Seeing the crescent moon or full moon? An investigation into student-teachers’ understanding of the phases of the moon.

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This paper addresses the understandings student-teachers have of the Moon’s phases before instruction, the influence of African cultural beliefs on these understandings and the effectiveness of two contrasting teaching methodologies at improving these understandings. The study comprised two sample groups both completing an Astronomy component in their respective courses: seven Geography major primary school student-teachers and fifteen Science Curriculum Studies secondary school student-teachers. In order to research the learning of the student-teachers, data was collected both before and after instruction using questionnaires and interviews. Student-teachers who are not English first-language speakers experienced difficulties when answering written questions. Little scientific understanding of Moon phases was found to be evident before instruction. Further, the students demonstrated a total of eight alternative conceptions. African cultural beliefs were found to be present and provided alternative conceptions of the Moon phases. It was found that a number of cultural beliefs remained, even after instruction. The teaching methodology in the Science Curriculum Studies course appeared to have greater instructive effect, but no student-teachers finally held a complete scientific understanding in either group. The paper concludes with recommendations for teaching strategies for this level of student in the South African system of Higher Education.

Introduction

Recently a theme called “Planet Earth and Beyond” was incorporated into the South African Natural Sciences Curriculum, with Moon phases prescribed for Grades 4-6 and the movement of the Earth and Moon as providing explanations for the Moon’s phases are prescribed as content for Grades 7 to 9 (Department of Education, 2002). Prior to this, astronomy did not form part of the physical science syllabus and so many South African teachers are not equipped to teach this section of work.

There is a rich tradition of African folklore surrounding the celestial bodies in South Africa. If these beliefs are still prevalent in the younger generation, they may provide alternative conceptions about Moon phases additional to or not previously recorded in other studies. The phrase ‘alternative concept’ is used to explain an idea which is contradictory to presently established scientific viewpoints (Hills, 1989 in Atwood & Atwood, 1996). Such alternative conceptions are useful starting points for assisting students towards more scientific conceptions (Driver, Guesne and Tiberghien, 1985). This provided further incentive for conducting this research.

This paper addresses the following questions:

1. What are student-teachers’ understandings of Moon phases before instruction at a university in Gauteng, South Africa?
2. Do African cultural beliefs influence student-teachers’ understanding of Moon phases?
3. How effective are two contrasting teaching methodologies at improving understanding of the Moon’s phases?

Theoretical framework

The theoretical framework of this research is that of the constructivist learning theory. According to Yager (1992), constructivism suggests that people have to build thoughts and frameworks that have individual value if education is to occur and the ability to accomplish or create something demonstrates that knowledge has been acquired. In our study, we assumed that the two sets of student-
teachers would come into their respective courses with their own ideas about Moon phases. This is based on Driver, Guesne and Tiberghien (1985), who found that learners enter science classrooms with thoughts and explanations about the topics they are studying due to daily encounters, even if no formal teaching relating to these topics had occurred previously.

The teaching methodologies discussed in this paper follow different strands of the constructivist approach to education. One follows Dewey’s theory of experience (Neill, 2005), which proposes that successful learning occurs through experiences. According to Neill (2005), Dewey claimed that learning occurs from all encounters and the accrued learning from these encounters affects the character of any forthcoming encounters. These ideas came across in the lecturer’s description of the course as following a progressive philosophy in which experiences are provided and learning occurs through these experiences (Rusznyak, personal communication).

The other methodology closely followed Yager’s (2000) philosophy of constructivism, in which emphasis is placed on problem-solution in small groups, with minor or no intrusion by the educator. Several of Yager’s (1992) suggested constructivist procedures and tactics were in evidence in this methodology, such as the students being involved in searching for information, formulating and describing models and problem-solving in small groups.

**Literature review**

Lemmer, Lemmer and Smit (2003) conducted a study of 232 South African university students’ ideas about the universe by means of questionnaires and interviews. About 40% of the students were of African origin and the remainder of European origin. The first question of the questionnaire required the students to make a sketch of the universe, in order to determine the type of worldview held by each student. They found that generally, the African students held what they termed an ‘organistic’ worldview, related to ancient Greek philosophical views of the world as an organism. The remainder of the questions investigated the worldviews more deeply. Specifically, question 13 asked about the importance of the full Moon, which is relevant to our research. The responses to this question included the following conceptions related to African folklore: the full Moon contains water, has the picture of a woman on its ‘face’ and foretells circumstances in the universe.

As in our study, Trundle, Atwood and Christopher (2002) looked at primary school student-teachers’ understanding of Moon phases both before and after instruction. Their pre-instruction results were based on three groups: 15 student-teachers completing a primary science methods course, not due to have any astronomy teaching, and two physics groups of 21 student-teachers each, both of which were to receive astronomy teaching specifically aimed at Moon phases. Over 90% of all student-teachers provided alternative conceptions or ‘alternative fragments’ – “a subset or subsets of alternative conceptual understandings” (Trundle, Atwood & Christopher, 2002:643). The most common alternative conception for the cause of lunar phases across all three groups, was that of the Earth’s shadow falling onto the Moon, which was given by 18 of the 57 student-teachers. Trundle et. al. (2002) point out that this result was also found in 11 previous studies, comprising in excess of 3000 subjects ranging from primary school learners to senior science teachers. A total of 35 student-teachers did not appear to comprehend that the Moon revolves around the Earth and almost all of the student-teachers did not know that half the Moon is always lit up by the sun throughout the cycle of phases. Their post-tuition results showed that a higher than anticipated number of student-teachers held either a scientific view or fewer alternative conceptions than before: Physics Group A - 71.4% and Physics Group B – 80.9% evidenced a scientific understanding post-tuition as opposed to 9.5% and 0% respectively before teaching.

**Research methodology**

The two sample groups in our study consisted of student-teachers completing a Bachelor of Education degree at the University of the Witwatersrand, Johannesburg, South Africa. Both groups were selected...
by convenience sampling (Brunsell & Marcks, 2005), since the student-teachers were studying at the same university as the authors and the Astronomy courses were covered at an appropriate time of year.

The first group, referred to as the Geography group, consisted of seven primary school student-teachers, four female and three male. Three of the students were English first language speakers. An 11-hour basic astronomy topic was covered as part of the Geography in Education I course, but not all the students were first-years. The main areas covered were the rotational motion of the Earth, the Earth’s revolution about the Sun, seasons, the motion of the Moon around the Earth, and Moon phases. Instruction was given in the form of demonstrations of teaching methods as opposed to traditional lectures (Rusznyak, personal communication), with the use of 3-D models, worksheets, simulations, a field trip to the Johannesburg Planetarium and a Star Party. The teaching methodology used with this group followed a progressive philosophy, which we assumed linked to Dewey’s theory of experience.

The second group consisted of fifteen secondary school student-teachers. This group is referred to as the Physics Group, as a 4-hour Astronomy component is covered in the second year Physics Curriculum Studies course, and consisted of nine male and six female students, five of which were English first-language speakers. The main areas covered were scale and motion in the solar system, seasons, day and night and Moon phases and eclipses. Instruction was given in the form of introductory and concluding lectures, with the use of posters. For the rest of the time, the student-teachers worked in groups, with each group building a model to demonstrate one of the areas of study, followed by a group presentation to the class, using the model. No formal instruction was provided on the topics – the student-teachers were expected to research these areas and then construct their models accordingly. It was assumed that the teaching methodology followed Yager’s philosophy of constructivism.

In order to research the learning of the student-teachers, it was necessary to measure understanding of Moon phases both before and after instruction. Questionnaires were used with both sample groups and interviews with three student-teachers in the Geography group. The items in the questionnaire were mostly open-ended questions, intended to provide detail about the student-teachers’ understanding, and developed from the literature and our own knowledge (in the case of the cultural beliefs).

Data analysis

To analyse understanding of the Moon’s phases, the same coding system developed by Trundle, Atwood and Christopher (2002) was used to code the student-teacher’s responses to each question, since one of the aims of Trundle et. al.’s research was very similar to this study. The table of alternative conceptions provided in their research was felt to be a useful starting point with which to compare results. Based on the overall set of codes for this section of the questionnaire, each student-teacher was then classified according to his or her overall conceptual understanding, as shown in Figure 1.

Pre-instruction results

The type and rate of occurrence of alternative conceptions distinguished before instruction in this research with regards to Moon phases is given in Table 1 and is based on Trundle, Atwood and Christopher (2002). The final column in the table gives some examples of other researchers with the same findings.

From Table 1, the most frequent reasons given for the occurrence of the phases are the time of year, month or night, which is previously unreported and the Earth’s shadow falling on the Moon, which has been reported in at least 12 other studies (Trundle, Atwood & Christopher, 2002). The ‘Time of Year/Month/Night’ was not a particularly scientific answer – five student-teacher’s held firmly to the belief that the phases are linked to the days of the month or year and so must be somehow caused by this. Student C6 included the time of night: “The time of the night influences the same side of the
Moon to appear different, for instance at night the Moon will first appear as the half Moon and at midnight it will appear full. Different dates of the months also contribute to the phases of the Moon.”

Figure 1. Various responses to questions on C2’s pre-questionnaire, indicating the alternative conception that the phases are caused by the Earth’s shadow falling on the Moon. Photographs: Left – French (2002); Right – Lockett (2004).
Table 1. Rate of occurrence of pre-instruction alternative conceptions.

<table>
<thead>
<tr>
<th>Alternative Concept</th>
<th>Geography Group (n=7)</th>
<th>Physics Group (n=15)</th>
<th>Total</th>
<th>Findings Reported by Other Researchers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Year/Month/Night</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>Not previously reported.</td>
</tr>
<tr>
<td>Earth’s shadow on Moon (eclipse)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>Trundle, Atwood &amp; Christopher (2002)</td>
</tr>
<tr>
<td>Earth’s rotation on its axis</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>Trundle et. al. (2002)</td>
</tr>
<tr>
<td>Moon’s rotation on its own axis</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>Callison &amp; Wright (1993)</td>
</tr>
<tr>
<td>Earth’s Tilt</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Trundle et. al. (2002) Callison &amp; Wright (1993)</td>
</tr>
<tr>
<td>Moon is source of light</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Not previously reported.</td>
</tr>
<tr>
<td>Moon’s rotation about the sun</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Not previously reported.</td>
</tr>
<tr>
<td>Saturn’s shadow</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Trundle et. al. (2002)</td>
</tr>
</tbody>
</table>

The rate of occurrence of African cultural beliefs distinguished before instruction in this research is summarised in Table 2. The amount of responses indicating a belief in African folklore was higher than had been anticipated for student-teachers in this age-group.

Table 2. Rate of occurrence of African cultural beliefs before instruction

<table>
<thead>
<tr>
<th>Folklore</th>
<th>Geography Group (n=7)</th>
<th>Physics Group (n=15)</th>
<th>Total</th>
<th>Findings Reported by Other Researchers</th>
</tr>
</thead>
<tbody>
<tr>
<td>A full Moon brings good luck</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Not previously reported.</td>
</tr>
<tr>
<td>The full Moon affects people’s moods or destiny</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>Not previously reported.</td>
</tr>
<tr>
<td>A newborn baby cannot be taken outside at night until it has been shown the full Moon.</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>Not previously reported.</td>
</tr>
<tr>
<td>A crescent Moon shape implies imminent rain.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>Not previously reported.</td>
</tr>
</tbody>
</table>

Cultural beliefs came through very strongly in student-teacher C9’s pre-interview. Early on in the interview, he stated that “The Moon can be seen because of the reflection of the universe”, but the interviewer did not realise that this was related to his cultural beliefs until further in the interview when she began to understand his viewpoint a little better. Basically, the student-teacher was stating that he believes that the Moon’s phases are caused by the ancestors and this is the way that the ancestors communicate with the people. The idea of community came through very strongly in the cultural explanation – being alone is equated with being separated from one’s community and is not seen as good. When asked about his ‘scientific’ explanations earlier in the interview, he explained that it was what he thought the interviewer wanted to know, but he actually believed that there isn’t a
scientific explanation for the phases. He commented that African cultures “… don’t see life as being scientific. We analyse it in a different way”, which relates to the organistic worldview (Lemmer et. al., 2003).

Post-instruction results

Table 3 provides a summary of conceptual understanding for both groups’ pre- and post-instruction questionnaires with regards to understanding of Moon phases and is loosely ordered from most scientific to least scientific understanding. The categories are based on those of Trundle, Atwood and Christopher (2002).

<table>
<thead>
<tr>
<th>Type of Conceptual Understanding</th>
<th>Geography Group (n=7) Pre-instruction</th>
<th>Geography Group (n=7) Post-instruction</th>
<th>Physics Group (n=15) Pre-instruction</th>
<th>Physics Group (n=15) Post-instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Scientific Fragments</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Scientific Fragments with Folklore</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Scientific and Alternative fragments</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Alternative</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Alternative with Folklore</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Alternative Fragments</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Alternative Fragments with Folklore</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>None</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>None with Folklore</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Firstly, some general comments about the Geography group: it is quite concerning that the number of student-teachers with no conceptual understanding increased from two to three. What is more concerning is that only one of these was the same student-teacher. The other two were previously ‘Alternative Fragments with Folklore’ and ‘Alternative’. Possibly, these alternative conceptions were not fixed and the student-teachers were even more confused after the course. However, student-teacher C1, who had previously shown no conceptual understanding displayed the greatest improvement and was finally coded as ‘Scientific fragments’.

In the Physics group, three student-teachers had been classified as having no conceptual understanding before tuition. All three of these student-teachers improved in their conceptual understanding. P12 is a good example of the progression from no conceptual understanding towards some scientific
understanding and generally showed the best progress. Figure 2 provides a comparison of P12’s answers to two of the questions. In each case, the pre-questionnaire answer appears first.

![Figure 2. Comparison of two questions from P12’s pre- and post-questionnaire](image)

Unfortunately, nobody in either group was classified as having a full scientific understanding. Having observed the Physics group construct their models, it is suspected that some did achieve a full scientific understanding, but didn’t articulate themselves well enough in the post-questionnaire.

C9 was the only student-teacher who answered the African folklore questions in the post-questionnaire. This was probably because the student-teachers were now asked to elaborate on their beliefs, whereas before they merely had to tick boxes to indicate their beliefs. Two possible reasons are: they are either not that influenced by the cultural beliefs or not confident enough to share them. C9 had previously discussed cultural beliefs in the pre-interviews and so now felt confident to discuss them. Initially, he had not freely discussed them in the pre-interview. Figure 3 provides some insights into C9’s beliefs. Note that question 12 was not intended to relate to folklore.

In the post-interview, although student-teacher C9 remained convinced that the Earth’s rotation on its axis causes the phases and retained his cultural belief in folklore, a scientific fragment was evident for the first time: “We can see the Moon because the sun’s rays reflect off the Moon”.

C9 made some interesting points shown in Figure 4:

1. the New Moon is visible and
2. only the Southern hemisphere sees all the phases
Figure 3. Cultural beliefs on C9’s post-instruction questionnaire

Figure 4. Transcript of C9’s post interview Question 5.

Figure 5 illustrates the post-interview cultural explanations: The cultural beliefs did not appear again until the final question, which was designed to probe these beliefs. The student-teacher gave both the scientific and cultural explanations for the phases of the Moon. He repeated and expanded on his explanation of the crescent Moon from the pre-interview, indicating how fervently and real the cultural explanations are to him:
I only agree with the cultural explanation of my people (the Tswana). I wrote down the “scientific” explanation in my questionnaires as well because that is what I studied in Geography. Going back to the crescent Moon, if you look at the shape here, it looks as if the crescent can carry water, so the ancestors are telling us to save water because the crops will need it and there might be a shortage. It has a value in the village. People should be aware of things in the future. The shapes of the Moon suggest a lot about the time of year and things to come. Different cultures interpret the phases differently e.g. the Zulu culture believe that the crescent Moon symbolises a teardrop (sorrow).

**Figure 5.** Transcript of C9’s post interview Question 6.

**Limitations of the research**

One of the limitations of this research was that it contained a small sample and therefore the results can’t be generalised. A second limitation is that English is the second and sometimes even the third language for the majority of these students, and therefore it was difficult to gauge the level of accuracy in responses. A similar problem was reported by Tan and Boo (2003) in an analysis of questionnaires completed by student-teachers in Singapore concerning the character of science.

**Conclusions and issues emanating from the research**

Little scientific understanding of the Moon phases was evident before instruction – a total of eight alternative concepts were found. The most common alternative conception was linked to time (of year/month/night). Overall, there were fewer alternative conceptions after instruction, with those remaining tending to be the more common pre-instruction ones.

African cultural beliefs influence understanding of the Moon’s phases. Since student-teacher C9 was so fervent about his cultural beliefs and remained so throughout the research process, there is an indication that the course did not sufficiently challenge his alternative conceptions. More research is required into the influence of African cultural beliefs on understandings of the Moon phases. We consider the cultural beliefs to be more prevalent than reflected in this study and personal interviews with the entire sample would be more effective in determining this.

Both methodologies improved understandings somewhat. However, the methodology used with the Physics Group appeared to provide a greater improvement in the scientific understanding of Moon phases, than that of the Geography group. It is proposed that this was because the students were
constructing their own knowledge rather than observing models. More research would be required into the persistence of this scientific understanding to truly estimate its value. The models used in the Geography course were excellent, but they required a firm background understanding, which the students lacked. Overall, it is extremely difficult to come to any meaningful conclusions for the Geography group because of less than ideal post-questionnaire conditions. So the results for this group could be strongly skewed.

Interviews with the entire sample group would have been most helpful to obtain a fuller picture of the type of understanding and to cross the language barrier. Barnett and Morran (2002) used pre- and post-instruction interviews in their study on primary school children’s understanding of Moon phases and eclipses. Like Barnett and Morran, we found that during the interviews, the questions provided a mechanism whereby the student-teachers restructured their knowledge. This was revealed in student-teacher C9’s interview transcript. This student-teacher’s first language was Setswana and he was classified as having the alternative conception that the phases were linked to the time of year. In the interview it became apparent that he actually attributed the phases to the Earth’s revolution.

The inclusion of Moon observations over a period of 2-3 months could be helpful with addressing the alternative conception that the phases are related to the time of night, month or year. It is recommended that more use is made of models, especially where students construct their own models and explanations in small groups.

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