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Teacher's misconception in curricular astronomy

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Abstract. *Misconceptions about astronomy concepts are found quite regularly in students, even after they have taken astronomy courses. There are numerous reasons for this [1, 2]. The authors in this paper have focused on the possibility that the existence of these misconceptions could be attributed to the misconceptions of the teacher-instructor and its transmission down to the students that he/she has been teaching. Keeping this in mind, the authors have prepared a questionnaire consisting of assertions split into 5 sections. The teacher-instructors were asked to gauge the truthfulness of the assertions in a survey. The responses to the section on Calendars and the section on Sun and Moon are covered in this article. It was concluded that the respondents of the survey face serious skill deficits in imparting conceptually correct astronomical knowledge to their students. This deficit in skill is not only due to a lack of information on the subject but also due to an inability/unwillingness of the teacher-instructor to make logical inferences/extensions from the knowledge he/she does possess on the topic.*

1 Motivation

Misconception about astronomical concepts are quite common amongst students. These misconceptions know no age bar and are found in high school and undergraduate students. The various misconceptions commonly found in students have been listed in scholarly works [1, 2, 3, 4], books [5, 6] and numerous websites maintained by outreach professionals [7, 8, 9, 10]. Most of the works listed above only list the misconceptions. A few discuss remedial measures on how to deal with these misconceptions and how one can help students to make the transition to correct conceptual understanding. However, not many researchers have explored the idea that misconceptions of the teacher-instructor impact the understanding of the students, especially at the high school level.

In South Asia, at the high school level, teachers are still considered by the students as the most authentic source of science information. The students draw perspectives on science from multiple spheres in their experiential world. We can term textbook as one of the knowledge spheres, but there are other spheres such as traditional knowledge imparted by elders in the family or anecdotal knowledge obtained from cultural traditions. The reliance of students on their teachers for assimilation of these spheres to make a coherent picture is near absolute, even in the age of the internet. Thus, the teachers are expected to anticipate students' preconceptions regarding day to day astronomical phenomenon, and be able to guide their students towards correct conceptual understanding. To probe the conceptual understanding of the teacher-instructors, a survey was carried out which contained assertions on various concepts in astronomy that the respondent would come across while teaching the subject. In this paper, we will discuss the responses made in the section on Calendars and the section on Sun and Moon, and try to interpret the results of the analysis made on the responses.

2 Existing Astronomy Curriculum in India and Sri Lanka

In India, Astronomy is taught in schools in grade 5 (1 chapter) under the subject of environmental studies [11] and grade 6 (2 chapters) under the subject of geography [12, 13] and in grade 8 (1 chapter) under the subject of science [14]. The relevant topics covered include rotation and revolution of the earth, the phases of the moon, time of moonrise on different phases, concept of leap year, solstices and equinoxes, time zones, stars, the pole star, constellations, the solar system, planets, other minor bodies in the solar system and satellites.

In Sri Lanka, astronomy as a subject, has only two chapters devoted to it in the school syllabus, one chapter in class 8 under the subject of geography [15] and one chapter in class 9 under the subject of science [16]. With respect to the Indian syllabus, the Sri Lankan syllabus skips the topics of phases of the moon, moon rise times and the concept of leap year. However, the Sri Lankan syllabus does cover the topics of Galaxies, the Milky Way, the ecliptic region, star maps, birth and death of stars, a brief introduction to the big bang theory, Galileo's contributions to astronomy and history of astronomy through the discussion of historical world models.

As the coverage is vast, topics are covered superficially and several key ideas related to these topics are omitted. For example, the textbooks mention that there should be an extra day in February, every 4 years, but does not mention the fact that centuries are to be considered leap years only when divisible by 400 (Gregorian correction). Similarly, the textbooks don't explicitly talk about geometry of eclipses or different sunrise points over the year or change in the length of shadow in a course of day or precession of the earth.

The impact of astronomy on our day to day lives is substantial. Most important is the development of the calendar system which is essential to the daily functioning of human life. Apart from the Gregorian Calendar, some of the calendar systems followed by India include the Vedic calendar (in North and West India), the Surya Siddhanta calendars used in East and South India and the Islamic Calendar. The Sinhalese Calendar is more prevalent in Sri Lanka (a variant of Surya Siddhanta calendars). In the Vedic Calendar, each year consists of 12 lunar cycles (months) but intercalary months are added every 2-3 years to bring the start of the year back to the vernal equinox. In Surya Siddhanta-based calendars, however, the months are independent of lunar phases and it uses a 365-day solar year.

3 DESCRIPTION OF SURVEY

The survey was conducted in Mumbai at the Homi Bhabha Center for Science Education (HBCSE) over two sessions with two distinct groups. The sample consisted of a total of 47 individuals divided into two subsets. The first subset was made up of 30 Indian science teachers hailing from different cities of India. There were 14 male teachers and 16 female teachers in this subset. All the teachers were working under the banner of an elite group of schools owned and run by the Government of India, established to educate children of government employees. They were all nominated for in-service training at HBCSE. The average teaching experience for this group was about 23 years.

The other subset was a group of 17 science teacher trainers from Sri Lanka, attending a training camp organized again at the same institute. The members of the group were selected by the Ministry of Education, Sri Lanka for advanced training. It consisted of 8 male teachers and 9 female teachers. The average work experience of these teacher trainers was about 15 years. As both groups were pre-selected through some other process, we may call this a cluster sampling based on convenience.

None of the members in either sample had prior astronomy training. However, all of them had prior experience in teaching astronomy units at the secondary level. Although these groups may not exactly be the most representative of the teacher populations in either countries, the authors wished to explore the possibility of significant difference in responses due to differing cultural and educational backgrounds. Thus, the two subgroups were analyzed separately.

3.1 Survey Methodology

The questionnaire that was developed was broken into 5 sections, with an average of 12 assertions per section. The sections were: Calendars, Constellations and Movement of Stars, The Sun and Moon, Planets and finally Social Beliefs about Astronomy. As mentioned earlier, paper will be concentrating on the survey responses to the section on Calendars and the section on Sun and Moon.

In the questionnaire, the respondent would have to determine the truthfulness of an assertion using the 5 point Likert type scale. The responses that were available to the Respondents were: Definitely False, Probably False, Don't Know, Probably True and Definitely True. There were 13 assertions present in each of the sections that will be discussed in this paper. All the statements in the survey were either part of the high school astronomy curriculum outlined earlier or were logical extensions of the topics that were covered.

The analysis of these responses have revealed a lot about the overall knowledge of these teachers with regards to astronomy. We also get an insight about which type of misconceptions end up being passed down to the students. Another aspect of the questionnaire was that some assertions in each section were correlated with each other. A correct response to one assertion with the right reasoning, would help the respondent to get the right response to other correlated assertions in the section. Again, an analysis of these pairs of statements have yielded interesting results. We identified 4 statements in this section as the ones specifically relevant to Indian cultural practices and as such the authors didn't expect to gather any relevant data from the subset of teachers from Sri Lanka. For purposes of discussion, the authors propose to call the Indian teachers group the IN group and the Sri Lankan teachers group the SL group.

3.1.1 *Data representation*

The representation of the responses will be via stacked bar charts for the individual questions and bubble charts for studying the responses for correlated questions. The colour scheme used for the individual questions can be read as follows: Green: correct response, Yellow: leaning to correct response with less confidence, Blue: respondent claimed to have no knowledge, Orange: respondent leaning to incorrect response and Red: respondent confidently chose incorrect response.

So if the assertion was False, the color scheme that one would see is: Green at the bottom, then Yellow on top, then Blue, followed by Orange and finally Red at the top. If the assertion was True, then the color scheme would be: Red at the bottom, followed by Orange, then Blue, then Yellow and finally topped by Green.

The authors have opted to use stacked percentage bar charts over pie charts because studies show that the human mind is more capable of estimating and comparing lengths than at comparing area as outlined in the study here [17].

For the bubble chart the colour scheme is as follows, Green: the respondent gave correct responses to both the correlated answers, Red: he/she chose one correct response and one incorrect response, Yellow: if both responses are incorrect, Blue: if both options selected were "Don't Know".

4 Discussion of Teacher responses: Calendars

In this section we do a quantitative analysis of the responses made by the respondents. We will carry out the analysis by grouping the assertions based on the astronomy concept being covered by them. The first set of correlated assertions are listed below.

I. LEAP YEAR:

a.] All years divisible by 4 are leap years.

This assertion is false. While most years divisible by 4 are leap years, centuries are not considered as leap years unless they are divisible by 400. These corrections proposed in 16th century under Gregorian calendar reforms were deemed as standard knowledge for all students in the previous generation.

b.] Year 1900 was not a leap year.

This assertion is true. As follows from the explanation above, 1900 is not divisible by 400, so it is not a leap year.

c.] Precession of the Earth's axis adds about one day in every four years.

This assertion is false. The Precessional motion of the earth does not have any measurable effect on the revolution of the Earth about the Sun and so it is not the cause of the leap year corrections.

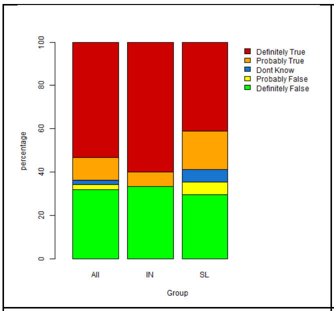

Fig 1: I-a

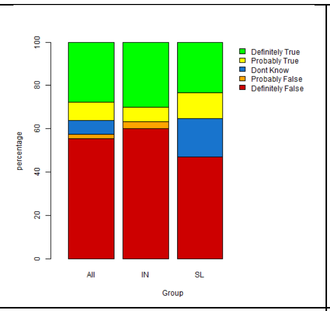

Fig 2: I-b

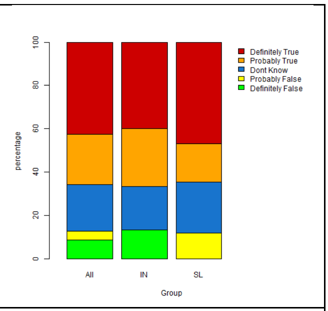

Fig 3: I-c

Assertion is False: Bottom to top-Green, Yellow, Blue, Orange, Red
Assertion is True: Bottom to top- Red, Orange, Blue, Yellow, Green

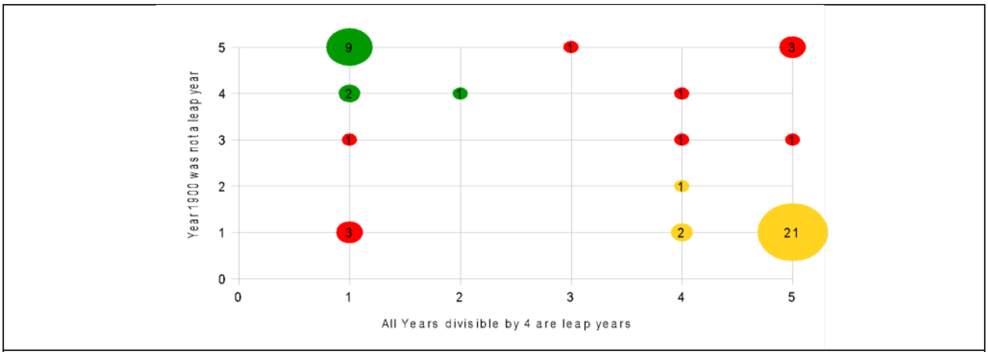

Fig 4: Correlation of responses to Assertions I-a and I-b

Here, the authors were testing whether the respondents were familiar with some of the finer details regarding the Gregorian calendar. The assertion I-b was set as a direct consequence of assertion I-a. The authors wanted to see if the respondents were able to see the correlation and thus give an answer that was consistent with their earlier answer. Only 25% of the respondents gave a correct answer for assertion I-a (Fig 1), as seen in the total and the subset responses. Also almost 60% got it wrong for assertion I-b (Fig 2). What surprised the authors when looking at correlation plot for the assertions I-a and I-b (Fig 4) was that a lot of respondents got both assertions wrong. This did suggest that most respondents were able to see the correlated nature of the question and so answered accordingly. 60% of the respondents got assertion I-c wrong (Fig 3). The authors think that this could be due to a lack of understanding as to what precession actually is.

II. Lunar Calendar

a.] A lunar calendar year (e.g. Islamic Calendar) is shorter than the solar year
This assertion is true. A lunar calendar lasts approximately 354 days.

b.] A lunar month is exactly equal to the revolution period of the Moon
This assertion is false. The revolution period of the Moon is approximate 27.33 days while a Lunar month (i.e. one cycle of lunar phases) is approximately 29.53 days.

c.] Revolution period of the moon is shorter than a full cycle of lunar phases.
This assertion is true. As explained above, the revolution period of the moon is shorter than a full cycle of lunar phases.

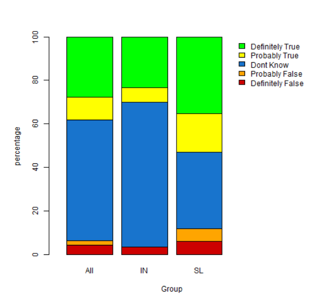

Fig 5: II-a

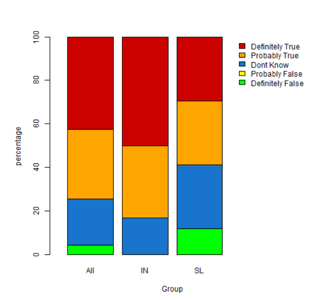

Fig 6: II-b

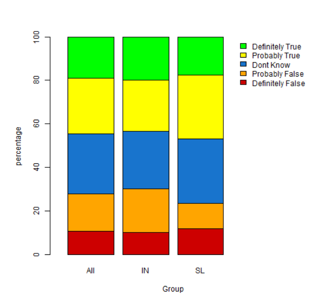

Fig 7: II-c

Assertion is False: Bottom to top-Green, Yellow, Blue, Orange, Red
Assertion is True: Bottom to top- Red, Orange, Blue, Yellow, Green

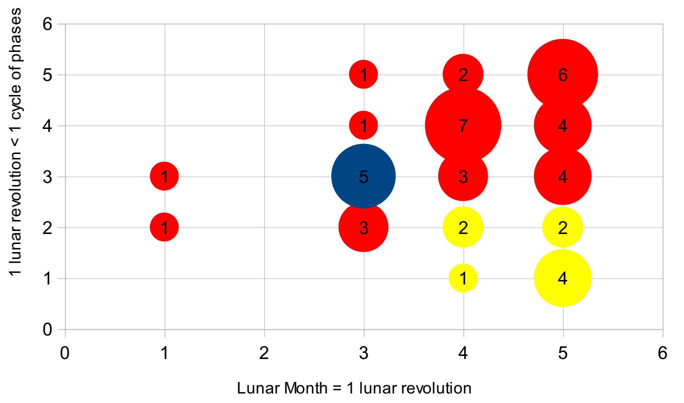

Fig 8: Correlation of responses to assertions II-b and II-c

Here the authors were testing whether the respondents were familiar with the concept of lunar phases and its connection to understanding lunar calendars. What was seen from the response to assertion II-a, is that most of the respondents were unaware of the concept of the lunar calendar and so couldn't compare them to a solar calendar (Fig 5). Almost 70% of the respondents got the concept of a lunar month wrong (Fig 6) but 40% were aware that the revolution period of the moon around the earth was less than a full cycle of lunar phases (Fig 7). This is also seen in the correlation plot between assertion II b and II c (Fig 8). The authors think that the results give the impression that respondents are fixated on the idea that the lunar calendar is based on the revolution of the moon since the solar calendar is based on the revolution of the earth around the sun.

5 Discussion of Teacher responses: Sun and Moon

III. Equinoxes and Solstices

a. On 23rd December, a place on the equator will see the shortest day of the year.
This assertion is false. The length of day (as per motion of the mean Sun) at the equator is always about 12 hours regardless of what month it is.

b. On 21st June, a place in the southern hemisphere will see the shortest day of the year.
This assertion is true. 21st June is the date of one of the solstices. On this day, the day is longest in the Northern Hemisphere and shortest in the Southern Hemisphere.

c. One 21st March, Guwahati will have equal day and night.
This assertion is true. 21st March is the date of Vernal Equinox. On this day the length of day is about equal to the length of night for all locations on the Earth. There may be slight second order differences in the lengths but that is beyond the scope of knowledge of the targeted group of teachers.

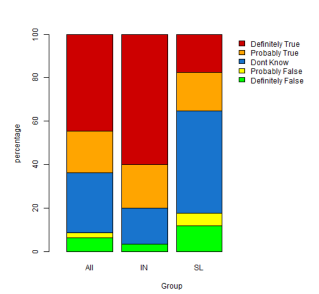

Fig 9: III-a

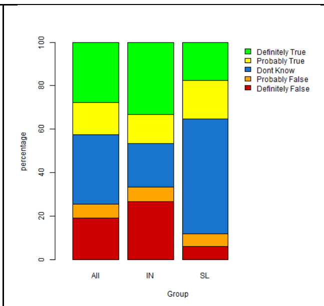

Fig 10: III-b

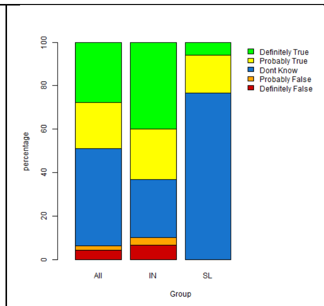

Fig 11: III-c

Assertion is False: Bottom to top-Green, Yellow, Blue, Orange, Red
Assertion is True: Bottom to top- Red, Orange, Blue, Yellow, Green

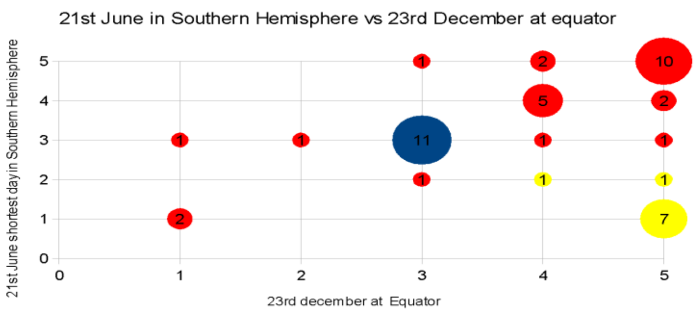

Fig 12: Correlation of responses to Assertions III-a and III-b

Here the authors were exploring if the respondents had understood the concept of equinoxes and solstices. What was seen is that 60% of the total respondents got the wrong answer for the assertion III-a (Fig 9) with a large number of respondents from the SL group stating that they did not have the knowledge to answer this question. Surprisingly 30% of the total respondents were aware about solstices (fig 10), though again 50% of the SL group respondents demonstrated a lack of knowledge of solstices. Responses to assertion III-c again showed that more than 50% of the respondents from the IN group knew the right answer (Fig 11). Majority of respondents (almost 80%) from the SL group claimed that they didn't know the answer. This was probably caused by this group not being aware of Guwahati, a city found in the eastern part of India. However, the assertion itself was independent of the name of the city and the teachers completely overlooked this point. The correlation plot of assertion III-a and III-b shows that the respondents were not able to correlate between the concepts of equinoxes and solstices. The lack of knowledge about equinoxes could be one of the main reasons for the behavior seen the plots above (Fig 12)

IV. Daily Motion of the Sun

a. The Sun rises exactly at the eastern point every day.

This assertion is false. The Sun would be rising north of east in the summer and south of east in winter of northern hemisphere. Only on the two equinox days, the sun will be rising due east (90 degree azimuth).

b. The Sun comes overhead every day at some point during the day.

This assertion is false. The sun reaches the highest point of its daily path at what is called the local noon. This highest point will be on the North-South (local) meridian but it is not necessarily exactly overhead (zenith).

c. The shadow of a person will be the shortest when the wrist watch shows 12:00 noon.

This assertion is false. The shadow of a person will be shortest at local noon. The time shown on the wrist watch depends on the time zone of the observer location, his/her actual longitude and equation of time. This time may not match the local noon at the location.

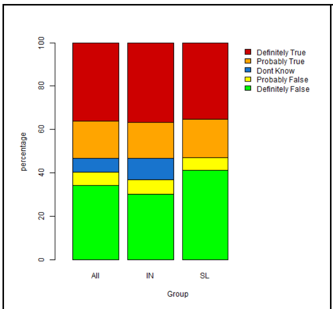

Fig 13: IV-a

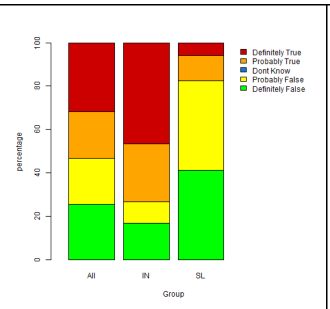

Fig 14: IV-b

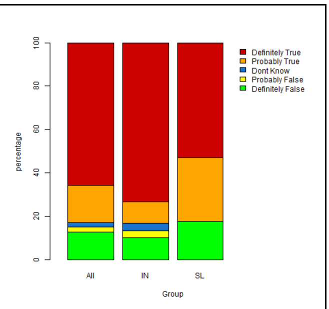

Fig 15: IV-c

Assertion is False: Bottom to top-Green, Yellow, Blue, Orange, Red
Assertion is True: Bottom to top- Red, Orange, Blue, Yellow, Green

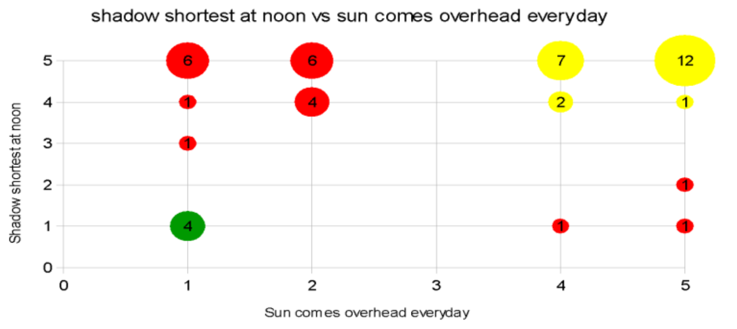

Fig 16: Correlation of responses to IV-b and IV-c

Comparing the responses to the assertions IV-b and IV-c provided some interesting results. More than 50% of the respondents in each subgroup did not know that the rising point of the sun shifts. The responses to assertion IV-b were also surprising. Most of the SL group understood that the sun does not come overhead every day but most of the respondents from the IN group failed to understand this. Again for assertion IV-c we saw that a majority of the respondents had no idea of the concept of local noon. All this tells us that the respondents had not understood what we mean by local time, and in general how the sun is seen in the sky as a function of latitude.

When we look at the correlation plot [Fig 16], we see that 22 respondents got assertions IV-b and IV-c wrong. And 18 respondents understood that while the sun does not come overhead it does reach its highest point every day, they didn't get the fact that we call the sun reaching the highest point the local noon of the location and that the time on the watch of the observer will not show 12:00 noon as that would be dependent on what time zone is being followed at that location. This inability to understand that local noon and 12:00 noon in a watch would only match if the watch showed the local time could be attributed to the respondents being confused about the concept of noon. We think this is because of the popular notion that noon is when the sun is directly overhead every day.

V. Eclipses

a. The Earth's shadow falls on the moon on the new moon day.

The assertion is false. This is one of the most common misconceptions prevalent amongst people. On a new moon day, the moon is between Sun and Earth and hence there is no question of Earth's shadow falling on moon.

b. The apparent angular size of the lunar disk and that of the solar disk are approximately the same.

The assertion is true. As viewed from the Earth, the angular size of the sun and the moon is nearly same and the value is about 0.5°.

c. If there was an eclipse in September, there cannot be an eclipse in the same year in December

The assertion is true. As the lunar orbit is inclined by 5 degrees to the ecliptic, if the moon is close to orbital nodes (a condition for eclipse) in a certain month, it will be 5 degrees above or below ecliptic after 3 months. Thus, the eclipse won't be possible.

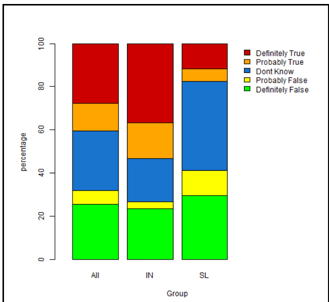

Fig 17: V-a

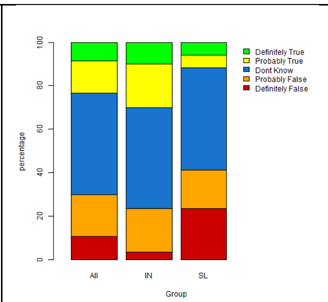

Fig 18: V-b

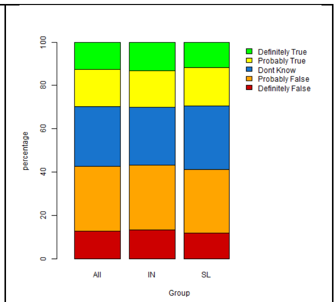

Fig 19: V-c

Assertion is False: Bottom to top-Green, Yellow, Blue, Orange, Red
Assertion is True: Bottom to top- Red, Orange, Blue, Yellow, Green

Looking at the responses to assertions V-a, V-b and V-c we see that most of the respondents claimed not to possess the knowledge required to respond to the assertions. The understanding of eclipses is important as it enables us to understand how the earth, sun and moon move with respect to each other. Eclipses helped Aristotle predict that the earth should be round, observations of the total solar eclipses have helped us study the corona, some solar observations can only be made during solar eclipses and much more. So the understanding of eclipses and how they occur is essential to all astronomy educators and thus this lack of knowledge was glaring.

6 Conclusion

Looking at the overall responses to the survey and highlighted responses reported in the previous two sections, we conclude that high school teachers face serious skill deficits to impart correct astronomical knowledge to their students. This deficit is not only in terms of lack of information but also, more worryingly, inability / unwillingness to extend their knowledge to make logical inferences. Although this was a small sample, the authors' experience with other school teachers and anecdotal evidence gathered from other astronomy educators suggest that these errors are commonplace among teachers. Given this scenario on ground, there is added responsibility on textbook writers to make every connection more explicit. Alternatively, curriculum designers must create enough supplementary material for teacher use. This will assist teachers to shore up their knowledge and in turn help them to provide better scaffolding in the learning process.

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