An explicit representational focus for teaching and learning about animals in the environment

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Abstract

There has been growing interest in linking the learning of science with the literacies of science and representations. Recent attention has been focused on learning theories that emphasise the sociocultural and situated aspects of learning, and in particular the notion of learning as participation in a discourse community. This paper will describe a learning sequence planned with Year 5/6 teachers, focused on invertebrates in the school ground environment, but with a representational focus in which students generated and negotiated representations, and discussed the adequacy of these. The paper will present data from video capture of classroom activities, students' work samples, and pre and post-unit testing, to explore what a representational focus might entail in teaching science, and the role of representations in learning and reasoning and exploring in science.

Introduction

The national Primary Connections resource (Australian Academy of Science, 2005) has familiarised Australian primary teachers with the idea of linking literacy with science. At one level the program could be seen as teaching literacy through science. More fundamentally however it represents the growing consensus that learning science entails students learning the literacies of the scientific discourse community, which uses a range of subject-specific and general representational tools to construct and justify evidence-based claims about the natural world (Ford & Forman; 2006, Lemke, 2004; Moje, 2007). These literacies include the integration of knowledge, reasoning skills, and subject-specific procedures to enable students to know when, why and how to use different representations to develop inferences from data, and know how to develop valid science explanations. There is also growing acceptance that these representational tools are crucial epistemological resources for speculating, reasoning, contesting explanations, theory-building, and communicating within this community and more broadly.

Literature Review

Researchers in classroom studies where students were guided to construct their own representations of scientific ideas (diSessa, 2004; Greeno & Hall, 1997; Prain et al., 2007; Tytler et al., 2006) have identified key principles to guide effective planning, implementation, and evaluation of student learning. A major principle is the need for the teacher to be clear at the topic's planning stage about the key concepts or big ideas students are intended to learn. This conceptual focus provides the basis for the teacher to consider which sequence and range of representations, including both teacher- and student-generated ones, will engage learners, develop understanding, and count as evidence of learning at the topic's end.

These researchers have also noted the importance of teacher and student negotiation of the meanings evident in verbal, visual, mathematical and gestural representations in science.

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There is a general claim that students benefit from multiple opportunities to explore, engage, elaborate and re-represent ongoing understandings in the same and different representations. Greeno and Hall (1997) argued that different forms of representation supported contrasting understanding of topics, and that students needed to explore the advantages and limitations of particular representations. As noted by Cox (1999), representations can be used as tools for initial, speculative thinking, as in constructing a diagram or model to imagine how a process might work. They can be used to identify the distribution of types, to classify examples into categories, to identify and explain causes, to show a sequence or process in time, sort information, and clarify ideas. Students need to understand that a single representation cannot cover all possible purposes or all aspects of a topic. Therefore they need to learn how to select appropriate representations for addressing particular needs, and be able to judge their effectiveness in achieving particular purposes.

These studies have also identified a range of benefits from this explicit focus on representational understanding and reasoning. Prain, Waldrip and Carolan (2007) claimed that this approach heightened students' sense of ownership of their work, increased student motivation and creativity, and that teachers reported improved student learning outcomes. Tytler, Peterson and Prain (2006) argued that this approach also had the merit of being consistent with science practices of meaning-making in the broader science community.

Research focus

In the current study we worked with two year 5/6 teachers in a shared classroom setting, to help them plan and implement a unit of work which included a rich range of teacher and student-generated representations, investigative activities, and discussion. This paper will explore what an explicit representational focus might entail, for teachers and students, and the role of representations in 1) supporting learning and reasoning in science, and 2) framing and developing science explorations.

Research methods, and results

The research team worked with two experienced primary teachers to develop a teaching sequence *Animals In The School Environment* that used an explicit representational focus to promote students' understandings of key concepts in the topic. During a series of planning meeting with the teachers, we jointly developed a (flexible) sequence for the unit that included many opportunities for the generation and negotiation of representations, and that focused on science content related to these concepts.

Key characteristics of the sequence were:

1. An inquiry approach involving students asking questions, exploring and investigating
2. An explicit focus on representations and the use of multimodal representations
3. A focus on the methods used in science to study animals
4. Students generating their own representations and using these to explore ideas

The major concepts developed during the teaching/learning of the unit included: ecosystem, habitat, diversity of animal populations, interactions between plants and animals in an ecosystem, animal structure and function and the adaptive purposes of behaviour. The two teachers combined their classes and co-taught the unit.

Planned unit sequence

Each session consisted of between 45 and 90 minutes of class time. The main features were:

1. Pre test exploring the concept of living things, the way scientists work in studying small animals, and the relationship between structure and function of small invertebrates. This was followed by a session unpacking these ideas.
2. Introduction to the school environment – identification of habitats to study. The overall questions are a) what animals are found in the school ground habitats? b) what characteristics do the animals have that enable them to survive? and c) how do the living things interact and depend on each other?
3. Students undertake a preliminary investigation of their habitat. They predict what they will find there. They spend time drawing and observing as much as they can. They report back as to what they have noticed and what they think happens in this habitat.
4. The idea of scientifically studying a habitat is introduced, and the need to develop quantitative data through sampling, measurement and representation. Students were introduced though discussion to the idea of sampling distributions.
5. Students explore their habitat, counting animals and recording a range of environmental conditions. They take notes as a group with a view to developing a poster.
6. Direct teaching occurs concerning diversity and classification (broad animal groupings)
7. Students develop and display posters representing an account of their habitat, and present preliminary ideas about how the animals and plants interact.
8. Activities are run using mealworms, to establish ways of describing animal movement, describing animal structures, testing animal behaviours/preferences. The difference between observation and inference is established.
9. Students collect animals to study. Their task is to identify them and build up descriptions of particular animals – their structures and their behaviours and how this is adaptive to their habitat. (Students spent considerable time using the internet and reference books to identify the animals and their features.)
10. Students construct a model of some aspect, for instance movement, of their chosen animal and present this to the class
11. Post test

Data collection and analysis

Data collected included: (1) video recordings of classroom sessions and of student interviews; (2) student workbooks; (4) pre and post tests; (5) transcripts of tape recordings of teacher and student interviews and (6) researchers' field notes. Interviews conducted with students were based on video stimulated recall.

Two video cameras were used to capture teaching and learning transactions– one tracked the 2 teachers (team teaching) and the main classroom interactions, and the other focused on a small group of students. The teacher and student group were radio miked. The student group's microphone was transported with the group when the group moved around. The video data were processed using 'studiocode' software to identify "Quality teaching and learning moments" which were then subjected to careful viewing and analysis. The analysis reported here included triangulation between video data, transcripts of student and teacher interviews, student work, pre and post tests and researcher field notes.

Results: The story of the unit

The full story of the unit is too detailed to report here, but we will focus on those events and results that particularly demonstrate the efficacy of a representational focus.

Habitat study

The ways in which scientists might work, probed in the pre-test, was reviewed, as preparation for the habitat study. The teachers introduced and encouraged the idea that the students should see themselves as scientists in this unit. Teachers explained that the entire cohort of Year 5/6 students would need to work as a team of scientists tasked with finding out what animals lived in the school grounds and why. The broad questions to be investigated by the students were clearly spelt out: *What is in my habitat? What exactly happens there - what is life like for the animals living there? How do the various living things interact and depend on each other?*

Students visited the habitat allocated to them and upon returning to class each group discussed the equipment that might be required to conduct their investigation and then predicted what they think happens in that particular habitat. The need to develop quantitative data through sampling, measurement and representation was discussed in detail. Students were taught techniques of sampling.

Teacher 2 detailed how to sample and draw up representations using tables, graphs diagrams and cross sections. Teacher 1 proceeded to explain the method and procedures students might use. This session therefore focused strongly on the representations students might use to study the animals living in their assigned habitat.

> Tr. 1: 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?

This discussion was aimed to help students understand that each animal lives in a particular ecological niche, which does not only involve interdependence with other living things but also dependence on non-biotic factors. Direct teaching occurred concerning diversity and animal classification. Following this, teachers discussed how students might study and represent animal behaviours and structures, and refined this with an activity studying mealworms.

Collecting data on habitats

Students went back to the area assigned to them and collected data on animals and plants in the habitat, and collected animals to study. Their task was to collect samples, and observe one or two animals in the classroom, [animals found were placed in plastic terrariums]. Students were required to provide descriptions of these animals, in terms of their structure and behaviours, and explain how this is adaptive to their habitat. They were also required to take notes concerning the multiple aspects of their environment discussed in the previous sessions.

Students drew animals in their log books and developed different ways of representing animal diversity and population (see Figs 1 and 2 for examples). The active thinking and learning involved is clear from the quality of detail of these entries and their fit to the purpose. These representational activities play a dual role in the habitat exploration – they communicate the findings, but they are also instrumental in framing the exploration. This is true at the broad level in that the representational task frames the nature of the activity and degree of involvement in it, but also at the specific level in that the nature of the representation and the choices made (type of drawing, level of detail, count of animals, graph of population) frame the way these animals and their diversity and population are thought of. The changing annotations demonstrate the active role these graphs played in guiding the data collection. The drawings show clear evidence of detailed observation of animal structures.

Figure 1: Student notebook sketches

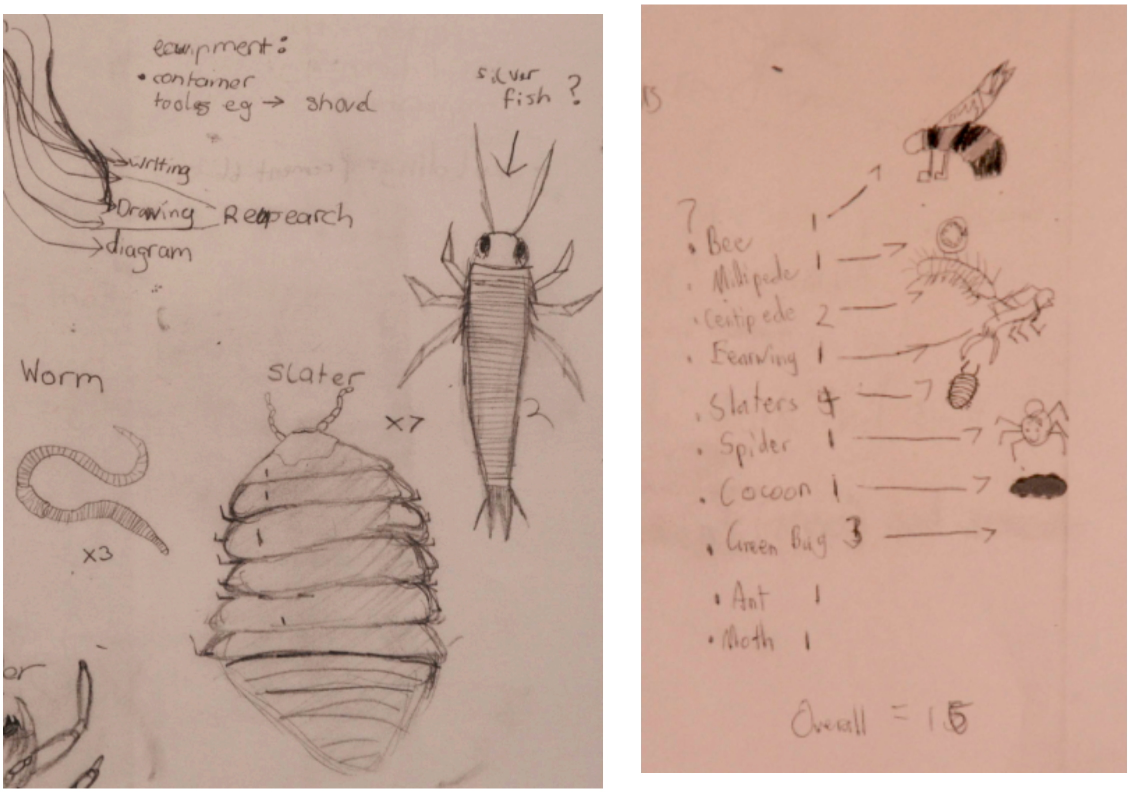
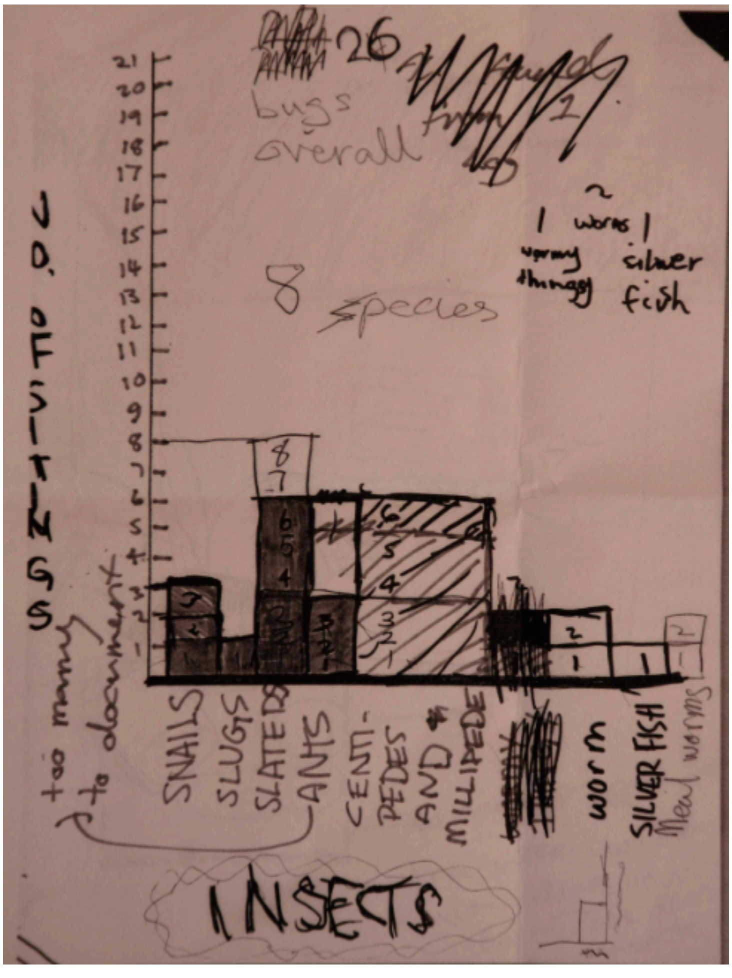


Figure 2: Student graphical representation of animal population



Observing animals in the classroom

Students observed selected invertebrates that they had collected. They did this during lunch and recess and in one dedicated session. Teachers noted that students were totally engaged and were developing scientific language. Their conversations included scientific terminology such as “ this here, is the mandible, and this is its structure for movement and defence”. There was ample evidence, both in many workbooks and in videodata that many students had understood that each organism has particular types of structures and behaviours that are essentially solutions to the problem of their survival.

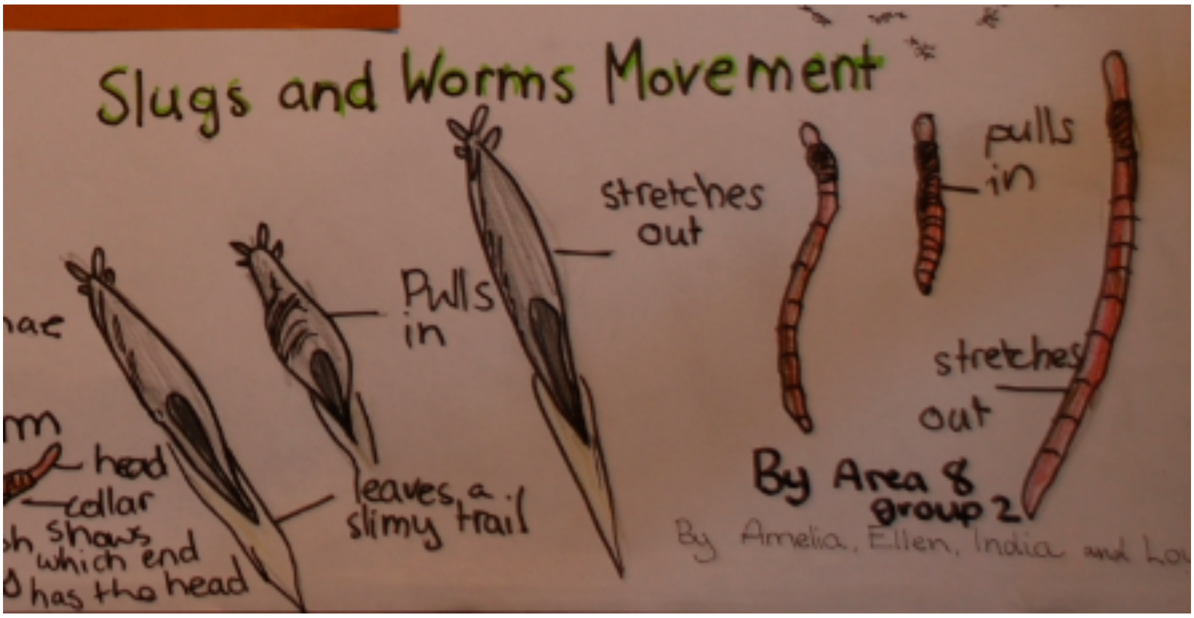
Workbooks contained a variety of representations, from graphs to detailed labelled diagrams of body structures and animal behaviours. Many of these were very accurate.

Preparation of posters for classroom presentation

Groups collated their notes to construct a large poster representing their particular environment. Re-representing their data on a poster again was the occasion for significant learning. All posters contained many representations. These included annotated drawings of animals and details of their structures (3 dimensional , cross sections, side view, magnification of certain body parts, as in Figures 1 and 2 above) population graphs, drawing of life cycles, transects , overviews, digital microscope images, and representation of animal behaviours.

An example of representation acting as a tool for reasoning is shown in Figure 3, from a poster, which shows an analysis of animal movement using sequenced drawings which focus on details of the movement, and interpret this.

Figure 3. Slug and worm movement

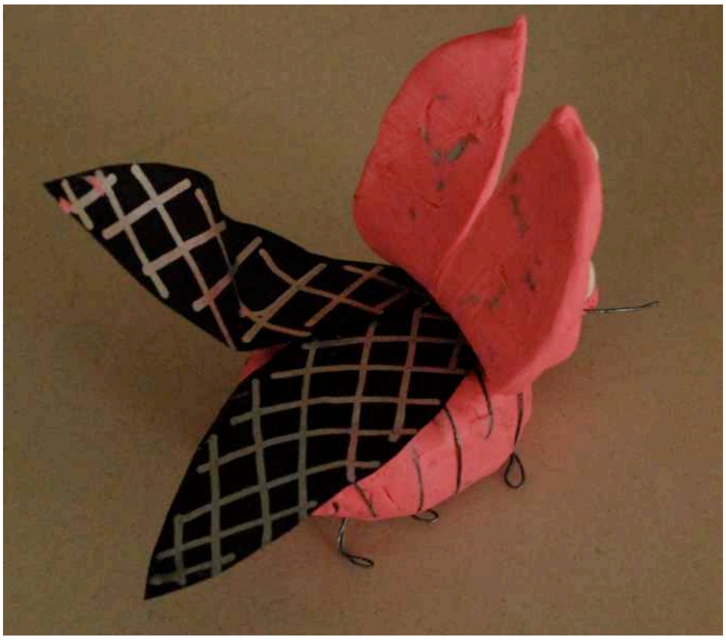


There was ample evidence in the data that they had construed what type of representation would best represent a particular aspect that they wanted to explain about.

Building a model

Teachers dedicated two sessions to enable the students to build 3D models of their invertebrates, to represent some aspect such as movement, or defence. Students spent a considerable amount of time observing animals to get a good facsimile of their chosen characteristic. For instance, the two students who constructed the ladybird model in Figure 4 were active in exploring the ladybird's structural features and its behaviour.

Figure 4: Model of a ladybird



Lee: Which one has wings?

Phil: Um they both have wings. The yellow one brandishes its wings when threatened but I haven't tried doing it with the red one yet. The red ..the yellow one I mean .. when I was trying to get it off it went on its side and its wings . . it put its wings out (gestures with arms to illustrate)

Lee: Hey. How did he get back upright?

Phil: Was he actually on his side?

Lee: No he was upside down

Phil: I think they've got hooks on their legs and they go like that (hold his arms above his head and waves his body and arms from side to side) and scratch the ground and then they roll to … they've got two hooks on each leg. And they've got three joints.

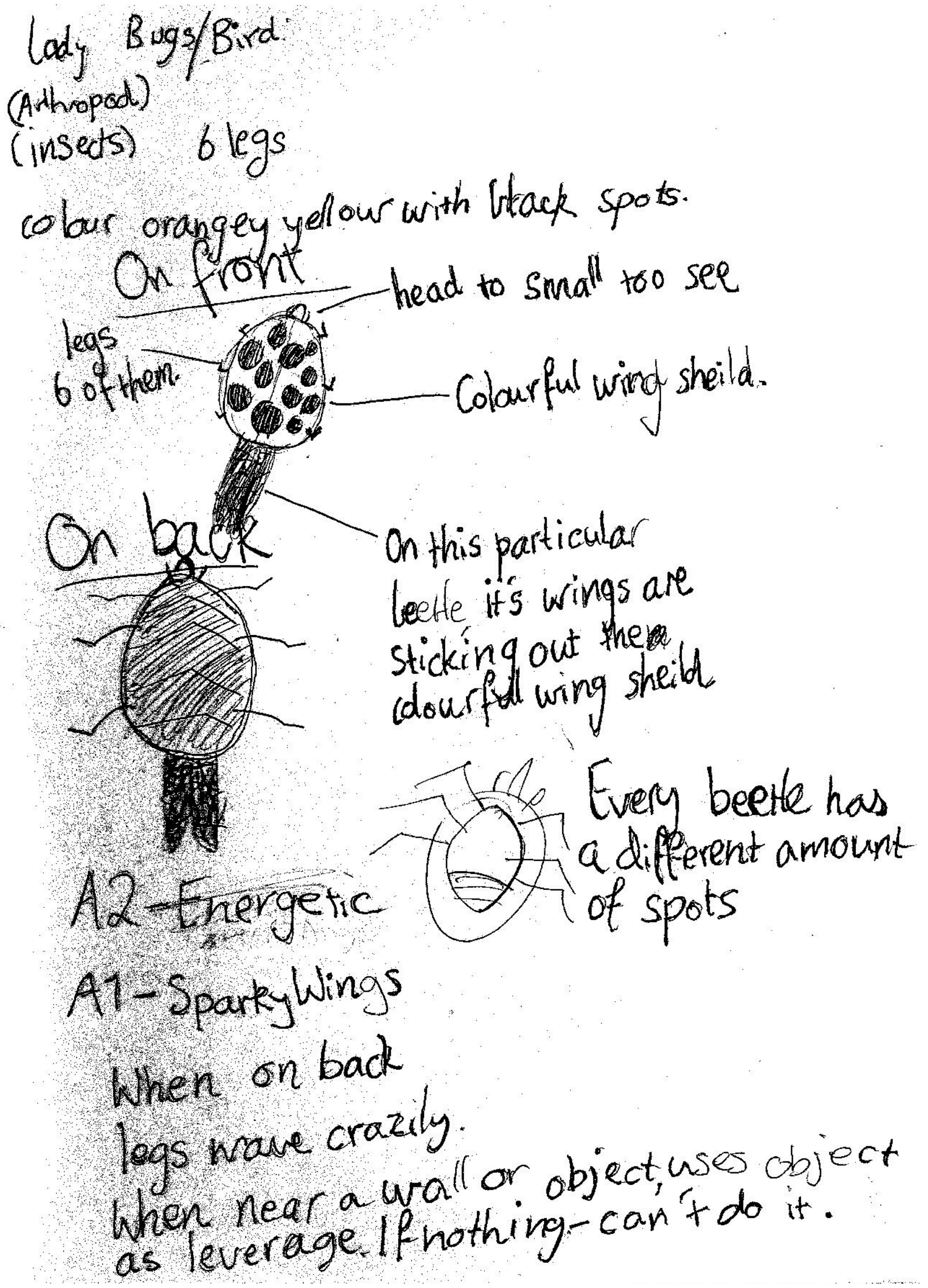
Lee: They've got TWO hooks on each leg? (looking closely)

Phil: Yeah two hooks. They've got one like this and one like this (demonstrates with hands and walks hands across bench. Lee makes notes.)

In this sequence Phil was observing the ladybird closely, and Lee was making entries in the notebook.

Figure 5 shows some notebook entries from Lee that were made during this sequence, showing the close observation of structure, and the behaviour of the ladybird.

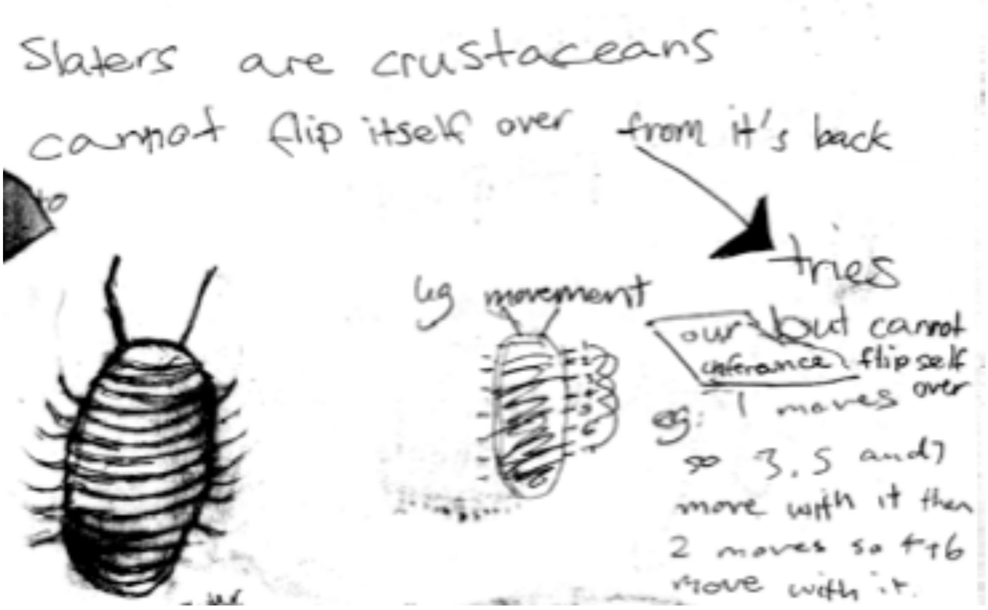
Figure 5: Lee's notes on observations of the ladybird



Phil and Lee questioned each other, and used gestures and verbal descriptions to develop their understandings, alongside the notebook sketches and finally the 3D model. The re-presentation in multiple modes constitutes the essence of quality learning. Once again, the representational task (constructing a model) acts to direct their inquiries and provides motivation, but the representations they construct act to frame their thinking about the animal's behaviour.

In another case, two students studying a slater represented the sequence of movements of its legs (Figure 6). In general, student workbooks reflected the various stages of development of their final model. There are sketches, 3D diagrams and descriptions about movement alongside notes from the internet about identification and movement of the animal.

Figure 6: Log book representation of slater movement



Discussion

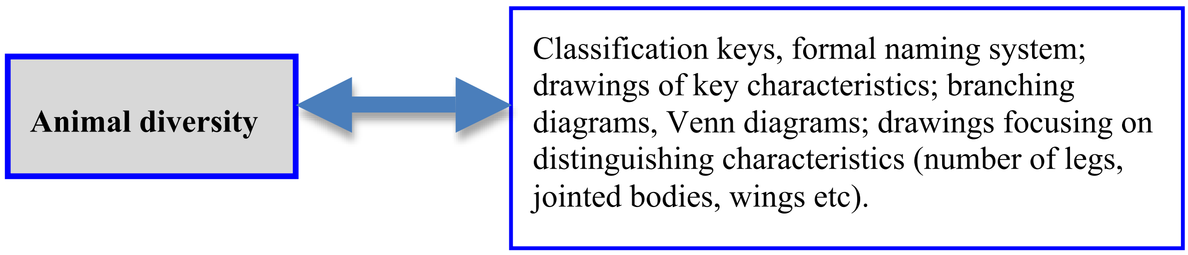
The learning gains included knowledge about concepts related to animals in the environment, knowledge about the nature of science and science investigation, and knowledge about the form and function of particular representations to generate meaning.

The role of representation in supporting knowledge of animals and the environment

Many science concepts were included in this unit, including animal diversity, animal structures and function, adaptive purposes of behaviour, and aspects of the nature of science dealing with the way scientists collect and represent evidence. Knowledge gains were evident in the post test lists and drawings, and also evident in the many opportunities students had to display their knowledge through talk, posters and diagrams, modelling, internet searching, and discussion in class. Students also made attitudinal gains. They became very enthusiastic about finding out about animals.

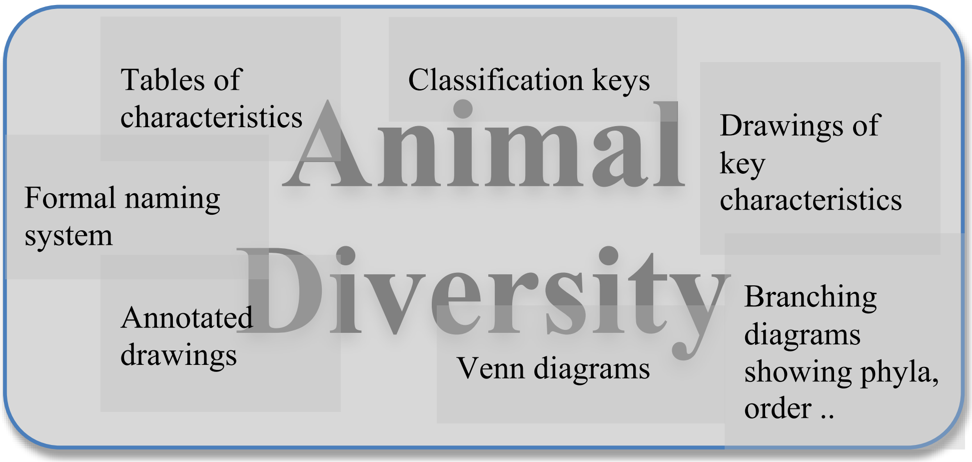
If we were to unpack the way representations relate to the concept of animal diversity, as an example, we might represent it as in Figure 7, with the range of representations each adding a different dimension to an understanding of diversity. To develop a comprehensive understanding of diversity would involve being able to coordinate these representations into a coherent explanatory narrative in response to a question or a problem.

Figure 7: The concept of animal diversity and its associated representations



In fact, Figure 7 has the capacity to misrepresent this relationship in that it could be taken to imply the concept is somehow transcendent, i.e. separate from its representations. Yet a concept such as diversity can only be thought about and communicated through constituent representations. Figure 8 is an attempt to illustrate this relationship, and that conceptual understanding cannot be separated from the capacity to work with these representations. The representations of science are the practices through which conceptual meaning is signified, where learners need to coordinate appropriate representations to show understanding of concepts in use. One commonly accepted meaning of a 'concept' involves its verbal formal definition, but this is only one form of representation. While it might be useful to be able to make a clear verbal statement about the 'meaning' of *animal diversity,* we are arguing that understanding the explanatory scope of this concept entails coordinating the representations through which this concept can be applied in practice.

Figure 8: The concept of animal diversity is constituted by a variety of representations



Curriculum designers in science typically focus on identifying clusters of concepts that comprise a topic, often not specifying what might count as evidence of students' learning of these concepts. While accepting the convenience of this approach, with its implied distinction between an idea and its expression in practice, we would argue that it does a disservice to the richly representational practices of science. Figure 8 attempts to argue that concepts or ideas are constituted by representations, that is, they cannot exist independent of the ways in which we represent them. Usually, many representations are necessary to capture key elements of a concept, with different representations offering partial and different aspects of the concept, and different levels of abstraction. What these students in our study are doing in learning about and utilising these representations, is participating in the practices of science, and giving expression to the concepts associated with animals in the environment. To fully explore each aspect of the diversity concept for instance would require using a number of representations each partial yet specific in elucidating an aspect of diversity. The concept of diversity is (incompletely) composed of this set of representations.

Viewed in this way, words like *classification*, *diversity* and *adaptation* are abstractions that stand for systems of representation that need to be called into being in any use or communication of that concept. For the students in this study, the representations were the reasoning tools by which they came to understand how the concept is used in science, to make sense of phenomena and construct and communicate explanations.

Representations and reasoning

It is possible that in teaching science concepts, the associated representations and their rules and conventions could be taught in a transmissive way. However, in the inquiry approach adopted in this unit, where students question, explore, and generate knowledge, the representations were a combination of teacher presented and student generated, and subject to challenge and negotiation. Representations were thus conceived of as active components of thinking and learning. Greeno and Hall (1997) make the point that representations should not be thought of as 'ends in themselves' but rather they serve as tools for thinking and communicating in science. There are many ways in which thinking and reasoning occur in science, and representations served different thinking and reasoning purposes used in this study. Carolan, Prain, and Waldrip (2008) identify a number of ways in which representations are used to support scientific thinking. In this unit there were many points at which students engaged in significant reasoning processes supported by the representations they were introduced to and/or generated themselves. Some of these reasoning processes are described in Table 1.

Table 1: Representations as tools for reasoning in science

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

Thus, the focus on students generating representations for the purpose of exploration of animals and their environment provided rich and varied opportunities to become active participants in the reasoning processes of science, and thus to engage with significant learning of major scientific ideas.

Missing from this list are important explanatory forms of reasoning such 'exploring causes', 'comparing cases', and 'providing narrative explanatory accounts'. Partly because of time, students were not challenged for instance to attempt to compare populations across sites, or explain why particular animals were found in particular locations, or consider why the populations were constructed the way they were. Thus, the opportunity was missed to challenge students to engage in serious causal reasoning through representation. In future versions of the unit the teachers and research team intend that these larger and more theory building ideas will be included as significant drivers. This will bring into play an extended set of forms of reasoning to add to Table 1.

Participation in a discourse community

In coming to know and use the representations associated with animals and the environment, students were becoming more knowledgeable participants in the practices of science. We can view their learning not simply in terms of the acquisition of knowledge about animals (the concepts of diversity, classification, distribution, structure and function, interdependence) but also in terms of their learning to participate in the inquiry practices of the science classroom. The unit operated to be closer to the knowledge producing practices of science than is often the case with more transmissive approaches to teaching and learning science. This unit, which emphasised the generation by students of their own representations, and reasoning practices, exemplifies the discursive nature of learning as knowledge generation and not simply of knowledge reproduction.

Further to this point, the students during the unit operated as a discourse community that established and communicated practices in exploration, reasoning and explanation. The groups exploring their habitats developed their own representational systems including language, and these were further shared in the class in what became a common purpose of locating, identifying, describing and modelling animals through the language practices of writing and drawing, internet searching, digital microscope images, gesture and talk. This was achieved through frequent classroom discussion of ideas, common tasks and opportunities to collaborate, and a communication focus.

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