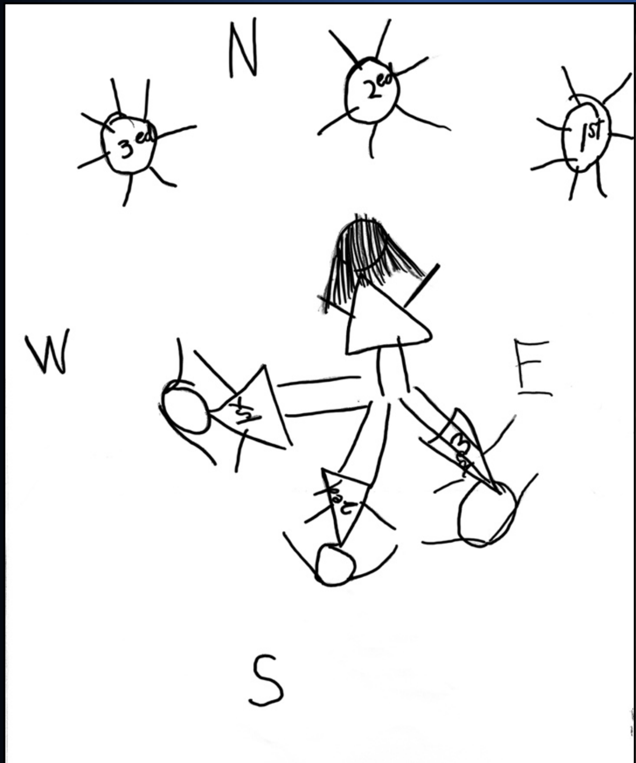
Astronomy – Day and Night
Year 1



IMS LEARNING

Students map their shadows across the day to track the path of the sun across the sky. They model the earth-sun system using a torch and shadows, earth globes and role plays, and develop an understanding about day/night and the earth's rotation. The sequence focuses on spatial relations of the sun and earth, coordinating an earth centred and space centred perspective. The mathematics involves measurement, time, direction through on-going spatial mapping, data recording and analysis, and visual representation of data. Students develop understandings of the ways science and mathematics use modelling processes to understand natural systems and mathematical patterns.

INTERDISCIPLINARY MATHEMATICS AND SCIENCE LEARNING

DEAKIN UNIVERSITY
MACQUARIE University
VANDERBILT UNIVERSITY
Australian Government
Australian Research Council

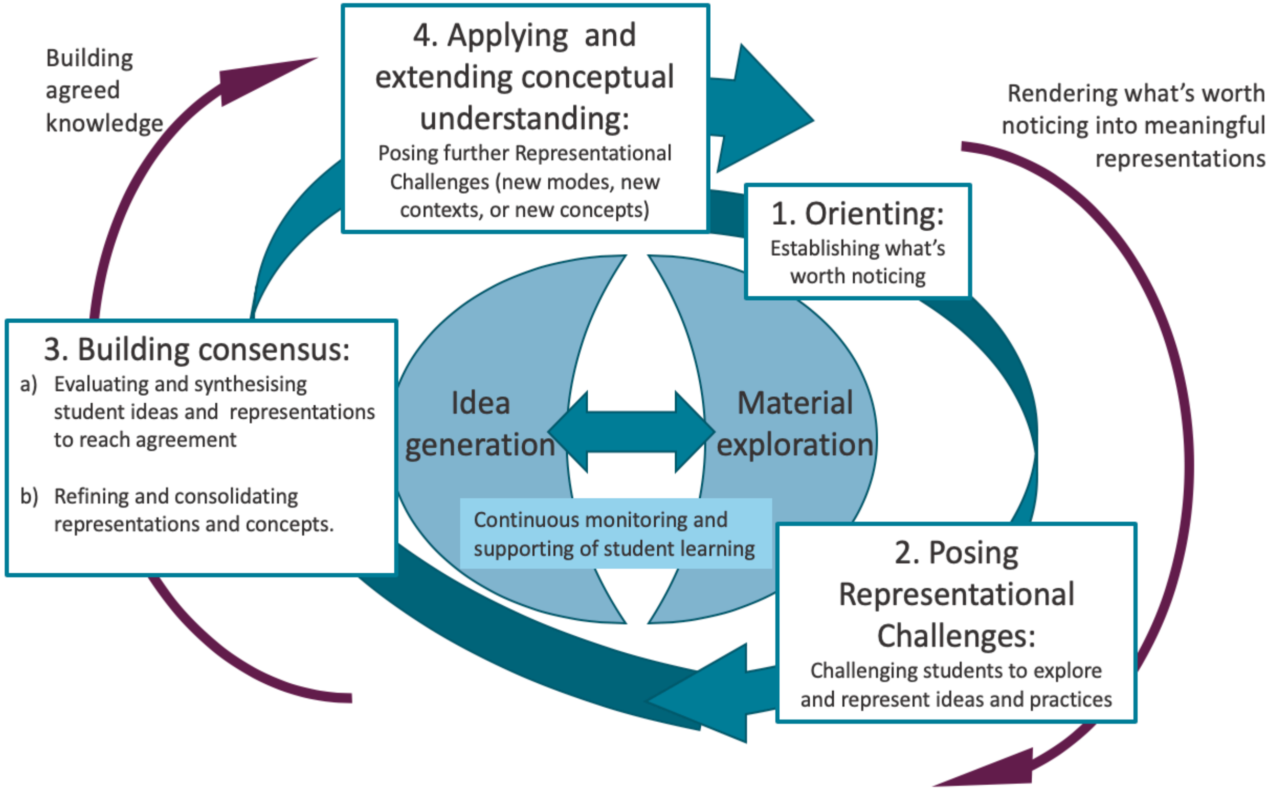
This teaching and learning sequence is one of a number that are designed to productively integrate mathematics with science, using a guided inquiry approach in which students construct, share, evaluate and revise multimodal representations to establish conceptual understanding. See website https://imslearning.org/

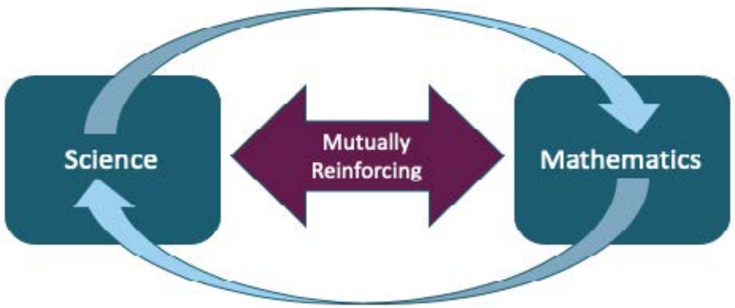
Interdisciplinary Mathematics and Science (IMS) Learning

IMS aims to enrich learning through two interconnected principles, which are key to the nature of the unit design and the pedagogy. The first principle concerns a focus on students constructing, evaluating, and refining multimodal representations, enacted through a four-stage IMS pedagogical model. The second principle concerns interdisciplinarity: the relation between science and mathematics. The project can be found at https://imslearning.org/
Below we describe the key features of the approach.

Student constructed representations

The teaching and learning sequences follow a guided inquiry pedagogy that focuses on students constructing, evaluating, refining, and extending multimodal representations. This is a literacy focus built on the insight that learning in both science and mathematics involves students being inducted into the representational practices that underpin explanation and problem solving. Representations can include diagrams, models, equations, graphs and tables, and symbols as well as written text. The approach involves a number of stages through which the teacher guides student learning. These stages, although distinct, often cycle and repeat within and across lessons. The model (to the right) showing these stages has been developed as an outcome of the IMS research.





Interdisciplinarity

In the teaching and learning sequences, the mathematics and science activities are built around 'concepts in common', with the principle that the learning in each subject enriches learning in the other. For instance, measuring, graphical work and data modelling generally are freshly developed in science contexts in ways that raise questions and promote deeper knowledge in science, and the science context raises questions that can be further explored mathematically.

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Stages of the IMS Pedagogical Model

Orienting: Teachers pose questions, explore students' ideas and orient them to the learning focus by a variety of means such as asking for predictions, questioning what they have noticed, asking for ideas about what could be measured, and eliciting prior knowledge. This provides a way to focus students' attention on what is worth noticing about the school environment, or about data sets for instance, and could be interesting to explore.

Posing representational challenges: Students are challenged to explore and represent their ideas and practices, for instance they may be challenged to represent the movement of their shadow over a day, involving decisions about what to measure and how to represent patterns in length, and angle, or to use particle representations to predict, investigate and explain why a saucer of water evaporates more quickly in warm, or windy places.

Building consensus: This involves two stages. First, using the student ideas and representations to compare, evaluate and then synthesise these to reach agreement about which aspects of these effectively show patterns in data, or suggest explanations. Second, these ideas are refined by students, and consolidated to establish a shared understanding of the concept and associated representations. In this process students develop knowledge of the role of representational work in learning.

Applying and extending conceptual understanding: Students are given new representational challenges to extend their new knowledge and practices in related situations, or further concepts are introduced through representational tasks, to repeat the cycle.

In these stages the teacher is constantly monitoring and responding to students' representations and ideas. The approach can be seen as 'assessment as learning'. The focus on student production has been found to allow the teacher significant insights into student thinking. The art of teaching in this way involves setting appropriate tasks, preparing students strategically through questioning and challenges, and guiding their work to reach consensus about the key ideas and their representations. The sequences all involve a close association of material exploration, and the generation of ideas.

These stages have much in common with the 5Es that underpin Primary Connections (PC). The stages line up as Orienting = Engage, Posing Representational Challenges = Explore, Building Consensus = Explain; and Applying and Extending Conceptual Understanding = Elaborate. The 'Evaluate' stage appears in the IMS pedagogy as a continuous process of monitoring and formative assessment (assessment 'for' and 'as' learning) throughout the stages. Most sequences have a summative evaluative task, but this sits outside the cycle. Distinct from the 5Es, the IMS stages are explicitly focused on representations as central to learning (consistent with the PC focus on literacy) and structured to lead from noticing what is of interest to investigate, through the generation of representations, to generating class agreement on key concepts as systems of representations and representational practices.

The teaching and learning sequences follow these stages explicitly, but they cycle in different ways, in different lessons and in different topics. In some lessons there are more than one cycle, or even interweaving cycles for science and mathematics. In other cases, a cycle is spread over a number of lessons. Sometimes, activities have more than one role, such as an extension representational challenge acting as an orientation into a further concept. Nevertheless, we believe the movement from opening up what is noticed, to exploration and representation construction, to evaluating and building consensus, is a fundamental and powerful aspect of effective teaching and learning. Tasks in the sequences are designed to be approachable at a range of levels. This, together with teacher open questioning and targeted scaffolding, enables differentiation of the learning.

Supporting differentiation of learning in the IMS learning design

In the IMS learning sequences the student- guided inquiry design enables diverse student learning needs to be responded to within the regular classroom. The open learning tasks are designed flexibly to enable students to work at their own level, and at their own pace, to develop their understanding and skills in a variety of ways. Variation in student responses offers a resource for promoting, encouraging and refining learning as students demonstrate, in different ways, what they know and understand. With teacher support, students learn from each other's ideas and productions. The focus on student-constructed representations, and open questioning and discussion, enables the teacher to monitor individual students' understandings and cater for their learning needs over time.

Features of the learning sequences that enable embedded and teacher-supported differentiation

There are three distinct aspects of the IMS pedagogy that enable differentiation.

Open questioning, guided inquiry and open tasks provide the teacher with insight into individual student learning and understanding that:

a) enables teacher decisions for on-the-spot feedback, and individualised monitoring and support of student learning through targeted learning adjustments, scaffolding, and extension challenges.

> *"Giving them (students) more freedom is a good approach because they're more capable than I thought they would be, but they still needed the support as well. So, giving students the initial freedom to do whatever they thought they could do and then helping them from that…"*

b) enables support for students to navigate tasks with multiple entry points, solution pathways and outcome possibilities, whilst negating possible student stigmatisation from the withdrawal from their peer group, or students assigned a different task.

> *"the fact that they are open-ended so they (the students) can come to a solution in a variety of different ways. There was not one student where I had to really modify an activity for, they could participate in the activity, they could all have success in the activity but they all got something from it and because it was open-ended…"*

c) enables the development of creative and critical thinking skills, and higher-order thinking, as student responses are not limited

> *"…I always found everything was just deeper level thinking."*

Peer learning, collaborative learning and student voice increases student engagement as students learn from and with their peer group.

Students learn collaboratively as a whole class and in mixed ability peer groups. Student are encouraged to share ideas, co-construct investigations, designs, data and representations. Through purposeful guided reflection, targeted scaffolding, prompts and extension challenges, students engage in comparative discussions and review of peer representations (e.g. graphical representations) to build their understandings.

> *"…we were able to cater for everyone without making it obvious to them that we had to modify the activities, which I think is really important for their confidence and self-esteem and learning too."*
>
> *"…coming from their peers and it's quite interesting because when they actually get feedback from their peers as well I find that they really do put it into practice a lot quicker, it's quite interesting, as opposed to coming from the teacher all the time, it's coming from someone different. That has been a really interesting pick up that we have found..."*

Multimodal representational challenges cater for diverse learner needs and provide differentiated insight into students' conceptions.

Teachers have identified that a focus on multimodal representation enhances learning for students with language difficulties, who are English Second Language (ESL), and/or have literacy support needs, since they are not so constrained by their language skills. Access to multiple modes reduces the effects of language demands as barriers to learning. Students' multimodal representations provide teachers with insight into individual students' knowledge, skills and learning needs.

> *"…this has been really interesting, seeing children that don't speak up as often really come up with some really insightful representations. I mean, they're a lot further ahead than what I thought."*
>
> *"show me what you know through your drawings' and often that speaks volumes because children find it difficult to articulate at the time. They might understand more than what they are conveying… But they are actually showing me so much of their knowledge through their diagrams."*

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Astronomy – Day and Night: Sequence Overview

In this **teaching and learning sequence** students will focus on spatial relations of the sun and earth, coordinating an earth centered and space centered perspective. It will develop an understanding about Astronomy – day and night and the earth's rotation through a shadow investigation and involves measurement, time, direction through on-going spatial mapping, data recording and analysis, and visual representation of data. Students will develop understandings of the ways science and mathematics use modelling processes to understand natural systems and mathematical patterns.

- Tracking the sun across the sky using shadow stick. Representing this on paper and then a drawing and explanation of the sun's movement.
- Tracking the sun on a horizon map and marking a north and east-west position. This could be coordinated with the shadow stick diagram.
- Mapping night and day to the rotation of the earth in relation to the sun. The spatial perspective is developed using video simulation and a globe (model of the Earth).
- Coordinating with the Earth's perspective via role plays. Start with simple relative motion and move to a role play where children imagine they are on a moving earth representing how the sun appears, acting out a story about morning, midday and evening. Establish spatial relations (such as: if we are facing north, sun rises on our right and sets on our left).

Lesson Sequence - Outline

Lesson 1: What do you know about the sun? (pre sequence assessment task)

Establishing prior knowledge of the sun and day and night with pre sequence assessment task. Setting up predictions of shadow movement, and procedures for recording shadows and the suns movement.

Lesson 2: Conducting a Shadow Investigation

Recording data to measure and interpret the suns movement by shadow recording and tracking of sun east to west, at a number of times throughout the day.

Lesson 3: Representations and Modelling Shadow Investigation Data

Students conduct data analysis and modelling of sun tracking east to west.

Lesson 4: Explanation and Modelling Earth's Rotation

Teacher guided explanation with modelling of Earth's rotation around the sun with video simulation, an earth globe, and role play.

Lesson 5: Clarify Day and Night Understandings (post sequence assessment task)

Students final representations and learning analysis and then complete the post sequence assessment task.

Curriculum Focus: Science and Mathematics Learning

Key Conceptual Focus	Key Curriculum Outcomes (Victoria Curriculum)
Science ideas and processes • Shadows are formed by blocking light and are in the opposite direction to the sun. • Representing shadow size position in relation to the position of the sun. • The sun moves from east to west (right to left if facing north), in the north part of the sky, because of the earth's rotation. • Explore ways of representing the movement / angle of the sun across the sky. • Day and night are caused by the earth's rotation. • Model the earth and sun to explain what we experience of day and night. • It can be night time in America when it is day time in Australia. • Role plays of rotating and observing sun rise and relating to modelling of earth-sun system.	**Science** **Earth and Space Science** Observable changes occur in the sky and landscape; daily and seasonal changes affect everyday life (VCSSU046) **Science Investigations** *Questioning and Predicting* Respond to and pose questions, and make predictions about familiar objects and events (VCSIS050) *Planning and conducting* Participate in guided investigations, including making observations using the senses, to explore and answer questions (VCSIS051) *Recording and processing* Use informal measurements in the collection and recording of observations in the school grounds (VCSIS052) Use a range of methods, including drawings and provided tables, to sort information (VCSIS053) *Analysing and evaluating* Compare observations and predictions with those of others (VCSIS054) *Communicating* Represent and communicate observations and ideas about changes in objects and events in a variety of ways (VCSIS055)
Mathematical ideas and processes • Representing spatial relations via compass directions, height of sun, modelling size. • Measurement of length of shadow- informal and formal measures. • Data representation: graphing shadow length.	**Mathematics** **Number & Place Value** Develop confidence with number sequences to and from 100 by ones from any starting point. Skip count by twos, fives and tens starting from zero (VCMNA086) Count collections to 100 by partitioning numbers using place value (VCMNA088) Represent practical situations that model sharing (VCMNA090) **Using Units of Measurement** Measure and compare the lengths, masses and capacities of pairs of objects using uniform informal units (VCMMG095) **Location and transformation** Give and follow directions to familiar locations (VCMMG099) **Chance** Identify outcomes of familiar events involving chance and describe them using everyday language such as 'will happen', 'won't happen' or 'might happen' (VCMSP100) **Data representation and interpretation** Choose simple questions and gather responses (VCMSP101) Represent data with objects and drawings where one object or drawing represents one data value. Describe the displays (VCMSP102)

Astronomy – Day and Night: Equipment/Resources

Lesson		Equipment/Resources
All Lessons		**Students:** student workbooks (unlined), pencils, coloured markers and rulers **Teachers:** Board (IWB/whiteboard) and or butchers' paper for shared recording, pens and computer
1	**What do you know about the sun?** Establishing prior knowledge of the sun and day and night. Setting up predictions of shadow movement, and procedures for recording shadows and the suns movement.	Pre-sequence assessment task (Appendix 4)
2	**Conducting a Shadow Investigation** Recording data to measure and interpret the suns movement by shadow recording and tracking of sun east to west, at a number of times throughout the day.	Blocks or streamers (for measuring using informal measures) Rulers can be used (as measuring sticks rather than the specific measurements) Chalk Compass Garden gnome or similar Camera
3	**Representations and Modelling Shadow Investigation Data** Students conduct data analysis and modelling of sun tracking east to west.	Torch Compass Garden gnome or similar Paper and markers
4	**Explanation and Modelling Earth's Rotation** Teacher guided explanation with modelling of Earth's rotation around the sun with video simulation, an earth globe, and role play.	Torch Paper with shadows *Globe / Earth ball Hoop Signs (Earth, Europe, Australia, Sun) Buetac/sticker Computer connection to screen
5	**Clarify Day and Night Understandings** Students final representations and learning analysis (Post-sequence assessment activity).	Student/Class work to review and *as above (Lesson 4)* Post sequence assessment task (Appendix 4)

Appendices

1 - Teacher Notes on the Sun, Earth, and Day and Night
2 - References and Resources
3 - Gnome Sundial diagram
4 – Pre/post sequence assessment task

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LESSON 1 – What do you know about the sun?

(Approximate duration 60 minutes)

Curriculum Focus:

Science ideas and processes

- Shadows are formed by blocking light and are in the opposite direction to the sun
- Representing shadow size position in relation to the position of the sun.
- The sun moves from east to west (right to left if facing north), in the north part of the sky, because of the earth's rotation.

Mathematical ideas and processes

- Representing spatial relations via compass directions, height of sun, modelling size.
- Measurement of length of shadow- informal and formal measures.
- Data representation: graphing shadow length

Resources/Equipment

Students: Pre-sequence assessment task (Appendix 4), student workbooks (unlined), pencils, coloured markers and rulers

Teachers: Board (IWB/whiteboard) and or butchers' paper for shared recording, pens and computer

Learning intention:

- Explain the formation of shadows by the sun
- Predict the movement of shadows from the sun over a day
- Consider ways of measuring shadow length using informal or formal measures

Lesson at a glance:

What do you know about the sun? Establishing prior knowledge of the sun and day and night. Setting up predictions of shadow movement, and procedures for recording shadows and the suns movement.

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LESSON 1 – What do you know about the sun?

(Approximate duration 60 minutes)

<table>
<tr><th>Conceptual focus</th><th>Pedagogical Stage</th><th>Lesson Outline (time allocations a guide only)</th><th>Assessment notes</th></tr>
<tr><td>SCIENCE:
Day and Night
Shadows
Predictions
Representations – diagrams (with labels)

MATHEMATICS:
Comparative analysis
Measurement (informal units)
Prediction</td><td>Orienting
Probing students’ prior knowledge of shadows and the movement of the sun
Students think about how to track the movement of shadows over a day, as a way of exploring how the sun moves</td><td>Pre-assessment of knowledge and skills
(15 minutes)
Pre-test for all students. Teacher read task with students answering independently on worksheet. Answers can be shown through text or drawings with labels.

Whole class discussion: Ideas about shadows from the sun
(10 Minutes)
Probing questions:
❖ What causes a shadow?
❖ When can we see shadows?
It may be useful if it is a sunny day to take the class outside and discuss the formation of shadows, the position of the shadow in relation to the sun.
❖ Do you think if you were to stand still in one place that your shadow would change during the day?
Record student responses on the board: e.g. yes is will get bigger, no unless the sun goes in, etc.</td><td>Can students link the formation of shadows to a light source?
Can students identify the conditions under which shadows are formed?</td></tr>
</table>

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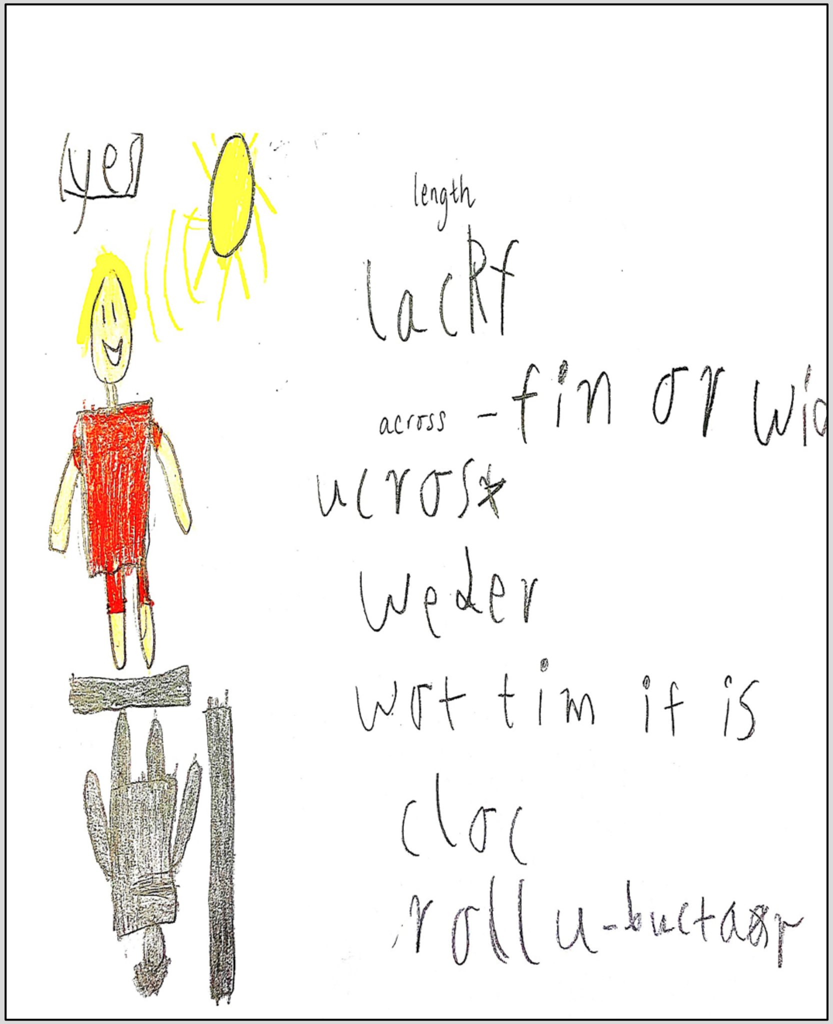
Students pre sequence assessment task drawings of shadow formation



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SCIENCE: Shadows Predictions Representations – diagrams (with labels) **MATHEMATICS:** Comparative analysis Measurement (informal units) Prediction	***Posing representational challenge*** As part of the orienting phase, students record and compare their predictions	**Predictions and tracking of Daily Shadow movement** *(15 Minutes)* **Whole class discussion:** **Probing questions:** ❖ *How could we track the position of our shadow over the day?* ❖ *How could we record this information in our workbook?* ❖ *How could we keep track of the shadow direction?* Students to record predictions in their Workbooks. Draw what they think will happen to shadows each time they measure then across the day. Include labels for all diagrams. As students are still recording their predictions, share examples of what students have done. Discuss the examples and highlight good use of labels, clear diagrams, clarity of representation, conceptual understandings. Each uses a different strategy to represent the movement of the sun and the resulting effect on the shadow. These diagrams could be enhanced by labels that describe understanding. **Gallery Walk** *(10 Minutes)* Students open their Maths and Science Workbooks on the desk and then walk around exploring others representations. After some time they return to their own workbook and explain what they saw and liked form others. They may then like to adjust their own representations to include these features.	Can students suggest ways to measure shadow length (in informal or formal units)? Can students nominate tables as a way to enter shadow length at successive times? Can students nominate drawing, as a way of tracking shadow direction? Can students recognise the use of compass points as a way of describing orientation? Can students construct clear diagrams of their ideas?
	Orientating Students are prepared for what data they will collect and how they will record	**Class discussion: Preparing for Shadow recording** *(10 Minutes)* Probing questions: ❖ *What kinds of things might we expect to notice when observing our shadow?"* Record student responses on the board. Responses may include: shadows will get longer/shorter, they will move during the day. Students may vote on the responses. Students may need to go outside to conduct short investigations for themselves, returning with observations for sharing and conclusions to offer.	Can students, from the previous discussions, identify length of shadows and orientation as important to track?

		❖ *What data might we collect when observing our shadows* Record student responses on the board. Responses may include: length/direction of shadow/position of sun in the sky. ❖ *How could we measure our shadows and record the data we collect?* Record student responses on the board. Responses may include: Negotiate with the class how we can measure the length of shadows. Possible ways might be with streamers, or blocks. **Next lesson:** inform the class that, in pairs, we're going to observe our shadows by standing in one spot and tracing around our shadows at a number of times during the day. Ask students what they think we can learn from watching our shadows during one day.	Can students suggest sensible ways of measuring shadow length?

LESSON 2: Conducting a Shadow Investigation (Sunny day needed)

(Approximate duration 65 + minutes)

Curriculum Focus:

Science ideas and processes

- Shadows are formed by blocking light and are in the opposite direction to the sun
- Representing shadow size position in relation to the position of the sun.
- The sun moves from east to west (right to left if facing north), in the north part of the sky, because of the earth's rotation.

Mathematical ideas and processes

- Representing spatial relations via compass directions, height of sun, modelling size.
- Measurement of length of shadow- informal and formal measures.
- Data representation: graphing shadow length

Learning intention:

- Explain the formation of shadows by the sun
- Tracking the movement of shadows from the sun over a day and relate this to the sun's apparent movement
- Measure shadow length using informal or formal measures as agreed

Resources/Equipment
Blocks or streamers (for measuring using informal measures)
Rulers can be used (as measuring sticks rather than the specific measurements)
Chalk
Compass
Garden gnome or similar
Paper and markers
Camera

Students: student workbooks (unlined), pencils, coloured markers and rulers

Teachers: Board (IWB/whiteboard) and or butchers' paper for shared recording, pens and computer

Lesson at a glance:

Conducting a Shadow Investigation Students record data to measure and interpret the sun's movement by shadow recording and tracking of sun east to west, at a number of times throughout the day

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LESSON 2: Conducting a Shadow Investigation (Sunny day needed)

(Approximate duration 65 + minutes)

Session focus	Pedagogical stage	Lesson Outline (*time allocations a guide only*)	Monitor and support learning
SCIENCE: Observe Measure Record changes in the length and direction of a shadow during the day Identify questions in familiar contexts that can be investigated scientifically Make predictions and compare results with predictions (following lessons) Record and present observations with drawings and tables Represent and communicate ideas using labelled diagrams **MATHEMATICS:** Counting Measuring Comparative analysis Display of data in tables and diagrams	***Posing representational challenge*** Students are challenged to track and record, and represent in graphical and diagrammatic form the movement of their shadows over the day	**Review and extension of last lesson discussion** *(10 Minutes)* **Probing questions:** ❖ *What kinds of things might we expect to notice when observing our shadow?* ❖ *What data might we collect when observing our shadows?* ❖ *How could we measure our shadows and record the data we collect?* Discuss student ideas for how to record the data (time of recordings, number of recordings) and how to measure (length/width/movement - shorter/longer/number of rulers/cm etc.). Ensure the correct location for the recording (concrete, enough room for pairs approx. 6m apart). **Recording Shadows** *(20 minutes)* Reinforce to children that it is not safe to look at the sun. Discuss what a shadow clock or sundial could do and how it is made. **Teacher modelling of tracing shadows** When the class is in the schoolground, the teacher models the recording of a small garden gnome's shadow, marking a spot where s/he sits, N S E W, tracing around the shadow at each set time, measuring the length of the shadow, and making a note of the direction of the shadow in relation to the direction of the sun (see figure).	Can students appreciate the value of formal measures? Can they sensibly suggest informal measures (e.g. blocks)? Are students aware of the compass points and which direction is North, in the schoolground where they will record? Work with pairs of students to ensure they note the relation of the shadow to the sun's position. Can they point to the sun's direction and realise the shadow is opposite? Are students careful to record times on their shadows?

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		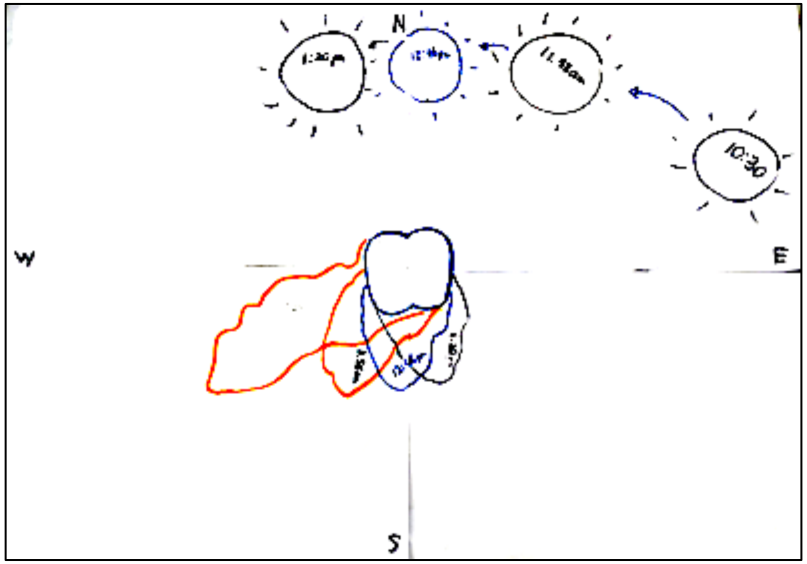 Example of teacher production of gnome shadow model: with sun direction also noted. Note this is for the Southern Hemisphere. **Student recording - repeated throughout the day** *(5 minutes each recording)* • Students paired and positioned facing North approx. approx. 6m apart (far enough for shadows not to cross). • Trace students feet and draw N S E W near the students' feet, ensuring that the students are facing north. • One student is the shadow maker the other student is the shadow recorder (if similar height the recorder could also step into the feet position and see if similar) • Measure and record in workbooks the shadow size (determine appropriate measure: number of rulers/cm etc.) • Notice other size changes e.g. width. • Record the time in the shadow and add (description of time of day e.g. morning/analogue) and in workbook (tabulating/listing/drawing and labelling - recording data).	Do students have the spatial skills to notice relative directions and changing directions? Do they have the language to describe this? Can students notice the relation between where the sun is in the sky, and the shadow direction and length? Can students explain that the shadow is caused by light from the sun being blocked? Can students be encouraged to attend to accuracy and completeness of their recordings?

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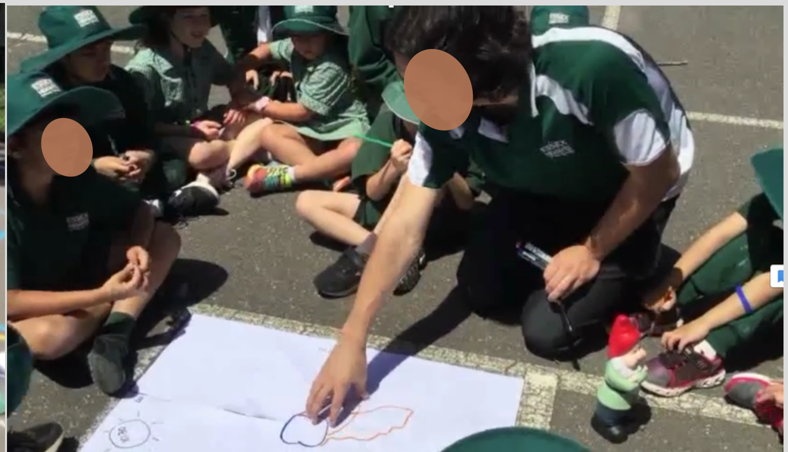
		  Image above shows the coloured chalk lines drawn around the shadows with the direction of sun marked in the same colour as a time recording. Check repeated entries are in correct place in maths and Science Workbook **Repeated recordings** – suggested at lesson transitions to minimise disruption. Recommend a minimum of 5 recording across the day (start of school, morning tea, before/after lunch and the end of the day). Student observations, data, representations of process, and communication of ideas using labelled diagrams could be represented in the workbooks as a simple report. **Student prediction - repeated throughout the day** *(5 minutes each recording)* After each recording ask students to predict. Check how predictions are recorded. Ensure they are not confused as data. **Probing question:** ❖ *Will the shadow change location for the next recording? How?* Predict where it will be and how long it will be. Discuss/Record on white board.	Are students able to discuss the purpose of colour coding and labelling? Can students see patterns in the shadow change, in length and orientation? Can they predict what will happen over the next period? Can they relate these changes to the sun's movement?

		 The above image is a student derived recording for two shadows. Note the compass directions and the colour coding. **Organisational note**: Students could take photos of their recordings at the end of the day to be used in analysis in the next session. Photo data could be included in student workbooks.	


Images of the teacher supporting students with orienting to the sun, and with modelling using the gnome's shadow. Sample of gnome shadow tracings

SCIENCE: Shadows Representations – diagrams (with labels) **MATHEMATICS:** Comparative analysis Measurement (informal /formal units) Angle and rotation	***Building consensus*** Students compare and evaluate the different recordings to get a sense of how best to represent, and the patterns of results	**Gallery Walk** *(10 minutes)* Students showcase their shadow recordings in their Maths and Science Workbook. Discuss various recording methods. Students observe other students work and make alterations to their own based on the ideas of others. **Summarising class discussion** *(5 minutes)* Reflect on the experience of tracing shadows, measuring the length, and recording this in the workbook. What did students learn about the process? What would they do differently next time to improve their process, if anything? Examine student predictions and discuss if the data supported their prediction, or not. With the class's help, construct a statement on the board concerning the preliminary findings based on the patterns of recordings.	Can students notice strong features of other's recordings – clear documentation, labeling, length and direction? In the final summing up, can students identify the broad patterns of shadow change, and relate this to the sun's movement?

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Lesson 3: Representations and Modelling

(Approximate duration 60 minutes)

Curriculum Focus:

Science ideas and processes

- Shadows are formed by blocking light and are in the opposite direction to the sun
- Representing shadow size position in relation to the position of the sun.
- The sun moves from east to west (right to left if facing north), in the north part of the sky, because of the earth's rotation.

Mathematical ideas and processes

- Representing spatial relations via compass directions, height of sun, modelling size.
- Measurement of length of shadow- informal and formal measures.
- Data representation: graphing shadow length
- Representing direction, rotation, and time

Resources/Equipment
Torch
Compass
Garden gnome or similar
Paper and markers

Students: student workbooks (unlined), pencils, coloured markers and rulers

Teachers: Board (IWB/whiteboard) and or butchers' paper for shared recording, pens and computer

Learning intention:

- Explain the formation of shadows by the sun
- Tracking the movement of shadows from the sun over a day and relate this to the sun's apparent movement
- Measure shadow length using informal or formal measures as agreed
- Graphing and representing shadow change

Lesson at a glance:

Students conduct data analysis and modelling of the shadow changes, and relate to the sun tracking east to west. The teacher helps with modelling the relation of shadow changes to the apparent movement of the sun in the sky.

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Lesson 3: Representations and Modelling

(Approximate duration 60 minutes)

Session focus	Pedagogical stage	Lesson Outline (*time allocations a guide only*)	Monitor and support learning
SCIENCE: Shadows and shadow formation Predictions Data representations – diagrams (with labels), graphs How the movement of the Earth around the sun can be used to measure time, e.g. by using a self-made shadow clock or sundial Representing time **MATHEMATICS:** Comparative analysis (possible graphing and tabulation) Measurement Prediction Time Directionality Birds eye view mapping **Data Representation**: Students draw / represent the changing shadows, direction and position of the sun	***Orienting*** Students are attuned to the nature of shadows, and supported to recognise patterns in their data Students are introduced to a torch-gnome model as an explanatory model, and it is suggested that movement of the earth might explain the apparent movement of the sun	**Video animations** *(10 Minutes)* Engage the students with some picture story book or video to intersperse with the measurements. • https://www.youtube.com/watch?v=DDnCGqwOdv0 • https://www.youtube.com/watch?v=Sz3PDETiplg Whole class discussion: Ask students to think further about what causes shadows. Hear student observations and thoughts without clarifying details with them. Allow the understandings to be developed through the following lesson. Remember to return to examine alternative conceptions and check for new understandings. **Exploration of the data** *(10 Minutes)* Using the data collected from last lesson identify attributes of student representations that make the data easy to understand. Ask students to reflect on their predictions and then their data. **Whole class probing questions:** ❖ *Did your shadow change during the day? How?* ❖ *What can you see in your photograph of the day's data collection?* ❖ *What can you see as a pattern in your shadow measurements?* Focus discussion on the Sun tracking across the sky from East to West and the shadows being the longest in the morning and the afternoon, when the sun was low in the sky and shortest when the sun was high, directly above in the sky. **Modelling and Visual Representation** *(15 Minutes)* Teacher Modelling of silhouette shadow with a torch using Gnome Shadow Diagram and Data collected from previous lesson (Maths and Science Workbooks and photos). Teacher models the movement of the sun from	Note alternative conceptions for addressing through the throughout sequence. Consider student retention of ideas. Use responses to determine pace of progression. Can students recognise patterns in the data? Can agreement be reached on the broad features of shadow change? Can students recognise the model as representing and explaining the relation between the changing position of the sun and relative shadows during the day.

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		East to West, replicating the way the sun tracks in the sky. Use a torch to provide a light source and match the shadows to those in the data. **Probing question:** ❖ *Did the sun move? How?* Then model the sun passes. Then, hold the Torch still and rotate the Gnome and paper to demonstrate the changing shadow due to the movement of the earth and the *(Rotation of the earth – not the sun).* **Probing question:** ❖ *What will happen to the shadow if the sun is still and we are moving?*  Casting a gnomic shadow using a torch, duplicating the movement of the sun to create the shadow patterns which were recorded from the previous lesson. **Teacher note** *Be careful when modelling East to West. Facing the children you will need to mirror the movement, moving the torch from left to right, for the children to see/experience East to West/Right to Left. Also, be careful of language used the sun* ***tracks*** *from East to West across the sky, rather than the sun* ***moves*** *from East to West across the sky.* Draw the student's attention to the position of the torch/sun and the resulting shadow direction and size. Explain to the students that they're to draw and record the shadow and relative position of the sun.	Note that this is a difficult transition between models. Focus on the sun tracking and then the earth rotating. This modelling should be seen as suggestive of a possibility, rather than proof. Watch for alternative conceptions about shadow formation. Can students give a verbal explanation while they are watching the model?

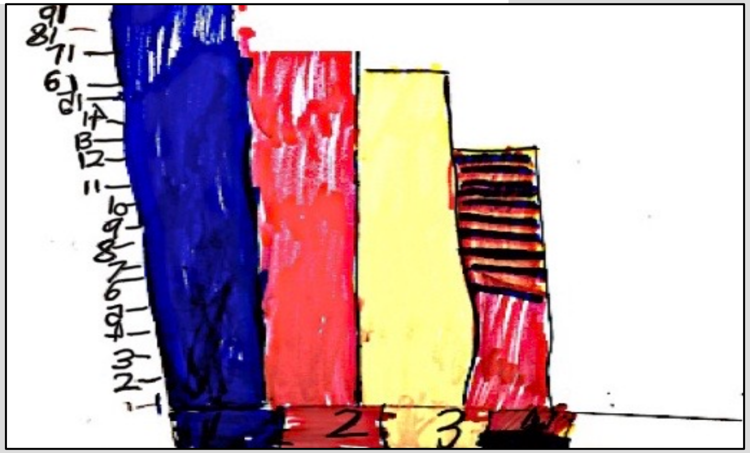
		 The teacher has a student model, with arms, the opposition of the light source and the shadow.	

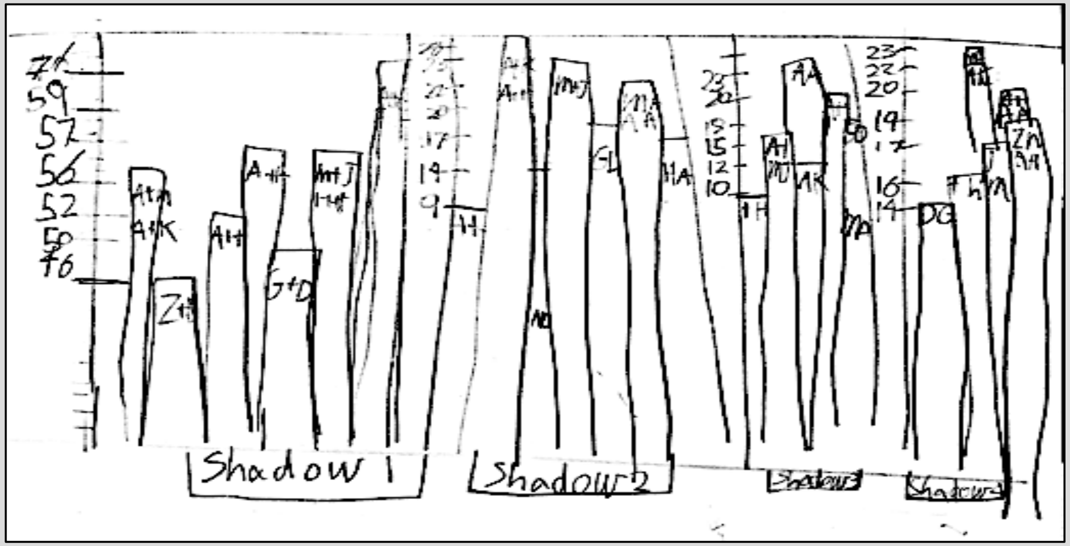
SCIENCE: Shadows and shadow formation Data representations – diagrams (with labels), graphs How the movement of the Earth around the sun can be used to measure time, e.g. by using a self-made shadow clock or sundial Representing time **MATHEMATICS:** Comparative analysis (graphing and tabulation) Measurement Time Directionality Birds eye view mapping **Data Representation**: Students draw / represent the changing shadows, direction and position of the sun	***Posing representational challenges*** Students construct graphical and diagrammatic representations of their shadow data for class comparison and discussion	**Students construct representations of their shadow data** *(15 Minutes)* Students complete their own representation of the shadows in their Maths and Science Workbooks that explain how shadows changed during the day. Students to refer to their own data (shadow length, direction, and time of recordings). Students may draw their own birdseye view map (optional) and place a cutout / figurine of themselves to make a 3D model, for the shadows. **Note variation in shadow length data:** Students to finish/finalise/draw/clarify and make inferences about the data they recorded in shadow length data. • *Shadow length – Students ordered their ribbons from times of recording (ordinal numbers, time focus, comparative length). Additional time may be required if students are to order streamer length. Students measured the length of the streamers (cm) as some were over 100cm (this proved difficult for some students).* • *Data collection Tables – some teachers used a whole class table to record data on shadow lengths (table added to each time they returned to class on recording day)* • *Shadow length Graphs – some classes graphed the lengths of their shadows in this time (Additional time needed). This worked best when students used informal measures such as feet/hands/blocks.*	Some students may need suggestions for how to represent the tracking of the sun and the shadows as a result. Now Students are using the shadow data to model an explanation. These strategies may be successful. What insights do the examples presented provide into the students capabilities? Check conceptual understanding as well as the accuracy of the representation and model use.

Examples of grade 1 work:

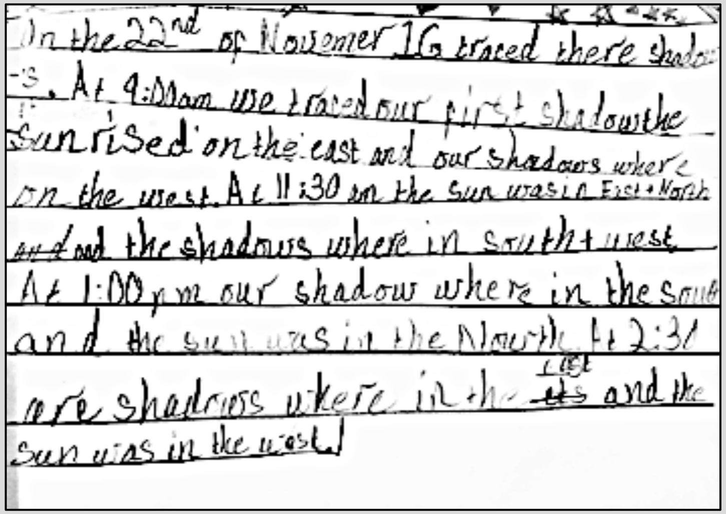
This class measured their shadows in blocks and some students graphed the whole class shadow lengths at different times.

One child's graph of shadow length from streamer measurements



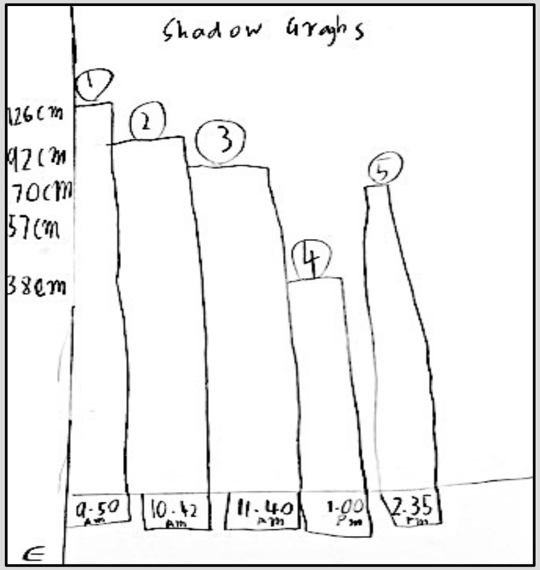


Verbal descriptions (dictated) (Not all students achieved these levels of competence)

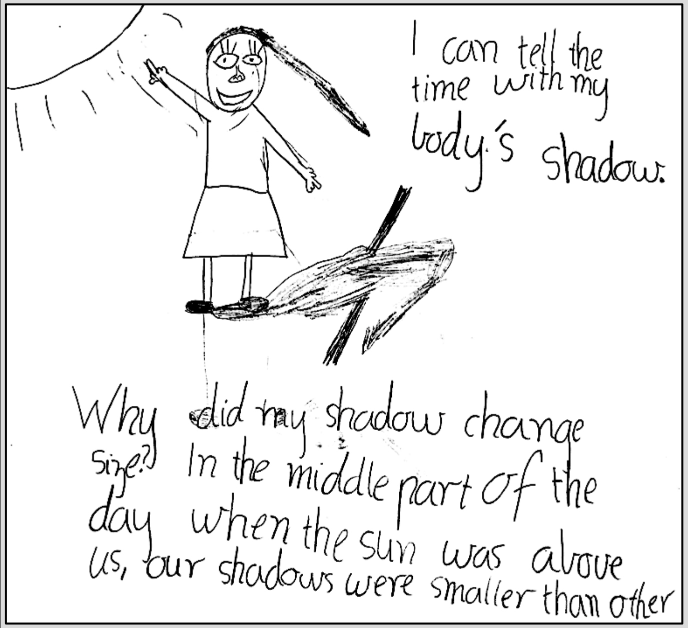

On the 22nd of Novemer 1G traced there shadows. At 9:50am we traced our first shadow the sun rised on the east and our shadows where on the west. At 11:30 am the sun was in East + North and the shadows where in south + west. At 1:00 pm our shadow where in the south and the sun was in the North. At 2:3[illegible] are shadows where in the east and the sun was in the west.

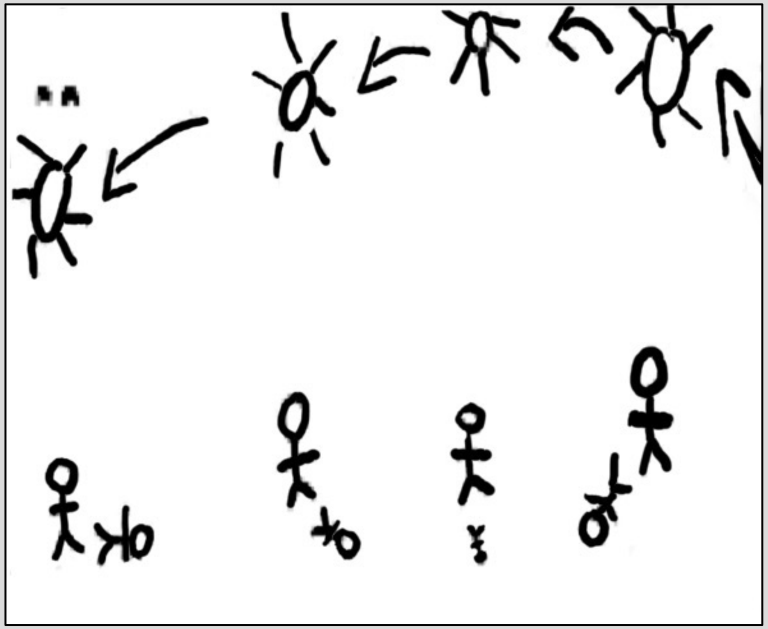
Shadow Recording 27.11.18

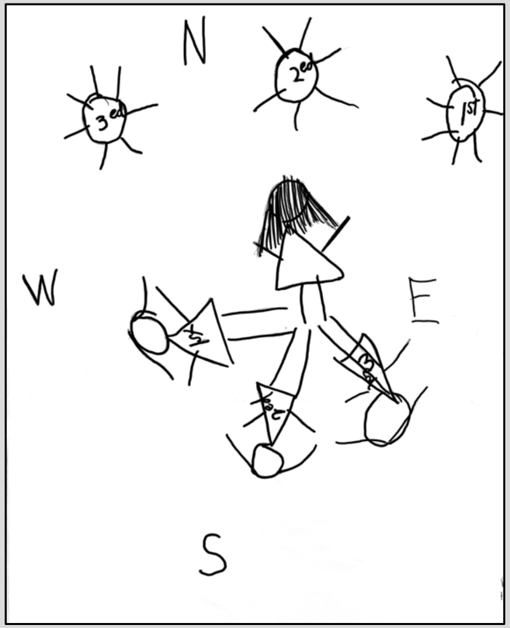
Time	length of shadow
9.50 Am	126cm (6 feet)
10.42 Am	~~922~~ 92cm
11.40 Am	57 cm (3feet)
1.00 Pm	38 cm
2.35 Pm	70 cm (3feet)



Images of shadow movement relative to sun (from post sequence assessment task)







Data Representation: Students draw / represent the changing shadows, direction and position of the sun	**Building consensus** Evaluating and synthesising student ideas Suggesting refinements, and consolidating representations to reach class consensus	**Gallery Walk** *(10 Minutes)* The teacher selects different work, and discusses with the class. **Probing questions:** ❖ *What does this show clearly?* ❖ *What doesn't it show?* **Concluding discussion** Teacher leads a discussion about making inferences and exploring the data. **"Where does the sun go during the day?"** Recognising the changing position of the sun and changes to shadows during the day. Opening up the question – **"Could the earth be moving, rather than the sun"?** which will be explored in the next lesson.	Here the focus with graphical work could be on labeling, even intervals for the length axis, time identification, and explanatory text. For the diagrams, can students reasonably describe the shadow changes, taking direction into account, and link these with the sun's position and direction across the sky?

Lesson 4 – Explanation and Modelling Earth's Rotation

(Approximate duration 60 minutes)

Curriculum Focus:

Science ideas and processes

- Day and night are caused by the earth's rotation.
- Model the earth and sun to explain what we experience of day and night.
- It can be night time in America when it is day time in Australia.
- The apparent movement of the sun across the sky is due to the earth's rotation

Mathematical ideas and processes

- Representing direction, rotation, and time

Learning intention:

- Explain day and night, and sun's movement, using models of a rotating earth
- Models provide us with explanations of phenomena

Lesson at a glance:

Teacher guided explanation with modelling of Earth's rotation around the sun with video simulation, an earth globe, and role play. Students explore how rotation affects the view of the sky from a given location. Students develop an understanding that the earth's rotation makes the sun appear to rise in the East and set in the West.

Resources/Equipment
Torch
Paper with shadows
Globe / Earth ball
Hoop
Signs (Earth, Europe, Australia, Sun)
Buetac/sticker
Computer connection to screen

Students: student workbooks (unlined), pencils, coloured markers and rulers

Teachers: Board (IWB/whiteboard) and or butchers' paper for shared recording, pens and computer

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Lesson 4 – Explanation and Modelling Earth's Rotation

(Approximate duration 60 minutes)

Session focus	Pedagogical stage	Lesson Outline (*time allocations a guide only*)	Monitor and support learning
SCIENCE: Day and Night Representations – diagrams (with labels) the sun tracks across the sky because the earth is rotating **MATHEMATICS:** Comparative analysis (possible graphing and tabulation) Time Directionality Embodied learning	***Orienting*** Students review shadow results to reinforce the sun's apparent movement Introduction of globe representation	**Recap model use and representations** *(10 Minutes)* Review learnings from previous lesson. What have students been wondering since then. Recap model of tracking sun with torch and gnome on paper with shadows recorded. Use students' representations to discuss details. Extend Student thinking. **Probing question:** ❖ *Is it day time everywhere in the world right now?* **Earths Rotational Movement** *(10 Minutes)* This is a guided inquiry sequence where the teacher directs student interaction. 1: Watch a video explanation of earth's rotation and day/night https://www.youtube.com/watch?v=QMPPCUopats Draw the students' attention to while it is day time and sunny on one side of the earth, on the other side it is night time and in darkness. Using the video - discuss the earth's rotation noting/pausing when the sun hits the East Coast of Australia (Sun rise). 2: Turn/pause an animated model of the Earth to explore how rotation affects the view of objects in the sky from a given location (Australia). **Probing question:** ❖ *Is it day/night? What would you we be able to see now*?(changing day to night)	Can students recap on the changing position of the sun during the day. Can students sensibly discuss the possibility that the apparent sun's movement could be caused by the earth rotating? Can the students recognise that as the earth is rotating, this results in successive daytime and night time? Can students translate the model to recognise the changing position of the sun across Australia and the globe? Can students distinguish between day and night and make inferences about; * Different times of day * The same time in different locations (Australia/world).

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	Applying and extending conceptual understanding Students are introduced to a new model and relate this to the previous video model. Representational re-description: Translation of previous models in exploring a role play	**Teacher modelling the earth-sun relations using a rotating earth globe** *(15 minutes)* Model the earth's rotation with a globe rotating *counter-clockwise* (eastward) with a torch stationary, representing the sun (dim lighting as much as possible so students can see torch light). **Probing question:** ❖ *When is it day/night in Melbourne/Australia?* Place a sticker/blutack on the location to assist students with the description. Vary location to probe understanding. Ask students for suggested alternative locations (such as the locations of any children who have immigrated or who have relatives overseas). **Role play of Earths Rotational Movement** *(15 Minutes)* **Teacher explains:** *"We're going to act out the earth rotating with the sun fixed"* 1) Two Students stand inside a hoop representing the earth. 2) Allocate continents e.g. Australia & Europe to children in the 'Earth Hoop'. 3) The Lamp/torch held by another student (in a fixed position) represents the sun (does not move) 4) Students in the hoop (Earth) turn around counter-clockwise, on the spot, holding the hoop. **Probing questions**: ❖ *Who/where is facing the sun/lamp?* ❖ *Are they experiencing day or night?* ❖ *Who/where is facing away from the sun/lamp?* ❖ *Are they experiencing day or night?* ❖ When is xxx experiencing morning? Summarise student learning through **probing questions**: ❖ *What is the earth doing?* (Reinforce it takes one whole day (24 hours) for the earth to rotate once). ❖ *Is it day and night at the same time in different places?* ❖ *If it is day time here what is it on the opposite side of the world?*	Can students flexibly discuss the time of day at different parts of the world? Can students interpret the model to determine differences in sunrise times in Melbourne compared to Perth? Can students recognise that the model allows us to explain the movement of shadows, using a toothpick placed at Melbourne's location? Can students interpret the role play to explain different times of day in different locations round the hoop? Can they articulate the link between this role play and the globe model?

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	Posing representational challenge Students construct a diagrammatic representation based on the three models explored ***Building consensus*** Evaluating and synthesising student representations Refining and consolidating students' ideas to come to a shared understanding of how rotation of the earth causes day and night, and shadow movement.	**Representation Activity / Summative Assessment** *(15 minutes)* Students construct their representations of what they've learned (observed, recorded, modelled) about day and night and the earth's rotation around the sun. Students may include information (e.g.: about how long a rotation takes). **Gallery Walk** *(10 Minutes)* Students set out their books and explore others' representations before coming back to alter their own to add greater clarity. Teacher selects different student representations. **Probing questions: during gallery walk for students and guiding questions for following discussion** ❖ *What can you tell from the different representations?* ❖ *How effective are they?* ❖ *What do they show?* ❖ *What don't they show?* **Concluding review** Teacher leads a discussion about using models to understand concepts. Reinforce the rotation of the Earth in relation to the sun and how this was modelled with the class role play using the earth and sun. **Next lesson:** inform the class that we're going to compare their understandings about day and night to what they thoughts at the start of the sequence. They will explore their pre-test and add their understandings now.	Do student productions show clearly the earth's rotation and the day/night distinction? Can students show how different continents have different times? Can students explain the link between this space-centered view, and the earth centered experience of the sun moving across the sky?

Lesson 5 – Review and Clarify Day and Night Understandings

(Approximate duration 40 minutes)

In this lesson, the learnings from the sequence are reviewed.

Curriculum Focus:

Science ideas and processes

- Day and night are caused by the earth's rotation.
- Model the earth and sun to explain what we experience of day and night.
- It can be night time in America when it is day time in Australia.
- The apparent movement of the sun across the sky is due to the earth's rotation

Mathematical ideas and processes

- Representing direction, rotation, and time
- Representing spatial relations via compass directions, height of sun, modelling size.
- Measurement of length of shadow- informal and formal measures

Resources/Equipment
Post sequence assessment task
Torch
Paper with shadows
Globe / Earth ball
Computer connection to screen

Students: student workbooks (unlined), pencils, coloured markers and rulers

Teachers: Board (IWB/whiteboard) and or butchers' paper for shared recording, pens and computer

Learning intention:

- Student revision and explanation of day and night, and the sun's movement, using diagrams

Lesson at a glance:

Students final representations and learning analysis (Post-sequence assessment activity)
Student summative explanation of the Earth's rotation around the sun and how rotation affects the view of the sky from a given location. Students demonstrate an understanding (summative task – Post-sequence assessment) that the earth's rotation makes the sun appear to rise in the East and set in the West.
Students discuss their understandings to build consensus and an agreed understanding.

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LESSON 5 - Review and Clarify Day and Night Understandings

In this lesson, the learnings from the sequence are reviewed

(Approximate duration 40 minutes)

Session focus	Pedagogical stage	Lesson Outline (*time allocations a guide only*)	Monitor and support learning
SCIENCE: Day and Night Representations – diagrams (with labels) the sun tracks across the sky because the earth is rotating **MATHEMATICS:** Comparative analysis Time Directionality	***Review of learning*** Students review their changes of understanding over the sequence, and complete an assessment	**Discussion: Compare what we know now** that we didn't before *(10 minutes)* **Probing questions:** ❖ *Did you think your shadow would change?* ❖ *What do you know now about your shadow and how it changes?* ❖ *What do shadows tell us about the sun in the sky?* ❖ *How, and why does the sun appear to move in the sky?* ❖ *What's really happening? How do we know that?* ❖ *Can you use models of the Earth and sun to explain night and day? Shadows?* **Post sequence assessment task** *(20 minutes)* Hand out pre sequence assessment with students' previous answers. They are asked to consider whether they now have a different view, and enter their responses in a different colour (not erasing). Teacher reads task with students answering independently on worksheet. Answers can be shown through text or drawings with labels. **Concluding discussion** *(10 minutes)* **Teacher asks:** *"What ideas did you have now, that were different to your ideas before?"* Teacher leads a discussion about using models to understand concepts. Reinforce the rotation of the Earth in relation to the sun and how this was modelled with the class role play using the earth and sun.	Can students recognise their changed ideas? Can students link the different models to their observations and experience?

Appendix 1

Teacher Notes the Sun, Earth, and Day and Night

Sun Facts

- The sun is a star
- The sun is a source of light
- The sun is at the centre of the Solar System and *does not move*
- The sun is nearly a perfect sphere
- In the Southern Hemisphere the sun rises in the East and sets in the West.
- At the centre of the Sun it reaches temperatures of 15 million °C.
- The Sun is 4.6 billion years old.
- The Sun is 109 times wider than the Earth and 330,000 times as massive (approx. one million Earths could fit inside the Sun).
- The Sun is all the colours mixed together this appears white to our eyes. NB: The sun is damaging to the eyes.
- The Sun is mostly composed of hydrogen (70%) and Helium (28%).
- The Sun is a main-sequence G2V star (or Yellow Dwarf).
- If a hollow Sun was filled up with spherical Earths then around 960,000 would fit inside

Earth rotation

The earth rotates about an imaginary line that passes through the North and South Poles of the planet. This line is called the axis of rotation. Earth rotates about this axis once each day (approximately 24 hours) in an Easterly direction.

Earth tilt

This tilt in Earth's axis or axial tilt is what is responsible for seasonal changes during the course of the year. When the tilt is away from the sun (in the Southern Hemisphere), we have winter and shorter days and vice versa.
In Astronomy the *axial tilt* is also referred to as the Obliquity.

Earth revolution

The path of the earth around the sun which is one complete cycle of an orbit is approximately 365.2425 days in length. (not the focus of this sequence).

Equinox

When Earth is in this position, sunlight shines equally on the two hemispheres. Twelve hours of sunlight and night time.

Solstice

The North Pole seems to lean away from the direction of the Sun. You can see that the North Pole is in complete darkness. At the same time, the opposite is true in the Southern Hemisphere. The South Pole seems to lean toward the Sun and is in sunlight. It is the Southern Hemisphere’s summer solstice and the Northern Hemisphere’s winter solstice.

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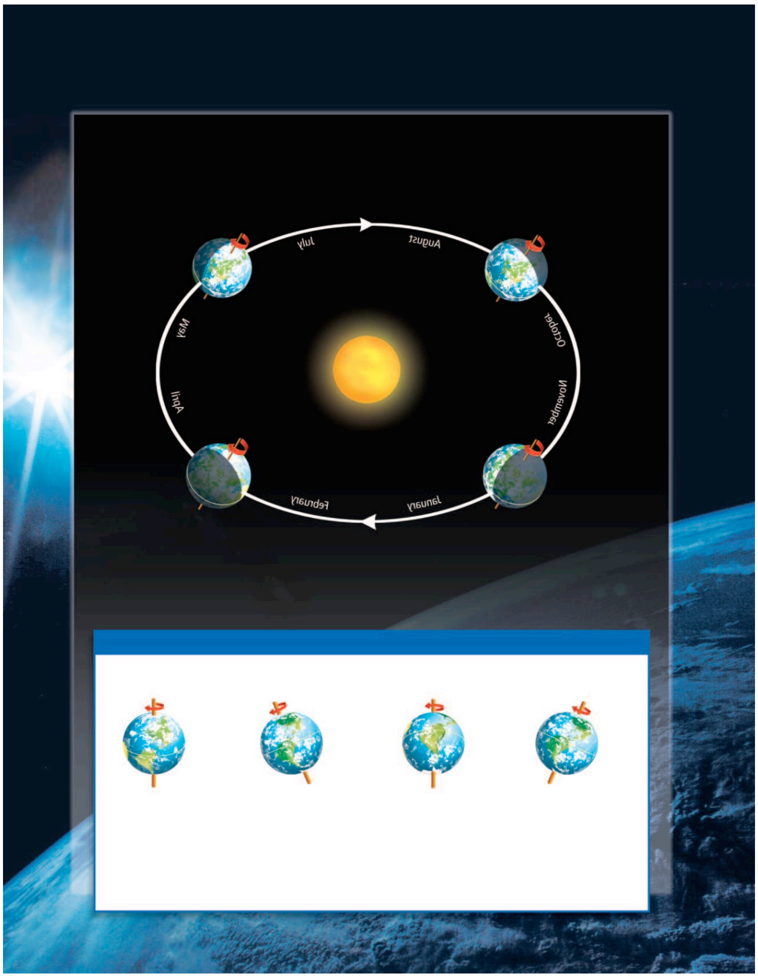
July
August
May
October
April
November
February
January

Appendix 2

References and Resources

- Keeley, P. (2014). *Uncovering student ideas in primary science, volume 1 : 25 new formative assessment probes for grades k–2*.
- Keeley, P., & Sneider, C. (2012). Uncovering student ideas in astronomy: 45 formative assessment probes.

CHILDRENS BOOKS TO READ

- Bulla, C. R., & Adams, A. (1965). *What makes a shadow ?* London : Black, 1965.
- Storad, C. J. (2013). Day and Night, edited by Digital Learning Britannica, Encyclopaedia Britannica, Inc.

LINKS

- TO VIEW THE SUN – LIVE CAMERA: MOUNT BURNETT https://skypi.mbo.org.au/allsky/
- Earth Rotation Animation & Quiz http://fusecontent.education.vic.gov.au/ba49272f-b66b-4716-87cb-d6888a254a35/p/index.html
- VIDEO EXPLANATION: Earth's rotation and day/night https://www.youtube.com/watch?v=d11eKW6CTd8 or https://www.youtube.com/watch?v=QMPPCUopats or https://museumsvictoria.com.au/learning/little-science/teacher-support-materials/changes-in-the-sky/ and https://visibleearth.nasa.gov/view.php?id=57760

APPS

- EARTH NOW – Live footage of Earth
- AUSTRALIA – Live Camera (3hr playback – watch weblink at 9:00am to see the sun rise on the East Coast) http://satview.bom.gov.au/ Video recordings will be available for during the day and sunset.
- LIVE GLOBE DAY NIGHT LINK & CLOCK https://www.mathsisfun.com/time-zones-world.html

LEARNING RESOURCES, QUIZZES & ACTIVITIES

- VIC ED: Earth Rotation - Modelling and Quiz VIC GOV http://fusecontent.education.vic.gov.au/ba49272f-b66b-4716-87cb-d6888a254a35/p/index.html
- Interactive Activities NASA - including the Sun images, facts and countdown until eclipse https://solarsystem.nasa.gov/interactives/
- Early Years NASA Sun Link https://spaceplace.nasa.gov/menu/sun/

LINKS & VIDEOS

- See a year in the life of the sun. #NASAViz https://svs.gsfc.nasa.gov/12154
- A NASA spacecraft records a trio of flares on the sun. #NASAViz https://svs.gsfc.nasa.gov/12336

Appendix 3

Gnome Sundial diagram

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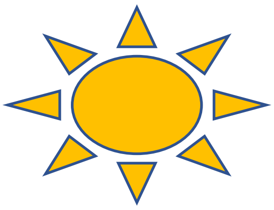
Appendix 4

Pre/Post Sequence Assessment Task



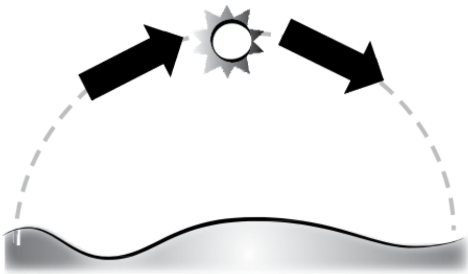
Name:

What are your ideas about the sun?

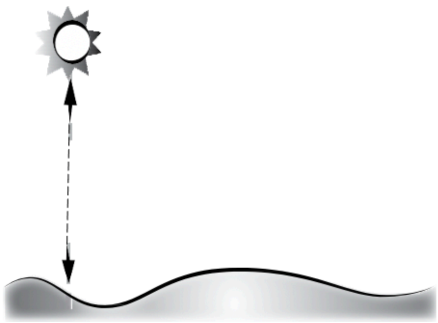
1. What do you know about the sun? Draw/Label/Write

2. How does the sun move in the sky? (***TEACHER READS DIALOGUE (Students circle answer below)***

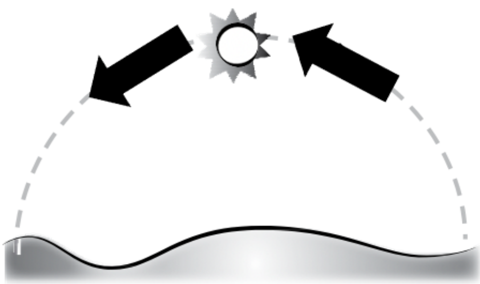
Avi – "I think the sun rises on one side and sets on the other like this.
It rises on my left (the west) and sets on my right (the east)"



Jessica: "I think the Sun rises in the morning and sets in the evening it looks like it does this"



Jasper – "I think the sun rises on one side and sets on the other like Avi,
but it goes the other way. It rises on my right (the east) and sets on my left (the west)"



Who do you agree with and why? EXPLAIN/LABEL WHY?

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3a) Draw a picture of the sun and earth when it is day.

3b) Draw a picture of the sun and earth when it is night.

4. How is a shadow made? Draw/Label/Write

Q5. Is a shadow different at different times of the day? How? Why?

How do your shadows change during the day?

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