A Longitudinal Study of Early Elementary Students' Understanding of Lunar Phenomena after Planetarium and Classroom Instruction

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Abstract: We examined the durability of students' understanding of lunar phenomena one year after a combination of planetarium and classroom lessons. Children (N=16) were interviewed before and after instruction during Year 1 and then again one year later. Analysis of the interview results and instruction reveals that many students retained an understanding of some of the key constructs targeted in the program. Results also suggest that students were more likely to learn and remember challenging constructs that they actively engaged with in both the planetarium and the classroom.

Background: Few research studies have been conducted to measure the impact of planetarium programs and instruction on children within the last 15 years (e.g. Plummer, 2009; Plummer, Kocareli, & Slagle, 2014). Even less frequent are studies that focus on the long-term effects that planetarium programming combined with classroom instruction has on children's conceptual constructs. This longitudinal study aims to not only quantitatively examine such impacts but also to begin to uncover what aspects of programming and instruction may have led to these results.

Investigating instruction and program elements associated with children's conceptual constructs and changes to those constructs is demanding and time-consuming. Uncovering how desirable changes in these constructs persist or change months or years after instruction is particularly important (Georghiades, 2000).

Although several longitudinal studies have been conducted on children's conceptual constructs within the area of astronomy, only one by Kikas exceeded one year (Lelliott & Rollnick, 2009). Kikas (1998) uncovered that students showed a regression in their scientific understanding of the day/night cycle and attributed this to a "rote learning" memorization style of instruction.

Other studies on astronomy interventions show short-term success in changing children's conceptual constructs (e.g. Hobson, Trundle, & Sackes, 2010; Plummer, 2009). However, determining if changes in children's conceptual understanding persist across longer periods of time is an even more important question for the planetarium and science education communities. Further, identifying areas of instruction (both through planetarium programming and classroom instruction) that may lead to long-term positive impact can have a significant influence on the development of such future instruction.

As has been identified in national documents such as *Framework for K-12 Science Education* (NRC, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013), science education should focus on observational astronomy in early elementary. Not only does this allow for an appropriate level of instruction for younger children, but it also may provide a foundation from which to build more complex explanations in later grades. This study focuses on early elementary-aged students' conceptual constructs in the area of lunar observational astronomy content.

Methods: The research reported here is a significant extension of an earlier study (Small & Plummer, 2014), which examined the impact of classroom instruction and planetarium programming for first grade students' understanding of lunar phenomena in a Philadelphia suburban school district. In the original study, children selected from four participating classes (N=36) were interviewed before and after instruction. In this current paper, we examined the extent to which a selection of those students' retained what they learned from instruction one year later.

Instruction: The instructional interventions included in this study featured the following over a three-day period:

- A pre-visit introductory classroom lesson, taught by the first author, which allowed children to share their ideas about observing the day and night.
- A modular designed (combination of live interaction and pre-recorded video segments) planetarium program called *The Moon*, which was created by Audio Visual Imagineering. The program featured science practices such as scientific observation and creating representations.
- A post-visit assessment and application classroom lesson taught by the first author.

Below is a summary of the major instructional elements that were part of each of the three lunar topics, each of which was addressed separately both in the classroom and in *The Moon* planetarium program.

1. The surface features of the moon

The planetarium instruction included live components that allowed students to compare and contrast the surface of the moon and the Earth and the surface of the near side and far side of the moon. Students were encouraged to use the vocabulary Maria, highlands and craters as they were comparing and contrasting. During the pre-recorded portions of the program, students watched a boy (the main character) drawing his observations of the moon's surface features in a sketchbook.

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The boy continued to label the surface features and was informed of what each of the surface features were and how they were created.

Classroom instruction included an opportunity for students to view a variety of photographs of the moon and discuss which ones could help scientist learn more about the moon's surface and why.

2. The daily apparent motion

The live components of the planetarium instruction encouraged students to actively engage by pointing to where they predicted the moon would rise in the sky, where it would set, and drawing with their arm the path that it would take throughout the day/night. During *The Moon* program this concept was modeled as the boy did the same gesturing. The boy also drew a sketch, similar to one of the interview question, of the daily apparent motion of the moon rising in the East, moving in a curved path, and setting in the West. The program respectively stated that this was the apparent motion of the moon in one day and mentioned that this was caused by the fact that the Earth rotates.

Classroom instruction included a manipulative opportunity for small groups of students to organize a set of images (with East and West labeled) of the moon at different times of the day to show rising, curved path motion, and setting. Students then drew pictures of the apparent motion of the moon in their small groups.

3. The monthly observations/phases

Within the live components of the planetarium instruction, students were asked to state the different ways that they have seen the moon in the sky. As students responded an image of the phase that they identified was placed on the planetarium dome. Students also had time to discuss the amount of time that it takes to see the entire moon phase cycle. During the pre-recorded segments of the planetarium program, the boy organized moon phase cards into a complete cycle and watched the complete cycle in the sky.

Classroom instruction allowed students the opportunity to organize moon phase cards into a complete cycle.

Data collection

Sixteen of the children in the earlier study participated in a follow-up interview, one year later, using the same interview protocol. The interviews engaged children in creating models and drawings related to lunar phenomena. In all interviews (one week prior to instruction, one week after instruction, and a delayed one year after instruction), three lunar subtopics were featured: the surface features of the moon, the daily apparent motion of the moon, and monthly observations of the moon. Each student was originally only asked questions from two of the three subtopics resulting in 11 students interviewed for each subtopic in the longitudinal study. Interview questions focused on observational features rather than causal explanations (i.e. students were not taught or expected to know the reason for the phases of the moon; instead, they learned the monthly observable pattern).

Analysis: Codes describing students' ideas were developed for each interview protocol and were used to analyze interviews collected at all three data collection time periods (pre-interviews, post-interviews, and delayed post-interviews). We first developed codes based on prior research on children's conceptions about the moon (e.g. Plummer, 2009; Trundle et al., 2007a) and then developed additional codes to capture the essence of all interview responses. To determine whether or not codes could be used reliably, both authors coded a subset of the interviews (~20%) and an inter-rater agreement of at least 80% was reached for each category. A detailed interview protocol and coding document are available upon request.

The Wilcoxon signed-rank test was used to statistically compare student responses across the three time points. However, we note the limitations to this statistical analysis; the small sample size for the longitudinal group reduces the confidence in the findings. We present them here as a way to suggest possible trends that will allow us to draw tentative conclusions about the long-term durability of student learning through this instructional intervention.

Results: The results presented below include pre-, post-, and delayed post (1 year after) data. The analysis we present will focus on comparing students' delayed-post responses to their immediate post-responses and their pre-instructional knowledge level to consider the relationship between students' retention of new astronomy ideas and how this may relate to the instructional intervention.

1. The surface features of the moon

Students were asked to draw a picture of the moon. These drawings were coded for the number of scientifically correct surface features they included (Table 1). The desired response was for students to include three surface features (Maria, highland, and craters).

Table 1. Students' drawings of lunar surface features

	Pre (N=11)	Post (N=11)	Delayed-Post (N=11)
Maria, Highlands, Craters	0	5 (46%)	1 (9%)
Two scientific features	0	3 (27%)	3 (27%)
One scientific feature	9 (82%)	3 (27%)	7 (64%)
None or other	2 (18%)	0	0

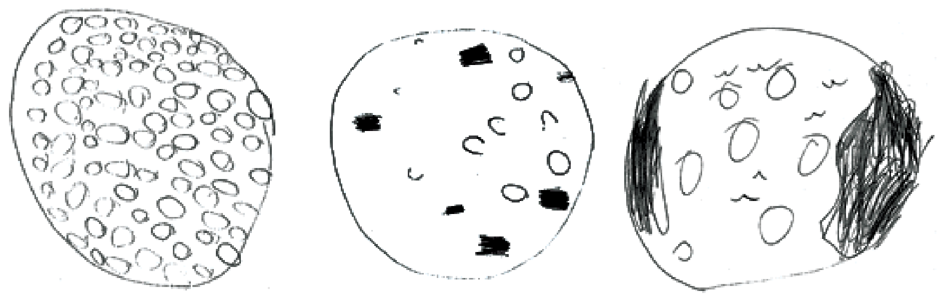

Figure 1. One student's drawings of lunar surface features: pre-instruction (one surface feature), post-instruction (three surface features), and delayed-post (three surface features, one year later).

Statistical analysis using the Wilcoxon signed-ranks test suggests that there was significant improvement between students' pre and post-instruction interviews ($Z=2.879$, $p<0.01$). There was also significant improvement between students' pre-instructional and longitudinal interviews ($Z=2.333$, $p<0.05$), suggesting that students retained some of what they had learned a year later.

However, differences between students' post-instruction and longitudinal interviews suggest that students did not retain all of what they had learned over that year ($Z=2.271$, $p<0.05$). When comparing the longitudinal to the post-instruction responses, zero students improved, five stayed the same, and six regressed; four of these six regressed back to their pre-instruction response while the other two maintained a level higher than their pre-instructional level.

2. The daily apparent motion

Students were asked to illustrate how the moon would appear throughout the day/night on a piece of paper with East and West labeled at the bottom. To capture the levels of understanding, codes were developed with the desired scientific correct conception including that the moon rises in the East, moves across the sky in a curved path, and sets in the West. Table 2 summarizes the overall findings.

The Wilcoxon signed ranks test suggests that generally the students improved from pre-to-post instruction (Z=-2.714, $p<0.01$) and retained the same level of knowledge from the end of Year 1 to the end of Year 2 (Z=-1.063, p=0.288). Eight students showed improvement and three students remained the same (including one that was at the target level of understanding) from pre-instruction to delayed-post. Five students maintained the same level of knowledge, two students improved, and four students regressed from post-instruction to delayed-post instruction.

Table 2. Students' drawings of the apparent motion of the Moon

	Pre (N=11)	Post (N=11)	Delayed-Post (N=11)
Moon rises E to W	1 (9 %)	9 (82 %)	6 (55%)
Moon rises and sets on opposite sides of the sky (not E to W)	0	1 (9 %)	2 (18 %)
Moon appears to move	5 (45 %)	0	2 (18 %)
Does not describe Moon's apparent motion	5 (45 %)	1 (9 %)	1 (9 %)

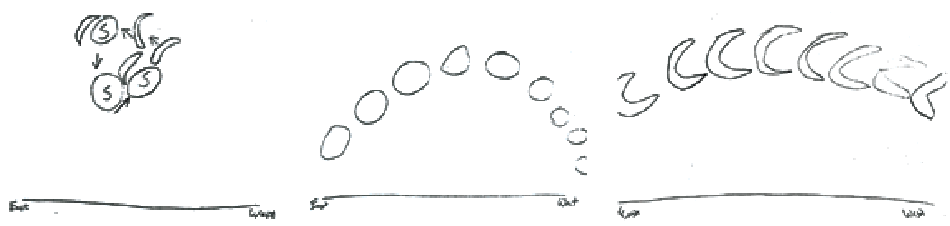

Figure 2. One student's drawings of the apparent motion of the moon: pre-instruction (moon appears to move), post-instruction (moon rises/sets East to West), and delayed-post (moon rises/sets East to West).

3. The monthly observations/phases

Students were asked to draw all of the ways/shapes that the moon can be seen in the sky. The desired scientific construct included representation of each of the eight phases (new, waxing crescent, first quarter, waxing gibbous, full, waning gibbous, last quarter, waning crescent).

Students drew a mean of 5 phases (S.D. = 2.7) prior to instruction, 7.6 phases (S.D. = 3.8) post-instruction, and 6.4 phases (S.D. = 3.9) in delayed-post interview. A paired-sample t-test was used to compare the number of moon shapes the children drew.

While none of the differences were significant at the $p < 0.05$ level, two of the comparisons suggest a trend. Students drew more lunar phase shapes immediately after instruction (t=2.189, p=0.053). There was limited improvement in comparing the longitudinal results to the students' initial number of drawings (t=1.273, p = 0.195) and students drew somewhat fewer drawings from immediate post to the longitudinal interview (t=-1.273, p=0.061).

Students were also asked how long in time it would take to observe the entire moon phase cycle. Prior to instruction 36% of students stated about one month. After instruction 73% reported about one month and 55% said the same in delayed-post interviews.

The organization of the moon phases that students drew was also analyzed with a target construct being a full cycle from new to full and back to new (Table 3). Students' organization increased significantly from pre to post (Z=2.041, $p<0.05$). The comparison of students' pre-instruction drawing to their longitudinal drawing was not significant at the 0.05 level but is suggestive of a trend towards improvement (Z=1.838, p=0.066). There was no significant difference between their post-interview and longitudinal interview (Z=0.647, p=0.518). Because of the improvement found from pre to post, with no difference between post and longitudinal, we suggest that some of the improvement may have been maintained over the year, though the small number of students limits the strength of this conclusion.

Conclusions and Implications

Similar to other educational studies, positive post-instruction results reflect the significant short-term impact that intensive instruction can have on children's understanding of science concepts.

Perhaps more important here was the duration of the desired conceptual change in many areas of the instruction. Similar to other longitudinal studies with students and pre-service teachers, some participants showed evidence of partial or full decay in their understanding of the target constructs as they shifted back towards their prior understanding (Kikas, 1998; Trundel et al., 2007b).

The topic that showed the least amount of decay in this study was on the daily apparent motion of the moon. In interpreting these results, careful attention should be paid to the elements of instruction on the daily apparent

Table 3. Students' drawings of the cycle of lunar phases

	Pre (N=11)	Post (N=11)	Year 2 (N=11)
Full cycle	0	4 (36 %)	0
Half cycle	2 (18 %)	1 (9 %)	6 (55 %)
Increasing pattern		0	0
Decreasing pattern	1 (9 %)	1 (9 %)	0
Random order	7 (64 %)	4 (36 %)	5 (45 %)
Alternative pattern	1 (9 %)	1 (9 %)	0

Figure 3. One student's drawings of the cycle of lunar phases: pre-instruction (random order), post-instruction (full cycle), and delayed-post (half-cycle, increasing pattern).

motion of the moon that the students experienced in order to understand why this topic had the most promising results for long-term student understanding of the scientific concepts:

The instruction for daily apparent motion of the moon included engagement in a variety of scientific practices, such as observing and predicting, and instructional modalities such as modeling, kinesthetic learning, and use of manipulatives. Instruction for the other two topics did less to fully engage students in constructing a new understanding through these types of instructional strategies.

Students were actively engaged in the apparent motion of the moon construct during both the planetarium and second classroom lesson; the second classroom lesson's activities for the moon's surface and lunar phases did not fully engage students in the aspects of the constructs that were most challenging to them and thus limited their opportunity to further work with the ideas they learned in the planetarium.

The instruction for this topic included activities that were more similar to the actual interview questions, which may have reinforced their understanding of the construct.

Students were asked to make predictions within this area of instruction allowing them to compare any alternative beliefs that they might have already to the scientific concept presented during instruction.

Implications of this study include the need for educators to pay close attention to how we match the constructs we are targeting for children to learn with how we design active instructional strategies, both in the planetarium and the classroom. We base this on our observation that the construct that students improved the most in, the apparent motion of the moon, was most directly targeted with instruction that engaged children both physically and mentally during the planetarium and classroom instruction.

Our findings also suggest that engaging children with scientific practices, such as predicting and modeling, may allow students to build on their current conceptual constructs and then modify or change them, if needed.

Trundle and colleagues (2007b) drew similar conclusions in a longitudinal study conducted with pre-service teachers focused on the moon. They suggest strengthening instruction by encouraging more "intentional learning" and providing a modest set of instructional activities that would actively engage participants in psychomotor modeling.

Trundle and colleagues also recommend that students predict and explain, preferably in writing prior to instruction, and then periodically compare observations and simulations with their pre-instruction views. Although, such activities may seem daunting in a unique environment such as a planetarium, we encourage creative solutions to incorporate suggestions of these findings for lasting positive impacts on children's conceptual constructs.

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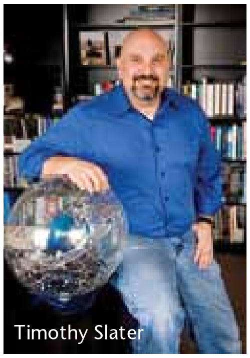
New source for astronomy education research


Timothy Slater

A new educational research resource is debuting this month. It's called the *Journal of Astronomy & Earth Sciences Education* (JAESE), and it's got one of the top names currently in this niche research field as its editor in chief: Timothy F. Slater at the University of Wyoming.

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