

Children developing an ability to move between frames of reference in astronomy: Towards a learning progression in celestial motion

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Overview of the Results

The findings presented here support our hypothesis that students will improve in their understanding of celestial motion when engage in instruction that supports their ability to visualize celestial motion through observations and hands-on modeling. Instruction that primarily focuses on the actual motions of the earth and moon does not result in the same level of sophistication. We also find that these conceptual areas (daily motion, lunar phases) continue to present a challenge for many students, even after targeted instruction, as few students reached the scientific level of understanding. Students need additional time with challenging aspects of the concept and teachers may need additional support in assessing students during instruction to better guide student thinking.

Purpose and Research Questions

Learning to explain daily celestial motion and the phases of the moon involves the ability to explain observed patterns of change with the rotation of the earth and the orbit of the moon about the earth. This study is part of a larger research project investigating a *learning progression on celestial motion*¹.

1. What are levels of sophistication in the daily celestial motion and phases of the moon construct maps in a learning progression for celestial motion?
2. What is the role of instruction in supporting students ability to learn to move between frames of reference in celestial motion?

We hypothesize that instruction that supports students to develop both mental models of apparent motion and the explanations using the actual motions of celestial objects is necessary to help students develop an ability to accurately move between these frames of reference. To test this, we interviewed children before and after four instructional conditions - each highlighting different instructional approaches to this topic.

References

1. Plummer, J. & Krajcik, J. (2010). Building a Learning Progression for Celestial Motion: Elementary Levels from an Earth-Based Perspective. *Journal of Research in Science Teaching*.doi:726 10.1002/tea.20355
2. Plummer, J.D., Wasko, K., and Slagle, C. (2011). Children Learning to Explain Daily Celestial Motion: Understanding Astronomy across Moving Frames of Reference. *International Journal of Science Education*. DOI: 10.1080/09500693.2010.537707
3. Kennedy, C.A., Wilson, M., Draney, K., & Tutunciyani, S. (2007). ConstructMap [Computer program]. Berkeley, California: Berkeley Evaluation and Assessment Center, University of California.

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Methods

Participants: Third grade students from three suburban elementary schools participated in four instructional conditions:

Traditional instruction: Focused primarily on lunar concepts and from a heliocentric perspective (N=24; four classes)

Planetarium instruction: A single program focusing on earth-based perspective (N=22; two classes)

Revised classroom instruction: Teachers received professional development on methods to connect earth-based observations with developing explanations using models (N=21; two classes)

Revised & Planetarium instruction: Revised classroom instruction and a single planetarium visit (N=32; three classes)

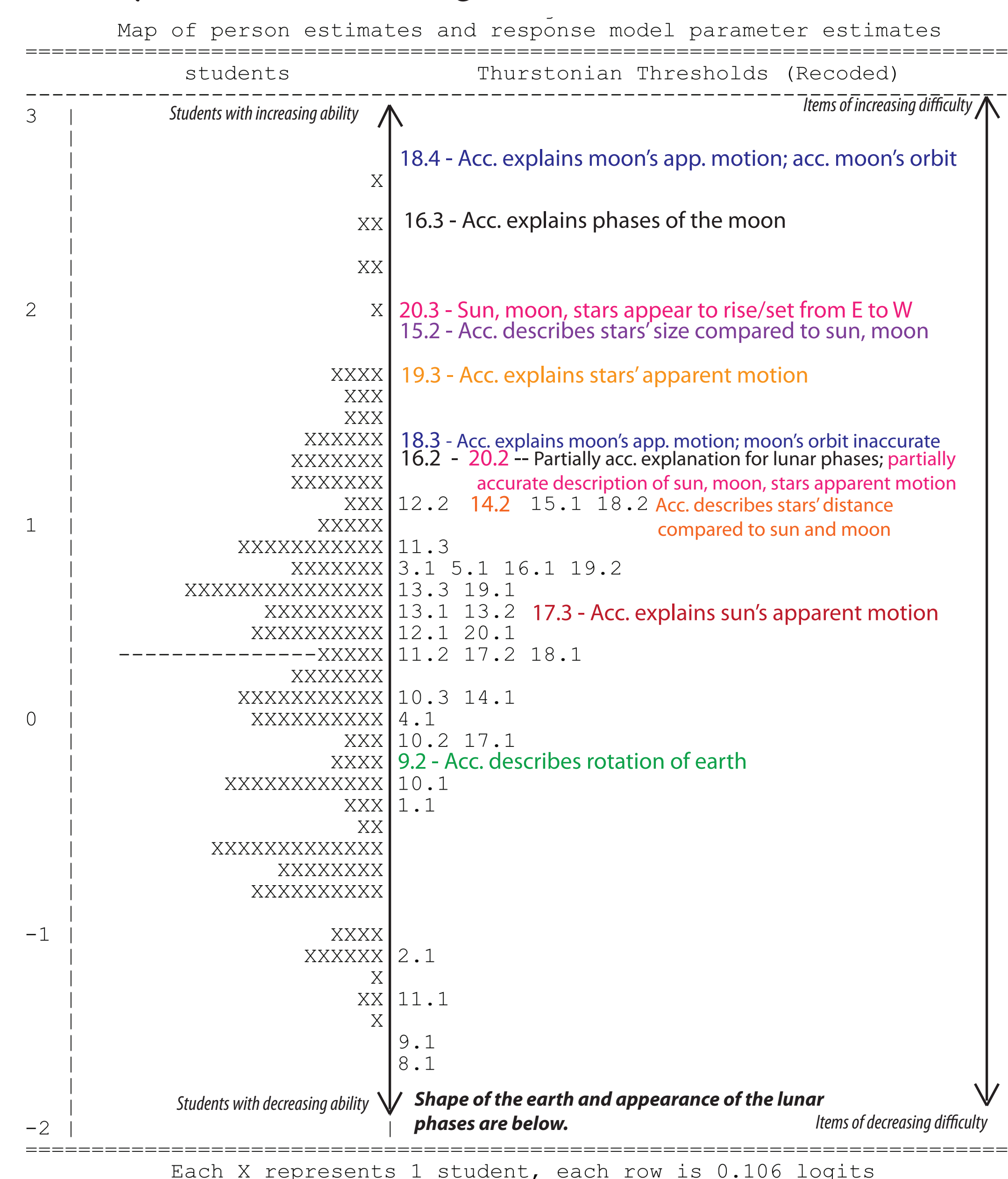
Interviews: ~15 min pre/post interviews with a sample of students from each classroom. Students demonstrated ideas in a mini-planetarium dome and explained using physical models.

Analysis: Interviews were coded following our previously published coding schemes². The software *ConstructMap*³ was used to perform item response modeling to describe students' proficiency levels in relation to the difficulty of items.

Results

Rasch Analysis using ConstructMap

Student X has 50% probability of getting an item at that same level (Thurstonian threshold) correct. The higher the X, the more likely that the student got items at that level or below correct.



Construct Maps for Daily Celestial Motion & Lunar Phases

Daily Celestial Motion

Complete

Sub-level 1: Accurately explains apparent of sun, moon, and stars with earth's rotation and describes their apparent motion accurately and in the same direction. Differentiates between moon's orbit and apparent motion accurately.

Sub-level 2: Same accurate apparent and explanation with earth's rotation.

Doesn't use moon's orbit in explanations of moon's apparent motion but orbit may not be accurate.

Scientific Sun Plus Moon OR Stars

Accurately describes and explains apparent motion of sun with earth's rotation.

May or may not use moon's orbit in explanation of moon's apparent motion.

Explaining stars with earth's rotation is more difficult that moon but may be learned in either order.

Scientific sun

Accurately describes and explains apparent motion of sun with earth's rotation but not the moon or stars.

Synthetic

Uses earth's motion in explanation for the sun's apparent motion. Explanation does not accurately use earth's rotation.

Naive

Objects appear to move because of their actual motion. Description of apparent motion likely to be non-normative.

Lunar Phases

Scientific explanation for the phases of the moon - able to demonstrate that the moon's phases change as the moon orbits the earth over about a month. Indicates correct alignments of the sun, earth, and moon for various phases.

Incomplete explanation for the phases of the moon. No alternative conceptions.

Moon's orbit is about a month

Includes both aspects of the accurate explanation and alternative conceptions about the phases of the moon.

Knows and can draw some of the shapes of the moon's phases. Knows that the change is a slow process and does not occur in one night.

Mapping student outcomes onto DCM Construct Map

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The frequency for each level on the Daily Celestial Motion construct map, before and after instruction -- for each of the instructional conditions.
Data for the phases of the moon construct map and additional statistical comparisons of the conditions appear in the paper.

	Traditional (N=24)		Planetarium Only (N=22)		Revised Classroom (N=22)		Revised Classroom Plus Planetarium (N=32)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Complete Scientific								
Sub-Level 1	0	0.0	0.0	4.5	0.0	14.3	3.1	6.3
Sub-Level 2	0	0.0	0.0	22.7	4.8	0.0	0.0	0.0
Scientific Sun Plus Moon OR Stars								
Scientific Sun	8.3	4.2	13.6	4.5	0.0	0.0	15.6	37.5
Synthetic	4.2	33.3	0.0	13.6	4.8	61.9	15.6	34.4
Naive		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-Level 1 (Earth moves)	20.8	45.8	22.7	9.1	42.9	9.5	12.5	21.9
Sub-Level 2 (Earth and sun both move)	12.5	4.2	18.2	13.6	0.0	9.5	6.3	0.0
Naive	54.2	12.5	45.5	31.8	47.6	4.8	46.9	0.0