Capabilities for living and lifelong learning:

What's science got to do with it?

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Introduction

The stated purpose for students learning science in the *New Zealand Curriculum (NZC)* is so they "can participate as critical, informed and responsible citizens in a society in which science plays a significant role" (*NZC* p. 17); that is, to develop scientific literacy. In the past several decades, many large-scale projects internationally have helped to build consensus about what scientific literacy involves.[1] Key aspects of science education curricula that aim to develop scientifically literate citizens include (but are not limited to) providing opportunities for students to:

- develop capabilities to engage with the practices of science
- engage with some "big ideas" in science in a range of contexts
- appreciate science as a human endeavour
- connect their science learning with their life outside school.

Nurturing curiosity, encouraging questions, and developing a respect for evidence should be key drivers for school science programmes if the aim is to develop scientifically literate citizens. These ideas are also reflected in *NZC* although not necessarily using the same words. Science education with a citizenship focus requires an expanded view of learning where the focus shifts from content acquisition to developing students' dispositions to act in particular ways. A recent curriculum initiative in New Zealand introduced a provisional set of "science capabilities" as a set of *ideas for teachers to think with*, in an attempt to support teachers to refocus their teaching. The capabilities were derived from the intersection of the generic key competencies in the *NZC*, the Nature of Science (NOS) strand from the science learning area, and the *NZC* purpose statement for learning science, which emphasises citizenship. This provisional set of capabilities consisted of five capabilities—gathering and interpreting data, using evidence, critiquing evidence, interpreting representations of science, and engaging with science.

Many schools have picked up this idea of "science capabilities" and now there seems to be growing pressure to assess them. However, assessing capabilities is not straightforward, and there is still a need for considerable thinking about how this might best be done. Capability building will require many interrelated experiences that make a powerful impression on students, and that build over time. Capability development cannot be a "one off"—and so any assessment will need to look at not only what students know and can do in a particular instance but whether or not they choose to *use* their knowledge and skills in a range of contexts over time. The multi-dimensional nature of becoming scientifically capable requires a shift from thinking about progress in linear terms to thinking about it in a more networked way. It also raises questions about *who* should determine when progress has been made.

This paper focuses on what progress in developing capabilities *might* look like. However, because a capabilities approach is new there is a need to develop stronger understandings of what is involved with this approach before we can think about progress. This is the focus of the next section of this paper. In this section, the ideas in the original "capabilities" curriculum initiative are represented in a slightly different way and then each capability is broken into clusters of behaviours that students might be expected to display.

The reason for representing the original capabilities slightly differently is both to emphasise the interconnectedness of the capabilities and also to emphasise their role *as ideas to think with,* rather than being things in their own right. This is an attempt to subvert the tendency for new ideas in education to be quickly changed into little more than slogans that require little thought—not to add confusion.

1 See, for example, Rutherford & Ahlgren, 1990; Osborne, Collins, Ratcliffe, & Duschl, 2001.

Developing capabilities to engage with the practices of science

Figure 1 presents a model of the capabilities required for engaging with science.

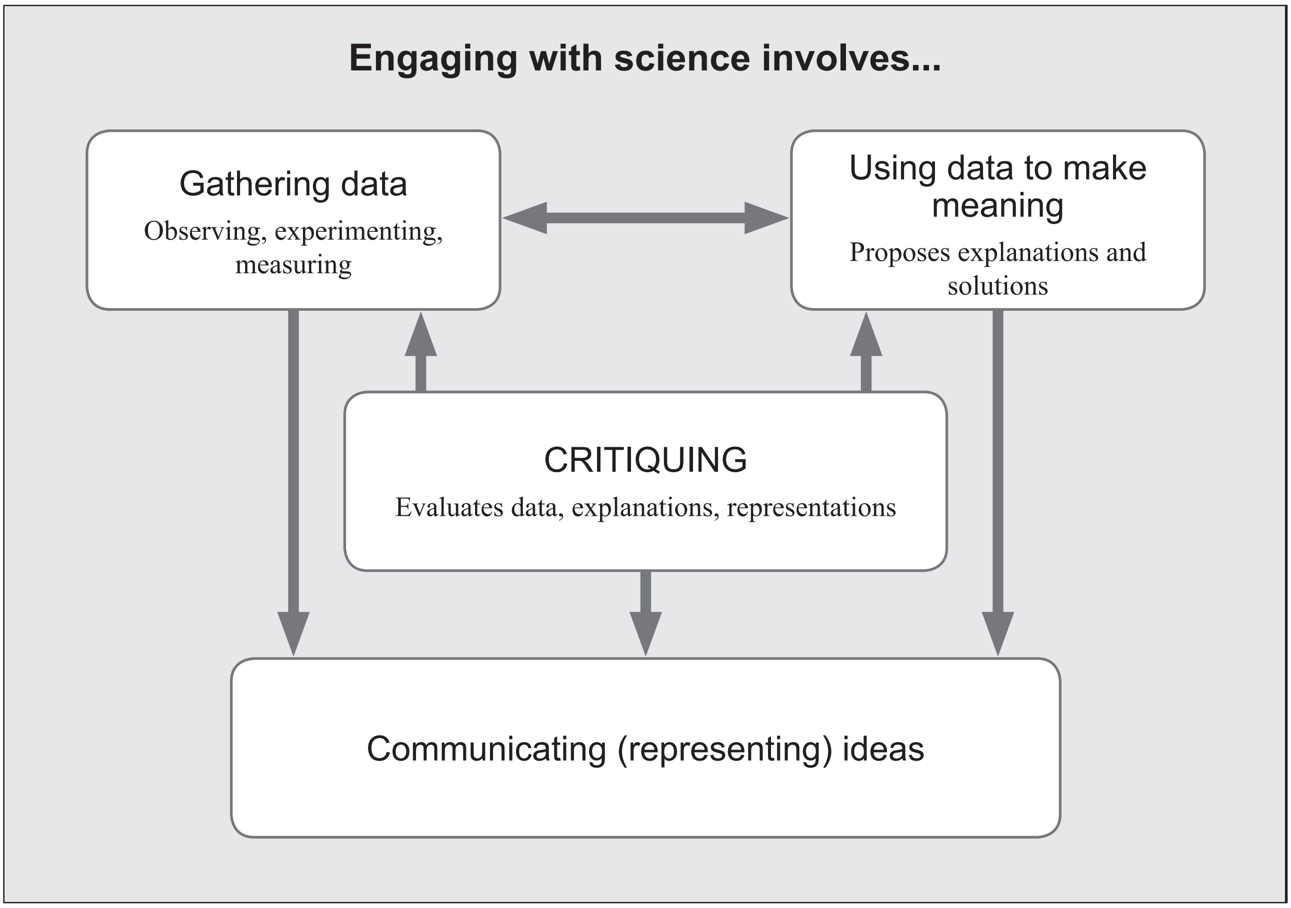


Figure 1: **Model of science capabilities**

Note: This diagram is adapted from the model of scientific activity in the *Framework for K–12 Science Education* (National Research Council, 2012).

In Figure 1, the capability that involves critiquing evidence is in the centre to reinforce the central role of critique in scientific practices. Osborne (2014) argues that engaging students in critique not only enhances their understanding of how knowledge is created in science but also enhances students' conceptual knowledge of science. Thus by engaging in the skills of critique and evaluation students are experiencing what it is like to *do* science and are also engaging in powerful pedagogical practices *for learning* science. This is a strong argument for developing evaluative skills as a key aspect of science education although research suggests that this is not currently common practice. Osborne (2014) quotes research by Weiss et al. (2003) that found only 14 percent of science lessons in the United States included constructive criticism and challenging ideas.

Students should be encouraged to evaluate the robustness of data, the meaning that is made from the data, and the ways that data are represented—hence the arrows to the other boxes in the diagram. The box in the top left, "gathering data", deals primarily with the real world while the box in the top right deals primarily with ideas. They are closely inter-connected. The ability to communicate is also important regardless of whether a student is gathering data, building explanations or evaluating. If students are *choosing* to *use* their knowledge of scientific practices in a range of contexts, then they could be considered to be engaging with science (the fifth capability).

Identifying components of capabilities

At the risk of losing the holistic nature of capabilities, each one is now split into components. The intent here is to produce something that is sufficiently fine-grained to be useful for teachers, but, given the complexity of capabilities, the risk is that by doing this the big picture is lost. These lists of components are provisional and were generated from the assessment tasks in the resources from the original capabilities curriculum initiative and from analysing student responses to these (and similar) tasks. These provisional lists also take into consideration *New Zealand Curriculum* science exemplars[2] that were designed to support the previous curriculum and the "crosscutting concepts" from the American *Next Generation Science Standards*.[3]

The student responses were generated as part of a small research project. Two researchers worked with groups of students from Years 1–10 (ages 5 to 15) in a range of New Zealand schools. Students completed a range of tasks such as:

- making observations and inferences from photos
- closely observing a burning candle and talking about their observations
- observing and drawing a shell
- drawing an explanatory picture to show how we see a tree in daylight
- deciding whether statements about floating and sinking were true or false and giving reasons for their answers
- sorting fruit and vegetables into categories.

Some activities were carried out with all age groups—others with only some groups. Sessions were audio-recorded and any written work and diagrams students produced were also collected.

The components listed in the boxes below are an initial attempt to specify some of the behaviours teachers could encourage in their students in order to support the development of their capabilities to engage with the practices of science. How useful these lists are to teachers is yet to be tested.

2 See http://www.tki.org.nz/r/assessment/exemplars/sci/matrices/index_e.html

3 For more information, see http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

Gathering data: What's involved?

Makes quality observations

Takes time, observes from different angles. Uses all appropriate senses when making observations.

Observations are focused and detailed; e.g., if observing a candle, the student does not comment on the patterns of the plate it is sitting on but does notice a little bump on the side of the candle.

Notices the components of what is being observed even if they do not know the names; e.g., if observing a candle the student notices the wick but calls it the string thing.

Notices attributes; e.g., size, colour, shape.

Observations are measurable.

Makes accurate measurement of things they are observing.

Notices changes; e.g., if observing a candle, the student notices smoke rising, flame changing size, the wax melting, and so on.

Notices patterns or relationships; e.g., the flame got higher when the door was opened.

Notices patterns in charts and graphs as well as in observations of the "real" world.

Asks questions

Asks questions based on their observations.

Develops questions that can be investigated.

Designs investigations.

Using data to make meaning: What's involved?

Attempts to work out how or why things happen.

Uses observations to support ideas; e.g., "I think ... because I saw...".

Considers all available data and uses what is relevant.

Uses patterns in data to support their ideas; e.g., "I think the wind makes the flame go higher because whenever the door opened the flame went higher".

Makes links to prior experiences to make sense of observations.

Attempts to use science ideas to make sense of their observations.

Uses "correct" science ideas to make sense of their observations.

Is willing to consider other possible explanations.

Builds on others' ideas.

Communicating ideas: What's involved?

Language

Uses precise, unambiguous language when describing observations; e.g., when observing a candle, uses objective descriptions such as "The flame is orange" not "The flame is pretty".

Uses context specific words; e.g., if observing a candle, the student uses vocabulary such as wax, wick, flame, burning, melting, and so on.

Uses words such as *maybe* or a tentative tone when proposing new ideas.

When posing explanations, uses cause and effect words such as *because, as, since*.

Use analogies to explain ideas; e.g., The heart is like a pump.

Includes scientific vocabulary.

Visual representations

Observational drawings focus on communicating salient features and include only what is observed; e.g., if drawing a flower, student does not include a smiley face on the flower.

Observational drawings, charts, graphs and diagrams include labels.

Observational drawings give a sense of scale/ proportion.

Constructs charts and graphs to show patterns.

Explanatory diagrams identify relevant features and show relationships between them; e.g., a diagram that explains how we see a tree in the day time would show a light source, the tree, the eye, the brain, and how light travels between these things.

Uses scientific conventions when labelling observational drawings, charts and graphs; e.g., connects labels with straight lines to relevant parts of drawing, uses titles for charts and graphs.

Constructs 3D models to represent observations and explanations.

Critiquing: What's involved?

Critiquing the quality of data

Identifies the features of robust investigations; e.g., controlling variables, multiple trials.

Identifies ways of strengthening investigations.

Gives and receives feedback.

Considers feedback and changes ideas if appropriate.

When designing an investigation students consider and evaluate a range of possible approaches.

Considers risk when making decisions.

Critiquing explanations

Asks questions for clarification.

Asks *why* someone thinks something.

Differentiates between observation and inference.

Identifies which data supports a particular claim.

Seeks disconfirming evidence; e.g., if trying to decide whether the claim that "All stones sink" is true, does the student look for examples that would falsify this statement (such as pumice) rather than examples that would support it?

Identifies additional questions that need answering to be surer of claims.

Is willing to suspend judgment if thinks there is insufficient evidence; e.g., student engages with "It depends" type thinking.

Shows awareness of "confirmation bias"; i.e., that we often notice what we were expecting to see.

Takes into consideration *all* available data.

Critiquing representations

Identifies what information a particular model/representation (including diagrams) gives and what it leaves out.

Identifies in what ways different models/representations are the same or different.

Identifies the author's purpose for choosing a particular representation or model.

Identifies the strengths and weaknesses of a particular model or representation.

Thinking about progress

As we develop a stronger sense of what capability to engage with the practices of science might look like, we will be in a better position to think about what progress might look like. One approach could be to think about which behaviours students display, to what extent, and in how many contexts. Students who demonstrate *some* of these behaviours described above *to some extent* in a *limited* range of contexts could be considered to be *beginning* to develop capabilities to engage with the practices of science. Students who demonstrate *most* of these behaviours *well* in a *wide* range of contexts could be considered to be *demonstrating capability*. All other students could be considered to be *developing* capabilities. This group would include students who demonstrate:

- *some* of these behaviours *to some extent* in a *wide* range of contexts
- *some* of these behaviours *well* in a *wide* range of contexts
- *most* of these behaviours *to some extent* in a *wide* range of contexts
- *most* of these behaviours *to some extent* in a *narrow* range of contexts

If the behaviours described in the previous section were put in to a matrix, teachers could perhaps use this to record evidence of students' developing capabilities as they see them. Teachers could use some coding system to show whether these behaviours had been observed in multiple contexts—and the complexity of the behaviour displayed. Alternatively, students themselves could record their progress on the matrix and provide evidence to support their judgements.

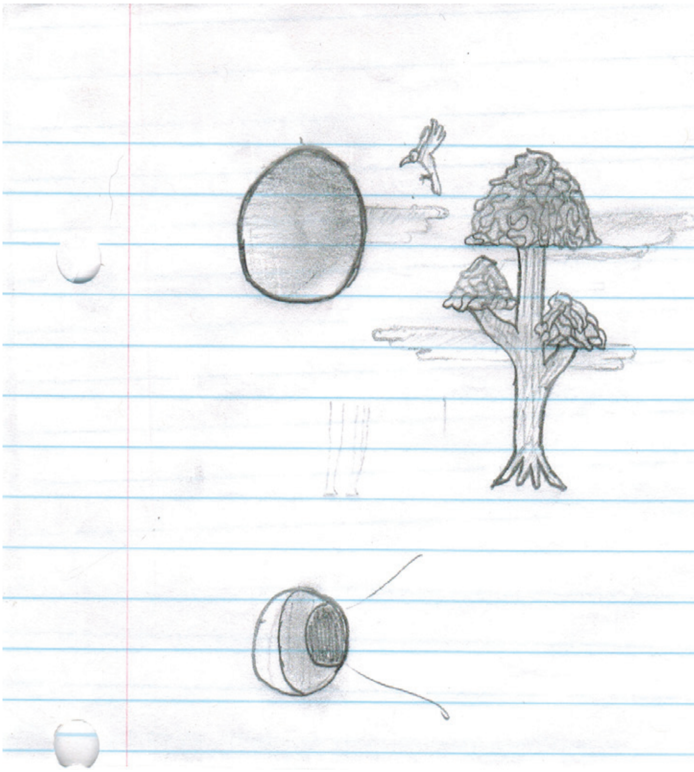
However, one of the problems with matrices is that the brevity of the statements in them often means it is hard for anyone except those who created them to make much meaning out of them. Consequently for this approach to be useful in supporting teachers' thinking, any such matrix would need to be accompanied by some exemplars to illustrate the sorts of things to look for.

Here is an example of what such exemplars might look like. In this task the student is asked to decide whether statements are true or false and to explain the reasons for her answers. The right-hand columns provide an interpretation of her responses.

STUDENT TASK			**ANALYSIS**	
Statements	**T/F**	**What makes you think so?**	**Component**	**Capability that is being built**
Heavy objects always sink.	*F*	*It depends on the liquid. What if it was a paste? Heavy things probably wouldn't sink then. Anyway big boats are heavy and they float in water.*	Considers other possibilities. Uses tentative language. Supports ideas with observations/ links to prior experiences. Provides disconfirming evidence.	Uses data to make meaning. Communicates ideas. Uses data to make meaning. Critiques explanations.
All rocks sink.	*F*	*Pumice is a type of rock and it doesn't sink. You see pumice floating at the lake.*	Provides disconfirming evidence. Supports ideas with observations/links to prior experiences.	Critiques explanation. Uses data to make meaning.
Air trapped inside things helps them float.	*T*	*An empty bottle with a lid on will float because it has air inside it. Inflatable boats float because of the air. When air is trapped in something it makes the thing less dense so that is why it floats.*	Supports ideas with observations/links to prior experiences. Draws on science ideas. Attempts to work out why something happens. Uses cause and effect words.	Uses data to make meaning. Uses data to make meaning. Uses data to make meaning. Communicates ideas.

The task itself does not assess the complexity of capability building but it does provide evidence of some behaviours that could be considered prerequisites for becoming scientifically capable. If these behaviours were repeated over time, at increasingly levels of sophistication, and in a range of contexts, the student could be considered to be making progress.

In the next example, a teacher gathers information about a student in two different ways to gain a more complex understanding of what the student can do. In this task the student was asked to draw an explanatory picture of how we see a tree in the day time. The purpose of this task was to find out how the student communicated his ideas. He identified the sun, a tree and the eye but did not include the brain. He also added a bird and some clouds—neither of which were relevant to the task. He made little attempt to show relationships between the elements except perhaps for the lines coming out of the eye.



This picture conveyed virtually no attempt to explain. However, when the student was asked to talk about his picture, the teacher was able to gather new insights, as shown in the transcript below.

Student: This is the sun and the tree and clouds. I started to draw a giraffe there but I rubbed it out because I was running out of time. The sun gives us light that helps us see because we need light to see...Your eyes aren't adapted to seeing in the dark because we are not nocturnal.

Teacher: Why can't we see when it's dark?

Student: The eye ball has layers—there's the outer—the white stuff—and then there's the pupil. The light comes into the pupil. That bit [points to diagram] is used for seeing in the dark.

Teacher: The pupil?

Student: No—the brown bit—for you it would be the blue bit.

Teacher: So the light comes into the eye from the tree?

Student: I don't know—I was just making a random guess.

When talking, this student showed a willingness to try and explain his thoughts, and attempted to use some science ideas, in a way that was not evident in his picture. This simple activity (drawing a picture and talking about it) provided evidence of some behaviours that could be considered prerequisites for becoming scientifically capable and at the same time gave the teacher a clear steer as to some next learning steps. This student was better able to communicate his thinking orally than visually although his last comment seems to imply either a lack of confidence in his own explanation—or a lack of interest in pursuing the task.

Assessment by its nature needs to be fine-grained—and capabilities are not. The approach being taken here involves making fine-grained assessments and mapping the results on to some "bigger picture" as a way of developing a sense of what progress in developing capabilities might look like. However, there are problems with this approach. What, for instance, does it mean to perform *well*? Does performing well look different for different age groups and if so how? Is it possible that for some of the components identified, for example, "engaging in close observation" performing well could look much the same for a 5-year-old and a 15-year-old and yet for other components, such as "uses precise language", performing well would look quite different?

What would science capabilities look like at different curriculum levels in *NZC?* Above Level 2 in *NZC* there is an expectation that students begin to use more scientific language and conventions but what else would differentiate the levels? Is it perhaps mainly the science content knowledge that determines the curriculum level? Is it even sensible to try and level capability development? And, perhaps most importantly, how realistic is it to expect teachers to map the progress of each child in this way?

An alternative approach could be to use the lists of "components" of capabilities and specific assessment tasks to identify next learning steps but to use a much more global approach to tracking student progress. This global approach could involve teachers making overall judgments (supported by evidence) as to how closely each student resembles an "ideal" profile.

Level 1 and 2

Is your student a lot like Izzy/quite a bit like Izzy/a little like Izzy/not at all like Izzy?

Izzy is intensely interested in trying to understand the world around her. She notices things in her environment—and changes that occur. She often talks about things she has noticed or brings interesting objects she has found into class. Her observations are detailed and focused and she notices patterns. She tries to work out what something is and how or why things happen. When doing this she uses her observations to support her ideas but also draws on previous experiences and her developing science knowledge. When trying to work something out she considers all the data she has and a range of possible explanations for what she is seeing. She works with others to build on and improve ideas. Izzy uses objective language to describe her observations. She also represents her ideas visually through drawings and diagrams.

Izzy engages in a range of science activities outside school. This includes talking with the family about science, engaging with science in the media, visiting museums and so on, reading science, and exploring the local environment.

Level 3 and 4

Is your student a lot like Hugo/quite a bit like Hugo/a little like Hugo/not at all like Hugo?

Hugo is intensely interested in trying to understand the world around him. He notices things in the natural environment—and changes that occur. He is interested in how things work and in finding out about how we know what we know. He seeks answers to his questions in a number of appropriate ways. He is familiar with standard procedures scientists use to obtain reliable and valid data such as controlling variables, making careful measurements, multiple trials, peer review and so on. He uses these to design and carry out his own investigations and to critique others'.

Hugo works with others to improve ideas. He builds on others' ideas, changes his views when appropriate and uses observations and his science knowledge to support his ideas. Hugo also uses resources such as the internet to obtain information—and checks the reliability of his source.

He critiques the quality of both data and explanations. He can differentiate between observations and inference, identify which data supports a particular claim and realises the importance of disconfirming evidence. He considers multiple possibilities and is willing to suspend judgement if there is insufficient data.

He communicates his ideas (orally and in written form) using precise, unambiguous language and includes some scientific vocabulary. He uses charts and graphs to show patterns in data and uses models (including diagrams) to explain his ideas. He uses some scientific conventions—e.g., labels, titles and so on—with visual representations. Hugo is able to compare and contrast different representations, identifying strengths and weaknesses.

Hugo engages in a range of science activities outside school. This includes talking with family about science, engaging with science in the media, visiting museums, reading science, initiating his own investigations, or involvement in environmental projects / action groups.

Level 5

Is your student a lot like Pippi/quite a bit like Pippi/a little like Pippi/not at all like Pippi?

Pippi is intensely interested in trying to understand the world around her. She is interested in how things work, and in environmental and other socio-scientific issues. Pippi is developing disciplinary knowledge of science. She appreciates science as *a* way of understanding the world and displays basic science conceptual knowledge and also an understanding of the ways in which scientists produce data that can be trusted (procedural knowledge). She also appreciates *why* such practices are necessary (epistemic knowledge).[4]

Pippi asks questions and seeks answers from a variety of sources. She checks the reliability of her sources and evaluates them carefully. When making decisions, she is willing to consider a range of possibilities and also considers risk. She can justify decisions she makes. When designing an investigation she considers and evaluates a range of possible approaches. Her data collection is systematic and accurate and she shows perseverance. She can identify ways of strengthening her and others' investigations. She gives and receives feedback and makes changes if appropriate.

She engages in critical dialogue (argumentation) with others. She uses observations and her science knowledge to support her ideas, builds on and critiques the ideas of others, and is willing to change her ideas in the face of new evidence. She can differentiate between observations and inference, identify which data supports a particular claim and realises the importance of disconfirming evidence. She considers multiple possibilities and is willing to suspend judgement if there is insufficient data. She shows awareness of confirmation bias.

She communicates her ideas (orally and in written form) using precise, unambiguous language and includes some scientific vocabulary. She uses charts and graphs to show patterns in data and uses models (including diagrams) to explain her ideas. She uses scientific conventions—for example, labels, titles, and so on—with visual representations. She is able to compare and contrast different representations, identifying strengths and weaknesses, and choose which is most appropriate for a particular purpose.

Pippi engages in a range of science activities outside school. This includes talking with family about science, engaging with science in the media, visiting museums, reading science, initiating her own investigations, or involvement in environmental projects / action groups.

These profiles may seem unrealistic, especially at Level 5, but if we really want to develop scientifically literate citizens we need to aim to do that by the end of Year 10 as science is not compulsory in NZC after that. Hopefully the high benchmarks illustrated in these profiles will provide teachers with ideas about how to further extend their students. This approach has the advantage of maintaining the holistic nature of capabilities.

Measuring progress in the development of capabilities is not easy but within our current educational paradigm, if we are serious about valuing capability development, we need to find ways of measuring progress—both for accountability reasons but more importantly to provide teachers with a sense of possible next learning steps. Finding meaningful ways of doing this is going to be largely dependent on building the capacity of teachers to think differently about science education. One way of supporting teachers could be to provide some "thinking objects" for teachers—resources that help illustrate what a change in focus might look like. In the appendix to this working paper there are a number of such resources still in a draft form. Hopefully teachers will find these useful to think with and that collectively we will be able to develop more robust understandings of what progress in building science capabilities might look like.

4 Epistemic knowledge is knowledge of the constructs and defining features of science and their role in justifying the knowledge produced by science. For more detail see the PISA assessment framework for 2015 (p. 21) at http://www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Science%20Framework%20.pdf

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Appendix

This appendix consists of a collection of “thinking objects” generated from working with students. It is intended that these “thinking objects” will be used by teachers in discussion with others to develop stronger understandings and as springboards for refocusing what they do with students.

Example 1

Here the responses of a group of 6-year-olds and 11-year-olds to the same observation task are compared. In this task the students are asked to closely observe a picture of a koura (freshwater crayfish) and describe what they notice.[5]

Suggested use of resource: In groups, compare the performance of the two groups before reading the commentary. What is common to each group? What is different?

Compare your thoughts with those expressed in the commentary. (You will notice that the commentary also includes information that you cannot access just from the transcript.)

<table>
<tr><td>Year 2</td><td>Year 7</td></tr>
<tr><td>The students describe the koura like this:

It's got little prickles on its hands. It's got a tail and the end looks like squirty seaweed. It's got things like antennae. It's got little legs that are very long and it's got 8 of them.

It's got nippers and one is black and one is light purple.

It's spiky and it's got stripes on its tail.</td><td>The students describe the koura like this:

It's a goldish yellow colour but its arms are orangey-red. It's got dots on its arms. It's got long antennae and the colour of the shell—the shell looks kind of faded and it's got lots of freckles all over it.

Its legs are skinny compared with the rest of its body. It has 6 legs and 4 claws. Its body is shaped like a hot chip. The body is covered with scales—sort of plated. It looks like it is wearing armour. It looks a bit like an insect or a long crab. It's got spiky bits around its eyes. It doesn't have eyelids. It's got orbs on the end of its tail.

The claws have got like three different parts—they are sort of segmented... and compared with the pebbles it is quite big.</td></tr>
<tr><td colspan="2">Commentary

Both groups of students took time to look closely at the picture. In both groups, the children listened to each other and built on each other's ideas. Both groups focused mainly on describing the koura rather than other objects in the picture although one of the younger students wanted to know why it was on a branch. The older group remained focused on describing their observations whereas the younger students also told stories about crayfish; e.g., "We put a crayfish we caught in a big bucket and it was trying to catch the fish and then it ate all the fish we had caught so we cut it open and fed all the fish to the kitten." (This tendency to want to tell stories was seen in several other groups of young students too.)

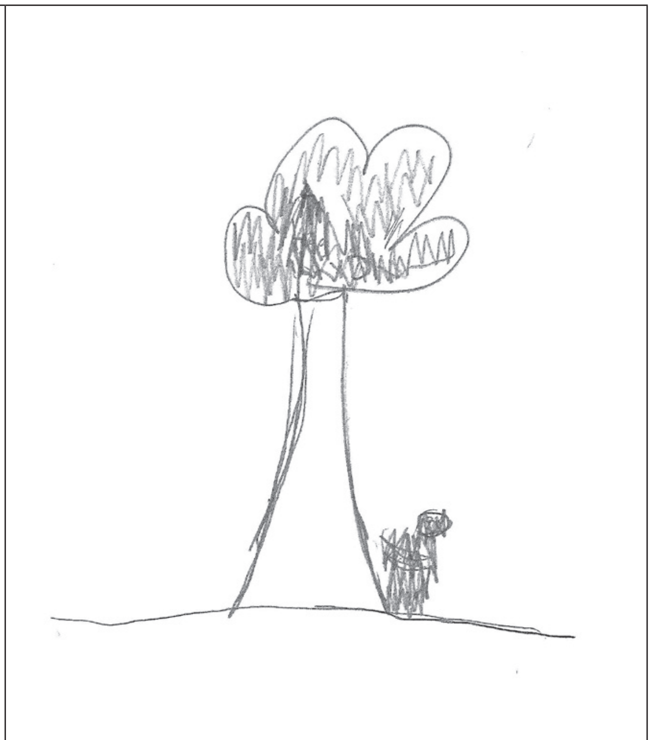
Both groups described several features of the crayfish using mainly everyday language. Both commented on attributes such as colour but the descriptions of the older group were much more detailed. The older students also likened it to other animals (perhaps an attempt at classification) and tried to give a sense of proportion (its legs are skinny compared to the rest of the body) and scale (compared with the pebbles it's quite big).</td></tr>
</table>

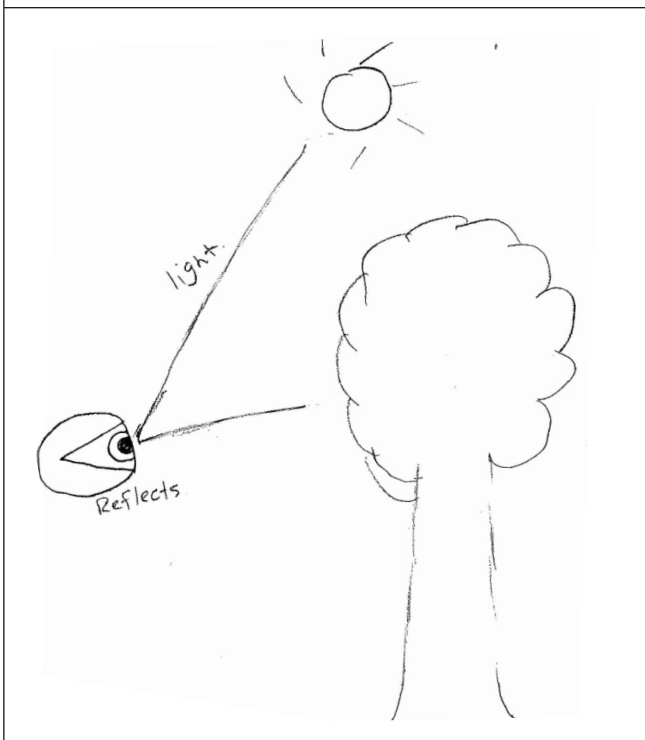
5 For more information about this task see http://scienceonline.tki.org.nz/Introducing-five-science-capabilities/Gather-interpret-data/Counting-Koura

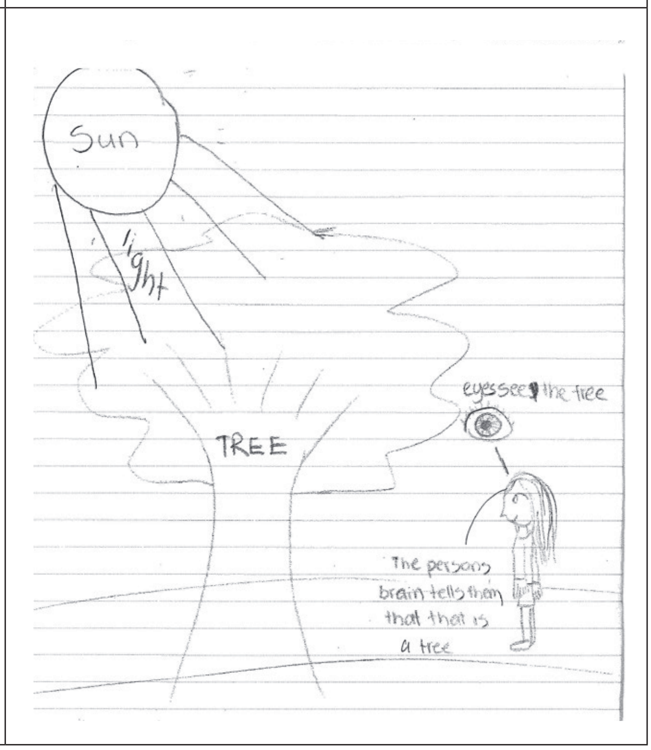
Example 2

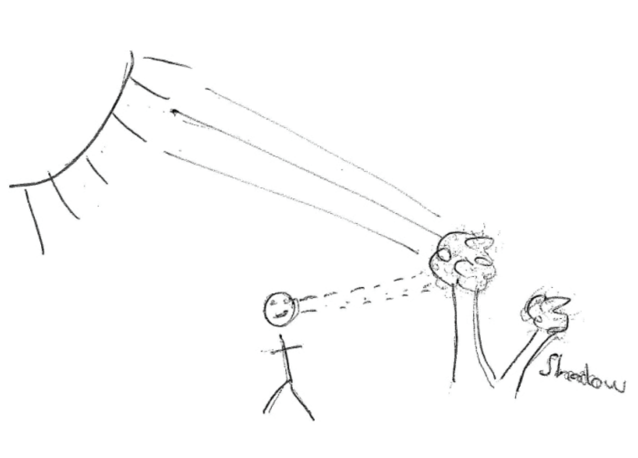
This example provides a number of responses to the task "Draw an explanatory picture to show how we see a tree in the day time". Three of the responses are analysed.

Suggested use of the resource: In groups, see if you can work out a sense of progression. What criteria did you use to sort the diagrams? You may like to use the analysed responses as a support—or you may like to compare your criteria and ways of thinking about progression with the analysed responses after you have done the exercise.





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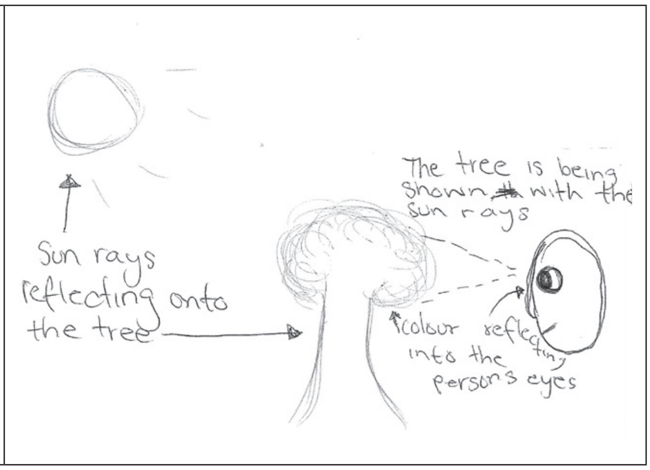
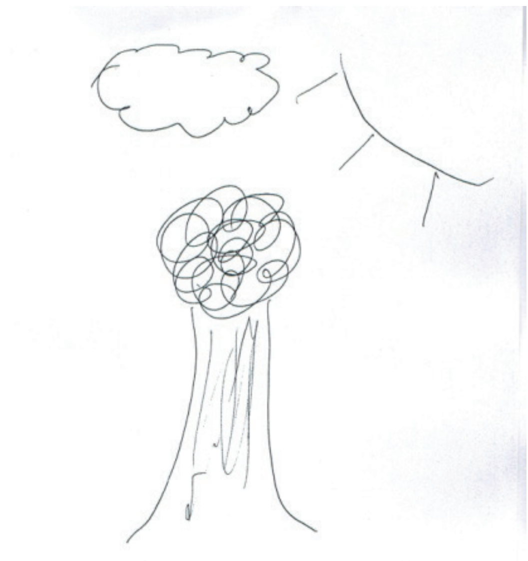

Sun rays reflecting onto the tree
The tree is being shown with the sun rays
colour reflecting into the persons eyes

Analysed responses

Student 1



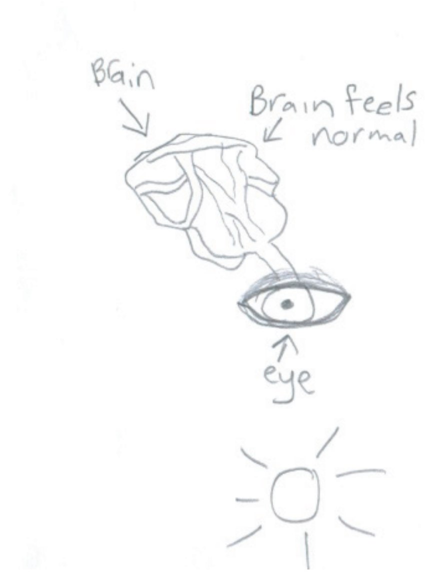
Does not identify all relevant elements.

Includes irrelevant features (cloud).

No relationship shown between things.

No attempt at explanation.

Student 2



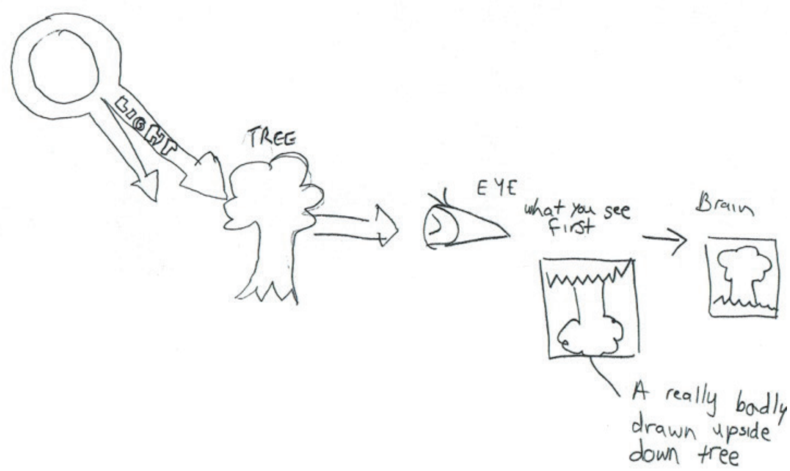
Identifies most relevant elements (tree is missing).

Connection between brain and eye shown but no other relationship.

Little attempt at explanation.

Some labels.

Student 3



Explanation uses "correct" science.

All relevant elements and relationships shown.

Labels.

Commentary

Although it is relatively easy to see some progression here in the students' ability to communicate their ideas pictorially, these pictures also serve to remind us of the multi-dimensional aspects of capabilities. Although Student 3 produced the best explanatory picture we know little about whether she could *use* either her knowledge about how diagrams are constructed, or the scientific explanation of how we see, in any other context. Hence if we want to get a sense of progress in her capability to engage with the practices of science we would want to see what she can do in different contexts.

Example 3

In this example, two groups of students (Year 2 and Year 7) were given a shell to observe closely and then asked to draw a picture of it showing what they noticed.

The majority of students in both age groups attempted to label their drawings. Interestingly there were differences in what they labelled. The older students labelled colours (the drawings were in pencil) but none of the younger students did—the younger students used labels to explain what their drawings showed; for example, bumps. One of the younger students also drew and labelled the desk the shell was on. The younger students also handled the shell much more before attempting to draw it—and focused on using all their senses.

Suggested use of the resource: Compare observational drawings from groups of students at all levels in your school? Are there age/stage-related differences in how they go about the task? If so what are these? How does the performance of your students compare with those described above?

Example 4

This transcript shows a teacher working with two Year 2 students. The students have been asked to observe closely a picture of a koura (fresh water crayfish).

Suggested use of the resource: Look at the transcript and discuss what you can tell about the capability of Student 1 (S1) to interact with science in this context before you look at the analysis provided. Did you notice similar or different things?

T: Tell me what you can see.

S1: I see prickles on its hands.

S2: It's weird that it's on a branch because normally crayfish don't go on branches.

T: So you've noticed something interesting.

S1: Maybe there was a branch that got falled in the water and it jumped on top of it.

T: Maybe...what else can you see?

S1: I see little legs that are very long. It got 8—it got 6 legs.

T: It's got 6 legs and they are very long that's …

S1: No eight. 1,2,3,4,5,6,7,8. It's got them there too.

S2: Look there are little nippers coming out of the big nippers.

T: Show me where. There? And that's what you (S1) thought were those extra legs. How would we know if they are legs or nippers?

S2: Because when they are little crabs they have little nippers like them and then they grow the big ones like those.

S1: No. Look. See there (pointing to the picture). It comes out from under there.

T: What good noticing. It does look as if it comes out from under there doesn't it?

S2: Except that one doesn't (pointing to the left one)—it comes out of the arm.

S1: Umm... No—look here.

T: You two are good lookers.

S1: My dad has caughten a crayfish before and he showed it to me and it was alive.

T: How do you think a crayfish moves? Does it walk or does it swim?

S1: It swims and when it swims it keeps its little claws out in case a fish comes and when it's not noticing it nips. And when it moves its arms and legs go like this (gestures) in the water.

T: What makes you think its arms and legs go like that in the water?

S1: Because my dad has caught one when we went to Tauranga.

T: So you have seen one moving?

S1: We put it in a big bucket and it was trying to swim to catch the fish and then it ate all the fish we had catched so we cut it open and fed all the fish to the kitten.

> **Analysis of capability of Student 1**
>
> She is able to observe closely and notice details.
>
> She listens to others' ideas and builds on them.
>
> She suggests possible reasons for things.
>
> She is able to count accurately at least to 8.
>
> Her mastery of English grammar and vocabulary is still developing.
>
> Although she initially focuses on describing details she notices, at the end of the transcript the child begins to tell a story about crayfish which obviously includes elements of fantasy.

Example 5

In this example, a group of Year 6 students have been observing the same picture of a koura. The transcription of these students talking highlights the sort of questions the teacher asks to strengthen students' capabilities.

Suggested use of this resource: Attend carefully to the questions and then record yourself asking questions with your students.

T: I want you to pretend that you were out somewhere and you found this creature. You have never seen one before and you have never seen a crayfish. How would you describe it to someone when you get back home so you can try and work out what it is? What things would you tell them about it? Now have another really good look.

S1: The back is plated over and they have two beady eyes with stuff like fur over the top of them.

S2: I'd say it had a really big plier and a big head and three parts to its body.

Encouraging more specific description.

T: Tell me more about its head. What shape is its head?

S2: Kind of pointed like a spear.

S1: Like an oval.

S3: Kind of like a rain drop.

S1 & 2: Yeah—a raindrop.

S2: It looks sort of like a crab with nippers and long legs and a mermaid's tail.

Encouraging more specific description.

T: Tell me in what ways is it like a crab and in what ways is it different because you said it is *sort of like* a crab.

S2: Crabs don't have these long tail like things and it looks like these guys go under water in caves

T: What makes you think they might go in caves?

S2: I've seen one.

T: Ok. How is it like a crab?

S2: It's got two nippers and these long hooky legs.

S3: And they have got the same sort of armour.

S2: True.

T: (To S4 who has been quiet to this point.) How would you describe it?

> Teacher invites student who has not yet participated in the discussion to join in. Note how this student builds on ideas that have been discussed by the other students.

S4: It has two long antenna and **crab like claws**—and two little claws. Six legs and **three separate parts** to the body and a head that is shaped a bit like a **raindrop**. The legs come off the middle bit and the end is the butt and the tail which is all **plated** and there is a funny little end bit to the tail that looks like hard scales. The tail looks like a **mermaid's**.

T: Ok. If you are telling me all this and I'm trying to work out what this creature is what would I want to know more about? What questions might I have? What would I want to know more about?

> Teacher setting purpose for observing closely—trying to develop a sense of what would be important to notice if you are trying to identify something.

S1: Did it attack you?

S2: Where was it?

T: Where was it? Yeah. Why would that be a good question?

> Encouraging student to explain their thinking.

S2: Because if you are trying to work out what it is you might want to know where it was because different things live in the water and on land and because you might want to know where to go to look for it.

T: What else might be helpful to know?

S4: You could ask what sort of habitat it was in.
T: Yes—that's the same sort of question isn't it—what else might I ask?

S1: Was it under water—did it have gills?

T: Oh yes...so was it under water all the time or was it coming up to breathe?

S3: Did it swim fast or slow?

T: Yes—Did you see it moving? Because do we know how it moves? I'd want to know how big it was

> Modelling important question

> Refining question

Students –Oh yeah!

S2: What colour was it?

S1: Maybe—the sound of it.

Example 6

In this example the teacher is supporting Year 7 and 8 students looking at the same koura picture to differentiate between observation and inference.

T: I want you to look carefully at this picture and describe what you can *see*.

S1: I see a koura on a floating piece of driftwood.

T: Do you know it's floating?

S1: It looks like it's floating.

T: What makes you think it is floating?

S1: Because it's from the above view so you can see it's above the water.

T: What makes you think it is water?

S1: Because of the ripples and it's sort of blurry.

T: So you can *see* slightly blurry pebbles so you are *inferring* that we are looking through water and because we said it was a freshwater crayfish before you are probably *thinking* that it will be in water. Is that right?

S2: I can see a whole lot of fish bowl pebbles. It's not like normal rocks—it's like polished pebbles

T: What makes you *think* they are polished pebbles?

S2: They look like store bought pebbles.

T: What about them makes you *think* they are store bought?

S2: They look shiny and new.

T: Tell me more—describe what you can *see.*

S3: I can see wavy lines coming off the driftwood—probably seaweed.

T: So you can *see* wavy lines and you are *inferring* it is probably seaweed.

S1: ... and the current is going that way.

T: What makes you *think* the current is going that way?

S1: Because the lines are going that way. If the current was going the other way the lines would be going the other way.

T: So what you are doing is making inferences. You are noticing something and you are thinking about what that might mean. I want you to focus on the koura and tell me what you can *see*.

S2: The claws are in different parts.

T: Tell me more.

S2: The claws have got like three different parts—they are sort of segmented.

S4: It looks like it is middle-aged to old.

T: What makes you say that?

S4: It just looks like it wouldn't be a baby one.

T: What have you noticed that makes you think it isn't a baby one?

S4: It's got bigger claws and a longer tail—it just looks older.

S2: And it's got a moustache.

S1: And compared with the pebbles it is quite big.

S3: But you don't know how big the pebbles are.

S2: It also looks like an older one because it's got long antennae and the colour of the shell—the shell looks kind of faded.

T: You *think* it's an older one because of the colour of the shell?

S1: And it's got lots of freckles all over it.

T: So you *see* the freckles and you *think* it is old?

S1: It could be—possibly.

Example 7

A small group of Year 5 and 6 students spend 10 minutes observing two unnamed substances (Demerara sugar and a margarine-like spread). In this short transcript the teacher's responses are annotated to make more explicit the role she plays in getting students to observe closely.

S1: That looks like butter but I'm not sure what that is (indicating the sugar).

S2: I think it is brown sugar that has been split apart because it usually comes in clumps.

S3: It can't be brown sugar—May be raw sugar.

> Explicit instructions: The focus is on students justifying their thoughts and working with others in the group.

T: I want you to collaborate in this—to share. If you say "I think it is such and such", it's a good idea to say why you think it is such and such because otherwise we will just go "it's this, it's this. It's this" but the really interesting thing for me is why you *think* that. That's how we go a bit deeper in our thinking.

S1: It's definitely butter.

S2: Maybe some Olivani—a spread.

> Reinforcing focus on thinking.

T: A spread? What makes you think that?

S2: It looks like a spread—you can see the density—it's pretty thick.

> Reinforcing the collaboration.

T: What do you think about what he's saying? Do you agree with him?

S3: Yeah—I think it's a spread. You can see the little lines along the top where the knife has been.

T: That's pretty careful observation. How has he been able to make this observation?

S2: By looking carefully at it. It's definitely a spread because you know when you scrape it out the knife leaves little patterns on it.

T: Is he agreeing with you then really?

S1 & S2: Yes.

> Reinforcing the importance of prior experiences when trying to make sense of something new.

T: It's interesting because what you are doing is bringing together some things about what you already know—some experience you have already had.

T: What about this one here? (indicating the sugar)

S1: I don't know what it is.

S2: It's definitely a powder. Let me have a smell.

S1: It smells weird. Coffee! Coffee!

> Emphasising observation is more than just looking. We use a range of senses—and our prior knowledge. What you already know influences what you observe.

T: Ah now we are having another sense activated here. So far you have been using your eyes and what was in your head already—now what are you using?

S2: Our sense of smell.

T: What does it smell like? Is it a pleasant smell?

S3: My aunty used to make coffee for herself. I've smelt this smell. I don't know if it was that specific smell.

> Encouraging deeper observation.

T: Ok so if you were going to take this further and use another sense, what sense do you think you could use?

S1: Taste?

S2: Maybe hear but that wouldn't work.

S3: Maybe touch.

(Sugar taken out of container—students now touching the sugar.)

S1: It's kind of sticky.

S2: It's see through. It's got a tint of brown.

Encouraging descriptive language.

T: It's got a *tint* of brown—I like that—a *tint.*

S3: It's quite thin but for a powder it's quite thick.

T: You used the word powder—what's that?

Encouraging students to pay attention to each other's ideas.

S2: It's not a powder. It's a solid but in lots of little pieces.

T: Ok so you've got a bit of a different idea from him there. He thinks it is a powder but you don't. How would you describe it?

S2: Powders are kind of pretty small and they're kind of like...mmm...how can I say this? Can I think? It's made up of a whole lot of little shapes.

T: In what ways are these two substances alike?

Probing for deeper thinking.

S2: They are both made out of atoms.

S3: Can I put my finger in both of them because I want to see if they both stick to your hand?

T: Yeah Why not? That's taking our observation a bit further.

Moving into more "active" observation. Encouraging students to initiate their own explorations

This same transcript can also give us some insights into the current capabilities of each of the three students.

All three students are already aware that observation involves using more senses than just sight.

S2 and S3 back up their ideas with evidence:

S2: *It looks like a spread—you can see the density—it's pretty thick.*

S3: *I think it's a spread. You can see the little lines along the top where the knife has been.*

S2 draws extensively on background experiences to make sense of what is being observed.

...brown sugar usually comes in clumps.

...when you scrape it out (the spread) the knife leaves patterns on it.

S2 has some scientific language (density, tint, atoms) but struggles to articulate the difference between a powder and a coarser granular material.

… powders are kind of pretty small and they're kind of like...mmm. .how can I say this? Can I think? It's made up of little shapes.

S3 also draws on background knowledge.

It can't be brown sugar...may be raw sugar.

S3 builds on others' ideas. The comment about brown sugar was disagreeing with S2's suggestion that the substance was brown sugar. S3 also followed S1's suggestion that the sugar smelt like coffee with this comment:

My aunty used to make coffee for herself. I've smelt this smell. I don't know if it was that specific smell.

S3 also displays curiosity and is keen to take the observations further.

Can I put my finger in both of them because I want to see if they both stick to your hand?