Enriching Multimodality in Learning: Integrating Computer Modeling to Support a Learner Generated Topic

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Abstract: In this paper, the researchers collaborated with an experienced physics teacher to design a multimodality modeling workshop involving a 3D computer model to facilitate the workshop participants' learning of their self-generated astronomy topic – lunar libration. The modified visual representation in computer model improved the quality of their observation experiences and assisted them to consolidate their understanding on lunar libration. Participatory learning environment created through the Embodied Modeling Mediated Activity (EMMA) encouraged learners to investigate their interest driven and self-generated inquiry. Researchers modified and integrated modeling software (i.e. Astronomicon) to support learners' interests. Multimodality was employed to mediate the self-directed exploration and collaborative discussion in understanding the lunar libration. This finding implies that it is important to establish a sustainable learning community to design and conduct multimodality modeling lessons in informal learning settings.

Keywords: multimodality, learner-generated topic, 3D computer modeling tool, lunar libration, learning community, informal learning

1. Introduction

Since 2008, with an emphasis on multimodality and embodied cognition, we have worked with an experienced physic teacher in Singapore to co-design the Embodied Modeling Mediated Activity (EMMA) workshops for promoting astronomy teaching and learning. Through adopting a design-based research, we focused on designing a participatory learning environment that supports learners' astronomy concept formation in informal settings. The affordances of multimodal modeling guided by effective teacher's instructional strategies were promising and positive in facilitating learning [13]. Learning astronomy through sky observation and multimodality modeling activities engaged learners to integrate new learning from observation into their existing knowledge [12]. In this study, we integrated 3D computer model to embed the motion aspect of the multimodality in learning. We investigated how computer modeling could improve workshop participants' understanding of astronomy phenomena.

The informal learning has more flexibility to address the social cultural aspect of learning since it emphasizes the authenticity in purpose, learning tools, learning context and responds to learners' interests and strengths [4]. Researchers were interested to design multimodal modeling activity workshops to cultivate inquiry-based and participatory learning. The modeling activities were designed such that learners use the best available learning tools and experiences to answer their own generated inquiry. Computer modeling was integrated to support learning. Researchers work collaboratively with school teacher, university professor and workshop participants to design appropriate modeling workshops.

The quality of the workshop design was improving through iterative cycle of refining, reflecting and implementing the workshop.

2. Theoretical framework

Modeling is the process of representing internal abstract ideas or coordinating the structures of the system by ways of simplifying, quantifying and representing with the purpose of explaining, predicting and communicating with others how the ideas work [18]. Drawing upon constructivist learning perspective, recent research in science teaching and learning has recognized the importance of multimodality in students' development of conceptual understanding [9, 15, and 17]. Especially in the domain of astronomy, multiple sensory modalities like visual, verbal, tactile, and kinesthetic are triggered when learners are engaged in the multimodal modeling activity. Many researches [2, 7] have showed the virtual computer modeling illustrated the advantages in facilitating students understanding in spatially related astronomical concepts and improving their visualization of the abstract concept. Furthermore, multimodal modeling also implies the important role of observation that could offer opportunities for learners not only to recognize inconsistencies between an observed experience and their own existing models but also to promote inquiry. Specifically, observation, whether was made in the authentic environment [19] or designed virtual environment [1], provides learners with embodied experiences. This does not only facilitate learners' conceptual learning but also enhance their motivation and interests [14]. Hence, such multimodal modeling calls for a new conceptualization of learning as participating in practice with an emphasis on bodily active engagement and the integration of sensory behavior and cognition, which have not been used very much in formal learning.

The learners generated issues or topics can mediate the learning about what and how learners will study and evaluated what they studied in problem based solving learning [10]. Moreover, the generated topics also helped learners to find the direction of individual learning that improve self-directed learning. Hurk and colleagues found that learners can determine important topics through effective discussion. Thus, it is advisable to engage learner with their self-generated topics in learning when the direction of learning were contextualized and knowledge is build within interaction in a community of peers and experts. Learner-centered design software allowed user to execute certain actions on the tool, to interpret and evaluate the data from the software to achieve learning goal and generate new learning [16]. Educator shall integrate technology tools in a constructive learning environment that promote learners to solve the self generated topic through discussion.

Wenger [20] stated that we all belong to certain communities of practices that allow us to know something or change ability through meaningful experiences by interacting with the members and social resources in the community. The individuals contribute to the practices and the community means to refine the practices to enable learning as meaningful. Researchers believed that community of practices in informal settings can be established through integrating members from different background based on similar interests in promoting modeling learning in Astronomy. The collaboration between informal learning organizations and schools can improve the science learning that encourage authenticity, different disciplines and multimodalities in learning context [4].

3. The Study

Based on embodied cognition and multimodality, we propose EMMA for bridging the sky-gazing practices and understanding of planetary motions/light through active participation. With EMMA, each mode of modeling (2D drawing models, 3D physical models and computer models) engages learners in in-depth inquiry process addressing their prior beliefs and experiences, followed by modeling exploration and discussion to enhance understanding. The curriculum design was situated in informal learning settings where multimodal modeling was employed as main approach to support learning of learners' generated topic. A design-based research has been employed so that we go through iterative cycles of co-designing, implementing and refining EMMA learning activity with participants and Physic teacher. New content was added based on learner generated topics, and modeling materials and tools were refined to meet the need of learners. Three astronomy phenomena were studied in these workshops: lunar libration, Venus transit and lunar eclipse. All topics were authentic and significant events in their observatory.

In this study, researchers worked with five male undergraduate Physic students. They had strong interests in Astronomy and were enrolled voluntary in a university's research-based project that required them to manage an observatory and conduct research on telescope installation and image processing, under supervision of an experienced professor Chen (pseudonym). According to Professor Chen, they were dedicated and diligent students who have good Physics knowledge, able to learn independently as well as to work collaboratively in group. Their names were abbreviated as HQ, KH, RY, CX and KY. Professor Chen was the collaborator in this study who taught Physics and astronomy courses in university. The modeling activities employed in this study were co-designed with an experienced Physics teacher, HJ (pseudonym). He contributed his content expertise and pedagogical ideas in the planning process.

Researchers integrated 3D computer modeling tool, called Astronomicon [6], to provide a conceptually and perceptually meaningful learning experience that might bridge the gap between their perceptions and astrophysical phenomena. Astronomicon was developed through design-based research targeting on beginning learner to explore common astronomy phenomena [8]. However, in this study, researchers modified the visual representation to leverage its' affordance to explore a unique astronomy phenomenon (i.e. lunar libration) that requires detail observation. Modeling with Astronomicon includes creating and manipulating 3D objects, viewing them from multiple perspectives, visualizing and collecting data of the system's process with provided symbolic representations (e.g., orbital plane, numeric data on time, etc.). Models can be created based on user define of the properties of planetary bodies. This allows learners to test their hypothesis by controlling certain parameters of the planetary bodies.

Pre-workshop meeting was conducted to understand learners' background and learning interests. Researchers introduced the concepts of modeling, modeling artifacts and computer modeling tool (i.e.: Astronomicon) in the meeting. Learners were interested to further explore the topic of lunar libration. Thus, researchers refined the lesson plan and learning materials to accommodate learners' generated topic. Learners spent approximately eight hours (in two workshops) in exploring lunar libration, lunar eclipse and Venus transit. The workshops took place at tutorial room. Multiple modeling materials were prepared such as Styrofoam balls, paper plates, globes, wooden sticks, etc. In order to embed the participatory culture, firstly, learners were encouraged to think of what they want to know and generated their own inquiry. Subsequently, they can select appropriate tools and create multimodal models (e.g.: virtual computer model, sketching and concrete model) during their discussion and exploration of the topic. After discussion, learners presented their understanding with their artifacts. Then, a third workshop was conducted for preparing learners to deliver their understanding to new learners. In this paper we only focused on the process of learning lunar libration through computer modeling.

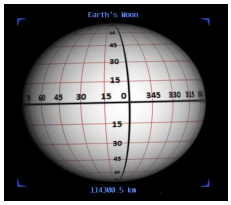
3.1 Data Collection and data analysis

Multiples data sources were collected throughout the process of planning, implementing and evaluating the curriculum. The planning and evaluation meetings and the modeling workshops were video recoded. Screen capture video program-Camtesia© was used to record learners' interaction with Astronomicon. Researchers wrote field notes and reflective journals to document the important learning moments. In addition, learners' artifacts such as pre and post concept maps, sketching were collected to triangulate our understanding about their reasoning and conceptual development.

4. Findings

4.1 Exploring lunar libration through computer modeling

Researchers equipped themselves with the knowledge of lunar libration through group study, supported by Physic teacher, HJ. The team identified that observation was essential to understand the impact of eccentricity on lunar libration. Scientists discovered there are almost 59% (instead of 50%) of the moon's surface can be observed through the telescope. Researchers applied computer simulation to imitate and illustrate the changes of the moon's surface. However, the default moon surface image could not illustrate the minor changes of moon surface (Figure 1 (i)). Therefore, the team designed a visual representation of a "moon-with-grid" graphic to replace the moon's surface image. After modification, the graphic showed clearer evidence of visible moon surface (Figure 1 (ii)).



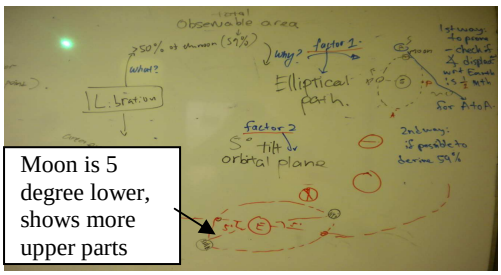
(i) Default moon image (ii) Imposed graphic of "moon-with-grid"

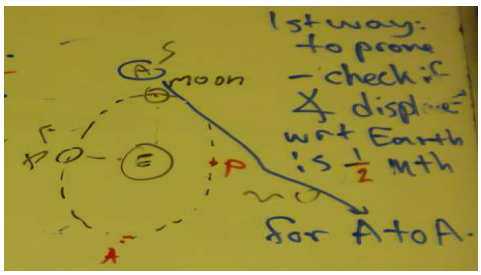
Figure 1. Modified visual representation of the moon.

4.2 Facilitating discussion with multimodal representations

Learners' initial inquiry question was "What is the exact mechanism for libration?" They first created individual concept map of lunar libration to hypothesize the factors causing lunar libration. Then, they co-constructed a concept map (Figure 2) to discuss their understanding and plan their strategies to prove their understanding. Collectively, they stated two factors that cause lunar libration. One of the members, HQ drew a diagram (Figure 2.0 (ii)) to explain how the moon's elliptical orbit causes lunar libration. He explained that when the moon is at apogee node (point A in Figure 2 (ii)), it rotates relatively slower and therefore we can see more surface area of the moon. At perigee node (point P in Figure 2 (ii)), the moon rotates relatively faster. After listen to HQ, another group member, KH described a way to prove their understanding through checking if there an angular displacement with refer to the Earth in the period of half of month (i.e. period from A to A). The above mentioned discussion was heavily based on learner generated visual representations and triggered their visual, spatial and kinesthetic imaginations. Factor 2 was

the inclination of the moon's orbital plane. Another member, CX illustrated the impact of the 5 degree tilted orbital plane in a diagram (Figure 2 (i)) and how it exposes more upper or lower part of the moon. Then, they tried to prove that these two factors allow them to see 59% of the moon. Diagrams and textual expressions were used to co-construct the concept map. Each member employed various modalities to deliver their understanding and they also used their hands gestures to illustrate the motion of the moon.



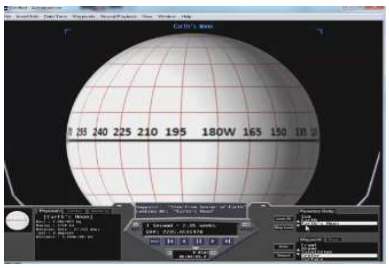


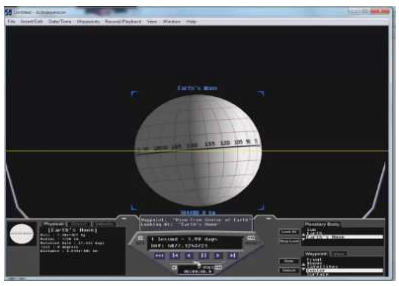
(i) Overview of concept map (ii) Diagram of apogee and perigee nodes

Figure 2. Co-constructed concept map

4.3 Interactive learning with Astronomicon

They were divided into two groups while investigating lunar libration using Astronomicon: group A with two members (CX and KY) and group B with three members (HQ, KH and RY). It was inevitable that learners encountered technical challenges while using new computer software. There was no problem on creating a system that consisted the Sun, the Earth and the Earth's moon. However, they had difficulties in changing the viewing perspectives (e.g., from center of the Earth or above the moon) to observe the moon. Researchers provided technical guidance, including guiding them to use the modified "moon-with-grid picture" (Figure 1) to improve their observation. After learners became familiar with the software, they started controlling moon's parameters to test their understanding. In Group A's first attempt, they set the moon's eccentricity and plane's inclination to zero. They presumed that only 50% of the moon would be seen. Their observation confirmed that the moon appeared static all the time, meaning 50% of visible surface (Figure 3 (i)). Thus, they were convinced that eccentricity and orbital inclination caused the lunar libration. In their second attempt, they set the plane inclination as 5.1454 degree and replaced the eccentricity as zero. Then, they observed the vertical displacement of the moon (Figure 3 (ii)). Astronomicon simulated that the moon was moving up and down vertically, which allowed more than 50% of the moon's surface to be visible. This provided the evidence of vertical displacement of the moon due to orbital plane inclination.





(i) Static moon (ii) Moon with vertical displacement

Figure 3. Evidences illustrated in Astronomicon

4.4 Using observational data as evidence

Learners retrieved vertical and horizontal displacement data from simulation as evidences to prove there were extra 9% of visible moon's surface. In their presentation, they used diagram (Figure 4) to delineate how they simplified the calculation by applying geometry concepts and simple percentage calculation of the angular changes. They made an assumption that the vertical displacement at the middle part of the moon would be equivalent to the displacement at the upper and lower parts of the moon. Astronomicon showed the maximum vertical displacement as 10 degree and contributed of 5.5 % of extra visible surface (i.e., 10°/180° × 100%) and the horizontal displacement as 13 degree, contributed another 7.25% (i.e., 13°/180° × 100%). In total, they deduced 12.75% of extra visible surface, which was more than 9% suggested by scientist. They explained their error was caused by a double counting region (see Figure 4). Due to time constraint they had not solved how to reduce the double counting area.

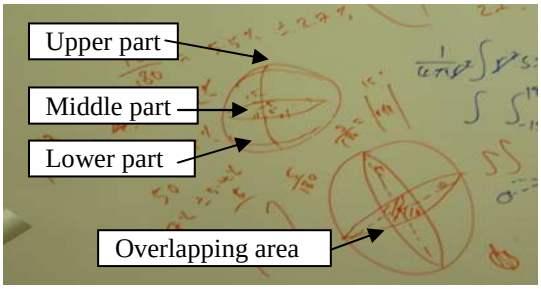


Figure 4. Group A presented their assumption and calculation through diagram

5. Discussion

5.1 Computer modeling improves visualizing and understanding phenomena

Understanding lunar libration required in-depth moon observation of the moon's movement in relation to its properties (i.e., eccentricity and inclination) and its visible surface. Despite of the technical difficulties, learners were engaged actively with the software. Based on various settings, they observed the impacts of different factors on libration and result in different exposure of the moon's visible surface. The modified visual representation afforded in-depth observation and exploration. They collected useful data from the model and applied their mathematical model to derive the extra percentage of visible moon's surface. This computer modeling was effective for these particular learners to execute and evaluate their learning [16] so as to consolidate their understanding. This finding was resonance with other research findings that computer modeling has the advantages to understand the motion of planetary objects in a 3D virtual environment. The features of allowing users to change viewing perspectives, providing virtual observation and supporting interactive modeling were the succeed features for deeper learning [3, 11].

5.2 Accommodate learner-generated topic with multimodality approach

EMMA aims to promote participatory learning that supports learner interests, closely related to sky observation and life experiences. In order to accommodate leaner-generated topics, researchers identified essential learning challenges by working with experienced teacher. Researchers integrate computer modeling to improve learners' visualization and to

enrich their multimodality embodied experience. Multimodality was highly recommended based on our pragmatic experience in informal settings [13]. Researchers established multimodality learning environment by providing choices of modeling tools (i.e. drawing, concrete model, computer model and mathematical model), observation data and diagrams. Thus, learners were encouraged to employ diagrams, written explanation, hands gestures, calculate with data to explore the phenomena and represent their understanding explicitly during their discussion. The interactions among members were enhanced in multimodality environment when each member contributed and supplemented each other ideas by various modalities. The learner generated topic encouraged active participation in group discussion and this had effectively scaffold their learning by identifying the causes of lunar libration. This positive finding encouraged educators to adopt learner generated topic in lesson design. The quality of learner generated learning issues can be improved through good facilitation during group discussion [10].

5.3 Community building

The community of practices provided meaningful learning through active participation [20]. In this practice, we noticed researchers, teacher and learners played unique roles in the lesson design and learning process. The learning outcomes were more holistic and inclusive not only for learners but for all the members in this learning community. Learners became active learners by suggesting the topic they were interested and solved the problem more effectively. Teacher contributed his Physic expertise to identify the core concept and essential observation. On the other hand, researchers contributed their expertise by leveraging the affordance of the computer model. In the learning process, learners generated their strategies in solving their problems. Their approaches provided new insights for researchers to improve the pedagogy. The roles of teacher and learner are interchangeable based on the situation [5]. Based on this collaborative practice, we noticed the importance of establishing sustainable learning community in informal context by integrating varied expertise to design meaningful lesson.

6. Conclusion and implication

Multimodality supported learners to illustrate their understanding explicitly and generate effective discussion. We suggested educators to employ multimodality to improve collaborative discussion that encourage each member to contribute their knowledge and experience. Computer modeling with visual and motion enhancement enriched the multimodality in learning environment that facilitated learning by improving learners' visualization based on modified visual representation. The interactive feature of creating model with user defined parameter helped learners to understand the attributive factors and the impacts on lunar libration. We hope this finding encourage teachers to integrate computer software to improve learning on topics that required spatial visualization.

Participatory learning culture was cultivated by designing lesson that accommodate to learners' generated topic. Learners were actively involved to solve their generated topics through discussion. This positive finding encouraged educators to adopt learner generated topic in lesson design. Collaboration between experienced teacher and researchers had improved the lesson design by contributing their expertise in refining the content, pedagogy and learning tools. We suggested some efforts are needed to sustain the collaboration between schools and informal learning organization that encourage authenticity, different disciplines and multimodalities in learning context.

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