Role Play Based Approach for Elementary Astronomy Education

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Elementary astronomy concepts, usually part of school curriculum, are often fraught with learning difficulties. Heliocentric, three dimensional model of modern astronomy require visuospatial abilities for comprehension. In addition misconception/alternate conception and other naive mental models hinder conceptual change. Thus there is a widespread prevalence of illiteracy even after many years of schooling. Using role play as a visuospatial scaffold, modules for teaching basics concepts in astronomy have been developed and used extensively during the International Year of Astronomy 2009 in India. The paper describes the pedagogical and cognitive imperatives that went into the design of the modules and preliminary qualitative results. The module is recommended as appropriate teaching/learning strategy in the context of low resources situation prevalent in most of the Indian schools.

Keywords: Role-play, Visuo-spatial reasoning, Astronomy, Activities

Introduction

Elementary astronomy is introduced in middle schools in India as part of geography curriculum with the aim of scientific literacy. Concepts such as day and night, heliocentric theory, phase of moon, eclipses, seasons are some of the concepts dealt in the middle school curriculum. Conceptualizing the solar system to explain natural phenomena such as phases of the moon is an abstract process and can be difficult for students, especially in middle school (10 to 13 years old), who are typically moving between concrete and formal thought. Studies show that heliocentric system is a difficult concept even after many years of traditional schooling. Interviews of Harvard graduates and faculty, conducted by education group at the Harvard-Smithsonian Centre for Astrophysics, are a typical indication (Trundle, Troland, & Pritchard, 2008). Readily observed in the video 'private universe', even graduate students and at times faculty were unable to explain even origin of the seasons and the phases of the moon. A study conducted in India (Padalkar & Ramadas, 2008) shows that while 90% of students knew that sun rises in the east and 94% of students thought that sun sets in the west, only 45% knew that moon rises in the east and only 50% of students thought that sun sets in the west. Perhaps the students are not able to relate the apparent motion of the celestial bodies with rotation of earth. The study on Indian students (Padalkar & Ramadas, 2008) concludes that students typical "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". Moving from declarative knowledge to procedural knowledge is a big cognitive leap that requires conceptual change and building of mental models. In absence of adequate teaching/learning strategies and materials learners end up memorising facts and repeating them.

These elementary astronomical concepts play an important role in shaping the students understanding as well as interest in science. As Sadler (1992) observes "certain elementary knowledge appears prerequisite for more difficult concepts. The understanding of day and night and earth's yearly revolution about the sun appears to be key to mastery of the sun's motion in the sky, an understanding of seasons and may other concepts. … it may be impossible for students to acquire powerful scientific ideas without great attention to the basics".

Teaching and learning basics of astronomy – Pedagogical imperatives

Astronomy, in Indian schools is taught with cursory attention. Other than textual materials, ill conceived diagrams are the sole teaching/learning tool employed in teaching these concepts. Diagrams are static and two-dimensional. As an abstract representation, often with symbols and invisible aspects of the model (say axis of earth), they are far removed from reality and require effort to comprehend. Also at times these images themselves pave way for generation of misconception-exaggerated depiction of elliptical orbit of Earth leading pupil to hold the variation of distance between Earth and Sun as the cause of seasons (Atwood & Atwood, 1996; Trundle et. al., 2008).

Research literature amply shows that misconceptions about phases, eclipses and other daily celestial phenomena are widespread. In a most prevalent misconception, children and adults confuse the explanations for phases and eclipses by assuming that lunar phases occur when the Moon enters the Earth's shadow. Other incorrect explanations such as 'cloud covers the moon', 'planet or the sun casts a shadow on the moon' have also been found among school students, (Baxter, 1989; Stahly, Krockover, & Shepardson, 1999). Various studies have pointed out that similar misconceptions/alternative conceptions are prevalent among Indian students (Samarapungavan, Vosniadou, & Brewer 1996). In our interaction with teachers we often found that learners (usually school teachers) view phase of moon as being related to one's position on Earth-implying that simultaneously different parts of the earth witness different phases. While learners may easily recall the names of Moon phases, they often do not understand the explanation behind the phases. Ability to memorize and recall right words often construed as knowledge masks learner's lack of in-depth understanding. This is indeed true of science in general and astronomy in particular. Thus for a scientific understanding of astronomical phenomena conceptual restructuring of the size, shape and position and relative location and dynamics of celestial objects are required.

Shift from the naive ego centric (geo centric–as seen from 'flat' earth) view point to object centric (as observed from a vantage point in space/heliocentric view of space) is intrinsic to modern astronomical explanations of celestial phenomena. Pedagogical implications of the implicit visual grammar (Hill, 1990) and frames of reference (Percy et al., 2000) so effortlessly utilized by astronomers and yet so apparently difficult for many learners to employ are imperative. A shift from naïve mental models as well as shift from the geocentric perspective demand conceptual changes at various levels.

For students to undergo conceptual change, four conditions must be fulfilled (Posner, Strike, Hewson, & Gertzog, 1982). First, students must be aware of and discontent with the power of existing conceptions. Second, any new conception must be understandable. Even if they find it hard to accept they should be able to comprehend it and understand its implications. Third, this new idea must be plausible. It must seem reasonable that this concept could be true. Finally, it must be productive. This new idea must predict and explain more than the student's old idea. Some novel phenomena should be explained which is not easy to be explicable by the existing conception. Conceptual change is facilitated when teacher use a variety of techniques (such as analogies, thought experiments, imagistic reasoning) to help students and construct an understanding of new concepts and when students have opportunities to strengthen their understanding of the new ideas through extended application and argumentation.

World does not approach compartmentalised into different subjects or distinct aspects; it is complex myriad of facts, problems, dimensions and perceptions. Nevertheless it is only through incremental, the stepwise elaboration of knowledge structures that understanding can be effected. This calls for a well designed activity schema; learner needs to understand certain concepts for making sense of other concepts. For example, understanding of light and shadows as well as dynamic model of earth-moon sun system is precursor to the development of the correct spherical mental model of lunar phases, which incorporates the changing position of the moon.

Basic cognitive requirements for astronomy

Topics such as day and night, phases, eclipses and seasons are customarily hard to grasp, especially at young age. The phenomena being described are seen from earth–day and night, phases, eclipses and seasons. However scientific models that explain these phenomena evoke mental imagery of arrangements of celestial objects as seen from a vantage point in space. This has implication for the development of astronomical perception, creating a possible conflict of object-centred (heliocentric and/or pictures from a vantage point in space as different from as it is viewed/visible from Earth) with observer-centric (egocentric) views. Traditionally diagrams are the sole tools that are employed to teach core astronomical concepts. These 2D diagrams usually expect the reader to make sense of a 3D relationship by orienting him/her inside the depicted scene, e.g., imagining how the Moon would appear from the Earth at different positions in its orbit. Students need to recognize similarities and make links between the object centred and egocentric viewpoints to facilitate assimilation and accommodation.

This implies, firstly the learner should have spatial reasoning ability. Astronomical phenomena are three-dimensional, dynamic, and occur in large-scale space and time. The learner must be able to comprehend the size, position, motion, alignment of celestial bodies correctly and arrive at a correct understanding of the spatial pattern. With spatial orientation the learner perceives spatial patterns or maintains orientation with respect to objects in space.

Secondly the learner should be able to visualise. Three dimensional nature of astronomy challenges one's mind. Further dynamic movement (like moon moving around earth) and its orientation (Sun-Earth-Moon orientation resulting in phases of Moon) resulting in observed phenomena require visualization of three dimensional world.

Thirdly, the learner should be able to make sense of shifting frames of reference. Learner has to master to shift swiftly between 'outside-looking-in' representation of celestial objects and an 'inside-looking-out' earth centred framework if he/she has to make sense of the scientific model/explanation.

Thus, grasping basic astronomical concepts require adequate spatial reasoning abilities, visualisation and multiple frames of reference (which include mental rotation as well as perspective taking). Woefully, teaching learning materials lack guided activities that facilitate the assimilation of increasingly abstract ideas represented by object centred diagrams and descriptions of celestial objects and phenomena. They show hardly any sensitivity to any of the visuospatial necessities of astronomy learning. Broadfoot and Ginns (2005, p. 53) observes that "inclusion of activities that develop and enhance student spatial abilities is highly desirable in the development of learning materials and teaching strategies for astronomy". Spatial orientation and visualisation, ability to visualize physical systems from different points of view, including mental rotation as well shift in perspective are thus cognitive imperatives for astronomy education. Nersessian (1992) argues that "imagistic representations have often been used in conjunction with analogical reasoning in science" and suggests them as a useful tool for effecting conceptual change. In a recent study (Subramaniam & Padalkar, 2009) corroborate use of imagistic reasoning for astronomy concept learning.

Role Module for Basics of Astronomy

To assist students in dealing with the cognitive challenges inherent in astronomy, several computerized models (Yair, Schur, & Mintz, 2003) were developed in the past decades. However such computerised models are rather difficult to implement in Indian conditions, especially in rural government schools. Thus a low cost- no cost alternatives are imperative.

As part of the International Year of Astronomy, a set of activities were designed and developed as modules for taking basic concepts of astronomy to young people. The motivation came from the International Astronomical Union's corner stone project UNAWE, which addressed the question of taking astronomy to young children, especially from disadvantaged section. Thus the activity was expected to be low cost or no cost and easily replicable. Role play, used as a technique in education, especially in social sciences and language learning to foster spontaneous exploration of various situations, fits the above needs. Its potential in science education is well documented (Aubusson, Fogwill, Barr, Perkovic, 1997; Lehtelä, 2001).

Thus we undertook development of a set of modules of role-play for astronomy education related to middle school astronomy on the topics of—day and night, phases of moon, eclipses, rising and setting time of different phases and seasons. In Indian context, it was found that learners were keen to understand certain concepts such as *Rashi* (zodiac), *Nakshartra*. In view of its relation to Indian astrology the words were familiar to most of the learner and hence the modules for these concepts were also included. Though the core of activities was 'role play', they were supplemented with pictures, cut and paste activities and worksheets.

The modules were shaped and revised through interaction with children and teachers. Interaction with para teachers of Chirag, Uttrakand, elementary teachers with SSA (Rajiv Gandhi Siksha Mission) Chhattisgarh and children of Digantar School, Jaipur helped in the refinement and fine tuning of the activity schema. The modules were extensively used by All India Peoples Science Network (a network of voluntary agencies involved in science popularisation) as well as by NCSTC, Department of Science and Technology in their public campaign during International Year of Astronomy–2009, total solar eclipse -2009 and annular solar eclipse 2010 programmes.

It is not that all the activities were constructed *de novo*, many of them were used by educators and science popularises for long. What had been hitherto fragmented and 'science for fun' was refined, new role-play situation/scenes were added and made into a structured modules with specific learning goals. Though role play is not a scripted drama, predesigned scenes/ situations provided a framework for exploration. When the activity is conducted adequate time is given for the children to themselves figure out their roles/positions, teacher/facilitator providing useful guidance.

In the role play activities, three participant role play as sun, moon and earth, with the head of the 'earth person' representing earth. Other children who are not part of the role play stand a few feet away and observe the "big picture–heliocentric view" of what is happening. Children are replaced after each step such that all of them get a chance to act-out. Steps are repeated and children are encouraged to explore various dynamics and relative positions.

In the schema (a set of activities with a definite learning goal) the first step was designed to create a demand for knowledge. *If half of moon is always illuminated then how phases are visible; why does moon raise 50 mts late every day; why it shows only one face towards earth.* The activity was so designed to elicit curiosity by revealing a problematic gap or by exposing limitation in learner's understanding. In the next step facilitator (teacher) or peer group of learners provide new information directly or indirectly which the learner used to build new knowledge. *How will moon look from Earth in a particular orientation; Moon takes about 27 days to go around earth; Time period of rotation and revolution of moon is same etc.* The learner either assimilates or accommodates and constructs new knowledge structures in memory that can be linked to existing knowledge. In the next step, the knowledge is reorganized, connected to other knowledge, and reinforced to support its future retrieval and use (three dimensional Earth-Moon-Sun systems linked to certain key understanding of light and shadows, perspectives and so on). However the steps do not preclude overlaps; knowledge construction and revision may be interleaved, and knowledge construction or revision can create new motivation. Nevertheless, the knowledge structures growing in the minds of the learner are through incremental and step by step process.

An exemplar – Phases of moon

To illustrate how the step by step activity schema is set out in this section we describe one of the modules related to 'phases of moon'. Before this module is taken, the learner has already underwent the concept of day and night; earth rotates in anti-clockwise direction and moon moves around earth in anti-clock wise direction and is fairly familiar with role play protocols.

Step1: One half of moon is always illuminated (day) whereas other half is always dark (night): The module begins with role play wherein three children act out as sun, earth and moon. Initially the facilitator shows how one half of the moon (say face) is illuminated by sunlight, whereas other half (backside) is in darkness. The moon is made to go around the earth and stopped in its path many times. At each alignment, participants are asked to discuss which part of the moon is illuminated and which part is not. Initially some participants think that 'face' part of the moon is illuminated at all alignments. However that misconception is rectified with interaction with the peers. As participants verbalize and describe the 'physical model' (three students in role play position before them), it becomes easy for them to arrive at a mental model that all times as moon moves around earth, one half is illuminated and other half is in darkness.

An activity sheet which contain empty circles are drawn around the earth, depicting position of the moon as it goes around the Earth is distributed. Direction of the sun is indicated. The participants have to correctly draw the terminator line, thus the knowledge acquired is used/applied. Those who make mistakes were able to get themselves corrected by the peers. Mostly mistakes occur because people recall the pictures of moon phase in their textbook and draw them.

Step 2: Which alignment would result in full moon/ new moon: The three children are aligned in such a way that new moon ensues. The earth child is made to rotate and facilitator probes how the moon will look from various parts of the earth. Using the understanding garnered (half of moon is always illuminated) participants make out that, that specific alignment would result in new moon. The facilitator then probes 'where does the moon go during new moon'. The participants then are able to reason that illuminated part of the moon is facing away from Earth and hence we do not 'see' the moon though it is physically present. The participants are then challenged to find the position moon should take to result in full moon. The participants realise that full moon and new moon phases are to do with relative alignment of sun, earth and moon, thereby apply their understanding to make sense of hitherto puzzling concept of new moon.

Step 3: Which alignment will result in first and third quarter moon: To solve this puzzle, the participants have to apply their prior knowledge (half of moon is always illuminated; specific alignments results in full/new moon) and mentally/physically manipulate the model (three children role playing). The prior knowledge (specific alignments results in full/new moon) gets articulated and expanded (specific alignments results in various phases of the moon)

Step 4: Waxing and waning of moon: Reflecting upon experiences and understanding, participants are able to, with gentle suggestions from the facilitator, make out that while moon moves from new moon position to full moon position it is in waxing phases and from full moon to new moon waning phases. As the understanding dawns, participants feel a sense of discovery.

Thus the learners are taken in a journey step by step-from motivation (perceive a need for understanding or feel curious), construction (experience a novel phenomena or learn a new fact from the facilitator) and refinement (apply understanding and reflect upon experiences and understanding).

Role play as visual-spatial scaffold

Although knowledge is actively constructed by the cognizing subject, learning is not only an adaptive process that organizes one's experiential world but knowledge acquired need to match with an independent, pre-existing world outside the mind of the knower. Learning process is more of a concept transformation process rather than accumulation process. By engaging in the set of activities learners are invited to new and novel thinking spheres.

Through guidance and questioning to provide explanations, learners are encouraged to reflect upon their mental models and hypothesis. Role play and the set of activities serve as scaffolding. Of course the scaffolds in the form of role play does not change the nature or difficulty level of the concept, however, with scaffolding learners are able to successfully explore the concept and derive the meaning. As a visual-spatial scaffold, learner can take an 'object centred' view while being an observer and can shift his/her position as 'earth person' to seek 'egocentric' perception. As the step by step role play activities progress learners are able to shift seamlessly from one point of view to another frame of reference. Understanding is achieved through reasoned discussion and interpretation and not just direct perceptual experience. While the role play provides concrete representation, it is the learners who provide the representation meaning and this form the shared basis for conversation about the phenomena under study. Learners can manipulate the role play and ask 'what if' questions and thus explore various orientation of role play objects. Spatial properties of role play actors–position, orientation, alignment and motion could be exploited with imagistic reasoning to make sense of the celestial phenomena. Role play also provided a scope for learners to evaluate their mental models, subject their ideas to scrutiny–tested against other ideas, observation and evidence derived from the modelling. Thus the imagistic representations of role play serve as a concrete physical model for analogical reasoning.

Qualitative Results

We have mainly conducted role play session with teaches/ para teachers (although on few occasion with children). Following qualitative points emerge from our experience:-

— We found that the role play encouraged the learners to discuss their own mental models. *Earth rotate like this; moon goes around earth like this etc.* Learners who were reluctant to articulate verbally their mental models were readily forthcoming in role play to try out their ideas say, *how should moon revolve around its axis such that only one face is towards earth at all time.*

— It also provided a non threatening, social and enjoyable opportunity for learners to develop and build on these models. The activities generate an atmosphere where learners can do and say things without fear of failure; to be able to express ideas and hypothesize with confidence was created in the role play situation.

— We noticed several "aha!" (Eureka moments?) situations when the learner could make sense of the model and explanation to the novel phenomena (such as even though moon revolves around its axis only one face is seen from earth; or moon will rise every day about 50 mts later; eclipse season recur roughly six month later).

— Learners found it difficult to verbalize the moon-phases phenomenon. However they were able to explain the same with hand waving and gestures or re-enacting the role play. Thus whether role play aid in verbalising is a question that needs to be explored.

— In an analogy, focus is on some salient aspects of the model and other facets are ignored. In role play, learner may choose to focus on trivial or inappropriate aspects of the analogy and ignore the critical and relational features. Role of the facilitator/ teacher is crucial to help students focus on critical attributes of the model. While explaining that when the Sun, Earth and Moon person are in line, we have new or full moon someone may recall the textbook statements and argue it would be eclipse. The teacher then has to have students of differing height to play the role of sun, moon and earth to avoid the confusion. The guidance provided by the facilitator was crucial and was more than hand-holding.

— The module encouraged peer learning. In many cases students negotiated their understanding with each other. Such negotiations may not necessarily lead to construction of scientific knowledge. Nevertheless negotiations helped learners construct science understanding. This process was, to a large extent, supported by the guiding questions and probing intervention from the facilitator.

— From experience it is clear that fixed rendition of set ideas hardly works. It is crucial to keep the role play dynamic and evolving, flexible and progressively modified.

Conclusions

We have developed a set of modules to teach basic astronomy concepts appropriate for the low resources situation prevalent in most of the Indian schools. Our experiences in using these modules amongst teachers and science communicators have been fruitful. Learners have found it an enjoyable learning experience. But role play strategy has more than affective gains. As the play act evolved in response to the discussion, it encouraged the learners to use analogical and imagistic reasoning and think scientifically. The learners were able to explore their ideas and test them with the model. Our experience concurs with recent study that argues for using gestures and body movements for teaching astronomy, especially imagistic reasoning (Subramaniam & Padalkar, 2009). We conjecture that spatial reasoning competencies and imagistic reasoning could be enhanced by role-play activities and that would help learner make sense of represent space, motion of celestial objects and astronomical phenomena. We hope the account of our experiences and efforts will interest researchers and teachers of astronomy who are looking for low cost- no cost modules for teaching astronomy to young people.

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References

Atwood, R.K., & Atwood, V.A. (1996). Preservice elementary teachers conceptions of the causes of seasons. *Journal of Research in Science Teaching,* 33(5), 553-563.

Aubusson, P., Fogwill, S., Barr, R. & Perkovic. L. (1997). What happens when students so simulation role-play in science? *Journal of Research in Science Education,* 27(4), 565-579.

Baxter, J. (1989). Children's understanding of familiar astronomical events, *International Journal of Science Education,* 11, 502-513.

Broadfoot, J. & Ginns, I. (2005). Astronomy education research down under. In J. Pasachoff & J. Percy (Eds.), *Teaching and learning astronomy-effective strategies for educators worldwide*, 44-56. New York: Cambridge University Press.

Hill, L.C., Jr. (1990). Spatial thinking and learning astronomy: The implicit visual grammar of astronomical paradigms. In J.M. Pasachoff & J.R. Percy (Eds.), *The teaching of astronomy*, Proceedings of IAU Colloq. 105, 247-248, Williamstown, MA, 27-30 July 1988, Cambridge: Cambridge University Press.

Lehtelä, P.L. (2001). Role-playing, conceptual change, and the learning process: A case study of 7th grade pupils. In H. Behrendt, H. Dahncke, R. Duit, W. Graber, M. Komorek, A. Kross, & P. Reiska (Eds.), *Research in Science Education – Past, Present, and Future*, 211–216. Netherlands: Kluwer Academic Publishers.

Nersessian, N. (1992). How do scientists think? Capturing the dynamics of conceptual change in science. In R.N. Giere (Ed.). *Cognitive Models of Science*, 5-22. Minneaolis: University of Minnesota Press.

Padalkar, S. & Ramadas, J. (2008). Indian students' understanding of astronomy. In electronic proceedings of the *Conference of Asian Science Education – CASE 2008,* Kaohsiung, Taiwan.

Padalkar, S. & Ramadas, J. (2009). *An* Indigenous approach to elementary astronomy–how cognitive research can help. *Proceedings of Episteme 3*, Mumbai: Macmillan.

Percy, J.R., Chandra, N.R., Kalchman, M., Mutlak, H., Woodruff, E., & Yoon, S. (2000). Frames of reference as an element in the learning of astronomy concepts. Bulletin of the *American Astronomical Society*, 32, 1573.

Posner, G.J., Strike, K.A., Hewson, P.W., & Gertzog, W.A. (1982). Accommodation of a scientific conception: toward a theory of conceptual change. *Science Education,* 66(2), 211-227.

Sadler, P.M. (1992). *The initial knowledge state of high school astronomy students.* Unpublished dissertation. Harvard University, Graduate School of Education.

Samarapungavan, A., Vosniadou, S., & Brewer, W.F. (1996). Mental models of the earth, sun and moon: Indian children's cosmologies. *Cognitive Development*, 11(4), 491-521.

Stahly, L.L., Krockover, G.H., & Shepardson, D.P. (1999). Third grade students' ideas about the lunar phases. *Journal of Research in Science Teaching*, 36(2), 159–177.

Subramaniam, K., & Padalkar, S. (2009). Visualisation and reasoning in explaining the phases of the moon. *International Journal of Science Education*, 31(3), 395-417.

Trundle, K.C., Troland T.H., & Pritchard T.G. (2008). Representations of the moon in children's literature: An analysis of written and visual text. *Journal of Elementary Science Education,* 20(1), 17-28.

Yair, Y., Schur, Y., & Mintz, R. (2003). A "Thinking Journey" to the planets using scientific visualization technologies: Implications to astronomy education. *Journal of Science Education and technology*, 12(1), 43-49.