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College MOON Project Australia: Preservice Teachers Learning about the Moon's Phases

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Abstract This paper is a report of the Australian segment of an international multi-campus project centred on improving understanding of the Moon's phases for preservice teachers. Instructional strategies adopted for a science education subject enabled Australian participants to make extended observations of the Moon's phases and keep observational data records which were shared in asynchronous on-line discussion with fellow preservice teachers in the USA. An adaptation of an online inventory of lunar phases was completed by participants before and after the observation cycle. The analysis of inventory data showed that although there was statistically significant overall improvement in mean scores for the inventory this could be accounted for by statistically significant increases in only some conceptual domains related to the lunar phases. In addition, the findings indicate that some concepts involved in having a deep understanding of lunar phases can be improved by instruction however, misunderstandings of other concepts involved in lunar phases are difficult to change and may require increased attention to developing students' visual-spatial capabilities.

Keywords Lunar phases · On-line discussion · Preservice elementary teachers · Science content knowledge

Background

Understanding of the lunar phases has been the subject of much research in the past. Black (2004) noted that "moon phases, an astronomical phenomenon involving movement of a half-lit body in space viewed from the unavoidable fixed position of Earth observers," was one of the most difficult of the concepts for university students responding to an Earth science questionnaire. Others, working with a range of students of different ages and backgrounds have shared this view (Baxter 1989; Bisard et al. 1994; Callison and Wright 1993; Dai and Capie 1990; Philips 1991; Trundle et al. 2002, 2007).

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Researchers have offered a range of explanations as to why students may experience conceptual difficulties with the Moon's phases. Stahly et al. (1999) suggest that the literature on understanding of the lunar phases shows one particular incorrect explanation of the phases to be most prevalent. They describe this as the "ecliptic explanation" (p. 160) in which phases are thought to be caused by a shadow from the Earth. Their work with Year 3 students, led them to the belief that the topic of lunar phases might be too difficult for children of this age group. Similarly, Suzuki (2003), who documented conversations that occurred during science classes for preservice teachers, also found that the ecliptic explanation was prevalent. She attributed this, in part, to the publicity given to the Moon during a lunar eclipse. Other difficulties in understanding Lunar phases, that are documented in research literature, are inability to appreciate the scale of the Sun–Earth–Moon system (Fanetti 2001), the struggle to develop mental models to explain Sun–Earth–Moon relationships due to the level of reasoning and spatial ability required (Callison and Wright 1993), and inability to work from a perspective other than that of an observer on Earth (Suzuki 2003).

Bailey and Slater (2003) reviewed the literature on astronomy education research and suggested that more work was needed in understanding the underlying causes of difficulties students have in astronomy and that more research into identifying effective instructional strategies was needed, especially investigations into effective methods for teacher preparation to teach astronomy topics. Studies by Callison and Wright (1993) and Dai and Capie (1990) conducted with preservice teachers found that misunderstandings of essential concepts of the moon persisted after a teaching intervention. In contrast, Trundle et al. (2002, 2007) also working with preservice teachers, found instruction on moon phases in an inquiry-based physics course to be effective in bringing about change. Similarly, Barnett and Morran (2002) found that grade 5 students' understanding of the Moon's phases and eclipses did improve as a result of engagement in a project based space science curriculum. Ogan-Bekiroglu (2007) used questionnaires, direct observation and models with preservice physics teachers and found that seeing the same phase of the Moon all over the world and the relationship between tides and the appearance of the Moon were concepts most easily understood by preservice teachers after instruction. However, preservice teachers continued to have difficulty explaining the daily difference in time of Moon rise.

With this background in mind, and in recognition of the importance of conducting research into effective instructional strategies (Bailey and Slater 2003), our major research questions were: (a) which concepts related to the lunar phases were most readily understood by our preservice elementary teachers following direct observation of two lunar phase cycles, peer discussion and reflection and use of models from curriculum documents?; (b) which concepts were most difficult to change and why these difficulties might occur? We also wished to engage in what Shulman (1999) referred to as "the scholar ship of teaching" by using the results of this study to analyse the astronomy module in a science methods unit that we taught, to ascertain how it contributed to improved understanding and what might need to be changed or added to improve learning in the future.

Research Methods

Research Context

Preservice teachers from four universities in USA and Australia (Ball State, Texas Technical University, Oklahoma State and ACU) participated in extended observations of the Earth's Moon from July 18 until October 31 2005, using a Moon Observation Diary (Smith 2005) designed originally by Dr. Walter Smith (Ball State University) and adapted for use in Australia (see Appendix 1 for extracts from the diary: introduction to the observation task, sample weekly observation page, list of questions to guide observations). Our collaboration was called the College MOON Project and was based on an original MOON Project involving elementary school children and preservice teachers (Ball State University 2005). The instructional strategies adopted for the astronomy component of a science methods subject in which the ACU preservice teachers were enrolled are described in the following discussion.

During October 2005, five weeks of asynchronous on-line discussion between preservice teachers in Australia and the USA took place. Preservice teachers were assigned to one of twelve on-line discussion groups and logged onto the College Moon Project (Ball State University) to participate. The discussion schedule for the five weeks was as follows:

Week 1 (Week of October 3):	Preservice teachers introduced themselves and described their teacher education programs to each other.
Week 2 (Week of October 10):	Students wrote about what they observed about the Moon from September 4–17, the most recent two week waxing period. Students' field notes included, recording the shape and location of the Moon, and time and date of the observations were attached to comments.
Week 3 (Week of October 17):	Students wrote about any similarities or differences between northern and southern hemisphere observations they found in Week 2's postings, in particular, how the Moon was shaped and where it was located around the world.
Week 4 (Week of October 24):	Students speculated about why the Moon changes shape as it does.
Week 5 (Week of October 31):	Students shared the results of their Moon-related course assignments.

Student discussions were downloaded for analysis in November 2005.

Toward the end of the on-line discussion period, a 2-hour workshop on strategies for explaining lunar phases in the elementary school classroom was conducted with the Australian participants. Preservice teachers used different sized balls and a light source to model the lunar phases and explored a relevant website from the Ministry of Education, New Zealand (2007). In addition, preservice teachers, working in groups throughout the semester, contributed to the compilation of an annotated bibliography on one of three topics, *Other Moons and Ours*, *Lunar Exploration and Cultures* and the *Moon*. A hands-on lesson on one of these topics was presented to peers in the final workshop.

The astronomy module in our science methods subject thus, had important aims in keeping with National and State documents, for example the Queensland Science: Years 1 to 10 syllabus (Queensland Schools Curriculum Council 1999). Firstly, to allow preservice teachers to engage in investigation by collecting and analysing data generated from direct observation of nature and to construct understanding by this process (Australian Science Teachers Association 2002; Goodrum et al. 2001). Secondly, to provide student teachers with first hand experience of the use of ICT in learning enhancement by means of their on-line discussions with preservice teachers from another country and use of instructional web sites (Ministerial Council on Education Training and Youth Affairs (MCEETYA) 2005).

Data Sources

Lunar Phases Concept Inventory (LPCI) The Lunar Phases Concept Inventory (LPCI) is a multiple choice instrument based on extensive qualitative investigation of university students' understandings of the Lunar phases (Lindell and Olsen 2002). Students at all universities responded to the Lunar Phases Concept Inventory (LPCI) (Lindell and Olsen 2002), or a version of it, both before the Moon observations began and after they were completed. American students used the web based inventory (Lindell 2004). All 20 questions on this inventory were posed from a northern hemisphere viewing perspective. Thus, a version that consisted of similar questions posed for a southern hemisphere perspective needed to be produced for Australian students.

In designing a southern hemisphere version, we found that some questions translated easily with only the diagram of the Moon needing to be altered. For example, Question 1 asked where in the sky one would expect to see the waxing crescent at sunset and involved changing the orientation of the crescent from right to left hand side of the Moon, in order to create a Southern hemisphere view. However, other questions contained the words "imagine you are in space above the Earth's North Pole." Changing to the statement "imagine you are in space above the Earth's South Pole" was an obvious alternative, suggested by Lindell "I think we should make it a true southern hemisphere version, with no mention of the northern hemisphere at all. That way it is consistent at most levels." (E-mail message 28/5/05). However, we, the Australian researchers, were interested in finding out if southern hemisphere students, who are accustomed to northern hemisphere perspectives in atlases and globes, would have difficulty making the imaginary switch to the southern hemisphere view. It was decided to put both versions of some questions into the inventory. Four questions were included in the inventory with both northern and southern versions, as shown in Fig. 1. In each adjusted question the words North Pole were changed to South Pole.

Both the original and modified versions of LPCI consisted of questions that could be ascribed to eight concept domains. Concept Domains of the LPCI were derived from detailed qualitative investigation of mental models of Lunar Phases held by post secondary students. Validity of items was established using traditional item analysis and concentration item analysis (Lindell 2002). Items included in the final version of the LPCI all had "both pre and post discrimination values above 30% as well as ...pre and post concentration factor values above 20%" (Lindell and Olsen 2002, p. 3). Figure 2 shows the concept domains in the LPCI according to Lindell and Olsen (2002).

Q3: The Moon orbits around the Earth; in which direction does it orbit if observed from a point directly above the Earth's North Pole?

Q16: If you could look down on the Earth/Moon/Sun system from a point in space located above the Earth's North Pole, you could observe the following alignments. Which Earth-Moon–Sun geometry would produce a Moon with a shape shown below?

Q19: If you could look down on the Earth/Moon/Sun system from a point in space located above the Earth's North Pole, you would observe that the Moon orbits around the Earth. At one point in time it is in position A, as shown below. At some later time, the Moon is now in position B. How much time has passed between the two observations?

Q20: In which direction did the Moon go around the Earth in Question 19?

Fig. 1 Questions having both northern (shown) and southern hemisphere versions

1	Period of the Moon's orbit around the Earth
2	Direction of the Moon's orbit around the Earth as viewed from a point above the North pole.
3	Period of the Moon's cycle of phases
4	Motion of the Moon as in from E to W
5	Phase and Earth-Sun-Moon positions
6	Phase-location in sky-time of observation relationship
7	Cause of Lunar phases
8	Effect on lunar phase with change of location on Earth

Fig. 2 Lunar phases concept domains (Lindell and Olsen 2002)

The questions for Australian preservice teachers were put onto WebCT (ACU) using the "quiz tool." This facility provided easy access for students and meant they could take the inventory at a time suitable for them. The quiz was available for about two weeks at the beginning of semester and again for two weeks at the end of semester. Each person who completed the inventory received a score on both occasions. WebCT provided a number of reports for instructors, including the number of students making each response to Inventory questions and each student's response to all questions. Other sources of data were the preservice teachers' Moon Observation Diaries; on-line discussions and annotated bibliographies which formed part of the unit's assessment; and open-ended comments on an end of semester subject evaluation questionnaire.

Results

For Australian students, taking the LPCI and making observational diaries and discussions available for analysis was optional, in line with university ethics requirements. Seventy two students completed the LPCI both pre and posttest and the following discussion of results is based on the analysis of the questionnaires from these students.

Scale Reliability for LPCI

Because pre- and post-test LCPI scores were employed in subsequent comparisons, the internal consistency of these 24 item-scales were computed. Cronbach's Coefficient alpha was use as a convenient index. Pre-test Coefficient alpha values were 0.58 for the full sample and both gender sub-samples. For the post-test LCPI, Coefficient alpha was 0.69 for the full sample, 0.75 for males and 0.65 for females. These values suggest only fair pre-test and sound post-test reliability. It is noteworthy that these values are similar to those reported by Lindell and Olsen's (2002) LPCI study in the United States which also found a marked improvement in scale reliability on the post-test scores compared to the pre-test scores.

Comparison of Pre- and Post-Test LCPI scores

Pre and post-test LCPI scores were computed for each student. To ascertain where statistically significant gains were found on these scores, matched pairs t-tests were performed on the data for the full sample and gender sub-samples. Table 1 shows the results of these tests. All three t-tests revealed statistically significant differences between pre and post test scores with positive gains evident.

Table 1 Paired samples statistics for various groups in the Core Science Methods Unit

Group	Pretest		Posttest		*N*	*t*-test	*df*
	M	SD	*M*	SD			
Full sample	8.17	3.14	12.54	3.76	72	8.32*	71
Male	6.91	3.08	14.91	3.96	11	4.48*	10
Female	8.39	3.12	12.11	3.59	61	7.53*	60

*$p<0.001$

To ascertain those test items for which statistically significant differences were evident between the pre and post tests, non-parametric tests were conducted for each item. Because results for each item were in paired binary form (viz. correct/incorrect) the McNemar change test (Sheskin 2000), which studies the change in respondent scores measured twice on a dichotomous variable, was employed. To control for inflated Type 1 error (alpha) in conducting 24 *t*-tests, the Bonferroni Inequality (Stevens 1992) was employed. The conservative use of this inequality required that the alpha for each analysis be set at the planned level (0.05) divided by the number of analyses (24). Accordingly, the *p* value for each of these McNemar tests was 0.002. Nine of these 24 tests were statistically significant in which the planned Type 1 error rate is over 7 times. Table 2 shows the concept domain, the questions or items related to each domain, the questions with significance of difference between pre and post tests scores clearly identified, as well as percentage of correct responses for pre and posttest.

Analysis of LPCI by Domain

Concept Domains in which gains in understanding were most easily demonstrated were Domains 5 and 8. Most other Concept Domains showed a statistically significant gain in one question in the set. The exception was Concept Domain 2 where no question showed a statistically significant gain. Domains will be discussed below in numerical order. Table 2 shows percentage of correct responses for pre and posttest for each question in each Concept Domain as well as LPCI questions for which there were statistically significant gains posttest.

Concept Domain 1 tested knowledge of the period of the Moons' orbit around the Earth. In both questions in this set just over 50% of participants had selected the correct answer in the pre-test. Question 2 relating directly to the period of orbit showed a statistically significant gain in number of correct responses posttest. Question 8 dealt with the relationship of orbital period to phase period, and although there was a percentage gain of 23% for correct answers posttest, this was not statistically significant. We conclude that the majority of preservice teachers did have a good understanding of this Concept Domain post test. However, there was reasonably good understanding of the ideas at the commencement of the project.

Concept Domain 2 (the direction of the Moon's orbit from above one of the poles) appeared to be the most difficult of all Domains. There were no statistically significant gains for any of the questions in this set. This Concept Domain was one most often tested with the "above the Earth scenario" and both northern and southern hemisphere questions were equally difficult for our students. Although there were more correct answers in the post-test for both items, increases were small. Our initial concern about preservice teachers using northern hemisphere perspectives when thinking about the Earth in space, was not supported by results from this Domain. The students experienced considerable difficulty trying to visualise both northern and

Table 2 Summary of LPCI (Southern hemisphere) items and domains with percentage of correct pre and posttest responses and test of significance for changes in pre- and post-test scores (N=72)

Concept domain	Item number	Question topic	% Correct pre-test	% Correct posttest
1	Period of the Moon's orbit around the Earth			
	2*	Time to complete one orbit	55.6	87.5
	8	Orbital period vs Phase period	54.2	77.8
2	Direction of the Moon's orbit around the Earth			
	3	Direction of orbit from above the North Pole	37.5	52.8
	3 (a)	Direction of orbit above the south pole	38.9	50
	20	Which direction did the moon travel	54.2	56.9
	20 (a)	Which direction did the moon travel	36.1	47.2
3	Period of the Moon's cycle of phases			
	5	Frequency of the new moon	86.1	97.2
	12	Time interval to get same phase again.	65.3	79.2
	17*	Time between full moon and last quarter (moon lit from left not right)	1.4	22.2
	19	Time between new Moon & first quarter	48.6	56.9
	19 (a)	Southern view of same image makes it new moon to last quarter.	20.8	34.7
4	Motion of the Moon as in from E to W			
	10*	Direction of Moon set	27.8	54.2
	14	Direction of Moon rise	58.3	69.4
5	Phase and Earth–Sun–Moon position			
	6*	Phase of Moon for a solar eclipse	13.9	47.2
	11*	Earth–Moon–Sun position for full moon (above north pole).	33.3	65.3
	16	Alignment of S_E_M to produce waxing crescent above North Pole	23.6	40.3
	16 (a)	Alignment to produce waxing crescent above South Pole.	20.8	31.9
6	Phase-location in sky-time of observation relationship			
	1*	Where to see the waxing crescent Moon at sunset (crescent lit left hand side rather than right	8.3	23.6
	9	Time at which the last quarter moon sets (lit from right hand side rather than the left)	4.2	5.6
	15	Phase of the moon that rises at sunset	12.5	25.0
7	Cause of Lunar phases			
	4*	Cause of the new moon	12.5	51.4
	18	Cause of phases	20.8	36.1
8	Effect on lunar phase with change of location on Earth			
	7*	Full Moon in USA (rather than Australia)	51.4	79.2
	13*	Moon's appearance half-way around the world (substituted Johannesburg for London)	33	53

*p<0.002

southern hemisphere perspectives when considering the Moon's orbit around the Earth. Visual-Spatial thinking (Mathewson 1999) has been highlighted as important in many aspects of science. For example, Black (2004) concluded that spatial ability or the lack thereof was particularly important in Earth science, while (Broadfoot 1995) found that spatial orientation and spatial visualisation were essential in astronomy. We conclude that a lack of spatial ability may lie at the heart of our students' failure in this domain.

Concept Domain 3 (Period of the Moon's cycle of phases) was also a domain where only one question, Question 17, showed statistically significant improvement post test. However, Questions 5 and 12 which did not show statistically significant improvement posttest were relatively well answered in the pre-test. The percentage of correct answers for Question 5, 'frequency of the new Moon' rose from 86 pre-test to 97 posttest, while the improvement for Question 12, 'time interval to get to the same phase again', was from 65 percent to 79 percent. In Question 17, 'time interval from full Moon to last quarter', a relatively difficult question, the percentage of correct answers rose from 1 to 22. Thus, although this was a statistically significant increase, many fewer preservice teachers knew the correct answer at the end of the Astronomy module when compared with Questions 5 and 12. Question 19 was one of those using the "above the Earth scenario" context, and thus, could have been more difficult for the preservice teachers to visualise than other questions in the set. Percentage of correct answers rose from 21 to 35 percent for the Southern Hemisphere version of this question and from 49 to 57 percent for the Northern Hemisphere version. Neither gain in correct responses was statistically significant; however, once again some weight is given to our hypothesis that the preservice teachers in the southern hemisphere would use a northern hemisphere perspective when imagining the Sun–Earth–Moon system from a position in space. Differences in the levels of mental modelling demand of the different questions in this set seemed important when considering results.

In **Conceptual Domain 4** (apparent motion of the Moon from east to west), one of two questions showed a statistically significant improvement on post-test while the other did not The improvement was in Question 10 asking about 'direction of Moon set', while that relating to Moon rise (Question 14) showed no statistically significant improvement, however, over 50% of students were correct in the pre-test, a situation similar to that in Domain 3 above. A possible conclusion is that Moon rise is more likely to be observed, particularly a full Moon rising, thus there was more room for improvement in the question about Moon set.

Results for questions in Concept **Domain 5** (phase and Sun, Earth, Moon position) showed statistically significant improvement on the post-test for two out of three questions (Table 2). These were, Question 6 asking the phase of the Moon producing a Solar Eclipse and Question 11, which probed understanding of the position of the Moon, Earth and Sun from above the North Pole to produce a full Moon. However, both versions of Question 16, asking the correct Sun–Earth–Moon alignment from above one of the Poles, to produce a waxing crescent Moon, showed no improvement. This seemed to us the most difficult question in the set. Just over forty percent of students could give the correct alignment if they used a northern perspective post-test (23.6% pre-test), while only 31.9% could do so from a southern perspective (20.8% pre-test). This result lends further weight to our initial conjecture that preservice teachers in the southern hemisphere would be more proficient in using a northern hemisphere perspective when imagining the Sun–Earth–Moon system from a position in space.

Concept Domain 6 (phase location in sky–time of observation relationship) was a concept domain we expected to have improved during observations. There was, in fact, a statistically significant increase in correct responses posttest for the position of the waxing crescent at sunset. However, very few students were able to say at what time of day the last quarter would set either pre or posttest and surprisingly few, 25% post test, were able to say which phase of the Moon would rise at sunset. Possible explanations are that, although observations were over 16 weeks, the time for extended observation may not have been long enough to allow some patterns to emerge. We neither stipulated specific times of day or night for observations to occur, nor did we ask for time of Moon rise and set each day to be noted. Additionally, preservice teachers were very busy during their final semester and may simply have done the observations without thought and not conducted an in-depth search for patterns in the data they collected.

In **Concept Domain 7**, (cause of the lunar phases) Question 4 showed a statistically significant improvement between pre and posttest. Only 12% (11 out of 90) of preservice teachers could explain the cause of a new Moon correctly pre-test, but 56% were correct post test. However, as shown below (Fig. 3) eclipse explanations (alternatives c and g) although diminished were not extinguished by teaching. Alternative c, explaining the cause of the phase as a shadow cast by the Earth was the most popular response of all pre-test, and the most persistent incorrect response posttest. Similarly, in Question 18 the persistence of the eclipse explanation can be seen by the relatively large numbers choosing responses c or g on both pre and post test. The small gain in correct responses between pre and posttest results was not statistically significant for this question. However, we consider this to be a more difficult question for a number of reasons: Firstly, the phase of the Moon was not named in this question as it was in Question 4; secondly, students were asked to think back to a previous question and decided the reason for the Moon's changed appearance, from full

4 A *New Moon* occurs when no lighted portion of the Moon is visible to an observer on Earth This occurs because

a. an object completely blocks the Moon.

b. the Moon is completely covered by the shadow of the Sun.

c. the Moon is completely covered by the shadow of the Earth.

d. the Moon is between the Earth and the Sun.

e. Both a and d.

f. Both b and d

g. Both c and d

h. None of the above

Results for Question 4

	a	b	c	d	e	f	g	h
N=90 Pre	0	10	45	**11**	6	7	9	2
N=93 Post	0	5	18	**52**	4	6	6	2

18 What caused the Moon to appear different in your two observations in Question 17?

a. an object is now between the Moon and the Earth

b. the Moon is now covered by the shadow of the Sun

c. the Moon is now covered by the shadow of the Earth.

d. the Moon's position relative to the Earth has changed.

e. Both a and d.

f. Both b and d

g. Both c and d

h. None of the above

Results for Question 18

	a	b	c	d	e	f	g	h
N=90 Pre	2	10	19	**20**	6	7	25	1
N=93 Post	1	5	15	**37**	2	12	17	4

Fig. 3 Web CT generated report of Question 4 and report for Question 18 showing total number of students making each response

Moon to an unnamed drawing of a phase (actually first quarter); thirdly, we consider the new Moon (in question 4) a relatively easy phase to picture, given its position between the Sun and the Earth when compared with first quarter; lastly, the correct response did not state exactly where the Moon was relative to the Sun and Earth, only that the position relative to Earth had changed. Although the correct response was the most popular posttest, the eclipse explanations c (the shadow of the earth explains the Moon's appearance) and g (the shadow of the earth plus changed position is the explanation) remained relatively constant. Of interest is the slight increase in number of participants selecting the incorrect option f in the posttest. This option suggests that the Moon has changed position relative to the Earth and also that the Moon is now covered by the shadow of the Sun. A possible explanation for this choice is an incorrect understanding of how shadows are formed. The unlit half of the lunar sphere is in a shadow cast by the Moon itself. However, the Moon blocks light from the Sun in order for the shadow to form. Using incorrect vocabulary to describe this effect may have caused a few to select option f.

Concept Domain 8 (effect on lunar phase with change of location on Earth) was the only domain where all questions showed statistically significant improvement at post test (Table 2). There was a statistically significant improvement in the number of students realising that observers in both the northern and the southern hemispheres will see a full Moon on the same dates (Question 7). When asked whether a last quarter Moon viewed in Australia would look the same to viewers in South Africa there was similar improvement. We were disappointed that there were no questions on the LPCI that required knowledge of the different appearance of some phases for northern and southern hemisphere viewers. We believed that our students had become aware, from on-line discussions with American students, that the lit side of the Moon, for waxing and waning stages of the lunar cycle, was reversed for northern hemisphere viewers. Comments and attempted explanations from preservice teachers in Australia and USA taken from the fourth week of on-line discussion are shown below to support our positions.

> Again it is logical that we see different sides of the Moon (mirror image) because of the different hemispheres – it is really hard to explain and would be much easier with a picture. Both of us see the moon rise in the east and set in the west, however because we are looking down (in the south) we see the illuminated part on one side, when you (in the northern hemisphere) see the opposite side illuminated. Does this make sense??? Easier to visualise the concept with a picture or concrete models.
> (Susan (pseudonym), Australia, Discussion week 4)

> I also agree with Olivia. We had a video conference with some students in Australia and were able to each draw a picture of what we saw on a specific date at a specific time and our drawings were mirror images of each other. It was a lot easier to understand when we looked at actual drawings. (Judy (pseudonym), America, Discussion week 4)

However, we were unable to test our beliefs using the LPCI and would like to add an additional question to this Domain 8 of the Inventory. We did conclude that the extended viewing of the Moon and the on-line discussion with US preservice teachers was effective in assisting participants to understand this concept domain.

Student Perceptions

Preservice teachers also responded to a subject evaluation questionnaire at the end of 2005. Questions were of a general nature, answered by selecting a response to a statement on a 5 point Likert scale ranging from "strongly agree" to "strongly disagree", and not specifically related to the astronomy module. However, some chose to comment in the available space on the reverse side of the form. The comments below are representative in that, although most enjoyed the observations, many found the task too great a workload.

> The Moon diary was a large workload, but was worthwhile as I wouldn't normally have taken any notice of it (*the Moon*), (Student, 2005).
> Loved the Moon observations, very useful and can be used in schools (Student, 2005).
> I loved the Moon diary. I have a better appreciation for the Moon and know more about it (Student, 2005).

However, others could not see the relevance of the experience at all.

> I think we should be learning how to teach science instead of scientific concepts that confuse us (Student, 2005).

These qualitative data have important implications for organisational aspects of the subject delivery. In response to these comments, we decided to begin the observation period after preservice teachers return from field placement in future offerings of the subject and thus reduce the number of lunar cycles observed. In addition, we were concerned about the final statement because of the implication that scientific concepts (understandings of science) are somehow removed from the task of teaching science. We concluded, like other researchers (e.g., Abell et al. 2002), some of the links between experiences provided in the methods subject and teaching and doing science, that we thought to be self evident, were too implicit to be appreciated by our students. Proposals for modifying instructional strategies are presented in the Discussion section.

Discussion

Our study confirms the work of others who found that the topic of lunar phases to be a difficult one for learners (Baxter 1989; Bisard et al. 1994; Callison and Wright 1993; Dai and Capie 1990; Philips 1991; Trundle et al. 2002). In response to the research question (a), we have been able to clearly demonstrate that some concepts involved in understanding lunar phases can be improved by instruction (Questions 6, 11, 4, Domains 5 and 7 – Table 2), which involved direct observation of two complete lunar phase cycles, peer discussion and reflection, use of models from curriculum documents.

However, for research question (b), the results also show that some other concepts involved in misunderstanding phases are persistent (e.g., ecliptic explanations) and our work has assisted us to identify particular concepts that are change resistant. We have concluded that the most difficult concepts to change were those requiring students to use three dimensional mental models in their reasoning and thinking about the Sun, Earth, Moon system in terms of their relative configurations in space (Questions 16, 16a, Domain 5 – Table 2). It is reasonable to conclude that lack of experience with mental modelling of this kind may have been the cause of difficulties with these problems. Our findings thus support the work of Black (2004), Callison and Wright (1993) and Fanetti (2001).

Although our students initially offered "ecliptic explanations" (Stahly et al. 1999; Suzuki 2003) for the lunar phases (Questions 4, 18 – Fig. 3), their responses changed markedly to the scientific explanation on posttest. However, we noted that for a minority of students ecliptic explanations persisted, showing that this misconception is difficult to extinguish completely. However, we can also see that better instruction about shadow formation in the context of learning about Lunar phases would be of benefit.

In keeping with the notion "scholarship of teaching" (Shulman 1999), the findings of this study have enabled us to analyse the astronomy module in the science methods subject in order to ascertain what modifications to instructional strategies may be needed for the future. The analysis is presented as follows.

We are planning to participate in the College Moon Project again in future years. On the second occasion we expect to be working with only one American university, Indiana University Purdue University at Indianapolis. Our students have a 6 week practice teaching block at the beginning of semester and then 7 weeks of classes at university commencing immediately after the completion of practice teaching. In addition to starting observations when students return to university, we have modified the Moon diary, making it more structured and rigorous by suggesting specific observations to make, for example, the time and place of Moon rise and set for particular phases, and recommending that students conduct observations at a fixed time each day. We have also decided on a written report to accompany the diary which is designed to encourage our students to be more analytical by requiring them to search for patterns in collected data. We have made these decisions in order to remedy the difficulties our students' had in detecting patterns that would enable them to readily describe the time and place to find particular phases of the Moon in the sky in response to children's queries.

We shall limit the observational period to 8 weeks so that the task does not seem so onerous. However, scientific work does often require systematic and painstaking observation over extended time periods. We feel that we have to find a balance here between giving our students a genuine experience of investigative science and avoiding a negative experience that could damage attitude toward science.

As many of the questions that showed marginal improvement on posttest were related to taking an above the Earth perspective (Questions 3, 16, 19 and 20), we are planning activities that will assist our students in the development of visual-spatial capabilities. One of these involves finding the true north from their lunar observation site using a shadow stick activity. Students will complete this activity in the first few weeks of their return after practice teaching so that they better understand directions of the Moon's movement in terms of Altitude and Azimuth, and apparent movement. In addition, we will provide discussion of observation sessions on three occasions during semester and assist our students to use their observation data to try to make 3D sketches of relative positions of the Sun, Earth and Moon for various phases.

In response to the preservice teachers' comments about the relevance of the Moon observation project to the actual teaching of science, the astronomy module has been enhanced to include more direct links to syllabus documents, particularly those about science investigation. In addition to linking shadow stick and Moon activities to these documents, a technology module in the same science methods subject is based on the construction of an Edible Lunar Vehicle. Preservice teachers will mentor school children in designing the vehicles and assist them in building and trialling the vehicles. Mentoring children's writing will be part of preservice teachers' English assessment. We see the experiences offered in our subject through the College MOON project and associated activities as providing student teachers with not only confidence to teach science but competence in the teaching of this particular area (Appleton 1995).

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Appendix

Introduction to the Observation Diaries

Welcome to the MOON Project. For the next few months, preservice teachers in USA and Australia will be studying the Moon together. At first you and other students in your class will observe the Moon every day and record those observations. We hope that about once each week you and the other students in your class will have a class discussion to report and compare the observations you have made. Are you making the same observations? Or are there significant differences in what you are seeing? After you have been looking at the Moon for awhile, we hope you will look for patterns in your observations.

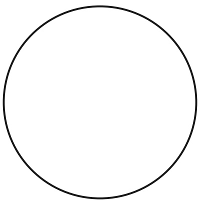
- Does the Moon stay the same shape from day to day?
- Can it always be found in the same place?
- Is it visible only at night?

When you enter the Internet discussion about the Moon, we hope you will compare and contrast what you and your classmates have observed in your home town with what others from around the world have observed.

While you are making those observations, comparing your observations with others in your class, and finding patterns in your observations, we hope you also will talk with adults about the Moon. We hope they will join you in making observations. We hope you and they will talk about how the Moon is portrayed in everyday conversation, music, poetry, movies, and literature. Do they have any special memories about the Moon? Are there any stories or songs or movies they know about the Moon?

In September you will start to use the Internet to share what you have learned about the Moon with other student teachers around the world. Then you can compare and contrast what you have learned. Does the Moon appear the same everywhere or are there differences? Do people have the same ideas, songs, and stories about the Moon around the world or are there differences?

Sample of Observational Chart Completed Daily by Preservice Teachers



Date ________
Time________
Angle________
Example of *Question of the week answered in observation diaries:*
What has the Moon's shape been this week?
When and where have you seen it?

Example of Question for On-line Discussion with USA

Are there any similarities or differences in how the Moon changes shape and location around the world?

Draw sketches and write notes about what your research partners from other parts of the world have reported from Nov 1–4 about the Moon's shape and location.

Additional Analytic Tasks Completed as Part of Assessment

Hourly observation of the Moon for four hours

Nightly observation of waxing Moon at approximately the same time for a week

Shadow stick activity throughout one day.

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