VISUALISATION AND SPATIAL THINKING IN PRIMARY STUDENTS' UNDERSTANDINGS OF ASTRONOMY

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The 13th ESERA Conference held at: Bologna, Italy 26th – 30th August, 2019
The theme chosen is "**The beauty and pleasure of understanding: engaging with contemporary challenges through science education.**"
https://www.esera2019.org/

Symposium - Paper presentation

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Astronomy is commonly taught in primary schools, with an initial focus on explaining day and night, the solar system and seasons. However, there is abundant evidence that students going into secondary and even tertiary studies in astronomy have limited understanding and indeed misconceptions of astronomical phenomena. A core difficulty for students is the need in visualising/explaining astronomical phenomena, to coordinate earth and space centred perspectives and representations. This presentation will describe lesson sequences conducted in 3 schools, over 12 classes, focused on Grades 1 and 4 (Ages 6 and 10) children's visualisation of day and night from earth and space perspectives. The sequence is part of a project that links science with mathematics through representation construction and modeling as core approaches to learning. Key features of the sequence were children's construction and coordination of spatial representations that linked the changes/movements in shadows (patterns) throughout the day with the movement of the sun in the sky and with earth's rotation in relation to the sun to explain day and night, and the pedagogy employed by teachers to build on children's representations to establish common understandings. The mathematics focus was on spatial reasoning including representations of length, rotation and angle, pattern representation, and temporal reasoning. Data included children's artefacts, pre- and post-tests, field notes and video capture of key lessons, and student and teacher interviews. The pre- and post-test data and children's interviews showed considerable shifts in children's understanding of day and night and earth-sun relations. Analysis of the video data, and field notes, showed the complexity of concepts and spatial reasoning for children, as well as the power of a guided inquiry pedagogy involving the construction and comparison/evaluation of representations. The study provides fresh insights into the challenges presented in constructing flexible understandings of astronomical phenomena based on the coordination of spatial and temporal representations from different perspectives.

Keywords: Astronomy education, visualization and representation, modeling-based learning

https://imslearning.org/

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Interdisciplinary Maths and Science Learning

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ENRICHING MATHS AND SCIENCE LEARNING: AN INTERDISCIPLINARY APPROACH

This is an international, longitudinal project which aims to investigate the effectiveness of an innovative interdisciplinary learning approach in mathematics and science. Through collaborating primary schools in Australia and the United States of America (USA), it will investigate how students' invention and transformation of representational systems can connect to support deeper reasoning and learning. The project will form the bases for new curricular designs that leverage students' representational practices across science, technology, engineering and mathematics (STEM) disciplines to promote more robust and generative knowledge.

> **Science gives the real problems for the maths to solve**
>
> **Year 1 student**

Tytler, R., Prain, V., Mulligan, J., White, P.J., Xu,, L., Lehrer, R., Schauble, L., Kirk, M., Speldewinde, C., & Neilsen, C. (2018). Enriching Maths and Science learning: An interdisciplinary approach.

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Key features of the IMS project

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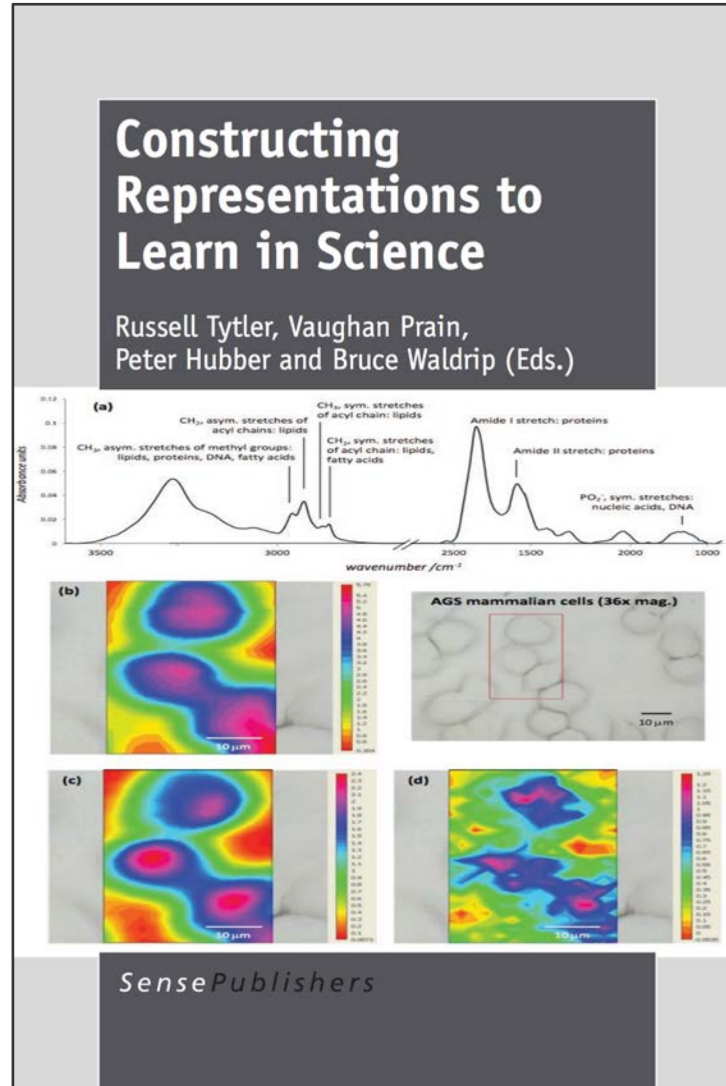
Learning as induction into the multi modal discursive practices of science and mathematics (Latour, Peirce, Lemke)

Model based reasoning, socio semiotic perspectives (Lehrer & Schauble, Lemke)

Pedagogy: guided inquiry where children generate data/observations and **invent, compare, assess and revise**, and coordinate representations.

Maths and science interact productively, each raising questions that advances the other. There is a focus on constructs that are common to both.

Representational tools are crucial resources for speculating, reasoning, contesting and justifying explanations, knowledge building, and communicating.



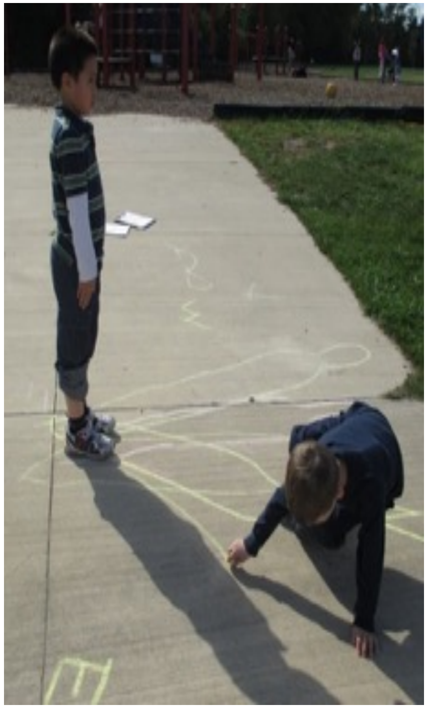
Year 1 Astronomy

Structure of the sequence

Lesson sequence

Lesson 1: What do you know about the sun? Establishing prior knowledge of the sun and day and night. Setting up of predictions 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, 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 & role play.

Lesson 5: Clarify Day and Night Understandings Students final representation and learning analysis (Post-test activity).

Science and maths ideas, representations

Science ideas

- Day and night are caused by the earth's rotation.
- Movement of the sun from east to west (right to left if facing north), in the north part of the sky, because of the earth's rotation.
- We can model the earth and sun to explain what we experience of day and night.

Mathematical ideas

- Representing spatial relations – compass directions, height and movement of sun, modeling shadow movement
- Measurement of length of shadow.
- Collating data to draw conclusions

Major representations

- Ways of representing the movement / angle of the sun across the sky
- Representing shadows in relation to the position of the sun – gnome shadow
- Role plays of rotating and observing sun rise, and relating to modeling of earth-sun system

https://imslearning.org/resources/

Interdisciplinary Maths and Science: Astronomy – Year 1 (2018)

Astronomy

Purposes of the Project: This sequence of activities has been structured to attend to several key research outcomes. To see more: https://imslearning.org/

- Engage in an interdisciplinary approach to Mathematics and Science learning that focusses on common concepts with synergistic, mutual gain to support deeper learning in both;
- Focus on learning outcomes, including assessing these outcomes;
- Teachers and students as co-researchers;
- Refine guided inquiry teaching and learning approaches;
- Facilitate student modelling and representation construction work;
- Teacher led strategies of modelling – invent, evaluate, refine, extend and use with meaningful, interesting tasks for students;
- Longitudinal tracking of students modelling and learning through the process above; and
- Produce exemplary teaching and learning sequences.

Sequence Overview

The sequence will focus on spatial relations of the sun and earth, coordinating an earth centred and space centred perspective. It will develop an understanding about Astronomy, day/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: if we are facing north, sun rises on our right and sets on our left.

KEY CURRICULUM OUTCOMES:

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)

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)

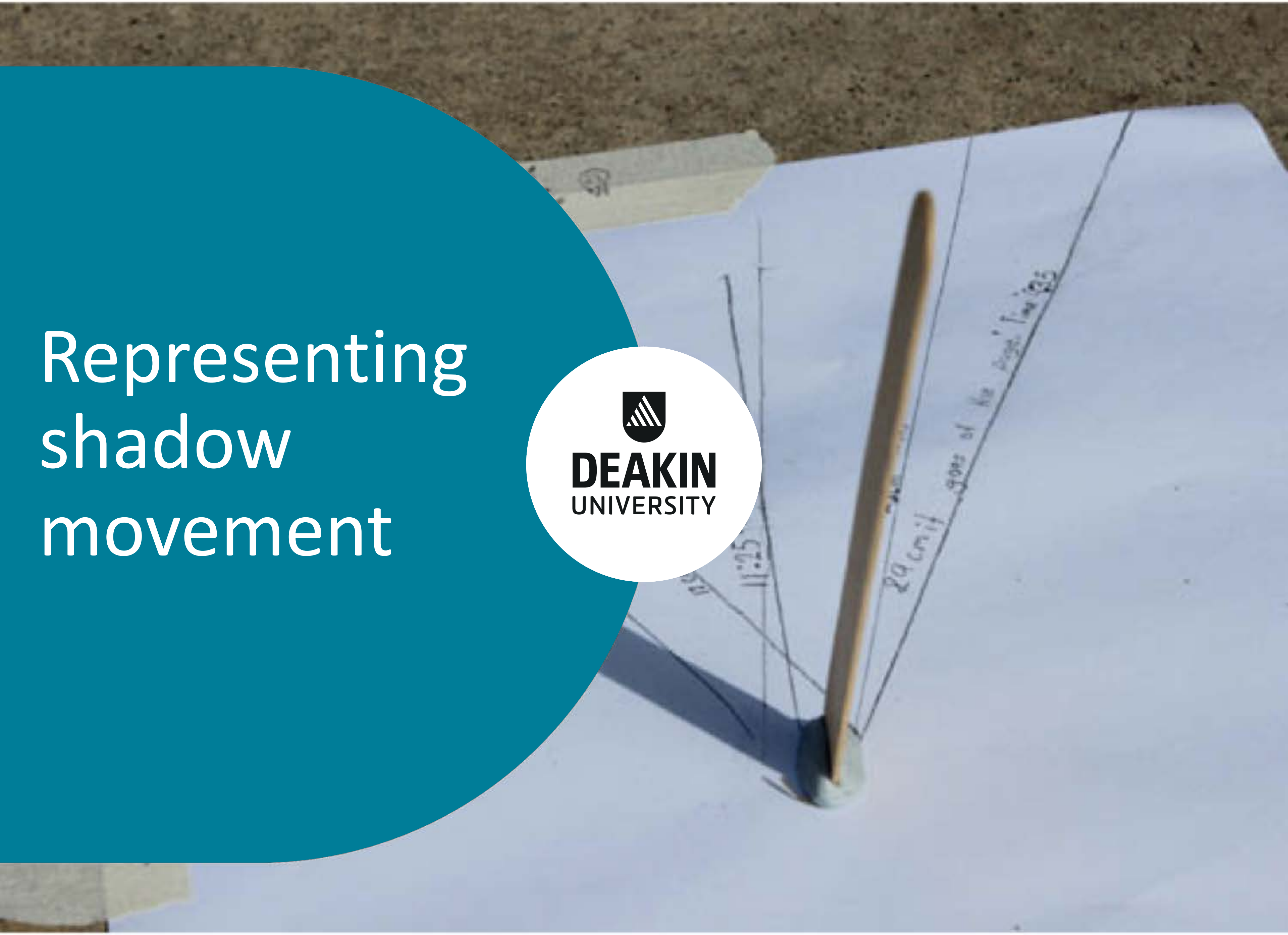
Data representation and interpretation

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)

Developed as part of the Australian Research Council Project: Enhancing Mathematics and Science Learning: An Interdisciplinary Approach https://imslearning.org Deakin, Macquarie, and Vanderbilt Universities.

Representing shadow movement



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Lesson 1: Children's prior ideas and preparation for shadow tracking

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Lesson 1: What do you know about the sun? *Establishing prior knowledge of the sun and day and night. Setting up of predictions and procedures for recording shadows and the suns movement.*

Children predict the shadow might 'move and change direction', 'get longer', 'get shorter' (because the sun's really big).

On observing shadows informally:

Student

"The shape of the shadow changed"

(written on board)

"It got smaller and turned to the side"

Teacher

What does that mean - it moved to the side.

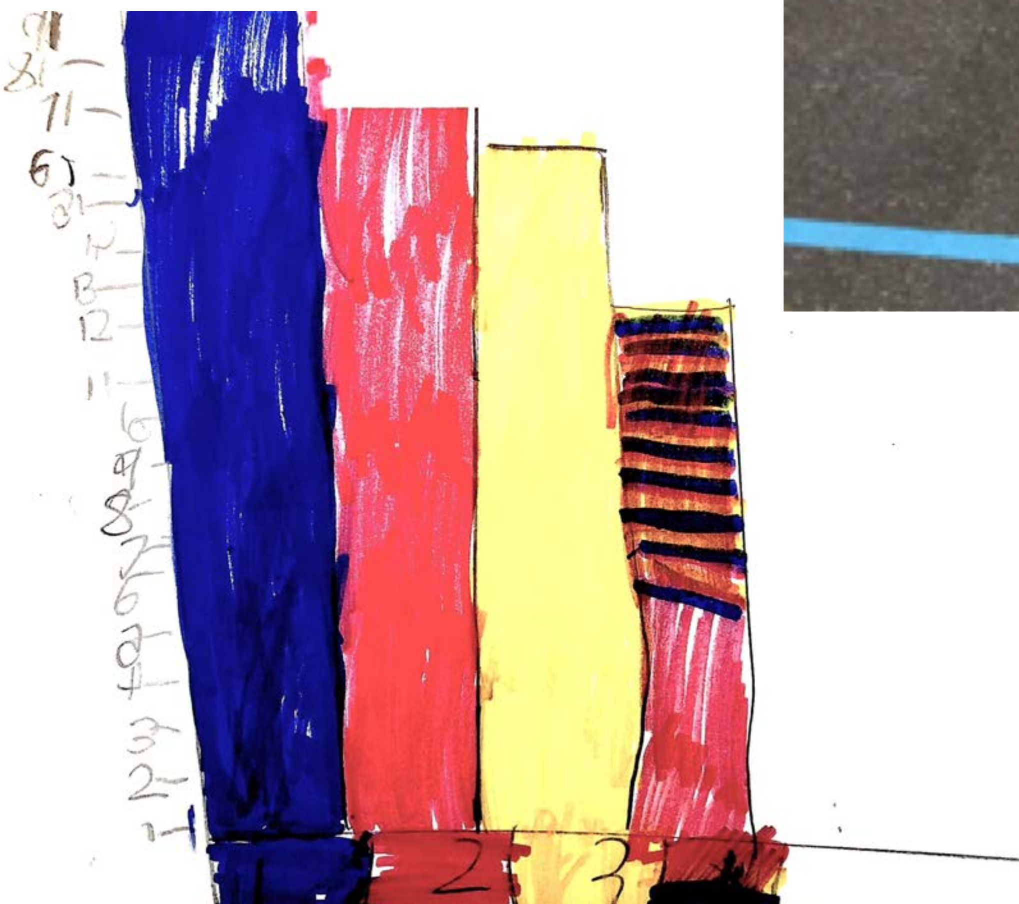
Jen (student) indicates with gestures

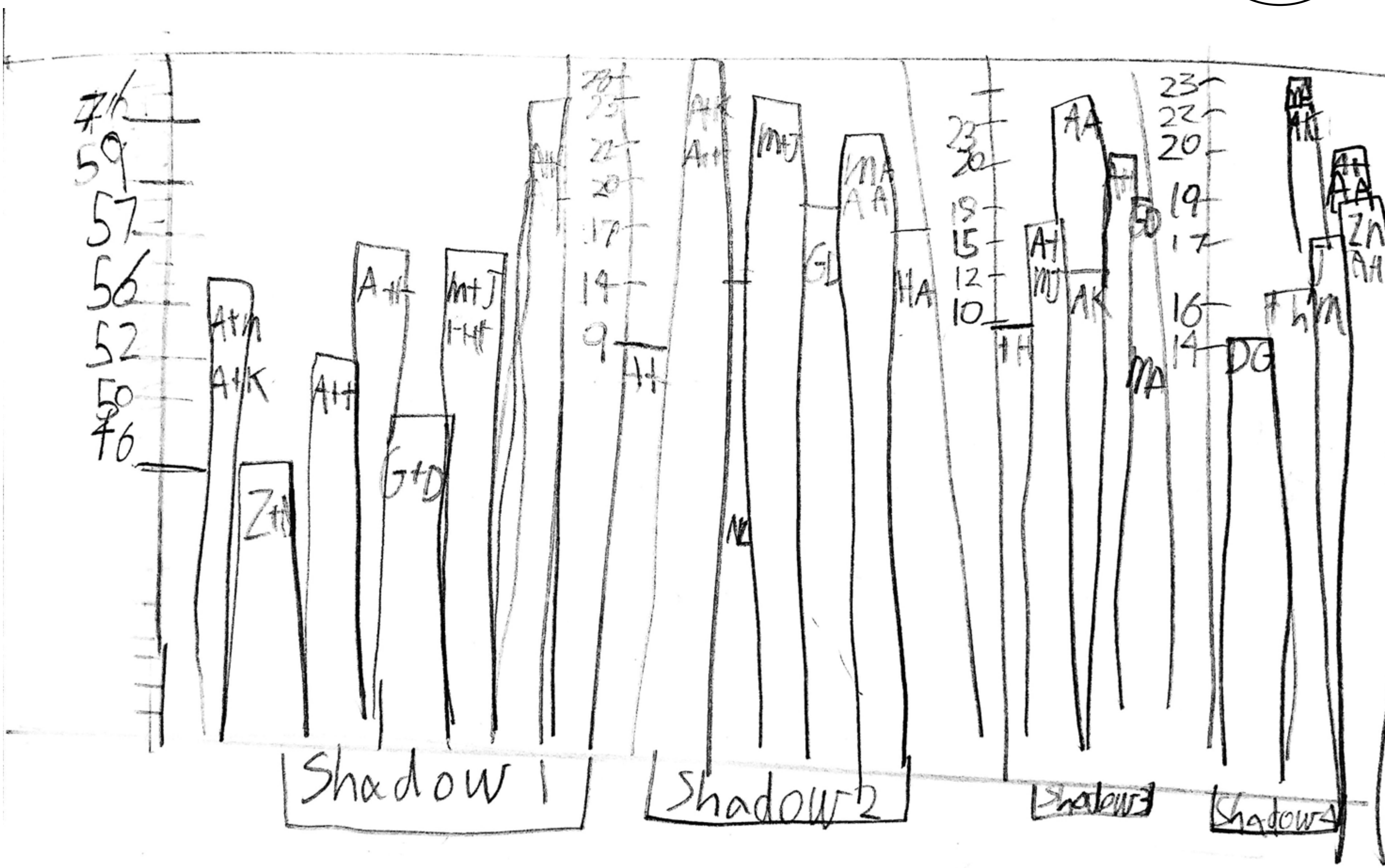
"Oh so you mean moved around"

- How are you going to show how your shadow's changed?
- How are you going to record how the time has changed?

Different classes made different decisions about measuring length: using streamers or using blocks.

Modeling shadow in relation to sun

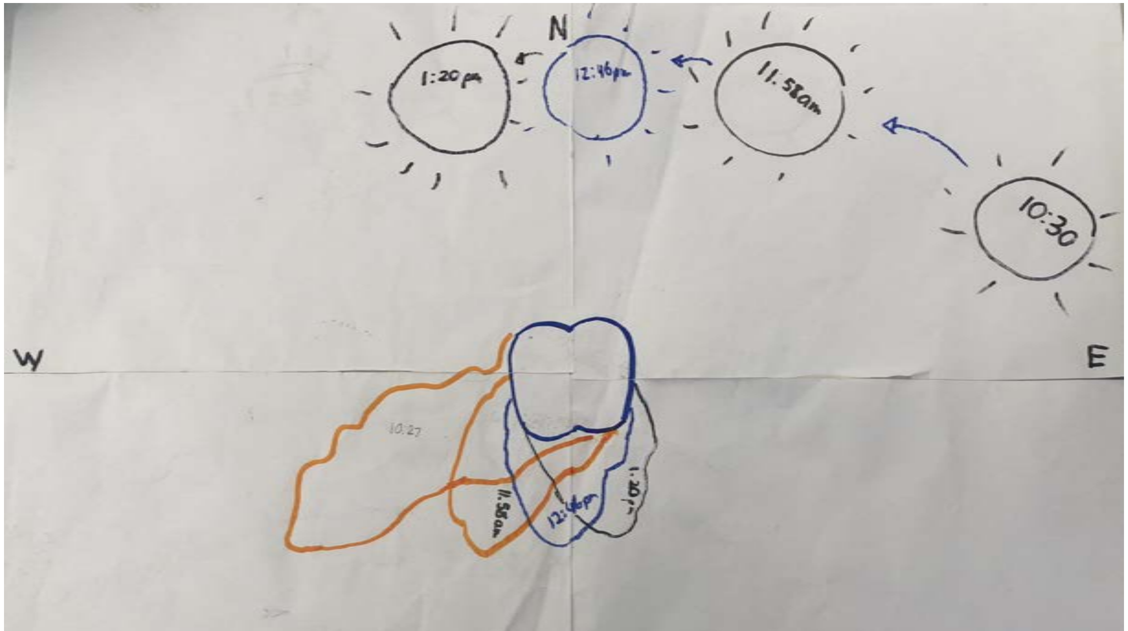



Shadow 1
Shadow 2
Shadow3
Shadow4
Z+H
G+D
A+H
A+K
M+J
DG

Gnome shadow modeling

Establishing sun and shadow relations using the gnome

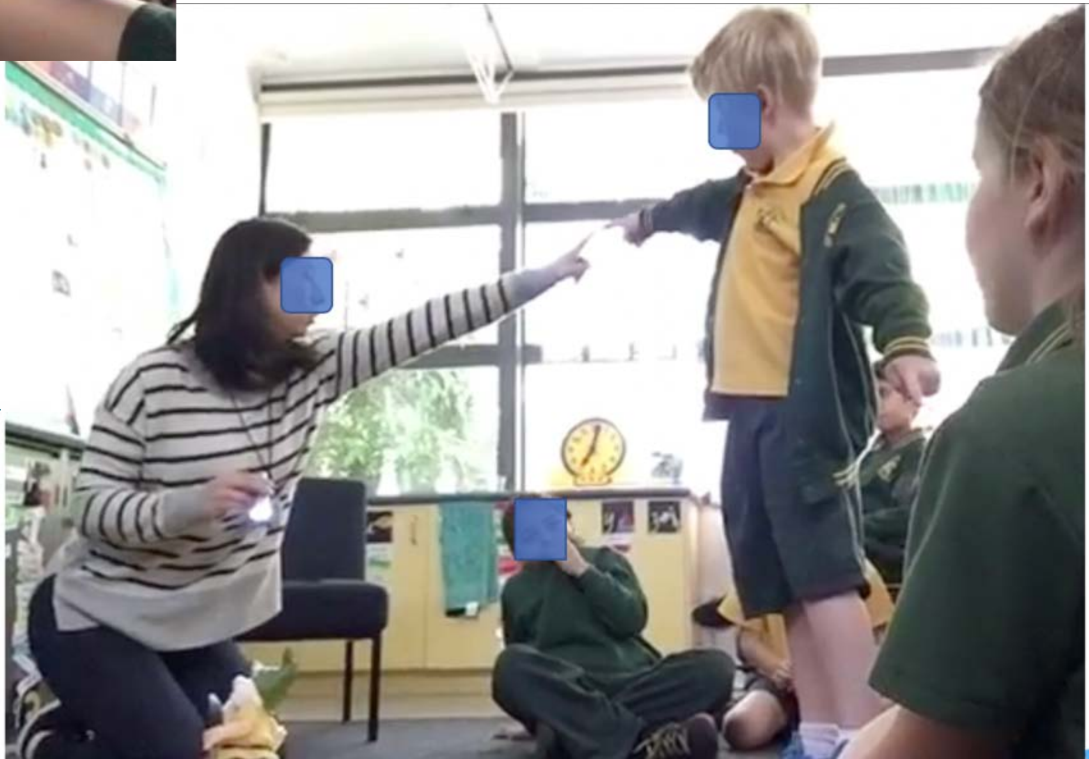

9.00
9.45
10.30
11.30
2.30
3.00
3.30
4.30
5.00


N
1:20pm
12:46pm
11:58am
10:30
W
E
11:58am
12:46pm

Modeling the sun's movement with a torch and gnome, then embodied representation

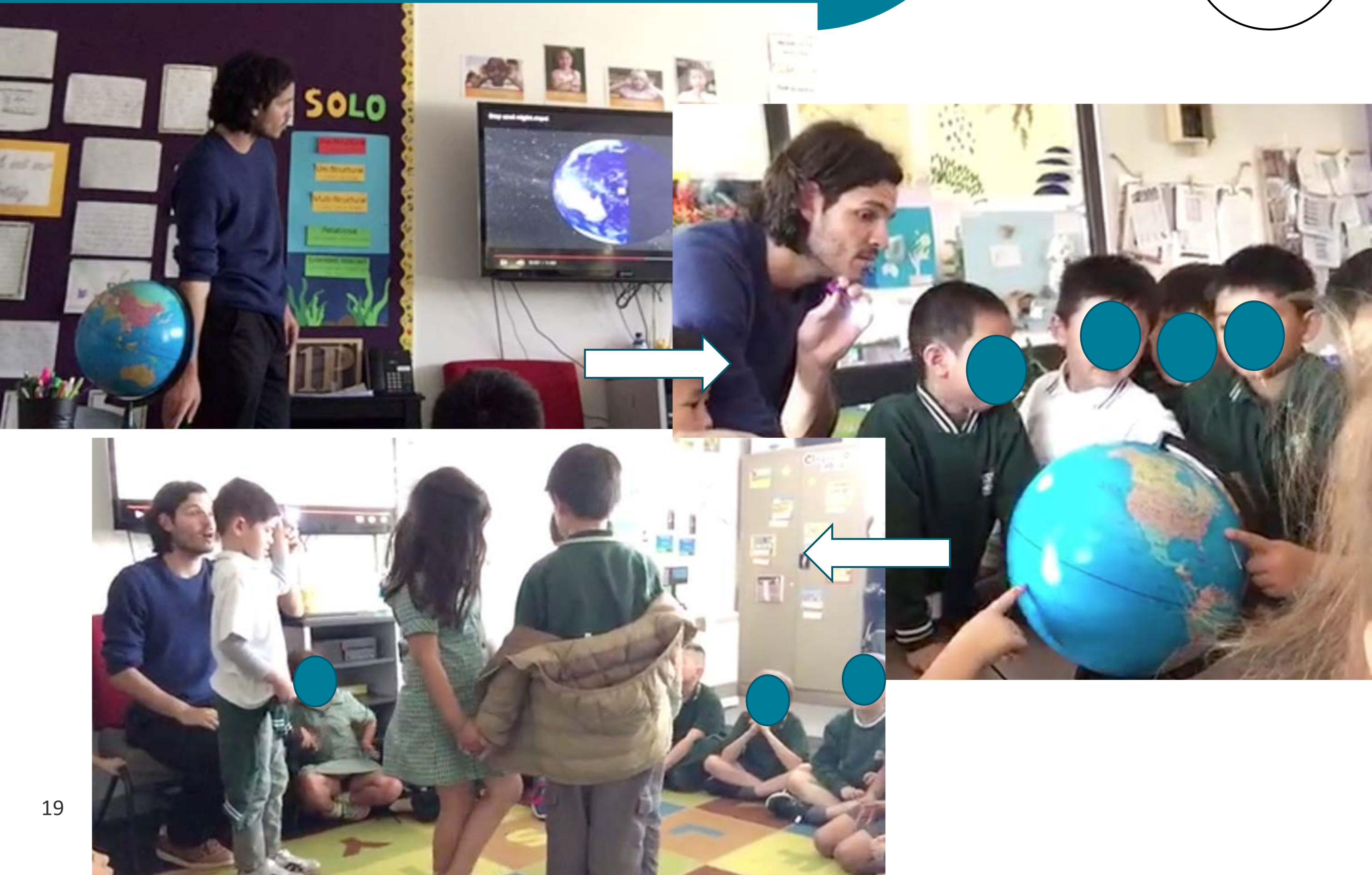
The teacher moves the torch to duplicate the sun's movement …

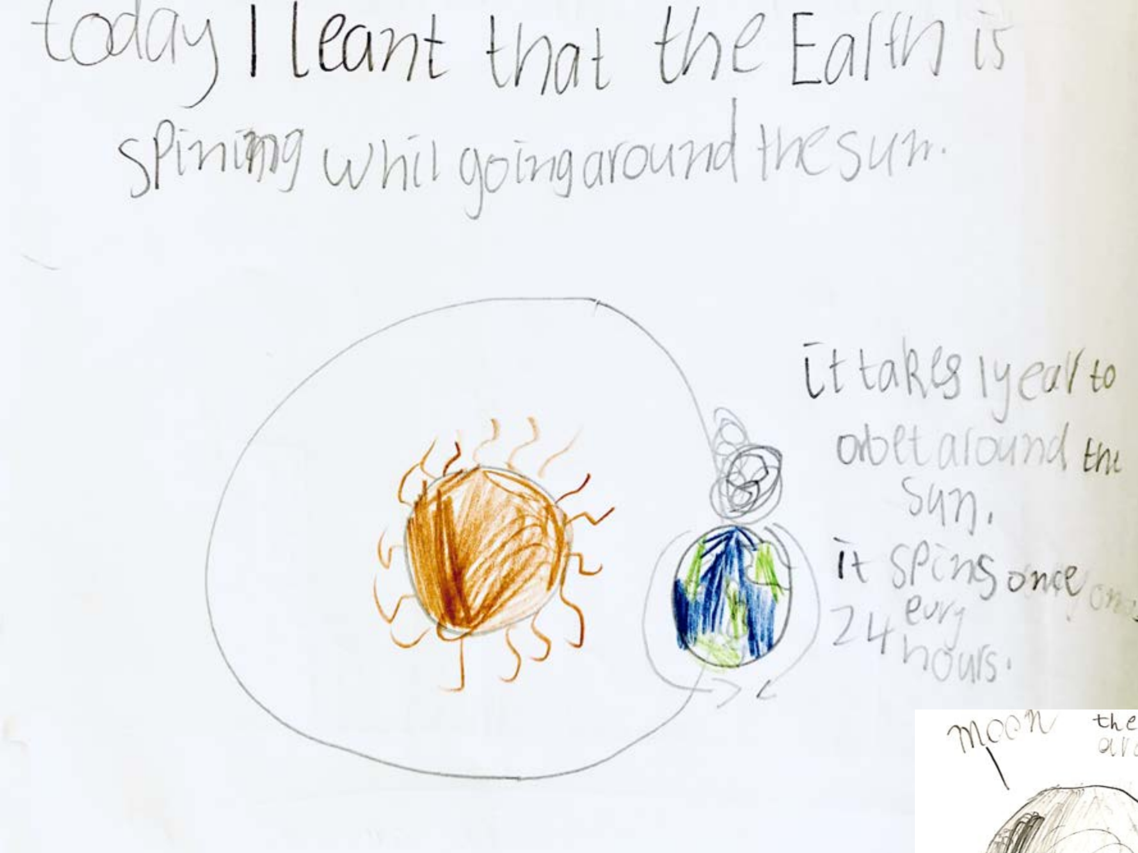
…. then has a student point to the sun and the shadow tip, to establish they are opposite in direction.

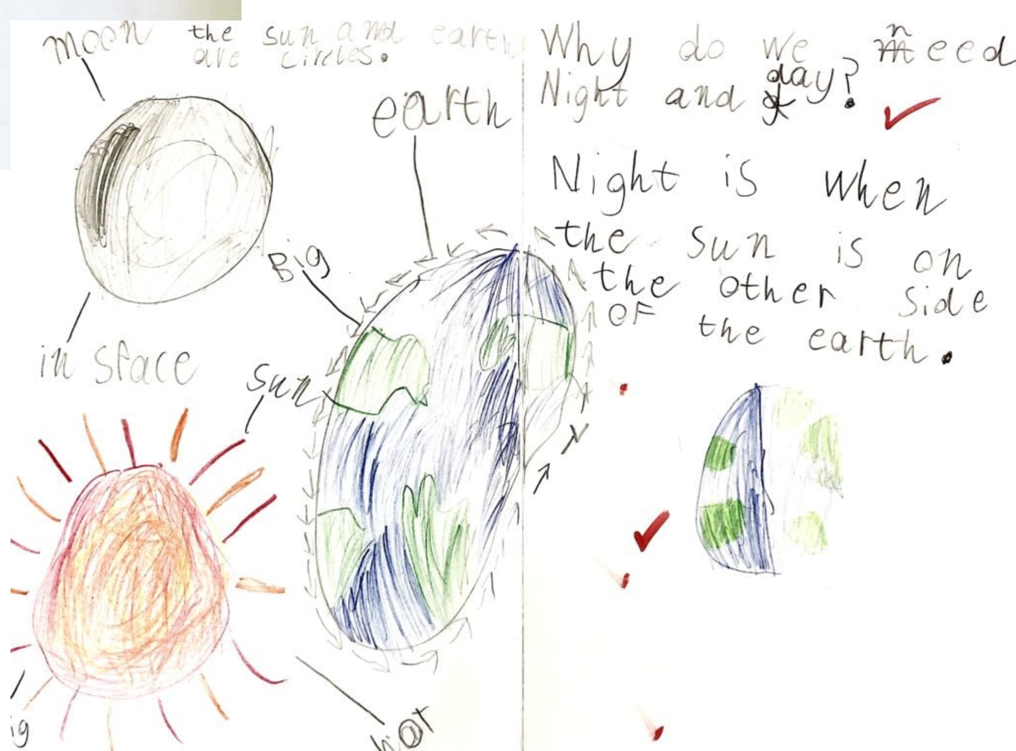


Day and night modeling

Modeling night and day



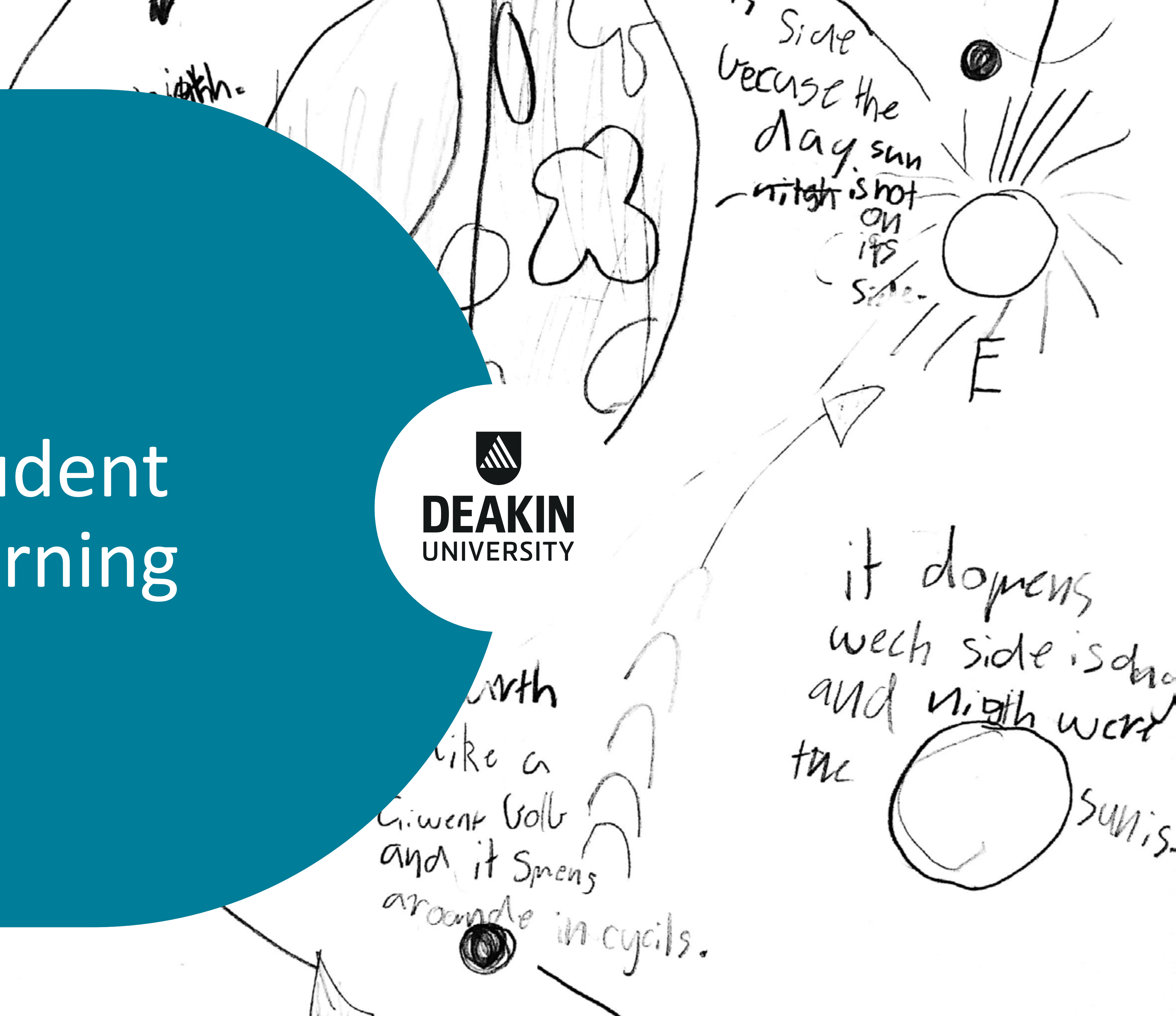

today I leant that the Earth is spining whil going around the sun.
It takes 1 year to orbet around the sun.
It spins once every 24 hours.


moon
the sun and earth are circles.
earth
Big
in space
sun
Why do we need Night and day?
Night is when the sun is on the other side of the earth.

Sequence of representations

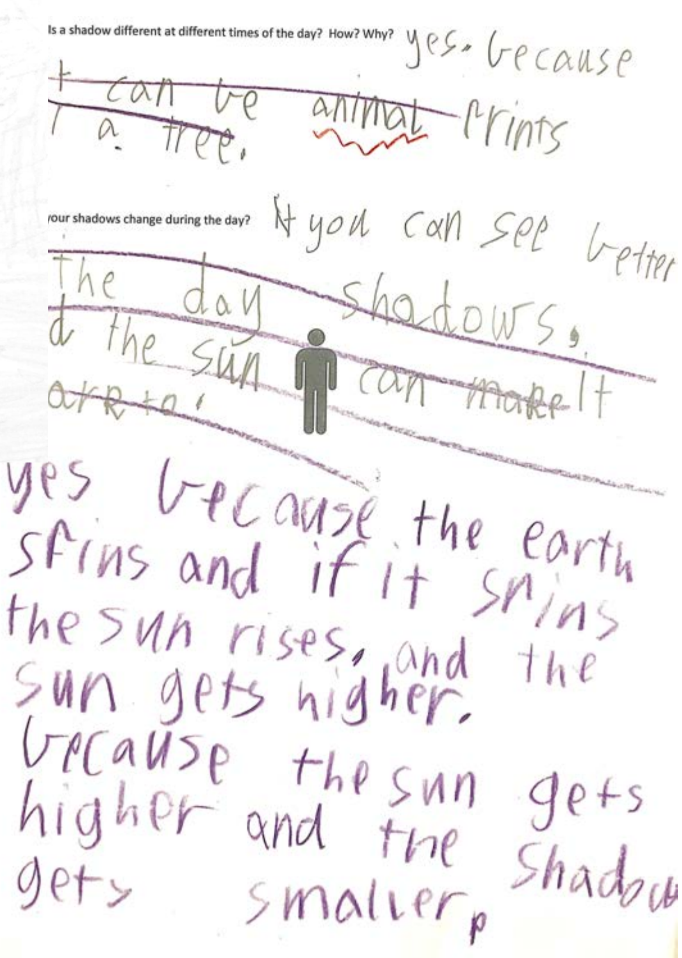
- Representation of changing shadow length
- Representation of changing shadow angle in relation to sun
- Gnome shadow angle and sun position
- Modeling of sun movement and gnome shadow with torch
- Video of earth rotating
- Earth globe and torch
- Role play of rotating earth

Student learning

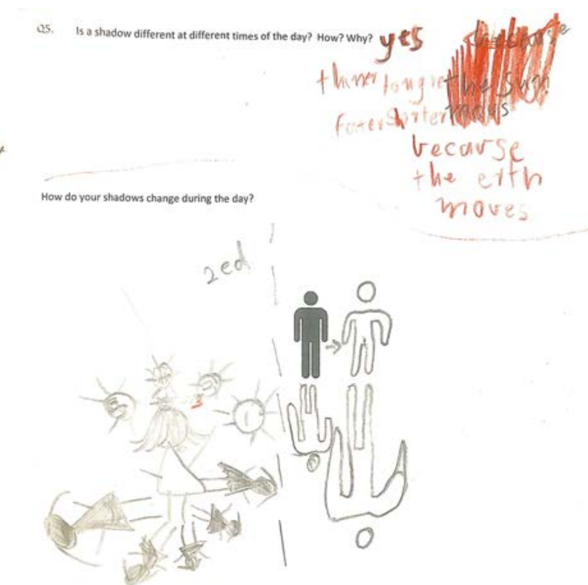


Changes to children's ideas about shadows

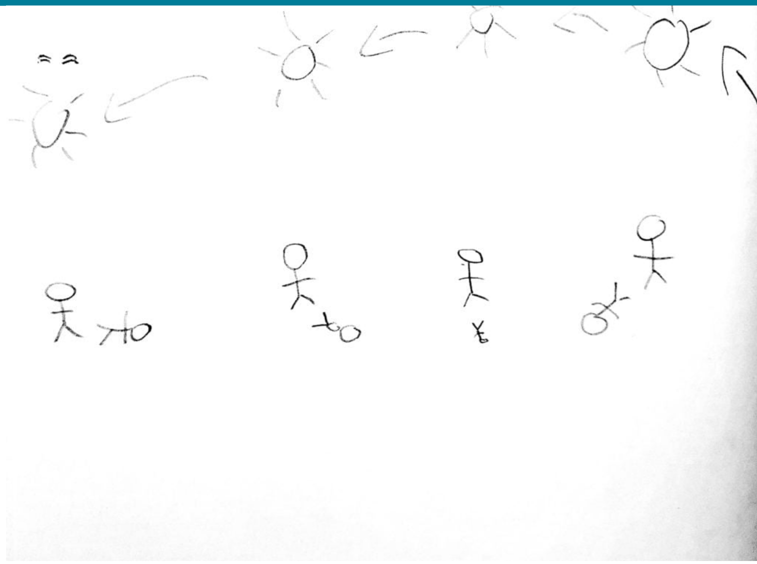
Naïve post test entry

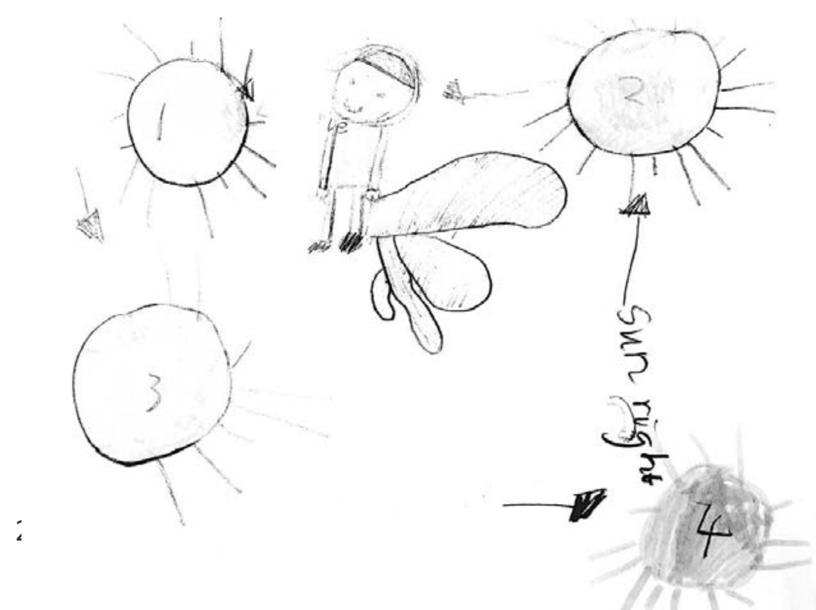


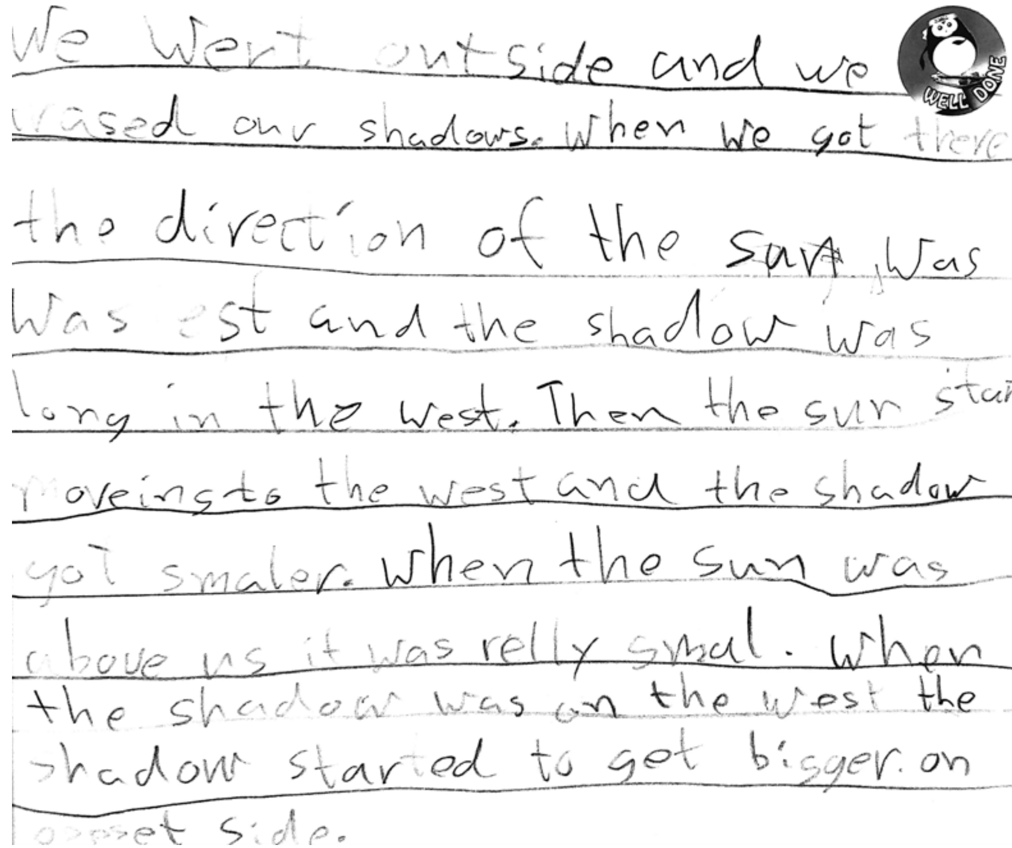
Changes to student ideas



Final representations






We went outside and we
traced our shadows. when we got there
the direction of the sun Was
Was est and the shadow was
long in the west. Then the sun start
moveings to the west and the shadow
got smaler. when the sun was
above us it was relly smal. when
the shadow was on the west the
shadow started to get bigger. on
opposet side.

Teacher perceptions of learning

Interviewer: Do you think they were able to make the connection between time of day in terms of measurement, different times in the day and the length of the shadow?

Colin: Some did and some did not at the start and then when we went back and we modeled it again in class with the globe and we looked at the shadows and the sun with a torch, when we did that activity we kind of then found that the children were kind of going, "Oh, the shadow's getting a bit longer here," so, **then we went back to our data, we had a look at the length of the shadows, what time of the day was it, we went back and had a look and then we said, "Can we see a pattern?"** and they kind of were able to then identify at the end that the morning and afternoon the shadows were longer and in the middle of the day it was shorter, "But why?" because the sun was higher in the sky.

Teacher perceptions of learning

Emily: This has been really interesting in seeing children that don't speak up as often really come up with some really insightful representations …. BUT …. In the shadows representations, they're still drawing them almost looking like people rather than a shadow, and not showing that full tracking of the sun and the shadow lengths changing.

Student focus groups

Student: And because even at different times of the day, the sun rises around you and then your shadow gets smaller and then when the sun's over here, your shadow gets bigger because when it's going to go around and around, then.

Student: It is in different times of the day because it's always like when the sun is here, the sun is big because-

Interviewer: When the sun is low, you mean.

Student: Because it's the opposite but when it's on the top, which is noon, it's actually small.

Interviewer: So, you're pointing up there high in the sky and the shadow is small.

Student: Yes, the smallest place and then after some hours more, it actually comes more bigger now because it's setting; it's going deeper.

On the other hand some students were confused still:

Interviewer: Why do you think it got smaller? Who can tell me?

Student: Because the sun is going up and then it's going more down but down to night time and then the shadow gets more smaller.

Pre- & Post test: Movement of sun in the sky

	Incorrect (sun moves up and down , or from west to east)	Correct	Unclear
Pre test	36	7 (14%)	7
Post test	5	40 (80%)	5

In focus groups, students often spontaneously used the globe to explain night and day, even orchestrating role plays.

If America is daytime and the earth is spinning around, then people's shadow in America would be bigger. Rotate the earth please. Then America's night time now, so Australia –

Findings

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The challenges to Year 1 students' spatial thinking, relating sun position to shadow length and angle.

The power of modelling and having children represent

The opportunities to develop children's measurement and representational skills

The engagement of students in the process

Thank You

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