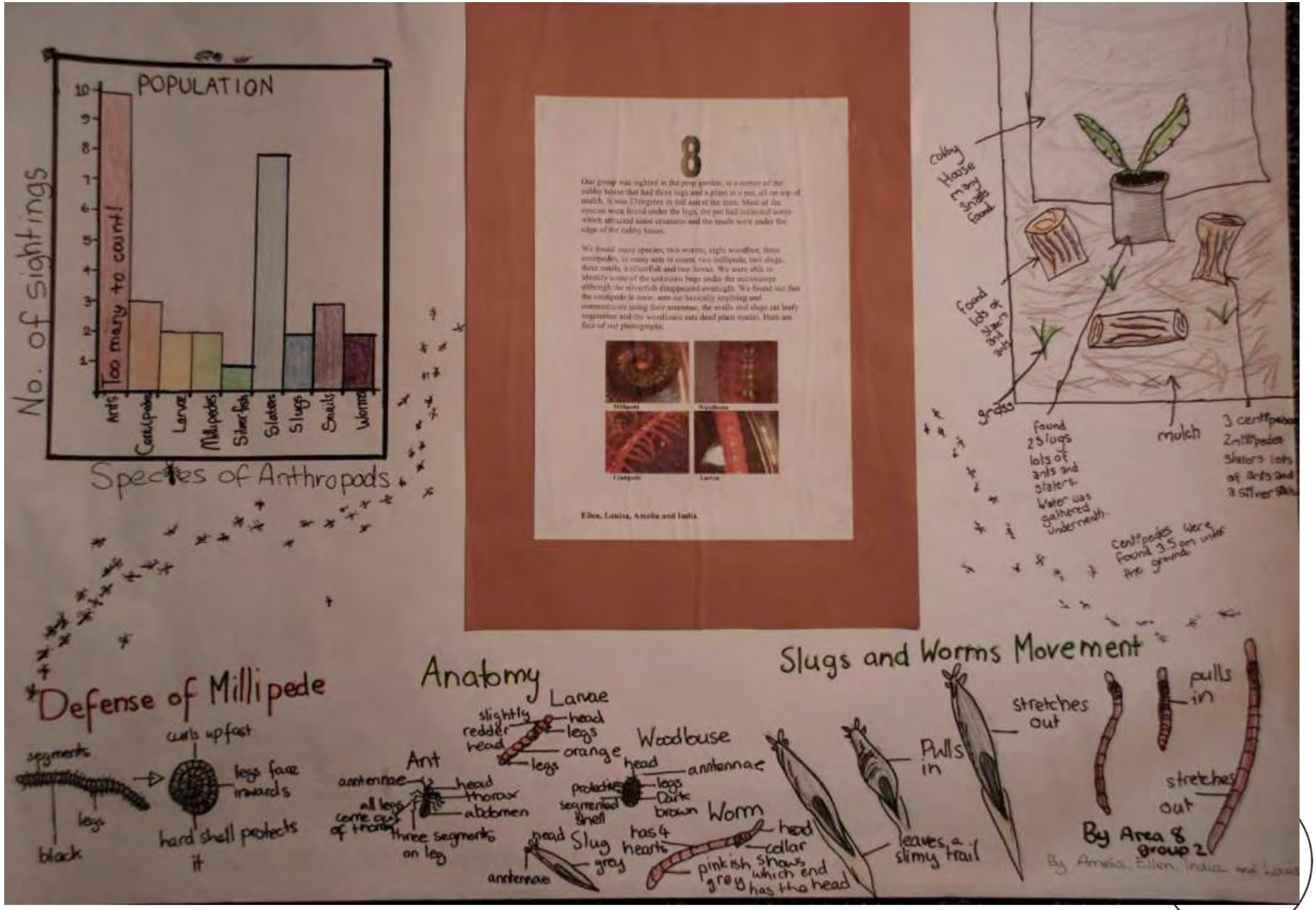
Students exploring a school ground habitat

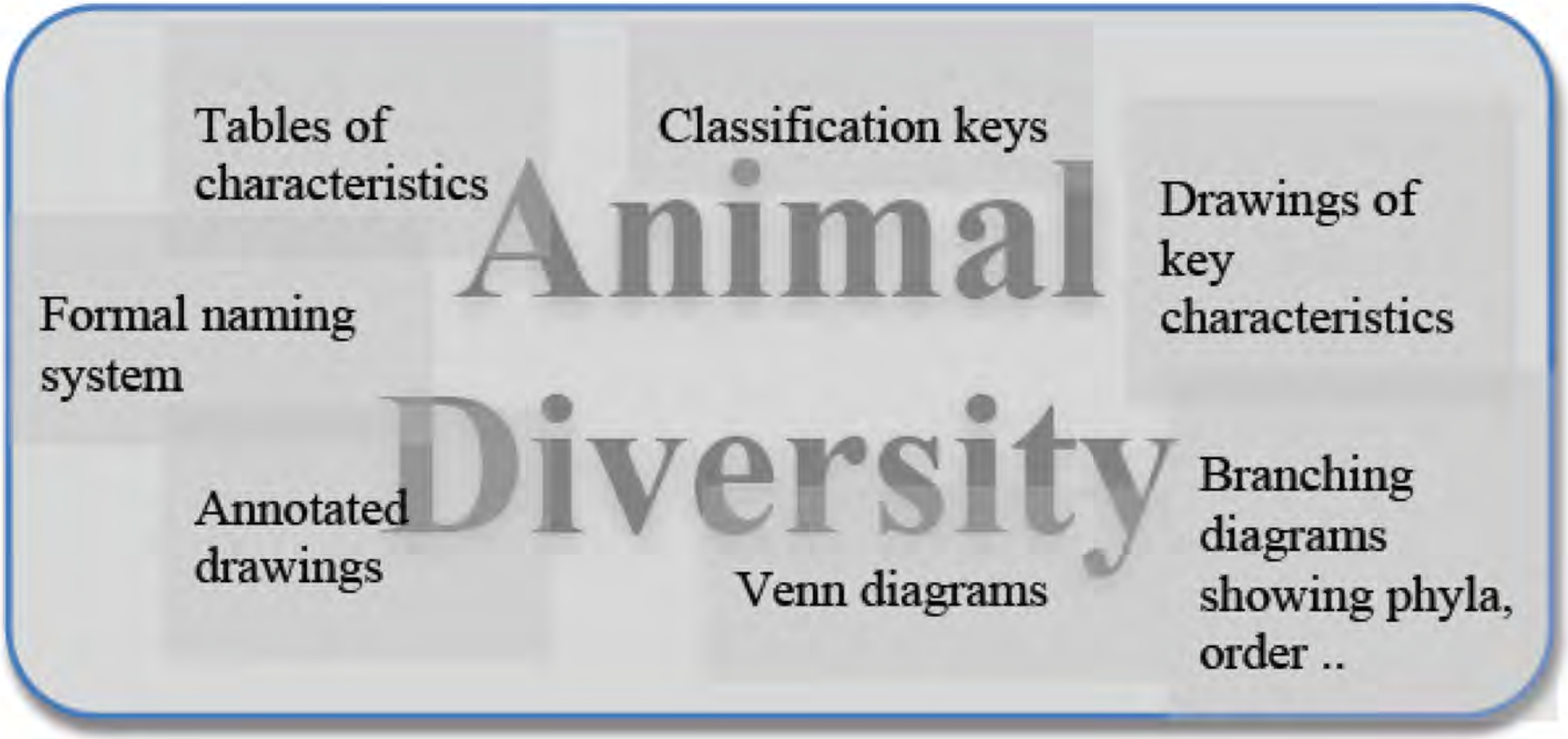
- Representations frame the conceptual activity



- Active generation of different representations of animal populations


POPULATION
No. of sightings
Too many to count!
Ants
Centipedes
Larvae
Millipedes
Silverfish
Slaters
Slugs
Snails
Worms
Species of Anthropods
8
Our group was sighted in the prep garden, in a corner of the cobby house that had three logs and a plant in a pot, all on top of mulch. It was 27degrees in full sun at the time. Most of the species were found under the logs, the pot had collected water which attracted some creatures and the snails were under the edge of the cobby house.
We found many species; two worms, eight woodlice, three centipedes, so many ants to count, two millipede, two slugs, three snails, a silverfish and two larvae. We were able to identify some of the unknown bugs under the microscope although the silverfish disappeared overnight. We found out that the centipede is toxic, ants are basically anything and communicate using their antennae, the snails and slugs eat leafy vegetation and the woodlouse eats dead plant matter. There are four of our photographs.
Millipede
Woodlouse
Centipede
Larvae
Ellen, Louisa, Amelia and India.
Cobby House many Snails found
found lots of slaters and ants
grass
mulch
found 2 slugs lots of ants and slaters. Water was gathered underneath.
3 centipedes 2 millipedes Slaters lots of ants and a silver skin
centipedes were found 3.5 cm under the ground.
Defense of Millipede
segments
legs
black
curls up fast
legs face inwards
hard shell protects it
Anatomy
Larvae
slightly redder head
head
legs
orange
legs
Ant
antennae
head
thorax
abdomen
all legs come out of thorax
three segments on leg
Woodlouse
head
antennae
legs
Dark brown
protective segmented shell
Worm
head
collar
pinkish grey
shows which end has the head
Slug
head
has 4 hearts
gray
antennae
Slugs and Worms Movement
Pulls in
leaves a slimy trail
stretches out
pulls in
stretches out
By Area 8 Group 2
By Amelia, Ellen, India and Louisa

The concept of animal diversity is constituted by a variety of representations



Representations as tools for reasoning

Form of reasoning	*Examples from the study*
Organising observations and data collection	○ Tallies of animals in the habitat ○ Tables and lists of abiotic features of the environment ○ Sketches with annotations of main characteristics of the habitat.
Identification of patterns in data distribution	○ Graphs of animal populations ○ Cross sectional drawings of habitat showing location of animals
Clarification of difference and variety	○ Drawings of animals in habitat and comparison with internet images. ○ Use of tables of animal classifications ○ Venn diagrams highlighting common features and differences between families of animals.
Identifying mechanisms	○ Time sequence drawings of animal movement and defence mechanisms ○ Modelling of animal movement, and animal structures

Representation Construction Approach

1. Sequencing of representational challenges involving students generating representations to actively explore and make claims about phenomena
   a. Clarifying the representational resources underpinning key concepts
   b. Establishing a representational need
   c. Coordinating / aligning student generated and canonical representations
2. Explicitly discussing representations
   a. The selective purpose of any representation
   b. Group agreement on generative representations
   c. Form and function
   d. The adequacy of representations
3. Meaningful learning
   a. Perceptual context – exploring material phenomena
   b. Engagement / agency
4. Assessment through representations

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Students modeling animal movement

The ladybird

Students observing and reasoning

Phil: I can see a head and thorax and abdomen on each of them. They're definitely insects.

Lee: (Pauses taking notes and leans over to look) Is that the same for the red bug? (they both focus on looking at the animals, and tap the box to get them into view.

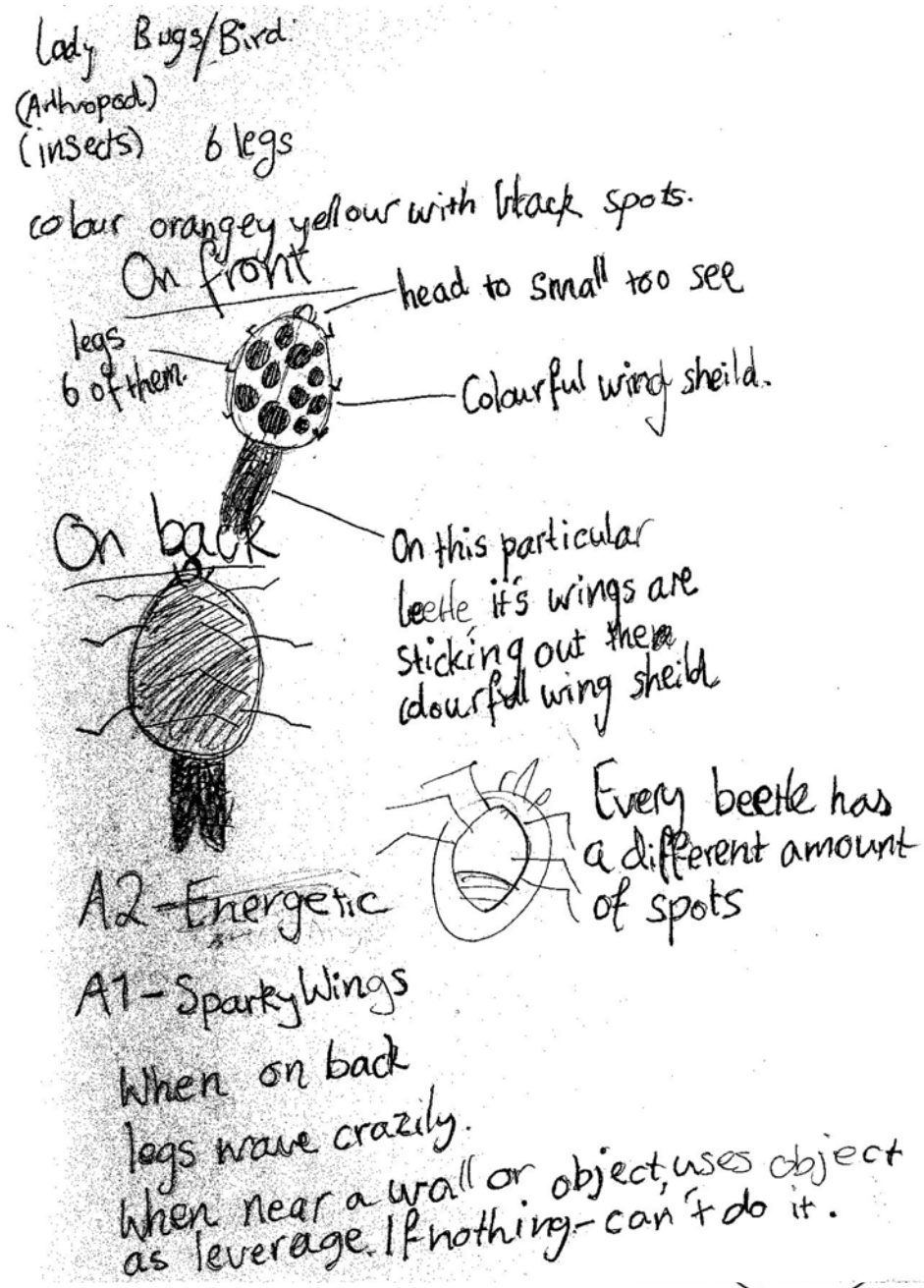
Phil: He'll come down. He'll come down. …. What do want to see with them?

Lee: I can see the back (looking closely, pen still poised) there's little shiny things ..

Phil: (Looking closely) I can see the back of this guy. They've both got butterfly patterns.

(Lee is making notes again.)

Lee: Let me see. Yeah it's all the same. Sort of silvery.



A variety of invertebrate models

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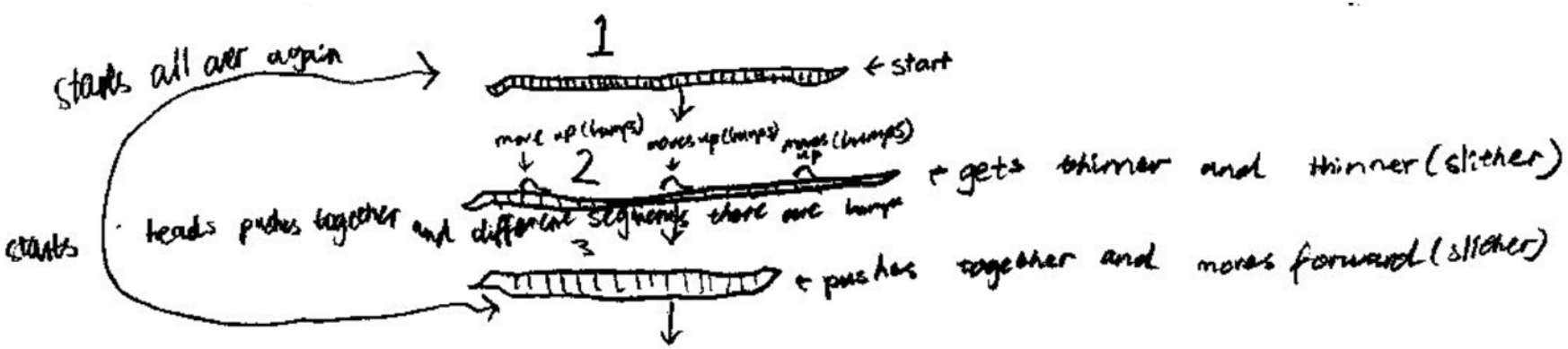
Techno-worm – abstraction in modeling

- At the start of this lesson Ivan carefully examined the representations in his workbook, read his annotations and discussed them with Ivan. Ivan had some rough ideas that he had drawn up on a piece of paper at home.



- They then selected mechano pieces, connects, flexi wire and blu tac to build a techno-worm.
- They wanted their model to represent as accurately as possible the amount of extension and ‘retraction’ of the earthworm. So they drew up a scale on an A3 paper (see below) to help them represent the exact extension and as the earthworm moved along a smooth surface.

Techno-worm communication

So we tested out by using blu-tac and a rubber band to see which one would represent better. So what we did with the blu-tac , we basically pull it one way [pulls the mechanical handle] *this is how it moves*: it moves forward one way, it goes a bit at the back, and moves forward one way, at the front, and then it moves a little bit at the front and then it moves a little forward at the back, then keeps repeating it.
And then we tried doing the same with the rubber band and the rubber band worked well because it retracted really easily.

Centipede model and movement

Paul moves the model using both hands - the entire model moves and individual segments undulate.

Jesse places his right hand over the left (representing the entire body of the centipede?) then moves his hands in a sideways undulating movement, describing “Generally it moves like a snake “ [Paul gestures, moves the model and adds: “it sort off … so instead of moving in straight lines it moves like a snake. [macro representation – movement of entire body of the centipede]

Jesse: “… so instead of moving in straight lines, it moves (he gestures to signify the undulation) so we used elastic so it could move properly

- Jesse: "*How we found out, how it moves is* (moves the model) *it went like* (uses right hand to simulate the undulating movement*). I also think it did this* (moves hands) *one set of legs forward and the other*" (raises both hands and moves them in a left-right, left –right motion). At this point Jesse moves very close to and just behind Paul, so as to represent the next consecutive segment. Both students then use their hands and their entire body, gesturing and moving in complete synch.

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http://polypedal.berkeley.edu/twiki/bin/view/PolyPEDAL/MediaSee, See How They Run, *Discover*, September 1994 Author: Carl Zimmer

- Anderson implanted electrodes in the centipede's trunk muscles and found that whenever a segment of its body was curved out to the left, contracting muscles would then begin forcing that segment to curve to the right. … In other words, the centipede was not passively bending as a result of its anatomy; it was actively trying to undulate. And the bending seemed to be saving it energy
- When Anderson set his centipede on the Jell-O track, he discovered something remarkable. At any moment, most of the centipede's legs are not on the gelatin, in fact, on average, only four touch the ground at a time.
- How does this help the centipede save energy? "I made stick figures of these things until I was bleary-eyed," says Anderson, but eventually he came up with a theory. Since the centipede is moving only four legs at a time, rather than 44, it takes less energy overall to operate its legs….

Representation and reasoning

- From the drawings and dialogue and targeted observations one can see instances of
  1. coordination of multiple representational modes including writing, talking, drawing and annotating, mathematical modeling, gesture and physical modeling to develop and communicate understandings
  2. representations focusing attention on aspects of the animal's behaviour as students reconcile what they are seeing with what they are trying to understand,
  3. further observations leading to refinement of representations, and
  4. discussion and new ideas leading to further observations and representations.

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Teacher talk

- In the second year running this unit, the modeling activity changed:
  - Less time was given to the construction phase
  - Less support was given to amass materials
  - There was a much more explicit focus on the purpose of the model to represent movement, distinct from physical reproduction

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Second year: Teacher talk was more focused

- LINDA examines work of individual students, notes that some students experienced difficulty in representing movement and individually scaffolds those students to represent movement:
  - [18:05] “Show some kind of movement, like in arrows or something like that.”
  - [19:18] “They are good, great diagrams. You don’t have to draw the exact creature, but you have to show how it actually moves. Order, when that one goes when, [points out] when that one goes when.” [Clarifies], so the front legs moves,
  - [21:08] “Now do they move together? At the same time? So how are you going to show me that?”
  - [21: 51] Show me in a diagram, show how it moves, that is interesting [reads annotations] the back one moves, then the middle one moves, then the back one moves again. Is that every time it …
  - The people that are going to be representing [movement of] worms somehow, you are going to really **think** how you are going to show [movement] , and what kind of [pause] equipment [pause] material you are going to use to represent that?

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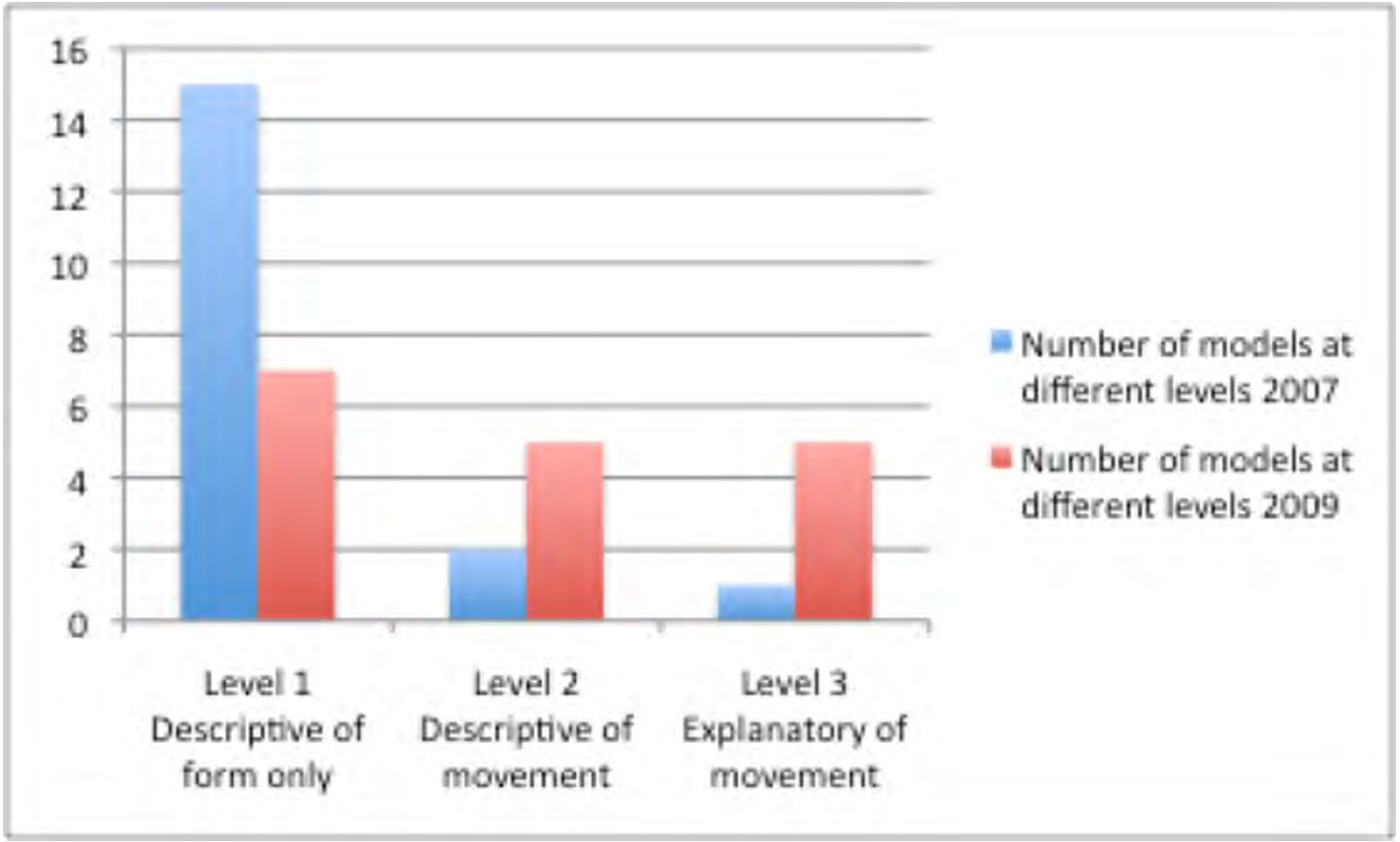
Changes from first to second animals unit

- In the second version of the unit the models were higher level, offering explanation rather than description.



Scientific epistemic practice: Evidence of student learning

Scientists go into a forest to study the animals. What would they take? What would their notebooks look like? What questions would they ask?

In the pre-test responses students' conceptions of these questions were very superficial.

The image illustrates the richness of post-test responses.