Astronomy education: A case for blended Learning

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Abstract:
This paper presents innovative blended pedagogy for teaching high school astronomy and preliminary observations on its pilot classroom trial.

Astronomy is rightfully an essential component of school science. Despite learning it during school years, and being a subject of interest among people, astronomy is known to be prone for alternative conceptions (lelliott & rollnick, 2009). A baseline survey done by Connected Learning Initiative (CLIx) in 4 states of India supports this claim. When asked an explanation of phases of the moon, only 17% students chose correct option. In response to this, a short pedagogic sequence to teach astronomy at Grade 8 or 9 level (called astronomy module henceforth) is being designed. Total 12 lessons are being planned for the astronomy module out of which 9 are classroom lessons and 3 are digital lessons.

Visuospatial thinking plays a crucial role in learning science (Gilbert, 2005) in general and astronomy in particular (Padalkar & Ramadas, 2010). The module focuses on building students' understanding upon these skills using diagrams, role-plays (during classroom lessons) and digital activities. Diagrams often present difficulty for student because of their abstract, 2 dimensional, static nature. To help students to evoke the real three dimensional dynamic system we designed innovative computer simulations morphing from realistic representation (of the earth in this case) to the corresponding diagram.

A pilot trial of one classroom lesson followed by a digital lesson based on the same content (rotation of the earth) was conducted at a Marathi medium school in Pune with 40 students of grade 8. We came across interesting observations which we report in this paper. For example, a girl used a gesture (right hand thumb rule) to determine the direction of rotation of the Earth which she had learned in the classroom lesson. These observations help us in improving the activity and designing further activities.

Keywords: Astronomy, Visuospatial thinking, role-plays, digital activities, simulations

Introduction
Basic astronomy is essential component of most middle and high school curricula. The syllabus typically covers explanation of commonplace phenomena such as day-night, seasons, phases of moon and eclipses based on the heliocentric model of the solar system. It also gives brief introduction of planes and other objects in the solar system. Despite devoting a couple of chapters to this topic every year and common interest in the field of astronomy, it is well documented that students and adult carry many alternative conceptions (lelliott & rollnick, 2009). The roots of these alternative conceptions can be traced back to inability to use visuospatial thinking (Subramaniam and Padalkar, 2009; Padalkar and Ramadas, 2010).

Learning this part requires students to visualize the model and simulate it to explain the phenomena. Naturally, most textbooks use diagrams along with the text to illustrate the spatial aspects (e.g. orbits) of the system. Concrete models and gestures (referred as role-plays in this paper) have been argued to be useful tools to enable visuospatial thinking in astronomy (Padalkar and Ramadas, 2010, Crowder, 1996). Equations are often used in advanced astronomy, but they are not useful for school students since students are not familiar with calculus yet. As educational technology became available, it has been used to teach astronomy in the following forms

1. Planetaria (Plummer, 2009; Plummer et al., 2014)
2. Virtual reality environments to introduce solar system (Chen, 2007)
3. Computer simulations
4. Computation
5. Videos and photographs
6. Games

(Authors are not aware of a systematic study on the usage of last four modalities to teach astronomy)

In order to learn science, students must master multiple representations and develop representational competence (Kozma & Russell, 1997; Padalkar & Hegarty, 2015). It is advantageous to use multiple representations to help students to construct richer and more accurate model of reality. Exposure to single representations may result in students believing that reality is same as the representation (Treagust & Chittleborough, 2001). In this paper we present a short pedagogic sequence in which we blend the different physical and digital representations in basic astronomy.

Significance

This study is a part of a large scale field action project called Connected Learning Initiative (CLIx). Developing exemplar educational material for Grades 8, 9 and 11 for science, mathematics and English is one of the mandates of this project. Corresponding material for teachers on how to use it in the classroom is also being developed simultaneously. Considering its effectiveness on a large scale, an appropriate use of digital media in the educational material is encouraged.

As a part of need assessment a baseline survey of CLIx was conducted in 4 states of India (Telangana, Rajasthan, Mizoram and Chhattisgarh) in 2016. It included the following question in the area of astronomy:

Phases of the moon are caused because ....

1. something covers the moon
2. the earth's shadow falls on the moon
3. only a part of lit half of the moon is visible from the earth
4. the moon's orbit makes an angle of 5 degrees with the orbit of the earth

Out of 5418 students who attempted this question less than 17% students could answer this question correctly (option 3). A little more than 38% students chose option 1 (occlusion), a rather primitive alternative conception. More than 23% students chose option 2 (earth's shadow) which is documented as most common alternative conception regarding explanation of phases of the moon (Trumper, 2000). Almost 21% students chose option 4: a fact but not the correct explanation. Note that the percentage of students who chose correct option is least among the percentage for each option.

This, along with earlier studies in Indian context (Padalkar & Ramadas; 2008, Mohapatra, 1991), demonstrates that Indian students lack basic understanding in the area of astronomy. In response, a short pedagogic sequence (12 classroom periods, which is what is usually devoted to this topic) called 'Basic Astronomy Module' is being developed. Three out of twelve lessons are planned to be digital lessons intended to be conducted in the computer lab.

Research Design

This study follows the 'Design Experiment' or 'Design Based Research' (DBR) methodology. The aim DBR is to design new, robust teaching methods (Brown, 1992; Lesh et al., 2000). The process of developing a part of instructional material, trialing it in different kinds of classrooms and improving it is iterated several times.

Unit 1 of the Basic Astronomy Module covers rotation and revolution of the earth and the related observable phenomena such as apparent motion of the sun and stars, occurrence of seasons and changes in the night sky over the year. (The other three units are devoted to the moon, the solar system and the universe). Three lessons are allocated to Unit 1 out of which one is a digital lesson.

In the present study we focused on the instruction on rotation of the earth and its consequences. Along with concrete models, role-plays and diagram, we wanted students to use animations and interactive simulations. We first defined the learning objectives of the classroom and the digital activities. Several ideas were put forth and discussed (and still being discussed!) out of which one was developed. A paper prototype was prepared and tested it with a few adults (some of them were experts in game design, some were experts in astronomy and some were lay people. However the limitation was, we could not test the paper prototype with students). The prototype was used as a basis to design the digital activity. While designing the digital activity, several possibilities such as adding sound effects, kind of representations we would use, amount of text of the screen, screen design etc. were discussed and debated. The learning objectives were referred from time to time to make many of the decisions. For example, adding sound effect could enhance the appeal of the activity but it will not lead to any specific learning (but would make the files heavy and add the hardware requirements such as sound cards and headphones in the computer lab) so they were not added. Once the activity was logically sound it was scripted and handed over to the technologists. The script included detailed instructions about how the screen should look, functions of each object on the screen, instructions for students and feedback after they complete each stage of the activity (a professional scriptwriter helped us in this process). The technologists shared the digital activity and after incorporating one round of feedback it was finalized.

One classroom lesson and one digital lesson were conducted in an urban, coed, Marathi medium school. About 40 Grade 8 students participated. The second author conducted the classroom lesson. The digital lesson was conducted 6 days after the classroom session in two batches so that each student can handle the mouse individually. Both authors noted their observations and took informal interviews after the digital lesson. The digital activity is being modified based on the feedback from students and teachers.

Description of the innovation

As mentioned earlier, the trial consisted one classroom lesson and one digital lesson.

Classroom lesson was based on the pedagogy developed by Padalkar and Ramadas (2010). It started with a discussion on the difference between the real earth and the globe. This was to emphasize that globe it one of the representations and it has limitations. This discussion was followed by the following three activities:

1. Outdoor activity with Geosynchron (Monteiro, et al., 2008): When axis of the globe is aligned to the earth's axis it is called geosynchron. First the globe was held in such a way that our location (India) came on the top of the globe so that students could observe that time of the day and the directions of shadows are exactly same on the geosynchron and the real earth. Then by slowly simulating the motion of the earth they could see how local time changes at different locations on the earth, day turns into night and vice a versa. Here they were introduced to the right hand thumb rule[1] to determine the direction of rotation of the earth.

2. Role-play to learn day and night: This activity requires empty space (not necessarily outdoor). The students stood in pairs, one student became the sun and other became the earth. Students were asked to consider that four people are standing on the earth i.e. head of the student (one on nose, two in two ears and one on the back of the head) and asked to identify time of the day for each of them. Then they were asked to rotate by 90 degrees and asked to do same exercise. This procedure was repeated three more times so that the earth completes its one rotation.

3. Role-play to learn apparent motion of the stars: Three pairs were merged, one student became the earth, one became the sun and remaining four become the stars. The stars stood surrounding the sun and the earth (since stars are present all around and far away). When the student who became earth rotated, she could see how different stars are visible at different position at different times and how they appear to move. One of the stars was asked to stand behind the sun and it was illustrated that some of the stars will not be visible at certain time of the year since they are behind the sun.

Students were encouraged to take different roles in successive role-plays and correct each others. A lot of question-answers, discussion accompanies all three activities. Students were also encouraged to use the right hand thumb rule to figure of the direction of rotation during the role-plays.

Digital Lesson: Considering that government schools will have limited number of computers, we assumed that two students will use one computer terminal. It is perfectly fine if students attempt the digital activities individually, but if they work in pair, they have a scope to discuss, which is even better! The digital lesson incorporated the following two activities:

[1] Right hand thumb rule: If the thumb of the right hand fist is aligned to the axis of the earth and pointing towards north, then curl of the fingers gives direction of rotation of the earth (anticlockwise if seen from above the north pole).

1. Watching an animation: The animation started with the realistic earth (with oceans and continents shown in different colours as shown in Figure 1a) and slowly transforming into a conventional diagram of the earth (Figure 1b). This activity is designed because diagrams are the most accessible spatial representation to students. They can be easily generated and transformed, and hence very common in learning science and in professional scientific activities. Interpreting diagrams and being able to use them to communicate and solve problems is one of the essential skills in science (Ainsworth, 2011). However, because of their static two dimensional nature they often pose difficulty to students (Mishra, 1999). The present activity was designed to address this difficulty. If the students can see the realistic earth transforming into a diagram, we hope that they will be able to recall what the diagram stands for. This will help them to mentally simulate the earth to explain phenomena such as rising and setting of the celestial bodies.

   Moreover, the animation is available for the earth as seen from three different perspectives: As seen from above the North pole (North polar view), As seen from above the equator (equatorial view) and a view in between these two (oblique view). The thumbnails of these simulations were present on the screen (see Figure 1). All these perspectives are used in different diagrams to explain different phenomena. Also, the availability of diagrams from different perspectives emphasized the three dimensional nature of the earth and we believe that it will help students to construct a three dimensional mental model.

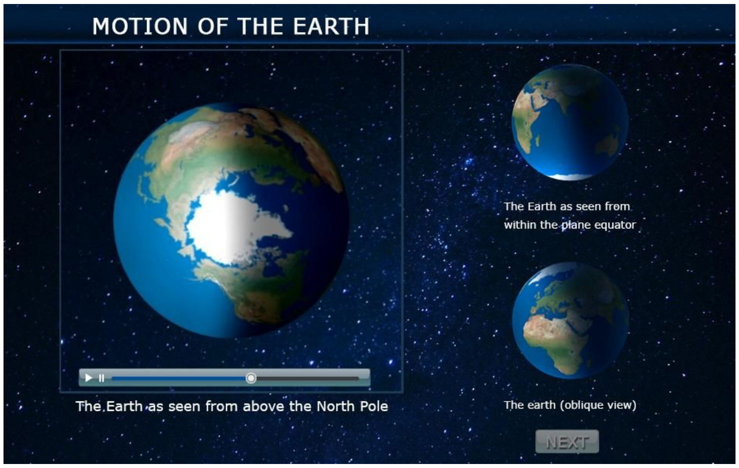

Figure 1a: Realistic representation of the earth in the beginning of the animation

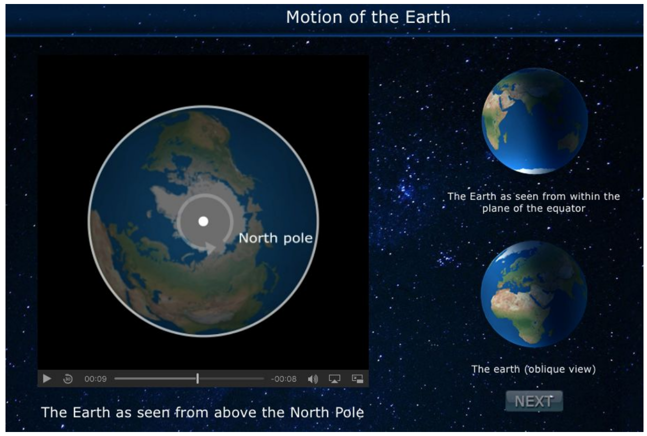

Figure 1b: Intermediate representation while transforming from a realistic representation to diagrammatic representation of the earth

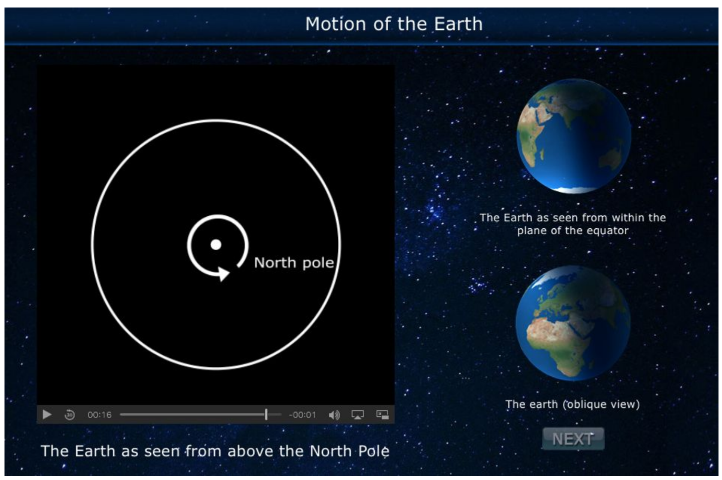

Figure 1c: Diagrammatic representation of the earth at the end of animation
Figure 1: Screenshots of the simulation of the earth (North Polar view) transforming from realistic, dynamic representation to diagrammatic representations.

2. Interactive digital activity: This activity is designed to revise what students learned in the classroom lesson with another kind of representations. Applying knowledge to solve the problems is an important step of mastering the content. The automated feedback facility in digital medium allows students to do such problem solving on their own.

   In this activity, the screen was horizontally divided into two halfs. The problem situation was presented on the left side, which was interactive. Here we used North polar view of the earth. The feedback appeared on the right side, where we used the equatorial view of the earth. The two different views were used so that students actively keep coordinating between two perspectives as they solve the problem and interpret the feedback. On the left screen, stick figures of four children (Sonu, Manu, Guddu and Chhotu) stand on different locations on the earth (see Figure 2a). As a problem, students were asked to make certain time of the day for one of the four stick figures. They need to rotate the earth using the mouse and bring the stick figure at correct position. After clicking ‘Check

Answer', if they are correct, they see the feedback as shown in Figure 2b. If they are incorrect, the stick figures jump back to the starting position and students get another chance.

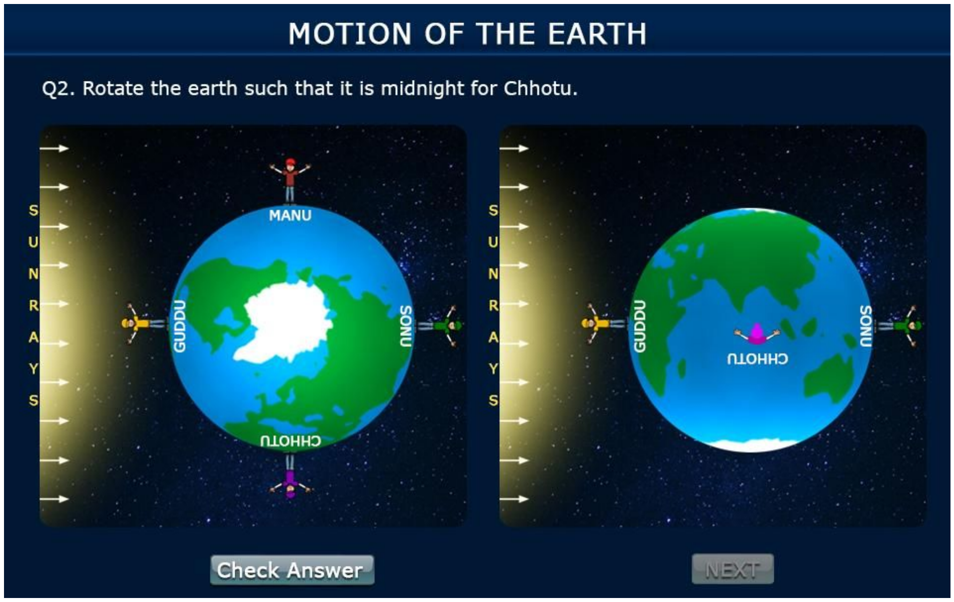

Figure 2a: Problem situation in interactive digital activity

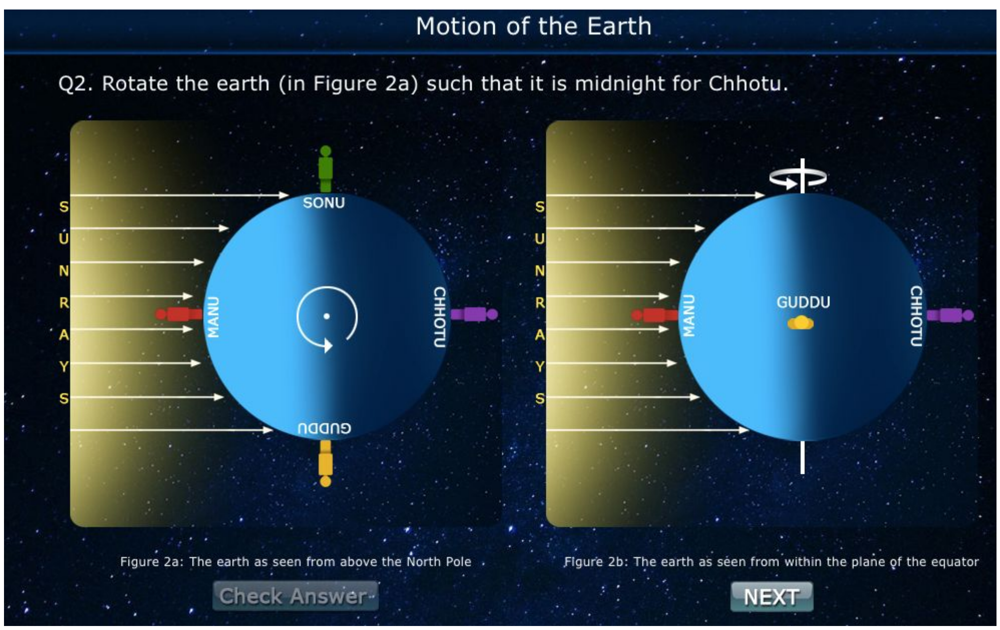

Figure 2b: Feedback situation in the interactive digital activity.
Figure 2: Screenshots of the interactive digital activity.

Observations and Findings

We came across many observations which we addressed during the revision. Some of the glitches were technical (e.g. it did not run on certain browsers). Some of the problems arose due to minor errors in designing. For example we had kept 5 degree error bar in the response of second digital activity. To bring the person within 10 degrees requires good mouse control and concentration. Many students, even after knowing intended position of the stick figures, rotated more than required and ended up giving incorrect response. We are eliminating such errors, but we will not mention all of them here. However, some remarkable observations along with the learnings from them are noted here:

1. Students were comfortable with new kind of representations: The classroom lesson included handling a model (geosynchron) and role-plays. Students did not get a chance to draw the diagram of the earth and explanation of apparent motion of the sun etc. In digital lesson when students were exposed to digital visual representations, they were comfortable in interpreting and handling them. Moreover, two representations of the earth were used simultaneously: North polar view to present a problem situation and the equatorial view when we presented the feedback. Both these views were new to students. But during informal interviews when we asked them they could tell each representation was from which perspective.
2. Lack of instructional Text: We had kept minimal instructions on the screen in order to minimize the text on each screen. For example, in the first digital activity (transformation from realistic to diagrammatic representation) the thumbnails for simulations from different perspective were present. There was no instruction which directed students to click on each of them one after another. We found that students could navigate without much difficulty. Once finished with one activity, they moved the cursor on different objects and if they realize that it is clickable, they clicked on it, thus moving to the next activity. However, adults found it difficult to navigate without instructions. They actively looked for instructions, if the instructions were not present they asked us, but did not actively explore the screen. This could be explained by the difference between digital natives and digital immigrant (Prensky, 2001). The children in the present sample were from urban educated families so it is not surprising that they were able to navigate on their own. However, our intended students (who represent the majority of Indian students) do not have much exposure to technology, neither do their teachers. So to be on safe side, we decided to add the instructional text in the revised version.
3. Lack of textual Feedback: In the digital activity, when students rotate the earth more than required, they cannot undo that action by rotating back (since the earth rotates only in one direction). When they clicked ‘Check Answer’ the stick figures jumped back to their original position. Because of similarities between the figures, this was not very obvious and students did not realize that they should go for another attempt. A more prominent textual feedback such as ‘That is not correct! Try again’ is necessary at such points, which we are incorporating in the revised version.
4. Lack of context to the problem situations: During classroom session in geosynchron activity and the first role-play, students were asked to identify local time for people at different location. They were asked to make noon, midnight etc. for a person at a particular location. Students were engaged while doing this. Some made mistakes, others corrected them and so on. They enjoyed to figure out where a person would be if the sun is setting for her and they tried to find out the answer for its own sake. However, during the digital activity we realized that even if they attempted the activity, made mistakes (rotating the earth more than required which resulted into next attempt), got confused

(especially between positions of dawn and dusk) and helped each other, they seemed a little uninterested. We thought this could be because they have already learned the principle behind it, that local time depends upon position of a person with respect to the sun, so intrinsic motivation to figure out was less. They still needed some practice, for which a digital activity, which they can do on their own (either individually or in pairs) was a perfect choice. But we thought that putting these problem situation in some content would increase their interest. Taking this thread ahead, we are developing a game (on the lines of treasure hunt) where they have to be at certain location at certain time to get what they want (which translated to a point). There is no time limit but the number of attempts and the total time available to play this game is fixed. So students which are quick and accurate will be able to get more points than the students who are slow and clumsy.

5. Integrating representations: In the classroom activities we encouraged students to draw parallels between concrete model and role-play. In the first digital activity, we actively integrated two kinds of representation: three dimensional simulations with their corresponding diagram. In second digital activity we came across instances of students spontaneously integrating representations from the classroom session with the digital simulations. For example, while solving a problem in the second digital activity a student used the gesture of right hand thumb rule to determine direction of rotation of the earth. We consider this a success because students not only master the content but seems to have developed some representational competence.

Conclusion and Discussion

Because of their novelty and enormous amount of creative possibilities, several digital tools are being prepared on commercial and non-commercial basis. Some of them follow pedagogic and design principles and some of them do not. Moreover, many of them are getting available to students without carefully testing their effectiveness. This poses the risk similar to that which a bad textbook or an ill equipped teacher poses to a learner. Teaching learning material of any kind needs to be carefully designed and tested for its appropriateness (Sarangapani, 2016). This is especially true for digital tools because firstly the user have little control over its design so they cannot modify it according to their convenience. Secondly, the process of preparing them is very complex and costly. So unlike printed material, in which content can be revised in every edition, it is difficult to rectify the mistakes in interactive digital material.

In this paper we have spelt out the process of creating digital resources. We gained important insights in the process of creating digital tools which are worth sharing with the wider community of educational technologists. To summarize our learning points:

1. The digital resources need to be designed considering the overall learning context. They need to be seen as part of a larger pedagogic sequence rather than an independent resource and hence should echo the learning objectives of the classroom activities. Needless to say that like any teaching resource, they need to appropriate for students' age and sociocultural background.
2. Continuous trialing with different samples should be part of creative process. Difficulty faced by or a strategy used by even a single participant can be enlightening.
3. As their name indicates, many things can coexist in 'multimedia' presentations. For example, you can have multiple diagrams, text and controls on the screen, you can have

sound effects, or even immersive environments (with 3D glasses on your eyes). There is always a possibility of getting carried away with the novel, interesting features. Well defined learning objectives serve as a lighthouse while designing digital activities and hence should be clearly spelt out before starting to prepare the activities.

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