Homi Bhabha Centre for Science Education
Tata Institute of Fundamental Research
V. N. Purav Marg, Mankhurd, Mumbai

Ph.D. Project on
"Spatial Cognition and Visualization in Elementary Astronomy Education"
Shamin Padalkar
Thesis Advisor: Prof. Jayashree Ramadas

Annotated translations of problem situations used in five sessions of guided collaborative problem solving

Marathi originals with diagrams are at:
http://www.hbcse.tifr.res.in/data/pdf/vthinking/pedagogic-questionnaires

Session 1: Parallel Rays

Parallel ray approximation for a distant light source.

Questionnaire 1: Measurement of angles between successively less divergent lines leading to parallel lines

Measure the angle between the given pair of lines and write the measure of the angle:

(Diagram: Four pairs of lines (a, b, c, d) subtending successively decreasing angles; case d being that of parallel lines)

Questionnaire 2: Drawing rays from the sun at increasingly larger distances to notice almost parallel nature of rays near the earth

A picture of the sun is given below. Dray the rays for this sun:

Pictures of the sun and the earth are given below. In each picture draw sun-rays going in all directions. Then colour only those rays which fall on the earth.

Write the measure of the maximum angle between the coloured rays in each diagram.

(Diagram: Three figures (a, b, c) with successively increasing distance between the sun and the earth)

Does the maximum angle between the rays increase or decrease on increasing the distance between the sun and the earth?

The actual distance between the sun and the earth is several times larger than shown. If we draw the sun and the earth at the distance they really are, what would be the angle between the rays?

Session 2: Shadows

Correlating shadows with angles of elevation of a light source.

Questionnaire 3: Shadows cast by parallel rays of light at different inclination to the ground or earth

1. Two sticks erected on the ground are shown in the following picture. The direction of sun-rays has also been shown.

Draw the shadow of the first stick.

Now draw more sun-rays. (Remember; the sun-rays falling on the earth are parallel.)

Now draw the shadow of the second stick

(Diagram: Two sticks erected on the ground)

2. Now the two sticks are erected on a slope. The direction of the sun-rays is shown. Now draw the shadows of these two sticks.

(Diagram: Two sticks erected on the slope of ground)

3. Similar two sticks are erected at two different positions on the earth. Now, if the direction of sun-rays is as shown in the picture, draw shadows of both the sticks.

(Diagram: Two sticks erected at two different positions on the earth separated by a longitudinal angle of 80°)

Questionnaire 4: Drawing angle of elevation of a point or parallel ray source at different inclination to the ground or the earth

1. Two friends, Bimm and Kimm are shown in the picture below. The shadow of Bimm in the morning sun-light is shown in the diagram. Draw the shadow of Kimm at the same time.

(Diagram: Two boys standing on the ground and shadow of one of them)

2. There is a lamp-post between two of them. Draw the shadows of Bimm and Kimm due to the lamp at night. Draw shadows at night in the same diagram by using coloured pencil.

(Diagram: Two boys standing on the ground and a lamppost in the middle)

3. Kimm sees the star Sirius at 40° as shaown in the diagram. Draw at what angle Kimm would see the star Sirius.

(Diagram: Two boys standing on ground and a ray from Sirius at an angle of 40° above horizon)

4. After few days Kimm went to another place to live. The positions of Bimm and Kimm on the earth are shown in the diagram below. The direction in which Kimm sees the star Sirius from the new place is shown in the diagram. Can you show the direction in which Bimm would see the star Sirius?

(Diagram: Earth as seen from the north pole; Bimm and Kimm separated by a longitudinal angle of 70°)

Session 3: Rotating Earth

Correlating global cues with local directions and angles of elevations; time differences

(Questionnaires 5 to 8: Local time at different locations of the earth, position of celestial bodies at each of these positions and changes in the positions of celestial bodies as a result of rotation of the earth.)

Questionnaire 5: Determining local directions at a point on the equator, given the global direction of the sun

In the following diagram, a picture of a girl called Rinku is to be drawn at such a place that it is 12 o' clock in the noon for Rinku.

(Diagram: Earth as seen from the north pole and sun-rays from the right side)

Draw a line of horizon for Rinku in this diagram.

Now indicate the East and the West directions of Rinku on that line.

Questionnaire 6: Determining local directions at a diametrically opposite point on the equator and locating stars at given angles of elevation from this point

1. Now, in the following diagram, a picture of Sonu, sister of Rinku, is to be drawn at such a place that it is midnight for Sonu.

Draw a line of horizon for Sonu.

Now indicate the East and the West directions of Sonu on that line.

(Diagram: Earth as seen from the north pole and sun-rays from the right side)

2. Now Sonu sees the star *Magha* overhead from her current place. Draw the rays coming from star *Magha* to Sonu.

(Remember; the rays falling from any star on the earth are parallel.)

3. At the same time, Sonu sees the star *Rohini* at 20° above the Western horizon. Draw the rays coming from star *Rohini* to Sonu in the same diagram.

4. At the same time, Sonu sees the star *Swati* at 45° above the Eastern horizon. Draw the rays coming from star *Swati* to Sonu in the same diagram.

Questionnaire 7: Determining local directions at three different points on the equator and

locating stars at given angles of elevation from these point; time zone differences

1. Now, Mithu, brother of Rinku and Sonu, is standing at such a position that the sun is just setting for him on the western horizon in the evening. Draw picture of Mithu in following diagram.

Draw a line of horizon for Mithu.

Now draw the East and West directions of Mithu in the same diagram.

(Diagram: Earth as seen from the north pole and sun-rays from the right side)

Now predict, where would following stars be seen to Mithu, using the diagram (If Mithu would not be able to see the star, then write 'will not be seen').

1. Where will Mithu see the star *Magha*?

2. Where will Mithu see the star *Rohini*?

3. Where will Mithu see the star *Swati*?

4. After how much time would Mithu see the sky that is currently visible to Sonu?

5. After how much time would Sonu see the sky that is currently visible to Mithu?

Questionnaire 8: Same as Q7 above, six hours later

Draw a diagram, similar to above diagram, which shows the positions of Rinku, Sonu and, Mithu after 6 hours. Draw stars *Magha*, *Rohini* and *Swati* in it.

(Diagram: Earth as seen from the north pole and sun-rays from the right side)

1. Where will Sonu see the star *Magha*?

2. Where will Sonu see the star *Rohini*?

3. Where will Sonu see the star *Swati*?

4. Where will Sonu see the sun?

5. What is the time for Mithu according to this diagram?

Session 4: Star-month

Observed night sky "*nakshatra*" and indigenous calendar

(Indigenous calendar and observational astronomy)

Questionnaire 9: Relation between the visible sky at a given point on the earth's orbit and the "*nakshatra*" (star group) and month named in the indigenous calendar

The sun, earth and the orbit of the earth are shown in the following diagram. The stars are very far

than they are shown in the diagram.

(Diagram: The earth and its orbit as seen from above north pole; location of some stars and constellations indicated in indigenous terminology)

1. From which side do we have to view (the model) to see the given picture?

2. Which stars would a person on the earth see at night?

3. Would the person on the earth be able to see the stars on the other side of the sun in daytime?

4. Would the person be able to see the stars on the other side of the sun, even for a short while, at any time during complete day?

5. Which Marathi month and *Nakshatra* is going on on the earth?

Session 5

"Seasons" - Day-night and North-South elevations of the sun during solstices and equinoxes (explanation of occurrence of seasons)

Questionnaire 10: Day-night at the poles and elevation of the sun at the equator during the summer and winter solstices

1. The following diagram represents the earth and its orbit as seen from within the plane of the earth's orbit. The line of the orbit and direction of the sun-rays are shown.

Now draw an axis of the earth making an angle of 66.5° to the line of the orbit.

Indicate the North pole and the South pole.

Draw the equator making an angle of 90° with the axis.

Indicate the Northern and Southern hemispheres in the diagram.

The angle between the parallel sun-rays and the axis of the earth is 66.5°. Indicate the day and night occurring due to these sun-rays.

(Diagram: Earth; Line indicating plane of orbit; sun-rays from right parallel to this line)

Now, draw a person on the equator in this diagram. For this person, is the sun exactly overhead, or towards North of zenith, or towards South of zenith?

If the earth completes one rotation around itself in 24 hours, there will be some parts on which sun-light will not fall. Which are these parts? Colour these parts blue.

If the earth completes one rotation around itself in 24 hours, there will be some parts on which sunlight will fall all the time. Colour these parts red.

Which hemisphere (Northern or Southern) will have more sunshine according to this diagram?

Which hemisphere will be warmer?

Which hemisphere will be cooler?

Which season would be going on in the Northern hemisphere?

Which season would be going on in the Southern hemisphere?

2. You know that the earth revolves around the sun. The above picture depicts the position in the month of June and the following picture shows the position of the earth after six months, which is in the month of December.

(Diagram: June (left of the sun) and December (right of the sun) positions of the earth as seen along plane of orbit)

Based on this picture, complete the following diagram for the month of December.

Draw the axis of the earth making an angle of 66.5° to the line of the orbit.

Indicate the North Pole and the South Pole.

Draw the equator making an angle of 90° with the axis.

Indicate the Northern and Southern hemispheres in the diagram.

(Diagram: Earth; line indicating plane of orbit; sun-rays from left parallel to this line)

Indicate the day and night occurring due to these sun-rays.

Now, draw a person on the equator in this diagram. For this person, the is sun exactly overhead or towards North of zenith or towards South of zenith?

If the earth completes one rotation around itself in 24 hours, there will be some parts on which sun-light will not fall. Colour these parts blue.

If the earth completes one rotation around itself in 24 hours, there will be some parts on which sun-light will fall all the time. Colour these parts red.

Which hemisphere (Northern or Southern) will have more sunshine according to this diagram?

Which hemisphere will be warmer?

Which hemisphere will be cooler?

Which season would be going on in the Northern hemisphere?

Which season would be going on in the Southern hemisphere?

Questionnaire 11: Day-night on earth and North-South elevations of the sun in the two

hemispheres at the time of equinox

3. In the following diagram, assume that the sun is exactly in front of the earth outside the plane of this paper.

(Diagram: Earth with equator & axis at 66.5° to the line indicating plane of the orbit)

From the part of the earth which we can see, if there is any part which is in darkness, colour it blue.

In the part of the earth which we can see:

Is it daytime everywhere in the Northern hemisphere?

Is it daytime everywhere in the Southern hemisphere?

Which hemisphere (Northern or Southern) will have more sunshine according to this diagram?

Which hemisphere will be warmer?

Which hemisphere will be cooler?

Which season would be going on in the Northern hemisphere?

Which season would be going on in the Southern hemisphere?

In which month would this situation occur?

4. Indicate whether the following statements (or diagrams) are right or wrong:

i)In December, it is winter in the Northern hemisphere.
ii)Following diagram:
(Diagram with direction of axis of rotation of the earth changed after 6 months. See previous and modify.)
iii)Seasons occur due to change in the distance between the earth and the sun.
iv)It is winter in the Southern hemisphere when it is summer in the Northern hemisphere.
v)Polar region are lit for six months and dark for the remaining six months
vi)In polar regions, the earth takes more then 24 hours to move around itself.
vii) It never gets dark on some parts on the earth.