VISUALISATION AND SPATIAL THINKING IN PRIMARY STUDENTS’ UNDERSTANDINGS OF ASTRONOMY

Presenters: Russell Tytler\textsuperscript{1}, Peta White\textsuperscript{1}, and Joanne Mulligan\textsuperscript{2}
1. Deakin University
2. Macquarie University

Team Members: Vaughan Prain, Lihua Xu Richard Lehrer, Leona Schauble, Melinda Kirk, Chris Speldewinde, Chris Nielsen

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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
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
Key features of the IMS project

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 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 sun’s movement.

Lesson 2: Conducting a Shadow Investigation Recording data to measure and interpret the sun’s 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 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
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/](https://imslearning.org/)

- Engage in an interdisciplinary approach to Mathematics and Science learning that focuses 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 [VCSS046]

- **Science Investigations**
  - Questioning and Predicting
    - Respond to and pose questions, and make predictions about familiar objects and events [VCSC050]
  - Planning and conducting
    - Participate in guided investigations, including making observations using the senses, to explore and answer questions [VCSC053]
  - Recording and processing
    - Use informal measurements in the collection and recording of observations in the school grounds [VCSC052]
    - Use a range of methods, including drawings and provided tables, to sort information [VCSC053]
  - Analysing and evaluating
    - Compare observations and predictions with those of others [VCSC054]

- **Communicating**
  - Represent and communicate observations and ideas about changes in objects and events in a variety of ways [VCSC055]

- **Mathematics**
  - Number & Place Value
    - Develop confidence with number sequences to and from 100 by ones from any starting point. Skip count by fives, tens starting from zero [VCMA026]
    - Count collections to 100 by partitioning numbers using place value [VCMA088]
    - Represent practical situations that model sharing [VCMA090]

  - **Using Units of Measurement**
    - Measure and compare the lengths, masses and capacities of pairs of objects using uniform informal units [VCMM099]

  - **Location and transformation**
    - Give and follow directions to familiar locations [VCMM099]

  - **Chance**
    - Identify outcomes of familiar events involving chance and describe them using everyday language such as ‘will happen’, ‘won’t happen’ or ‘might happen’ [VCMP096]

  - **Data representation and interpretation**
    - Choose simple questions and gather responses [VCMP101]
    - Represent data with objects and drawings where one object or drawing represents one data value. Describe the displays [VCMP102]

Representing shadow movement
Lesson 1: Children’s prior ideas and preparation for shadow tracking

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 sun’s movement.

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

On observing shadows informally:

• 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.

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”
Modeling shadow in relation to sun
Gnome shadow modeling
Establishing sun and shadow relations using the gnome
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 learnt that the Earth is spinning while going around the sun.

It takes 1 year to orbit around the sun.
It spins once every 24 hours.

Why do we need Night and Day?

Night is when the sun is on the other side of the earth.

The sun and Earth are circles.
Sequence of representations

1. Representation of changing shadow length
2. Representation of changing shadow angle in relation to sun
3. Gnome shadow angle and sun position
4. Modeling of sun movement and gnome shadow with torch
5. Video of earth rotating
6. Earth globe and torch
7. Role play of rotating earth
Student learning
Changes to children’s ideas about shadows

Naïve post test entry

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

yes, because

It can be animal prints

We shadows change during the day?

If you can see better

The day shadows

And the sun can make it

Are to

yes, because the earth spins and if it spins

The sun rises, and the sun gets higher,

Because the sun gets higher and the shadow

gets smaller

Changes to student ideas

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

yes

Because the earth

moves
We went outside and we traced our shadows. When we got there the direction of the sun was west and the shadow was long in the west. Then the sun started moving to the west and the shadow got smaller. When the sun was above us it was really small. When the shadow was on the west the shadow started to get bigger on our left side.
**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.
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.

**Interviewer:** When the sun is low, you mean.

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

**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

<table>
<thead>
<tr>
<th></th>
<th>Incorrect (sun moves up and down, or from west to east)</th>
<th>Correct</th>
<th>Unclear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre test</td>
<td>36</td>
<td>7 (14%)</td>
<td>7</td>
</tr>
<tr>
<td>Post test</td>
<td>5</td>
<td>40 (80%)</td>
<td>5</td>
</tr>
</tbody>
</table>

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

- 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

Russell Tytler
russell.tytler@deakin.edu.au

Peta White
petajwhite@wn.com.au

Joanne Mulligan
joanne.mulligan@mq.edu.au