INDIAN STUDENTS' UNDERSTANDING OF ASTRONOMY

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Abstract: We present findings from our study of middle-school students' understanding of basic astronomy. We have administered tests on observation, information from textbooks, information from cultural sources and explanations to Class 7 students from three different settings, from communities with low educational and economic backgrounds. Based on their responses in these tests and subsequent interviews, and in the light of current literature on mental models and visuospatial thinking [9] we are developing a pedagogy to enable students to explain daily phenomena related to the sun-earth-moon system using model-based visuospatial reasoning.

Keywords: astronomy preconceptions, Indian middle-school students, indigenous knowledge, earth-sun-moon system

Introduction

By the end of middle-school students are taught the heliocentric model of the solar system and the explanations of daily astronomical phenomena. Despite this early exposure students and adults all over the world have problems in understanding the heliocentric model and using it to reason about daily phenomena such as occurrence of day and night, seasons and phases of the moon [2]. In Indian culture, as in most other traditional cultures, astronomical phenomena are associated with astrology, a fact that underlines the need for their scientific explanation and understanding [10].

The reasoning involved in explaining these daily astronomical events is based on a model of the sun-earth-moon system, and it makes use of the spatial properties of the model such as shapes, sizes, positions and motions of the bodies [5]. Students however begin with some rudimentary models and understanding which derive from their prior experience. In this paper we assess Class 7 students' knowledge from textbooks and cultural sources as well as their observations and explanations for phenomena. These findings form the starting point of our pedagogy, more details of which can be found in a forthcoming paper [8].

1. Sample

We work with 68 Class 7 students from three different schools in the State of Maharashtra, India. One school serves a suburban slum area of Mumbai, which is the capital of Maharashtra and the largest metropolis in India; another school is a residential school for tribal students and the third school is in a farming village. The latter two schools are within 10 and 20 Km. respectively of a small town in South Maharashtra. The local language as well as the language of instruction is Marathi. The urban students attended our sessions voluntarily out of school hours while the rural and tribal samples consisted of two entire classes.

Being from low socio-economic backgrounds, the drop-out rates in these samples are high. Out of the 90% students who enroll in Class 1 in rural Maharashtra only about 69% reach Class 8 and only 18% continue their studies beyond Class 10 [12]. Schools have limited resources in terms of space for classrooms, laboratory equipment and other materials. Students do not have access to extra science books, educational videos or computers; in fact they often come to class without minimal tools such as pencils, erasers or notebooks.

Unlike students from urban educated backgrounds, these students are less influenced by modern science; on the other hand, they are more exposed to indigenous traditions. The adults in this society use Indian calendars to regulate agricultural activity and festivals and, as a result, astrology plays an important role in their lives. One of our aims was to see whether this indigenous cultural tradition could contribute to students' understanding of astronomy.

2. Methodology

Oral classroom interaction was conducted in each of the three schools, with students from Classes 4 and 7, to assess their range of experience and knowledge. Based on these interactions and on their textbooks, questionnaires were prepared and administered, after which followed our intervention (relevant observations from the night sky observation, which was part of our intervention phase, are quoted later). The first of the questionnaires was based on everyday observations, the second on textbook information, the third on indigenous knowledge, and the fourth tested reasoning and explanation. The questionnaires were followed by interviews with 12 students to clarify some doubts and to understand their mental models and explanations in detail.

3. Findings

We present here some results from each of our four tests. Further analysis of the data is in progress

3.1 Observation: In a free response question, students listed the things they had observed in the sky: moon (95%), sun (92%), stars (92%), clouds (76%), birds (32%), and airplane (26%). Some responses seemed less plausible, like, planet (31%), satellite (6%) and rocket (5%). Later we found that students had no idea what a planet or satellite might look like, and by "rocket" they might have referred to a kind of firecracker.

81% students said that they had seen the sunrise (at least occasionally) and 94% that they had seen the sunset. Several students admitted that they had never watched the sunrise. 90% students said that the sun rose in the East but none could describe the direction of sunrise within their own surroundings (eg. that they had seen the sun rise from behind a particular tree or building). Likewise 94% students could merely state that "the sun sets in the West". Only 48% could state that the position of the sunrise and sunset changes over the year and only 3% students knew that the sun does not come overhead every day. Though these visual observations were lacking, 62% students knew that the time of sunrise changes every day and 61% knew that the time of sunset changes. None of the students knew the observational meaning of "horizon" although some had heard the word ("*kshitij*" in Marathi) in a literary or poetic context. We later found the "horizon" to be a useful concept in pedagogy.

One question asked students to draw the sun and the shadow of a vertical stick in the morning, afternoon, evening and night. Most (66%) students drew approximately correct elevations for the sun but fewer (50%) showed the shadow to be on the opposite side of the stick as the sun. None of the students used any geometrical method using the direction of the sun rays to locate the shadow.

In the night observation session we found that students could not identify any of the planets, stars or star-groups, although they had heard some of their names, like, *Saptarishi* ("The Seven Sages" i.e. the "Great Bear") and *Mruga* ("Deer" i.e. "Orion"), and had seen pictures of planets in their textbooks. 39% recalled having seen a shooting star. Around 65% students stated that the stars do not remain in the same position throughout the night and over the year. Only 30% said that stars are present in the sky during the day and 18% could explain that stars are not seen in the day due to the bright light of the sun.

44% students knew that moon is not seen every night and 24% had seen the moon in the daytime. 84% knew that the shape of the moon changes every day. Comparatively fewer students knew that the moon rises in the East (45%) and that it sets in the West (50%). This was a sharp drop compared to those who could state the direction of sunrise and sunset (90% and 94% respectively). Looking at these discrepancies, we guess that most students did not relate the apparent motion of the celestial bodies with a common cause, in this case, rotation of the earth. A comparatively large number of students (73%) knew that the time of moonrise and moonset changes every day. A relevant fact here is that several religious fasts are practiced whose timings are associated with moonrise.

3.2 Textbook information: About 60 - 75% students knew the terms "star", "Planet" and "satellite / moon" and could correctly match these terms with a few specific cases. Other terms that the students used, and could also show approximately correctly in diagrams, were, "Equator" (67%), "North Pole" (60%), "South Pole" (62%), "orbit of the earth" (53%) and orbit of the moon (7%).

98% students showed a roughly round earth in their diagrams. On the precise shape of the earth however, there was some confusion. In response to a forced-choice question, 60% students said that the earth is round like a ball, although in the subsequent question on where people live, at least 15% showed people inside the earth. Other responses for the shape of the earth were, like "an egg" (23%), "a plate" (13%) and "a bowl" (2%).

82% students knew that the earth moves. 67% mentioned "rotation" or "revolution" or "both rotation and revolution". But surprisingly more number of students (70%) could state the time periods of rotation and revolution. Note that the latter is a common factual question asked in exams.

Almost all (95%) students knew that the sun is a luminescent object while the earth (93%) and the moon (67%) are not so. Most students had little idea of the relative sizes or distances of the celestial objects. Only 38% could rank the sequence (shooting star, moon, earth, sun) by size. In a sub-sample of 18 students, only 1 student could rank the bodies (lightning, moon, sun, Pole star) by their distance from the earth.

These responses point towards learning of facts and terminology in an uncritical manner. Misunderstandings are common. The information is fragmented and does not serve to create a coherent model for comparison and reasoning.

3.3 Indigenous knowledge: Indigenous knowledge traditions in India are closely bound with religious practice. 80.5% of the Indian population belongs to the Hindu community, which is itself quite heterogeneous in composition. The students in our sample all are from the "Hindu" community in a broad sense. Although different versions of the Hindu calendar are in use, but the students in our sample, all from the State of Maharashtra, followed a single calendar system [3].

The various versions of the Hindu calendar are all lunisolar in nature. Originally developed from an observational base, these calendars are now derived from tabulations and their format is integrated with the Gregorian calendar. A widely used printed calendar (found in literate households) marks the Gregorian months as also the weeks and the solar days, along with symbols and colour coding to show lunar months, days and special events, festivals and national holidays (both religious and secular). The traditional calendar is still used to organise agricultural activities through the year as also numerous festivals and fasts which are named after the phase of the moon. Women in the households tend to practice fasts and rituals more than the men do. Schools too celebrate festivals and declare local holidays for the more prominent festivals. Most importantly these traditional calendars contain notings on numerous observational facts such as phase of the moon, in which division of the sky and zodiac sign the moon is seen, the daily times of sunrise and sunset, the times of moonrise and moonset on important days, and also the name of the month, which shows which star group or "*nakshatra*" is visible on the sky through the night. (A "*nakshatra*" or lunar mansion is one of the 27 or 28 divisions of the sky, identified by their prominent star(s), that the Moon passes through during its monthly cycle, as used in Hindu astronomy and astrology [15]).

When students were asked about the festivals occurring on different phases of the moon they were initially puzzled. It had not occurred to them that the festival dates had any observational significance. After we hinted that the names of the festivals, in most cases, incorporated the term for phase of the moon on that day, students wrote some responses. Out of 476 such responses given by 60 students, 65% correctly matched the festival with the phase of the moon.

The Marathi names of months are taught in school, though without reference to their observational significance. 75% students could name 6 or more of the Marathi months but they did not even know names of corresponding (and similarly named) *nakshatras*. They knew that "*nakshatras*" are stars but they were unable to identify them in the observation session. In comparison, 45% students could name 6 or more of the zodiac signs (although again without knowing their relation with star groups in the sky).

We conclude that students were more conversant with names of zodiac signs (which have astrological meaning) than with names of *nakshatras* which have a significant time keeping role in astronomy. In fact 43% students stated that they do believe in astrology, while only 17% said they did not. These responses show that students are exposed to indigenous knowledge through out-of-school resources, but this knowledge, being bound with astrology, remains unintegrated with observation on the one hand and school learning on the other.

3.4 Explanation and understanding

This test was focused only on students' models of the earth: its round shape, gravity and occurrence of day and night. From the earlier test on textbook information, students were categorized according to their four common models of earth shape: Plate, Bowl, Egg and Ball. These models differed in some respects from models identified earlier by Vosniadou [14] and Samarpungavan [11]. When probed in interviews with selected students these models were found quite robust. All the students drew people oriented vertically or almost vertically within the frame of the paper. 75% showed these people inside the circle denoting the earth (these excluded students depicting a hollow earth model) while 9% showed at least a few people on the perimeter of the circle, though all on the upper one-fourth or so portion of the perimeter. 47% students drew rain only on the upper half of the round earth while 11% drew it inside the earth. Only 9% drew the rain falling (radially) around the upper two-thirds portion. We conclude that "up" and "down" are assumed to be absolute orientations and that gravity has remained unintegrated with the idea of the round earth.

As for explanation of day and night, 73% students reproduced the correct textbook diagram though only 9% wrote an explanation for the apparent movement of the sun in terms of the earth's rotation. Yet when asked what would happen if the earth stopped rotating, 62% responded that day and night would not occur (thus an intuitive connection between the earth's rotation and day-night must exist). When asked specifically if the stars and moon would still appear to move, 25% said no, they would not. Only two (one tribal and one rural) student answered correctly that only the moon would continue to move because unlike the sun and the stars it actually does move around the earth.

The discrepancy between the students' diagrams (which were fairly correct) and their verbal explanations (which were lacking or confused) leads us to believe that the diagrams were learnt by rote and not connected with the dynamic model of day and night.

4. Implication for Pedagogy

The pretests showed that students need to build an observational base of daily events in the sky. Their mental models need to be developed, beginning with their model of a round, rotating earth incorporating the notion of gravity. The information that they have gained from their textbooks and from indigenous sources needs to be integrated with their observations and with their mental models. We are in the process of designing a pedagogy which uses physical (concrete) models and experiences, going on to connect these models, through a sequence of gestures and diagrams, to dynamic mental models [8].

Physical models in astronomy are constrained by not being able to incorporate scale information, change of perspective and also aspects of motion [1]. We try to overcome these limitations through the use of a. body gestures (to provide kinesthetic feedback) [6] that might be helpful in carrying out perspective transformations and mental rotations [4] and b. schematic diagrams (which would serve as a tool of analysis and interpretation) [13]. For more on our pedagogy see [8]. The effectiveness of the pedagogy will be tested at the end of three cycles of teaching over the course of one year.

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