Thinking Spatially about the Universe: A Physical and Virtual Laboratory for Middle School Science
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Spatial Thinking and STEM
Spatial skills correlate with performance in science domains, and likelihood to enter a career in STEM (e.g. Hegarty, 2004, Wei et al. 2009)

Pre-Post Interview Data
Subset of students (Table 1) participated in videotaped pre/post interviews where students used a model Sun/Earth/Moon to answer questions about the cause of lunar phases.
- Equal numbers of students chosen with High/Middle/Low perspective taking pre-test scores.
- Equal numbers of boys and girls chosen.

Open Response: Knowledge Integration & Student Ideas
We scored open response questions using a Ki progression where a score of 0 indicates no scientifically valid response, 1 indicates a response with only misconceptions, and a 2 or higher indicates a response with scientifically valid statements (Linn, 2000).

Table 1: School/Demographic Characteristics, 2015-2016

<table>
<thead>
<tr>
<th>District</th>
<th>Grade</th>
<th>Experiment</th>
<th>Total Students</th>
<th>Students Interviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6th</td>
<td>Pre</td>
<td>72</td>
<td>12</td>
</tr>
<tr>
<td>B</td>
<td>6th</td>
<td>Post</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>C</td>
<td>7th</td>
<td>Pre</td>
<td>184</td>
<td>0</td>
</tr>
</tbody>
</table>

Interview Coding
- Explicit connection between mechanism or model with the phenomenon
1. Perspective taking: Describes how an object will look from the viewer’s location and how this is explained using the relative position of objects in space.
2. No perspective taking: Does not use a change in perspective (viewing from a different location) in explanation.
- No connections: Does not show how the model or a mechanism can explain the phenomenon

Sample Open Response Question on Pre/Post Assessment

Student A:

"I am not sure what the Moon looks like on the Earth." The student draws the Moon in the sky.

"I don’t know what the Moon looks like on the Earth."

Comments:
- Does not explain the Sun's position and the Earth's relative position.
- Does not connect the space-based view of the Earth and Moon.

Student B:

"The Moon is not fully covered by the Earth from the Sun’s light, it is only 10% so you could see it of the Moon.

Comments:
- Correct, but incomplete explanation would receive a Ki score of 1.
- The same model may present multiple scientifically valid ideas and shows how they connect. This would receive a Ki score of 2.

Sample Student Drawing

Students who only used the foam model had larger gains on Question 2 regarding Earth-Moon scale.

Students who only used WWT had larger gains on Question 10 that asks them to predict what the Moon would look like when a particular position relative to the Sun and Earth.

Spatial Thinking and Moon Phases

Perspective taking (PT) in understanding lunar phases:
- Describe the phase of the Moon as it appears from the Earth (Earth-based perspective)
- Imagine the Moon illuminated by the Sun (Space-based perspective)
- Use PT to visualize which part of the lit-up Moon will be visible from the Earth

MOSAIC Data - Distractor Driven Multiple Choice Astronomy Questions

Distraction-driven multiple choice (MC) questions from the MOSAIC/Astronomy and Space Science Concept Inventory (Sadler et al., 2010)
- 11 questions about Moon Phases and Eclipses on pre/post assessments.
- A subset of 6 questions given after students used a single model (foam vs. WWT) as a mid-assessment to learn whether each of the two different models help students understand particular topics better than the other.

Mid-assessment Results
- No statistically significant difference in overall gains between WWT vs foam model on mid-assessment (after half of students only used WWT and other half only used foam model).
- Students who only used the foam model had larger gains on Question 2 regarding Earth-Moon scale.
- Students who only used WWT had larger gains on Question 10 that asks them to predict what the Moon would look like when a particular position relative to the Sun and Earth.

Next Steps
2015-2016
- Complete field testing of ThinkSpace Moon Lab at School 2 in June 2016.
2016-2017
- Complete development of Seasons Lab and begin testing in classrooms.
- Continual field testing of Moon Lab in additional classrooms.

Perspective Taking Assessment

Sample interview response that uses perspective taking: "It’s like here may be?...excess the moon of the Sun–> that cause the Sun is going to shine on this half--the sides of Moon facing the Sun–> you can only see side... and the Earth--you can only see the part of the Moon which is covered in the Earth."

Answer choices for indicating perspective taking increase from 0 (foam only) to 1 (WWT only) to 2 (combined foam and WWT)

Overall Results
For 2 cohorts who have completed the ThinkSpace Moon Lab (Teacher 1 and 2), students show significant gains for both Moon phases content and perspective taking:
- For 11 MOSAIC Moon content MC questions, Cohen’s effect size = 0.71 ± 0.08.
- For 15 Perspective Taking (PT) questions, Cohen’s effect size = 0.31 ± 0.05 (even with 46% of students scoring 20% on the pre-assessment).

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Distractor-driven multiple choice (MC) questions from the MOSAIC/Astronomy and Space Science Concept Inventory (Sadler et al., 2010).