Chapter 16
Embedding Assessment Within Primary School Science: A Case Study

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The reluctance of primary school teachers to teach science in their classrooms is well documented with issues such as limited science content knowledge and low levels of confidence in teaching the subject matter cited as key deterrents. The barriers posed by these issues often result in primary school teachers implementing occasional science lessons that pique their students' interest, but not extending these lessons to promote the development of strong conceptual understandings or monitoring what learning has occurred. However, this is not the case in all primary school classrooms. This chapter documents the approach used by one teacher, Lisa (a pseudonym), to create a coherent set of science learning experiences to meet the learning needs of her students as well as piquing their interest. This case study focuses on her use of assessment. Through embedding assessment into her science teaching and learning approaches, Lisa was able to monitor the development of her students' science ideas, use evidence gathered from her students to inform her own practice and engage her students in assessment as part of their learning experience rather than the much more common approach of treating assessment as an additional or separate process. As Lisa's story unfolds over the chapter, the significant role that assessment can play in developing and strengthening science teaching and learning in primary classrooms is highlighted.

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Assessing Science Learning as a Part of Science Teaching

Assessment is a tool for monitoring and evaluating student learning, but it is the ways in which teachers use this tool that are crucial. Teachers should monitor students' developing science understandings and, based on this, provide them with opportunities, experiences and feedback that will further enhance their learning.

Leach and Scott (2002) refer to the gap existing between students' everyday views or prior understandings of science and the accepted scientific view as 'learning demand'; the greater the difference between these two ways of thinking, the greater the learning demand faced by the student. In undergoing the conceptual growth involved in changing naive existing ideas to scientific ideas, students need to also take responsibility for their own learning through being aware of their existing understandings and how these understandings can be further developed (Baird 1990; Gunstone 1994). It is this process of students monitoring their learning, with the support of their teachers, which assists in bringing about this growth.

Feedback on learning assists students in the process of closing the gap by moving them towards scientifically recognised understandings for the phenomena they are experiencing and exploring (Black et al. 2003; Cowie 2002). Teachers need to consider both how this feedback is managed and offered and how it is integrated into their teaching and learning approaches. In providing feedback on the development of students' science understandings, teachers need to be aware of the purposes for which they use assessment and how they embed assessment within their practices to best support learning.

This chapter draws from a larger study, which examined the science teaching practices of primary school teachers (Fitzgerald 2010), and focuses on one of the participating teachers: Lisa. In this chapter, we explore the ways in which Lisa embedded assessment within the teaching approaches she used to deliver a science-focused unit of work. These practices are being documented to provide some insights into the assessment strategies being used in primary school classrooms. Capturing this is important because when assessment becomes embedded in teaching and learning, it often gets lost among the general classroom goings-on and those 'outside' the immediate classroom are unable to develop a clear sense of what is being assessed and why. This chapter will focus on un-embedding Lisa's use of assessment to enable her assessment practices and the learning consequences of these to be better understood.

Lisa: A Case Study

Lisa, the teacher whose teaching is the subject of this case study, used an instructional approach structured around the 5Es model (engage, explore, explain, elaborate and evaluate). The *Primary Connections* teaching and learning programme that Lisa used in her science teaching is based on this model (Australian Academy of

Science 2007). *Primary Connections,* widely implemented in primary schools across Australia, is a unit-based programme that has been designed to support teachers in teaching science and associated literacies (Hackling and Prain 2005). This case study draws on video footage collected from Lisa's classroom over the course of the astronomy-based *Spinning in Space* unit, consisting of nine weekly lessons averaging 90 min in length. The video data were supplemented with weekly interviews with Lisa, which further explored her objectives for the lesson and her thinking behind the strategies and approaches that she used. Work samples were collected from a small focus group of her students, a volunteer group of students based on Lisa's suggestions of students who would work well together and be willing to communicate their ideas with the researcher. In this chapter, little attention is given to this data source.

This case illustrates the ways in which Lisa enacted each of the 5Es phases of inquiry over the unit. The presentation of the case study is framed by the 5Es—engage, explore, explain, elaborate and evaluate—and the data presented serve to uncover the ways in which Lisa, as the teacher, embedded assessment within her practice to support student learning.

Engage

The engage phase occurs during the first few lessons of a unit and is designed to stimulate the students' interest in a topic. The role of the teacher in this phase is to provide students with learning experience(s) that actively makes connections with their past learning experiences and elicits the students' prior knowledge and understandings of the topic (Bybee 1997). In this case, Lisa used Lesson 1 to conduct the engage phase of the 5Es model.

The *Spinning in Space* science unit fitted within the broader whole-curriculum class theme for the term, Planet Earth. As Lisa explained to her Years 3 and 4 students (aged 7–9 years), in science they would focus specifically on the relationships between the Sun, Earth and Moon and what causes day and night. In this lesson, she encouraged students to think about their own understandings and experiences of the topic. She explained: 'I wanted them to start thinking about what causes day and night, and I wanted them to start make connections about things that they see in their own life and own experiences'.

Lisa generated interest and curiosity in the topic by showing two clips of footage from *YouTube*. The first clip was a series of satellite images of Earth and the second clip used time-lapse photography to show changes to the city of Melbourne over 24 h. She was selective about her choice of footage because she wanted to engage the students, not perpetuate or develop any alternative conceptions about the topic. 'You actually have to be very selective because a lot of the videos actually show the Sun moving across the sky because that is what people want to see.' Her choice of moving images connected with ways in which the students experienced these phenomena in their lives.

Lisa used whole-class discussion to tease out an observation made by one of the students, who noticed during the time-lapse imagery that '[the city] was going from day to night' (video footage). This short interaction led to a brainstorming session about the differences between day and night. Lisa used prompts such as 'How do we know when it is day or night?' and 'What might we see if it is day or night?' (video footage). This provided all students with the opportunity to contribute their ideas (video footage).

A TWLH chart (a strategy for recording what you *t*hink you know, what you *w*ant to know, what you have *l*earnt, and *h*ow you know what you have learnt) was used by Lisa as another way of eliciting the students' ideas about the new topic. In Lesson 1, the focus for contributing to the chart was limited to the sections of the chart headed T, what the students thought they knew about the topic, and W, what they wanted to know. Below is some dialogue between Lisa and her students documenting what they thought (T) they knew about the Sun, Earth and Moon (video footage).

Teacher	What are some of the things that we think we know already about the Sun, Earth and Moon? Ben, start us off.
Ben	When the Moon is a crescent, it's in the shade.
Teacher	In the shade? Can you explain that just a little bit more, Ben?
Ben	It's in the shade of the Earth and when the Sun comes around the Earth is blocking the Moon, so it only gets a little bit of Sun and you can see a shadow.
Teacher	OK. Thank you for clarifying that for me, Ben. Great. Simon, what else do we think we know?
Simon	That the Sun and Moon travel from one side of the world to the other each time.
Teacher	OK. Interesting. Leah?
Leah	The Sun shines at day and it goes away at night.
Teacher	Thank you very much for that Leah. Andrea?
Andrea	One side of the Earth has the Sun and the other side of the Earth has the Moon.
Teacher	Great. Rachel, last one.
Rachel	When the Sun goes away, it's the Sun having a rest.
Teacher	OK.

The students also had the opportunity to pose questions about what they wanted (W) to know about this science topic. Some questions included the following: How does the Sun disappear at night? What is the Moon made of? How does the Earth spin if there is no wind or air?

Lisa involved students in creating a word wall, a strategy for brainstorming words specific to a topic. The students contributed words related to the Sun, Earth and Moon, such as 'craters', 'star' and 'gravity', as well as words not directly linked to the topic, such as 'Venus', 'aliens' and 'calculus' (video footage). Lisa entered all the students' responses into a Word document, despite the focus drifting away from the key aspects of the topic. While this session took a different path to what she expected, Lisa believed it was important for students to express their ideas and experiences during this engage lesson.

> Every child should feel that what they're saying is valued even though it may simply not be relevant. You don't want to be cutting them off in the engage lessons when you really want them involved.

Lisa revisited the word wall in Lesson 2 as a way of refocusing students' attention. They brainstormed more words related to the Sun, Earth and Moon in small groups before sharing their ideas with the whole class (video footage). This resulted in words that better reflected the topic such as 'hot', 'light' and 'gas' for the Sun; 'oxygen', 'gravity' and 'round' for the Earth; and 'phases', 'crescent' and 'craters' for the Moon (video footage).

Lisa elicited each student's existing ideas about the topic through their individual responses to a worksheet about how day and night occur and their labelled scientific diagrams showing the relationship between the Sun, Earth and Moon. The students answered three questions about day and night on the worksheet.

While this lesson was structured to engage student interest in the new science topic, interlaced throughout were assessment strategies. In particular, diagnostic assessment strategies played a particularly dominant and important role in Lisa's teaching during the early stages of this unit. It is widely recognised that students enter into science lessons with prior knowledge about the concepts to be taught (Duit and Treagust 2003). While these understandings may seem sensible and coherent to the individual, it is not uncommon for a mismatch to exist between these ideas and the views that are universally accepted by the scientific community. Lisa's use of diagnostic assessment in this lesson enabled her to generate evidence about her students' existing ideas related to this astronomy-based topic and begin to identify the existence of alternative conceptions. This gathering of information was achieved both formally, in this case through the students' responses to the worksheet, their diagrammatical representations, the TWLH chart and word wall, and informally, as evidenced by the whole-class discussions that were instigated.

A significant next step is how this diagnostic information is then used to inform the development of the unit and the scientific understandings of the students. Consistent with constructivist teaching approaches, Lisa could have used the understandings that she had had gathered from these various modes of diagnostic assessment to assist in identifying the specific learning targets for each of her students and then adapted her teaching approach to best enable her students to reach these goals. However, in reality, this is not always easy to achieve. An existing unit of work, the *Primary Connections* module, was guiding Lisa's teaching approach and the identification of individualised learning targets for 27 students is a time-consuming task. In this case, Lisa used the evidence gathered through the diagnostic assessment tasks as points of reference to be revisited over the unit, such as the TWLH chart and word wall, or to be used by herself to gauge the development of students' understandings over the unit, such as the labelled diagram and worksheet responses.

Explore

The explore phase allows teachers to provide students with hands-on experiences of the science phenomena behind the topic. The role of the teacher in this phase is to provide students with a range of shared experiences to allow the concepts and processes relevant to the unit to be identified, explored and developed (Bybee 1997). This phase involved Lessons 2–4 of Lisa's teaching and learning sequence.

Lisa used several activities in Lesson 2 to enable students to explore the relative sizes of the Sun, Earth and Moon. A think-pair-share strategy was used to promote student thinking about the types of objects that are the same shape as the Sun, Earth and Moon. The students referred to objects such as an orange, balloon and various types of balls (e.g. basketball, netball, baseball) (video footage). These ideas led to a whole-class discussion about distinguishing spheres from circles. Lisa encouraged students to share their understandings of these concepts (video footage).

Teacher	It's really hard to draw these shapes on a piece of paper. But how is a sphere different to a circle? Simon, what do you think?
Simon	It's a three-dimensional shape.
Teacher	Fantastic. Simon, what do you mean by three-dimensional?
Simon	It's sort of like a cube, but round shaped.
Teacher	OK. Thank you, Simon. Georgia, what do you think?
Georgia	Well, two-dimensional shapes are flat, but then three-dimensional they're all different shapes. They're like two-dimensional shapes that have been pumped up.
Teacher	Fantastic. That's a good explanation, Georgia. Thank you. Naomi, what would you like to add?
Naomi	With a sphere, if you put something in the middle, it should be the same distance to each edge around it.
Teacher	Wow. Thanks Naomi. Andrea?
Andrea	Mine's a bit like Georgia's. A sphere is rounded, but a circle is just flat.
Teacher	Fantastic.

Lisa showed the students three spherical objects: a peppercorn, a marble and a basketball. The students agreed in a whole-class discussion that the basketball could be used to represent the Sun, the marble the Earth and the peppercorn the Moon. Lisa turned the classes' attention to the Sun and the Moon by explaining that there is a common misconception that the Sun and the Moon are the same size as they appear to be the same size in the sky when viewed from Earth. To explore this idea, the students moved outside to complete an activity in small groups. The activity required one student to hold a tennis ball (representing the Moon), while another student holding a basketball (representing the Sun) moved away from the first student until that (first) student perceived both balls to be the same size. Lisa led a discussion following the activity to assist the students in connecting their experiences of this activity with the idea that the apparent similarity in sizes of the Sun and Moon are due to the Sun being much further in distance from Earth than the Moon.

The following dialogue captures how Lisa used questioning to assist students in making connections between the activity and the concept (video footage).

Teacher What did you notice? What did you see? Ella?

Ella When we were taking the basketball back, when the basketball looked about the same size as the tennis ball we normally stopped around the start of the cricket pitch.

Teacher OK. Fantastic. So which one was further away Ella, the tennis ball or the basketball?

Ella Basketball.

Teacher OK. Fantastic. How does this then relate to the Moon and the Sun? How does this help us understand how the Moon and Sun look about the same size?

Andrea Because the Sun is further away than the Moon and because when we did [the activity] we held the Moon and said stop when [the Sun] looked about the same size. Even though [the Sun] was further away than the Moon, it looked the same size because it is bigger.

Teacher Fantastic. So which one is bigger, Andrea?

Andrea The Sun.

Teacher Why did the Sun look about the same size [as the Moon]?

Andrea Because it was further away.

Teacher Fantastic.

The students created scale models of the Sun to further strengthen their understanding of the relative sizes of the Sun, Earth and Moon. Lisa elicited the students' personal experiences and understandings of model making before undertaking the activity. Lisa explained that 'a model is a representation of the real thing, so it's not the same size, it's a lot smaller, but it's a way to show what a car [for example] might look like' (video footage). Lisa created scale models of the Earth (1-cm-diameter circle) and the Moon (2.5-mm-diameter circle) for each group, while in small groups the students created 1-m-diameter models of the Sun. Lisa asked the students to predict how far they would need to stand apart for their Sun model to look the same size as the Moon model.

The students wrote about their experiences of these activities in their journals. Based on the students' journal entries, Lisa recognised the different connections that students made between the activities and the relative sizes of the Sun, Earth and Moon.

> There's a few in the class that sort of missed the idea, and the thing is that some of them can verbalise that to me, but they're not always able to write that. But when you look at the focus group, they've all got that idea that the basketball was further away or now they've transferred that to the Sun is much, much bigger than the Moon [due to] a much further distance.

The assessment focus shifted in this phase of the unit from determining what the students know about the science concepts as the topic is begun to developing an understanding of how their ideas are forming during the learning process. To assist in this process, Lisa engaged her students in a number of activities that continued to move their understandings towards the scientific explanations for the phenomena under study. Formative assessment practices, as they were used in this instance, are inherently part of the instructional process. Therefore, the ways in which these teaching and learning sequences were structured enabled Lisa to gather information about how her students' understandings were developing.

As seen with Lisa's use of diagnostic assessment, the gathering of formative information from students played out in formal and informal ways. This notion that the formative assessment used by teachers can be categorised as formal or informal has been explored and described by Cowie and Bell (1999) using the terms 'planned' or 'interactive' (p. 102). They argue that planned formative assessment occurs when the teacher decides what will happen before the lesson starts, whereas interactive formative assessment occurs when the teacher responds spontaneously as opportunities arise. Over the three 'explore' lessons, the planned formative assessment included students completing journal entries, participating in modelling activities and contributing to the TWLH chart. The products provided Lisa with concrete examples of her students' understandings. In developing these products, students were provided with the opportunity to reflect on and articulate their understandings.

An important aspect of formative assessment is that students are involved in this process to ensure that they are also informed about the development of their own understandings (Black et al. 2003). In this phase of the unit, this was probably most recognisable in the completion of the TWLH chart in Lesson 4, where the students were able to identify what they had learnt over the previous lessons and what evidence they had to support that they had learnt those ideas. Two students explained to the class what they had learnt about shadows and how they knew this (video footage).

Teacher What is something that we have learnt (L)? Think back to the activities we have done. Rachel, what's something we have learnt?

Rachel We learnt about day and night.

Teacher What about day and night? You need to be more specific.

Rachel How it's dark at night and light in the day.

Teacher How do we know that Rachel?

Rachel Umm.

Teacher How (H) do you know when it's day and night? Which of our senses do we use?

Rachel Because when it's night, we can't see many things because it is dark and in day, you can see lots of things.

Teacher Well done. Excellent. Brilliant. And I like how people are matching up what they've learnt with some observation or some activity that we've done that helps them to know that.

Interactive formative assessment took place over the three lessons mainly through the opportunities that Lisa and her students had to engage in discussion, which allowed students to express their science understandings and opened up avenues for Lisa to recognise and respond to their ideas. With the goal of formative assessment essentially being to gain an understanding of what students know and do not know in order to adapt teaching and learning appropriately, techniques not commonly viewed as assessment tools such as teacher observations and classroom discussion have a particularly important place in this process (Boston 2002). While it is evident that Lisa did draw upon a range of formal/planned and informal/interactive procedures to inform the formative assessment process, what was not clear was exactly how she used this information to modify her practices over these lessons to assist and enhance student learning in science.

Explain

The explain phase requires students to discuss and develop explanations of the scientific phenomenon they are encountering to make sense of their observations and experiences. The role of the teacher in this phase is to provide students with opportunities to represent their conceptual understandings and ensure that they are aligned with current scientific understandings (Bybee 1997). Lisa used Lesson 5 to conduct the explain phase of the 5Es model, providing the students with learning experiences that introduced them to the current scientific views about what causes day and night and supporting them to represent their understanding through creating and performing a role-play (video footage). Her focus was for students to recognise that day and night were caused by the Earth rotating on its axis.

Lisa used five different demonstrations to represent how day and night occur. She believed that it was important that several examples were provided to support the development of students' understandings of the scientific explanation for how day and night occur:

> I really had to get across that idea that it was the Earth moving and not the Sun because a lot of them still had that idea that it was the Sun that was moving across the sky. And the Sun does appear to move across the sky, but that's because the Earth's rotating. I just wanted to make sure because we were in that explain phase that I was very clear that that was what was actually happening.

First, using a basketball to represent the Earth with a small wooden stick attached as an object on the Earth and a torch to represent the Sun, Lisa asked the students to share their observations of what happens to the shadow of the stick as the Earth rotates. The students noticed that the shadow was moving and Lisa reiterated that as the Earth moves, so do the shadows being formed on the Earth, while the Sun stays in the same position (video footage).

Second, Lisa asked a student to represent the spinning Earth by spinning around in front of the data projector, which represented the Sun. As the student rotated around, Lisa asked the class several questions related to what they observed happening (video footage).

Teacher Now pretend that Keisha is the Earth and the data projector is the Sun. As Keisha starts to rotate, what do you notice about Keisha as she is rotating slowly? What parts of her are in the light? What parts of her are in the dark? Georgia, tell me, what do you notice?

Georgia The light is shining on her.
Teacher Where exactly is light shining? Would someone else like to add to that? Andrea?
Andrea When she turns around, the dark side is always opposite her because it's not facing the data projector. So if she was the Earth, one half would be like a shadow on the Earth.
Teacher Excellent. As Keisha is standing now, which part of her is in the light? And you can all see this, so I should see all hands-up. Dana?
Dana Her back.
Teacher Which part of Keisha is in the shadow or hasn't got light shining on her? Leah?
Leah Her face.
Teacher Fantastic.

Third, Lisa added three more students to this model. The four students formed a circle and rotated around in front of the projector. Again, Lisa asked the rest of the class to respond to questions, such as 'When do the students start to come into or go out of the light?' (video footage). To create a more direct link to the occurrence of day and night, Lisa then connected this model to the Sun (data projector light) and the Earth (the ring of four students) by asking the students to identify which parts of the Earth were experiencing day and night. After repeating this line of questioning several times, Lisa asked the students to explain why they thought those parts of the Earth were experiencing day and night. Fourth, Lisa showed the students a clip from *YouTube* based on time-lapse footage from the space station Galileo showing the Earth rotating around its axis. After watching this clip, Lisa provided the students with the opportunity to share their observations with the class. She also used questioning to elicit what the students knew about how long it takes the Earth to rotate once on its axis (i.e. daily) and once around the Sun (i.e. yearly). Finally, Lisa used three student volunteers to demonstrate the movements of the Sun, Earth and the Moon. Lisa asked the student representing the Sun to remain still, while the student representing the Earth rotated around while moving around the Sun. She then added the student representing the Moon, who moved around the Earth.

Following this teacher-led modelling, Lisa provided students with the opportunity to explain their understandings of how day and night occurred by creating their own role-plays, which they performed for the class. Lisa felt that this activity was an effective way for the students to show their understandings of the phenomena being studied.

> It worked really well and [despite] the low literacy level of a lot of the kids actually doing it, the role-play was really good. I'd use it again, especially like I said [with] the low literacy levels in the classroom it's a good way, a different way for [the students] to explain their science without having to write it down.

However, as the students performed their role-plays, Lisa noted some confusion among the groups regarding the role of the Moon in causing day and night. For example, one group explained 'when the Moon is on one part of the Earth, it's night time [and] on the opposite side, the Sun is shining so it's daytime' (video footage).

Another group explained ‘day is made by the Sun shining on the Earth, but when the Moon comes to this side and blocks the Sun’s light on the Earth that makes night time’ (video footage). Lisa addressed this issue by again modelling how day and night occur using a torch (Sun), globe (Earth) and a tennis ball (Moon). She did explain that sometimes the Moon does block the Sun’s light from reaching Earth, which is known as an eclipse. Lisa believed, in hindsight, she should have left the Moon out of the role-play to lessen the conceptual confusion of the students.

> Unfortunately, I should have left the Moon right out of it because then they got that idea that the Moon was causing the day and the night. But I think by following that up at the end, talking about that idea of the eclipse rather than day and night really helped. [However] when I went around and was reading their responses to what causes day and night, [some of the students] still had [the notion] that the Moon causes day and night.

This phase of the unit also included the use of formative assessment to monitor and provide feedback on the ongoing development of the students’ ideas. However, in contrast to the previous sequence of lessons, Lisa was now more intent on students’ developing and representing strong conceptual understandings that were aligned with current scientific explanations of the astronomy-based phenomena being studied. Again, a structured sequence of activities was implemented; in this case, a set of demonstrations and a series of role-plays, which enabled Lisa to gather some planned formative information. Information through the more informal mode of interactive formative assessment was also gathered from the student group through discussions that took place around the set of demonstrations that Lisa orchestrated, the *YouTube* clip that was shown and the role-plays performed by small groups of the students. Resulting from this array of information was Lisa’s realisation that an alternative conception had formed in the students’ understandings regarding how day and night occur.

In effectively using formative assessment to improve student learning, it is important that feedback is given promptly to enable students to take account of it in their learning (Scottish Qualifications Authority 2009). By doing this quickly, students are motivated to make changes to their understanding while it still holds meaning to them. Lisa was able to react instantly as part of her response to the students’ role-play performances through an additional teaching sequence. In this instance, Lisa’s rich science pedagogical content knowledge enabled her to recognise students’ stages of conceptual development and respond in ways that supported their conceptual growth and change.

Elaborate

The elaborate phase focuses on students planning and conducting an investigation as a way of applying and extending their conceptual understandings in a new context. The role of the teacher is to challenge the students’ conceptual understandings by providing new experiences in which the students can develop a broader understanding of the science phenomena under examination (Bybee 1997). This phase involved

Lessons 6 and 7 of Lisa's sequence, during which Lisa provided students with the opportunity to conduct an investigation which examined two questions: 'What happens to the length and direction of shadows during the day?' and 'When are the shadows the longest and the shortest?' These questions were designed to assist students in applying and further developing their understandings of the ways in which the Earth moves in relation to the Sun and how this causes day and night.

Lisa worked with the students in a step-by-step approach to plan the investigation (video footage). She informed the students of the variables they would change (the time of the day) and measure (shadow length and direction). The students were provided with an investigation planner, one of the resources included in the *Spinning in Space* module, and used this to individually record a prediction about what they thought they would find out from the investigation, identify the variables that needed to be kept the same during the investigation and respond to the question, 'How are you going to keep it a fair test?' Lisa explained how the equipment associated with this investigation would be set up by sketching a diagram on the board. The class then moved outside onto the school oval where Lisa modelled how the equipment would be used and demonstrated how the students would record their findings over the day. In small groups, the students set up their shadow-stick investigation. They conducted their investigation by recording the length and position of the shadow cast by the stick at hourly intervals from 10 am to 3 pm.

The students shared their observations of the shadow-stick investigation with the class in the following lesson. Lisa used questioning to further elicit their observations and understandings of how the shadow was formed (video footage).

Teacher What did you notice happening with the shadows during the day yesterday? What did you see? Ewan, what did you see?
Ewan The shadows kept moving anti-clockwise.
Teacher OK. What did you notice happening, Leah?
Leah Well, when the Earth spins …
Teacher No. I don't want explanations. I want to know what you saw.
Leah Well, the shadows were moving around.
Teacher What else did you notice about the shadows during the day? Joseph?
Joseph They got smaller.
Teacher The shadows got smaller. You saw them getting smaller. What else did people see? Ella?
Ella I saw them getting bigger.
Teacher You saw them getting bigger as well. Michael, what did you see?
Michael I saw them move in a different direction to where the Sun was.
Teacher Fantastic observation, Michael. Rachel?
Rachel The shadows moved to the left.
Teacher Fantastic. Why do we get those shadows? How were the shadows being formed? Imogen?
Imogen The Sun was on this side and the pencil was in the middle and on the other side the shadow was formed.
Teacher And why is that shadow formed Imogen? Can you explain that for me?

Imogen Ah, because the pencil is in the way of the Sun.
Teacher And so the pencil is doing what to the light to get a shadow?
Imogen Blocking it.
Teacher Good work, Imogen. Excellent answer.

The interpretation of the data and overall evaluation of the investigation was based on questions outlined in the investigation planner (e.g. What happened to the direction of the shadow during the day? What challenges did you experience doing this investigation?). Initially, the students participated in a whole-class discussion focused on assisting them in evaluating their investigation, particularly some of the challenges they faced, because Lisa found that the students experienced difficulty in this area. The students then worked in small groups to discuss their data in relation to six questions. The dialogue below captures how one group of students interpreted aspects of their data. During this dialogue, Lisa entered the discussion and used questioning to monitor the students' understandings of the key conceptual areas (video footage).

Teacher Why did the shadow change?
Ella Because the Earth rotates, so the Sun is pointing from a different direction to make the shadow.
Teacher So what is moving? The Earth or the Sun?
All The Earth.
Teacher So why is the Sun in different positions in the sky?
David It's not really in different positions in the sky, it just looks like it's in different positions.
Michael The Earth is spinning.
Teacher That's right. Because we are moving, the Sun appears in different positions in the sky. Great. It actually does look like that David because in the morning it's over here (pointing to the East), lunchtime it is up there (pointing to the zenith) and in the afternoon it's over there (pointing to the West). So it is in a different position because of the Earth's rotation. OK, go on. What's your next one? What happened to the direction of the shadow during the day?
Ella It changed in an anti-clockwise direction. It moved in an anti-clockwise direction.
Teacher OK, great.
David And it changed by moving to the left.
Teacher OK, good. What happened to the position of the Sun during the day?
Georgia It's moved!
Ella It looked like it moved, but it was actually our Earth rotating.
David Well, let's just say, it didn't move, it just looks like it did.

This phase of the unit had two objectives: to extend the students' conceptual understandings of the topic being studied and to evaluate their investigative skills. In assessing student achievement across these dual-purpose lessons, Lisa drew on both formative and summative assessment practices. For example, as in previous lessons, Lisa integrated both planned and interactive modes of formative assessment into her teaching and learning approach. In this instance, the planned was made up of individuals' responses to a set of predetermined questions, and the interactive occurred through Lisa's monitoring of the small group discussions that were encouraged to tease out ideas linked to these questions. In contrast to the explain phase, Lisa's use of this information seemed more focused on further clarifying and reinforcing the students' conceptual understandings in preparation for the final evaluative phase of the unit than on determining how her future lessons needed to be modified to address gaps in learning. Therefore, her use of formative assessment was applied differently to the ways in which it is usually envisaged.

The use of summative assessment in this lesson connects to a more formal process of recognising the students' achievement of the investigating outcomes. This process resulted in the production of a final product from each student, which consisted of his or her responses on the investigation planner. While Lisa used this information to gain insights into the level of each individual's investigative skills, it is difficult to capture an overall sense of individual achievement of investigative outcomes through this type of product, which was completed as part of small group work and involved skills that were examined over a short period of time. It needs to be recognised that the students would have been developing their science investigating skills over the whole course of their primary education to this time (the previous 3–4 years). Therefore, Lisa's use of summative assessment in this case is an example of being provided with a snapshot of an individual's learning at a particular point in time (Garrison et al. 2009).

Evaluate

The evaluate phase provides students with the opportunity to reflect on their learning experiences over the unit by creating a product that represents their conceptual understandings. The role of the teacher is to encourage students to express their understandings and to create an appropriate opportunity from which to assess student progress over the unit (Bybee 1997). The evaluate phase involved Lessons 8 and 9 of Lisa's teaching and learning sequence, in which students created a poster (Lesson 8) and presented it to their peers (Lesson 9) (video footage). Lisa used an assessment rubric to provide scaffolding for what science information students would need to include on their posters. Lisa invited the students to use their experiences of creating posters to add other criteria to the rubric. Through a whole-class discussion, the students added Presentation, Titles and Spelling as additional areas to be assessed. As part of their poster, the students were required to include their understandings of the sizes, shapes, positions and movements of the Sun, Earth and Moon.

The TWLH chart was also revisited in Lesson 8 to enable students to reflect on what they had learnt (L) from the *Spinning in Space* topic so far and what evidence they had to demonstrate how (H) they developed this understanding. The following dialogue captures how students explained to the class what they had learnt about day and night and what evidence they had to support how they knew this (video footage).

Teacher	What can we add to our TWLH [chart]? What is something else that we have learnt? Ruby?
Ruby	When one side of the Earth is facing the Sun, it is day.
Teacher	So what would be the point that would lead from that? If one side is facing the Sun and that is daytime, what then goes with that? Ella?
Ella	The side that is not facing the Sun is called night time.
Teacher	Excellent. What evidence or what have we seen in the classroom to know that? We know from our own experiences, but what evidence have we seen in the classroom to help us understand that? We've done a couple of things to help us with that. Ben, what was one of those things?
Ben	The light through the windows.
Teacher	Yes, we can see that. But what activities have we done in the classroom to help us understand that day and night occurs? Leah?
Leah	When the people stood in front of the data projector and we could see them coming in and out of the light as they spun around.
Teacher	Excellent. One of our role-plays. Great what other role-plays did we do to help us understand about day and night? Michael?
Michael	We did a role-play where we had to explain how day and night occur.
Teacher	Fantastic. OK, is there anything else that we want to add? Actually, there was something that we did to help us with day and night. What other evidence have we looked at? We looked at it last week. Andrea?
Andrea	Images.
Teacher	That's right. We have also looked at images from space. And this leads back to what we talked about yesterday, different ways of learning. We've used the role-plays to help us, we've used pictures to help us.

Students presented their finished posters to their peers in Lesson 9 (video footage). The students were each given one minute to explain their posters to a small group of their peers. Lisa deliberately chose not to assess the students on their presentation skills, focusing instead on the conceptual understandings that were evident in the poster:

> I'm not going to have an assessment rubric on the presentation as such because we do, do a lot of assessing with their listening and speaking with their news. But because they're trying to explain their science, I don't want them actually worrying about anything else. I want them to concentrate on telling each other about the science.

This final phase of the unit provided students with the opportunity to represent their learning over the course of the unit and as a formal summative process enabled Lisa to identify what each student had achieved and what conceptual understandings had and had not been acquired. To begin this process, the TWLH chart was revisited. The completion of this activity provided an opportunity for students to share what they had collectively achieved in this science unit. This information also acted as a reminder of what had been covered over the unit and was used by students to inform the creation of their own individual summative piece of work. While the notion of individual summative assessment can provoke anxiety in some students (National Centre for Fair and Open Testing 1999), Lisa adopted several strategies that acted to keep adverse effects to a minimum. The production of a poster as a means of showing what had been learnt was considered by students to be an enjoyable task and also provided them with some flexibility and choice in the ways they presented their learning. The negotiation between Lisa and her students about what should be included in the marking rubric also engaged students in the summative process as their opinions about what mattered, in terms of how their posters would be assessed by her, were valued. Finally, the poster presentations, which were not assessed, provided the opportunity for students to showcase their work, and ultimately their learning across the unit, to their peers in ways that were nonthreatening and celebratory.

In the final lesson of the unit, it became evident that Lisa thought of summative assessment as a two-way process when she finished the lesson and the unit by asking students to reflect on their learning experiences using a PMI chart (i.e. a strategy for recording *P*ositives, *M*inuses and *I*nteresting things). She highlighted the importance of thinking carefully and identifying at least three points for each area. Lisa had found in the past that students had difficulty reflecting on their learning and, in particular, identifying minuses.

> The thing is [that] they always associate the minus [section] with bad and getting into trouble, and I think that's just a logical progression. Whereas, [I'm] trying to get them around to see that the minuses actually help us learn and help us do it better for next time.

The opportunity that she provided students through the PMI chart strategy was essentially summative feedback for her that took into account student opinions of the unit and how it supported their learning in science. This information was invaluable to Lisa and her teaching practice but also engaged students in the process of thinking critically about their own learning in science. Therefore, Lisa's approach to summative assessment not only provided her with information about student learning over the unit but also identified what helped, what did not and what improvements could be made to better support student learning in the future.

Using Assessment to Support Student Understanding in Science

Constructivist approaches to teaching and learning emphasise the influence of learners' prior experiences on the ways their understandings are constructed from new experiences or information (Fensham et al. 1994). Conceptual change models for teaching science seek to examine students' existing ideas about particular science phenomena before engaging them in different learning experiences. These approaches are focused on challenging existing ideas and developing understandings more closely aligned to currently accepted scientific views (e.g. Scott et al. 1992; for a perspective written specifically for intending and practising primary science teachers, see Skamp 2008). Assessment plays a key role in identifying these ideas and monitoring how understandings develop.

The level of conceptual change, or learning demand, required over the *Spinning in Space* unit of course varied from student to student. For example, the focus group students explained that many of the science phenomena introduced in the unit were not new to them (video footage). Therefore, the shifts required in their thinking may not have been significant. However, this clearly was not the case for all students. For example, Rebecca explained in Lesson 1 that day changed into night because 'the Sun [has] a rest' (video footage). While the amount of conceptual change required may have differed from student to student, each was individually supported by Lisa through the multiple opportunities she embedded within her teaching practice that enabled her to monitor students' learning and provide feedback on their progress.

Lisa's use of an inquiry-based approach allowed her to embed diagnostic, formative and summative assessment techniques into her ways of teaching as well as into her students' learning (Australian Academy of Science 2007). Evidence of these three types of assessment being used as part of Lisa's repertoire is highlighted within the case study. However, perhaps most notable was Lisa's use of formative assessment, particularly during the explore, explain and elaborate phases of the *Spinning in Space* unit, to monitor and provide feedback on the development of students' conceptual understandings.

This case study of Lisa's science teaching and learning approach with a particular focus on her embedded use of assessment is an example of the ways in which expert teachers use assessment as a pedagogical tool to foster student learning. By actively monitoring students' science understandings and providing appropriate feedback on the development of these understandings through embedding assessment within teaching approaches, teachers can better support their students' learning in science. A central issue in raising the quality of science learning and teaching, in all primary, secondary and tertiary classrooms, is finding ways to help many more teachers develop the knowledge, skills and confidence to use assessment in this highly engaging and positive way (see Nilsson and Loughran, this volume).

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