

Designing and Assessing Modeling and Visualization Technologies (MVT) Enhanced Learning

BaoHui Zhang, Michael J. Jacobson, Beaumie Kim, Feng Deng, Suneeta Pathak, Hans G. Lossman
Learning Science Lab, Nanyang Technological University, Singapore

Email: Baohui.Zhang@nie.edu.sg, Michael.Jacobson@nie.edu.sg, Beaumie.Kim@nie.edu.sg,
Feng.Deng@nie.edu.sg, Suneeta.Pathak@nie.edu.sg, Hans.lossman@nie.edu.sg

Xiuqin Lin, Beijing Normal University, China, xianyoulin@126.com

Pratim Sengupta, Uri Wilensky, Northwestern University, Evanston, IL, USA

Email: g-sen@northwestern.edu, uri@northwestern.edu

Kenneth E. Hay, Indiana University, Bloomington, IN, USA, kehay@indiana.edu

Abstract: Models are the core of scientific theory. Some researchers have argued that modeling is fundamental to scientific inquiry (e.g. Clement, 2000). There has been increased literature on how to use inquiry and modeling for science learning. However, challenges still exist. For example, how do different modeling tools and learning activities shape student learning trajectories? How do they impact student science learning? What are the assessment measures that can serve as formative and/or summative purposes in the different learning environments? This symposium introduces how computer-based MVT (i.e., NetLogo, Biologica, and Astronomicon) were integrated into different learning environments, and highlights how alternative and formative assessment measures have been used for assessing student learning progression and outcomes. The symposium concludes with some general principles for designing MVT enhanced learning environments and understanding of models and modelling as assessment toolkits to gain an insight into student conceptual development.

Symposium Overview

Models are the core of scientific theory. Some researchers have argued that modeling is fundamental to scientific inquiry (e.g. Clement, 2000). There has been increased literature on how to use inquiry and modeling for science learning. However, challenges still exist. For example, how do different modeling tools and learning activities shape student learning trajectories? How do they impact student science learning? What are the assessment measures that can serve as formative and/or summative purposes in the different learning environments? This symposium first introduces how computer-based MVT (i.e., NetLogo, Biologica, and Astronomicon) were integrated into different learning environments. Then, research design and results will be presented through research projects done in different countries (i.e., the US and Singapore). The symposium will highlight how alternative and formative assessment measures, such as process videos, dynamic interviews, log files, student physical models, and written responses, have been used for assessing student learning progression and outcomes. The symposium concludes with some general principles for designing MVT enhanced learning environments to promote conceptual understanding and transfer of learning, and understanding of models and modelling as assessment toolkits to gain an insight into student conceptual development.

The first paper focuses on assessments in particular, and explores the role that formative assessments play in the process of learning in the NIELS Learning Environment (NetLogo). The authors demonstrate how formative assessments in NIELS can themselves act as scaffolds for learning. They enable the researchers to gain an insight into conceptual dynamics of students, by making explicit the underlying knowledge elements that are activated in the learners' minds as they engage in these activities. The second paper investigates the effect of different instructional design conditions when integrating the Biologica program for teaching genetics. Process data (in the form of various types of formative assessments) demonstrate students' learning trajectories and how different instructional designs affect student learning outcomes. The final paper in this session discusses the epistemological affordances of various modes of modeling in the Astronomicon learning environment. This study emphasizes the importance of articulation - i.e., making students' thinking "visible" to themselves as well as their peers (Bereiter & Scardamalia, 1987; Schoenfield, 1985; Collins, 1996) - as an instructional strategy, and in addition, highlights the effect of creating a public artifact on students' motivation and on the process of their knowledge construction.

Learning Activities as Tools For Formative Assessment - Case Study of a Computational Multi-Agent Based Electricity Curriculum (NIELS)

Pratim Sengupta and Uri Wilensky

The new reform agenda in US education (benchmarks for Scientific Literacy, 1993; National Standards for Science Education, 1994) argues for designing curricula that help learners develop habits of mind to reason scientifically and engage in scientific inquiry. Duschl & Gitomar (1997) argued that assessment activities in classrooms can help achieve such goals, as well as provide information about students' progress towards these goals. In this paper, we discuss these issues in the context of designing learning activities and assessment toolkits for NIELS (NetLogo Investigations In Electromagnetism, (Sengupta & Wilensky, 2006, 2007), a curriculum based on a suite of interactive, glass-box simulations modeled in the NetLogo modeling environment (Wilensky, 1999). By analyzing results from 5th and 7th grade classroom implementations of NIELS, we a) demonstrate the underlying design principles that guided our choice of activities from an instructional point of view, and b) highlight how these activities enable us to gain an insight into conceptual dynamics of students, by identifying the underlying knowledge structures that are activated in the learners' minds as they engage in these activities.

Recently a number of proposals (Eylon & Ganiel, 1990; Chabay & Sherwood, 1995; White, Frederiksen, & Spoehr, 1993; Sengupta & Wilensky, 2006) elaborated the need for introducing students to microscopic level models of electricity. The goal of such models is to enable students to relate the macroscopic phenomena (such as electric current & voltage) in terms of simple rules of interactions between individual-level microscopic objects (electrons, ions, etc). We designed NIELS based on our theoretical argument (Wilensky & Resnick, 1999; Sengupta & Wilensky, 2006, 2007) that it is possible to engender an expert-like understanding of the relevant phenomena by bootstrapping naïve knowledge elements, provided these elements are activated not only at the macroscopic level, but also at the microscopic level of description of the relevant phenomena. These knowledge elements are object-based and primitive – i.e., they arise from our earliest interactions with the physical world (diSessa, 1993; Inhelder & Piaget, 1967). The primary goal of every NIELS model is to provide students with a qualitative sense-of-mechanism of electric current, voltage etc. and related phenomena in simple electrical circuits in terms of these knowledge elements. Furthermore, by translating the relevant phenomena in terms of primitive object-based knowledge elements, we envisioned that NIELS models would enable much younger students (e.g., 5th graders) to makes sense of the same phenomena that even high school and/or college students find difficult to understand.

Every NIELS models is accompanied by an Activity Booklet that contains relevant content (physics) background, instructions that scaffold students' interactions with the model, and prompts for students to log their observations and describe their observations in details. Often, after logging their observations, students are asked to relate the microscopic level rules to macroscopic phenomena and vice versa. And finally, the activity sheets also prompt students to provide detailed mechanistic reasoning of relevant phenomena. In addition, one of the researchers in the classroom conducts short interviews with randomly individual students while they interact with the models. In these interviews, students were often asked to provide mechanistic explanations of other related phenomena, and in addition, further questions were asked to clarify ambiguous terms in their written responses. The data thus collected in 5th and 7th grade classrooms (n=23 & n = 26 respectively) was coded in terms of students' mention of objects and interactions at the microscopic level, the macroscopic level, and the underlying knowledge structures that these responses were indicative of. The knowledge elements were coded based on diSessa's (1993) schematization of P-prims and Chi, Slotta & Leuw's (1994) schematization of object-schemas.

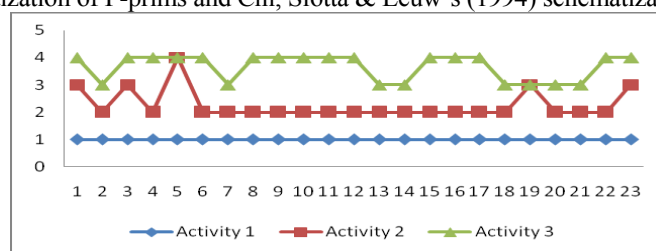


Figure 1. Knowledge Elements In Students' Explanations In Model 2 (Current In A Wire).

In NIELS models, while some activities specifically ask students to focus only on micro-level agents and rules of interaction between these agents (e.g., Activity 2 in Figure 1), others prompt them to focus on only macro-level representations (e.g., graph of current vs time) (e.g., Activity 1 in Figure 1), whereas some prompt them to relate these two levels of representations by asking them to design novel scenarios and/or experiments (Activity 3 in Figure 1). These activities not only support the students' knowledge construction process, but also make this process (of knowledge construction) explicit through their responses, which bring to light the epistemological roles of each activity. We argue that such formative assessment tools allow us to understand the gradual development of learners' understanding through making explicit the evolving complexity of their explanations (and in some cases, their observations). Figure 1 below shows a sample analysis of the evolving complexity of 5th grade students' explanations in three successive activities in one of NIELS models (Model 2: Current In A Wire). The Y-axis denotes the number of different knowledge elements that we identified in each explanation, while the X-axis denotes student-id. Note that in Figure 1, as students progress through the design space of the learning activities, they are able to co-ordinate multiple knowledge elements. In our paper, we will discuss in detail how such formative assessment tools provide us

with a complete cognitive trajectory of each learner while they interact with the NIELS models, as well as enable us to perform comparative between-student analyses.

Exploring Modeling and Visualization Technology (MVT) Enhanced Biology Teaching and Learning in Singapore

BaoHui Zhang, Michael J. Jacobson, Beaumie Kim, Feng Deng, Xiuqin Lin, and Suneeta Pathak

Introduction

How to integrate computer-based modeling tool for learning conceptually challenging science topics? In this paper, we discuss how Biologica™, a computer-based modeling tool, was used in different learning conditions for teaching and learning genetics. The software was developed by the Concord Consortium. It is a scriptable modeling tool for genetics and population dynamics (Buckley et al., 2004). There have been studies that used Biologica as more standalone software for individual student use from different theoretical perspectives. In this study, we explored different ways to integrate Biologica in order to maximize its potentials for promoting student conceptual understanding in Singapore context.

Genetics has been a challenging topic for students because they had difficulties in connecting the visible traits to the underlying mechanism of inheritance (Stewart, 1982; Tsui & Treagust, 2007). BioLogica allows students to manipulate objects such as DNA, genes, chromosomes, gametes, of genetics represented at different levels. Students are able to see directly the results such as an offspring's physical traits by combining parents' genes (Buckley et al., 2004). Students' moment-by-moment actions and input as required by the software can be recorded as "log files" to reveal student learning progression (Buckley, Gobert, & Horwitz, 2006).

The larger-scale research involving Biologica has focused on learning associated with individual student use of the program. Implementing Biologica in Singapore brings strong factors, such as teachers and education system, that impact student learning significantly. Using a counter-balancing design approach (Pollatsek & Well, 1995), we hope to find out how different teaching sequences for using Biologica and traditional teaching might impact students' learning outcomes (e.g. their understanding of genetics concepts). Another approach was a lab book approach, with which teachers guide the class with whole class discussions and small group interactions according to a researcher-designed student lab book as opposed to the individualized Biologica-only tasks. This study involved four Secondary Three classes in a Singapore school with three conditions (see, Table 1 below) in order to compare the effects of different learning sequences and activities. Some formative measures were taken in order to track student learning progression and gauge class instruction. Considering the content and length of lessons, we choose six topics out of the 12 Biologica activities for the four classes: Introduction, Rules, Meiosis, Monohybrid, Horns Dilemma, and Invisible Dragon.

Methods

The study was conducted in an all boy school in Singapore. Among them, A and B were the two best classes, and C and D were weaker classes. The traditional approach for Class A and B was taught by a senior teacher, Mr. Z., who has been teaching for 25 years in the school. The Biologica sessions of Class A and B were taught by a young teacher, Mr. L., who has been the school for a year and it was the first time for him to teach Biology. Class C and D were taught by a young teacher, Ms. Y., who has taught for about four years.

Table 1: Biologica unit implementation at MSH, research design.

Class [N]	Sequence				
A [25]	Pretest	Traditional (Mr. Z.)	MidTest	Biologica (Mr. L.)	PostTest
B [36]	Pretest	Biologica (Mr. L.)	MidTest	Traditional (Mr. Z.)	PostTest
C [29]	Pretest	(MidTest) Biologica plus lab book (Ms. Y.)			PostTest
D [34]	Pretest	Biologica (Ms. Y.)	MidTest	Traditional (Ms. Y.)	PostTest

Table 1 shows the design of the curriculum arrangement. The implementation took place over a three-week period during school vacation time. The traditional way of teaching took about 6 periods (40 minutes per period) as planned. The Biologica cycle actually took 8 periods. The three classes, A, B, and D, were designed to be two conditions (a) Biologica first, and then traditional approach; and (b) Traditional first, and then Biologica. Class C provides each student a lab book to provide more scaffolds when students were using the Biologica software. There were pre-, mid-, and post- content assessment. Basically, they were the same 33

multiple choice questions (MCQs) plus two open-ended transfer test items, and one structured question that is aligned with Singapore O-Level exam. Besides the pre-, mid-, and post-tests to assess student content understanding, we also collected log files, pre-, mid-, and post-surveys of student attitudes towards science and science class, and student computer screen recordings and conversation (process videos), and target student focus group post-interviews. Field notes were used to organize and triangulate our analysis.

The improvement in test performance (33 MCQs) within each class was tested by paired t-test. The improvements from pre to mid and pre to post were compared among the four classes by GLM (the general linear models) controlling for the pre score. The effect of the Biologica under the counter-balanced design was examined by GLM after re-organizing the data based on the design.

Results and discussion

Our preliminary analysis of the 33 MCQs scores indicated that all four classes improved significantly ($p < 0.01$) when comparing their pre-test and post-test performance. After controlling for the pre-test score, the differences from pre- to post- tests were 10.26 ($se = 0.79$), 11.51 ($se = 0.67$), 7.82 ($se = 0.83$), and 5.70 ($se = 0.68$) for the 4 classes, respectively. All pair-wised comparisons were significant except for the pair 3A and 3B. We also found that the improvements from pre- to mid-tests were also significant for all classes (10.73 ($se = 0.80$), 11.27 ($se = 0.78$), 7.55 ($se = 0.79$), 4.08 ($se = 0.68$), respectively) while none of the changes from mid- to post-tests were significant. Based on the 33 MCQs, 3B improved slightly more than 3A from pre- to mid- to post-test, but they did not have a significant difference. This seems to indicate that using the Biologica application allowed students to learn equally well as if they were taught by an experienced teacher measured by the MCQs. We expect our analysis of the transfer and structured questions to indicate some differences in terms of the effects of different conditions. Both teachers and the students we interviewed preferred condition 2 if they had a choice of the teaching sequence and did not need to consider preparing for O-level exams. During the post-interview, Teacher Z. mentioned that he prefers Biologica first and then traditional for his teaching. He felt that Biologica first and then traditional teaching or a combination of the kind should help students the most because students were able to understand the certain genetics concepts through their hands-on activities using Biologica and then they were more ready to listen to the teachers and to make more sense of teacher instruction.

We found that students in both 3B and 3D, which were in the same condition (condition 2) (Biologica first and traditional second), had a significant improvement from pre to mid-test, but 3B improved significantly more. Therefore, it seemed that the software helped the stronger students to improve more than the weaker students. This was especially apparent when comparing the mid-test results of the two classes.

It was interesting in our focused interviews with the target students from each class that they preferred traditional teaching if they had to choose between traditional teaching and the use of Biologica alone because teachers would prepare them for O-level exam better. If there was no consideration of the O-level exam, most of them would choose Biologica because they thought the software allowed them to think independently. They also liked that the software was quite visual and allowed them to manipulate the objects to see the outcomes. Class C used Biologica and student lab book without the traditional teaching sessions, it was interesting to see that although they had just finished half of the 6 topics, students made more significant improvement compared to its counterpart, class D in mid-test.

Our analysis has been very preliminary. We have open-ended structured items and transfer items that will provide richer information about student learning progression compared to the MCQs. They are still being analyzed. Further, our process videos, log files, and surveys of student attitudes towards science and science learning should provide much richer information about the learning processes and student learning outcomes. The final conference paper will provide a full reporting of these analyses and a consideration of their implications.

Acknowledgement

This material is based on work supported by the Learning Sciences Lab of NIE (LSL 16/06 ZBH). The authors would also like to thank Dr. Janice Gobert for her contribution to our research design.

Integrated Modeling-Based Inquiry for Addressing Astronomy Misconceptions: From Sky, Sketches, and Styrofoam to 3D Computational Models

Beaumie Kim, Hans G. Lossman, and Kenneth E. Hay

The mysterious nature of heavenly bodies has fascinated mankind since ancient times. Amateur astronomer groups that observe the night sky together is common around the world. The development of intricate telescopes and image capturing technology brings even more accurate and beautiful images of the skies, and thus better understanding of different heavenly bodies. The fundamental understanding of astrophysics, the planetary motions and light, however, still remains hard to grasp with the same sky-gazing practice. The history of science provides a rich literature on the development of astronomy as a science subject

of its own. The records and studies reflect both current and past social practices as well as the common misconceptions of laypersons and astronomers. People have a tendency to develop personal or private conceptions about phenomena even though they have no direct experience of those phenomena. These misconceptions often relate to a kind of 'pre-belief' held by the person. Normally we tend to draw conclusions based on what we know and experience. The 18-minute video, "The Private Universe", shows how knowledgeable individuals retain their personal theories - in this case, about the causes of Earth's seasons - even after the classroom lessons have proved them wrong (Schneps & Sadler, 1989). These 'hard-to-change-beliefs' often cling on all the way up to adulthood. Some of the more common misconceptions, like the astrophysical relation of the Sun, Earth and Moon, are rooted in an underestimation of distance between the bodies while there is an overestimation of relative sizes of the bodies. Other typical misconception people have is that the Sun and the Moon always is on opposite sides of the Earth, that people are seeing different phases of the Moon depending on their locations and that seasons are caused by the relative distance between the earth and the sun (Hansen et al., 2004; Philips, 1991; Sadler, 1998). Some studies also suggest there are misconceptions about astronomy itself, such as 'astronomers spend most of their time looking through telescopes,' 'physics has no bearing on astronomy,' 'astronomy is not a science,' and 'astronomy is only the study of stars' (2001).

Astronomicon was specifically developed with the purpose of addressing such misconceptions. With this 3D modeling environment the learners are able to build and simulate their own solar system to make observations and draw conclusions (Hay, Shaw, & Hauschildt, 2000). Astronomicon's domain specific advantage is the embedded knowledge of physics and the complex relationships you can observe when changing the input data. The physical properties of the planetary system - e.g., mass, distance and axial inclination - is given a priori to us, whereas the inquiry of planetary motions, light and system change comes a posteriori on the basis of the inquirer's observations (e.g. moon phases, seasonal changes). Previous research (Kim & Hay, 2004) indicates that learners naturally employ traditional models of expression (i.e. sketching planetary motions, and physically modeling with their hands and other objects in the environment). This is also how ancient and modern astronomers have communicated their ideas until today. This research has taken into account how early astronomers, like Galileo Galilei, observed the regular patterns of the motions of visible celestial objects, and then communicated his ideas about the connection between physics and geometry of planetary motions through his diagrams (Latour, 1990). By using these kinds of traditional methods in combination with computational models and modern technology we hope that we can challenge the learner's naïve experiential claims and misconceptions.

The Astronomy Day I & II

Despite the public interests in astronomy and astronomical knowledge, the school curriculum in Singapore has just set a minimal time for this science area. This project initially planned a two-night astronomy camp with the Science Centre, Singapore (SCS), at which a group of 12-14 year old students are provided with an opportunity for an in-depth inquiry into the world of astronomy. We developed a camp program, in which the participants alternate among sky-gazing, sketching of ideas and observations, building and modifying Styrofoam models and doing modeling-based inquiry using Astronomicon. Modeling-based inquiry (Hay, Kim, & Roy, 2004) is a specific pedagogical approach that focuses on computer modeling to investigate phenomena that might be difficult to do without such technology. The process of modeling-based inquiry (MBI) includes:

1. Initiate an inquiry question (e.g., How will the Earth look like from the Moon?)
2. Plan for model and collect data (e.g., Assuming that the Earth would have phases seen from the Moon, collect physical/orbital parameters of Sun, Earth, and Moon);
3. Model the phenomenon (e.g., Create Sun, Earth to orbit Sun, and Moon to orbit Earth);
4. Validate the model and revise if necessary (e.g., Running the model, realize that Earth and Moon are too close so that Moon collides with Earth);
5. Use the model as a source of data to address the original question and visualize data to explore relationships (e.g., Make a viewpoint to observe Earth from the Sun; observe from above the Sun in order to understand Sun-Earth-Moon relationship);
6. Develop a warranted conclusion (e.g., Conclude that Earth has phases seen from the Moon within same period of time, but show different faces unlike the Moon. This is due to the changing positions and angles among Sun-Earth-Moon);
7. Present conclusion to colleagues (e.g., Present the conclusion by comparing the timed observation data and screen capture of different viewpoints).

The chance to create personal representations and public artifacts allows learners to have a ownership of their learning and deeper understanding, that is, more meaningful and motivational (Bransford et al., 2000). The learners' artifacts and how they talk about them also provide important formative assessments for teachers and researchers. They not only become public but also help learners to self-assess their ideas by seeing and listening about others' work.

We advertised this event to the selected secondary schools that have a record of visiting the SCS for astronomy education programs and are located not too far away from the vicinity of SCS. One school responded

with the interest of brining a group of 13 and 14 year old girls participating in an international girls' club every Friday afternoon. They get together for activities that provide opportunities to develop their character as responsible citizens, and provide service to the community. Accommodating the schedules of the school and the SCS, we decided to modify the program into a 2 separate astronomy days.

Smith, diSessa, and Roschelle (1993) has suggested that instead of trying replacing misconceptions with expert knowledge, we should let learners bring forth their misconceptions and discover the reasoning behind them. During the two Fridays of astronomy day, we had a series of physical or computational model making session and presentations. We had two researchers and three SCS staff as facilitators. Each day guiding teacher and seven students arrived about 2PM and left about 10PM after night sky observations. We let them form three groups of two or three students according to their preference.

Table 1: Astronomy day program.

Day I	Survey	Styrofoam model (solar system) Presentations	Astronomicon model and observations (scale and orbits)	Observatory Inflatable planetarium
Break	Lunar phases exercise assignment			
Day II	Styrofoam model (Sun-Earth-Moon) Presentations	Astronomicon model (lunar phases) Presentations	Survey	Observatory Interviews

The survey is adopted relevant questions from Astronomy Diagnostic Test version 2.0 (Hufnagel et al., 2000), and modified to include additional three questions to ask them explain concepts with sketches to confirm their answers from multiple choice questions. They developed a physical model in Styrofoam balls and other materials to help them explore the planetary motions, and then explained what they made to the audience (teacher, facilitators, and other students). Students created the solar system model within Astronomicon and observed planets' movements. Observatory sessions came as the last activity that connects the God's view exercises in the classroom to the Earth's sky-gazers' view.

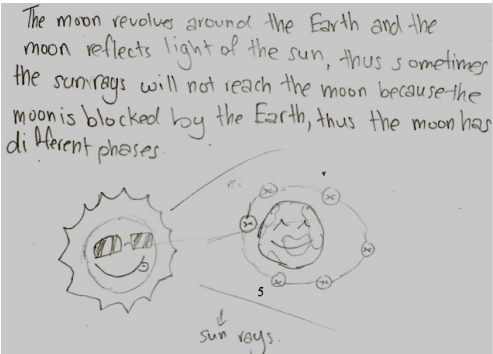
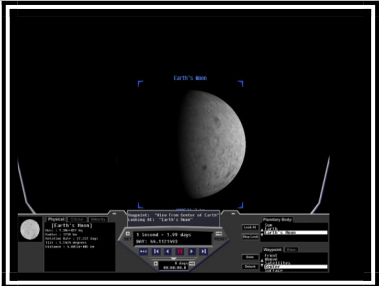
Before coming back for the second day, we asked students to complete basic lunar observation exercise. They either posted them on their club's blog or emailed them to us. At the beginning of the second day, we talked about what lunar phase that day was and what seasonal changes northern hemisphere people were experiencing (February 29, 2008; last quarter to waning crescent; winter to spring). They made and presented Sun-Earth-Moon Styrofoam model based on that information. For Astronomicon exercises, we give different exercises on lunar phases to three groups (comparing lunar phases and phases of Earth seen from the Moon; comparing three theories on lunar phases; exploring relationship between revolution and rotations and its effect on lunar phases). After their presentations, we did a short Astronomicon demo and discussion on the cause of seasons on Earth. We used the same survey instrument, and while they are doing the night sky observations, we conducted small group interviews (2 or 3 students each time).

Preliminary Findings

We finished the data collection on the 29th of February and are still processing the multimedia data (video and audio recordings and screen captures). In the previous research we found that students often turn to naïve scientism believing their model represents real phenomena that doesn't need validation. Another observation was that some participants saw the making of the 3D model as the primary goal rather than viewing it as a component for learning progression to better understand certain phenomena (Kim & Hay, 2004). We believe that the current approach help learners to focus on their ideas rather than the model building itself. By making most of the participants' thought processes explicit we hope to better understand how conceptual change comes about. This was made possible as they work in pairs, sketch and write down their ideas and build both physical and virtual models. We are able to make the following observations because most of the learner activities were made public.

From the pre-survey, many students showed common misconceptions about the scales, orbits, phases, and seasons of our solar system. The initial look at the post-survey result was not very encouraging as underestimation of the scale was address by seeing a "dot" of the Sun and the invisible Earth and the Moon using Astronomicon but did not show any improvement in their choice of answers. Same happened for the orbit of the Earth. When we ask students about the orbit during the interview, few said, "because you said the Earth is not a perfect circle..." and one mentioned, "because we had to choose 'circular orbit' for the modified model and 'elliptical orbit' is the real one..." We did not realize that the literal meaning of words would make them fall immediately back to their preconceptions. We saw some improvements on the phases of the moon, especially the students who grappled more with Astronomicon for exercises. One of the students, Joanna had the misconception that Earth's shadow blocking the Moon caused phases. Figure 1 shows her initial drawing and explanation of lunar phases from the pre-survey and her Astronomicon exercise posted on the blog.

On the second day, we purposely gave the comparing lunar phase theories exercise, which includes “shadow theory” to her group, so that Joanna might be able to discover her misconceptions. They spend a long time to build the shadow theory model and finally were able to make the shadowed phases happen, which they called, “lalaland Moon” (see, Figure 2). At the beginning of their presentation, they displayed their initial thoughts (similar to Figure 1 writing) and Joanna emphasized, “this is what we thought before this exercise.” However, in presenting the accepted theory model, her explanation the phases fell back to “shadow blocking” (see, Figure 2). Finally during the interview, we asked her again to explain how phases occur. She confidently explained new moon and other phases until she reached the full moon. She again immediately became confused and said, “then this is new moon again...” We spend a bit more time with her for reasoning through her dilemma. We believe that this is just the beginning of her conceptual change, where her confident “shadow theory” is being challenged and she is discovering her reasoning behind it. During the symposium, we will discuss our further analysis of data and deeper understanding of the students’ progression.

(Initial thoughts)

a) Why you think we see different phases of the moon?

- We see different phases of the moon as the moon revolves around the Earth, and since the moon reflects light from the sun, sometimes the Earth's shadow will block some parts of the moon, thus we see phases.
- The Earth revolves and rotates and sometimes, the Sun's rays cannot reach the moon to be reflected, thus we see phases.

(With Astronomicon modeling and observation)

b) How are the Earth and the Moon lit? Why do you think they are lit in such a way?

The moon and the Earth both reflect light from the Sun as they both do not produce or emit their own light.

c) How do the phases of the moon change?

When the Earth rotates and revolves, the rays of the sun may be blocked thus only lighting up a part of the moon, thus we see phases.

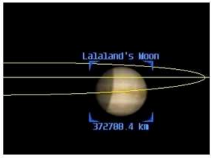
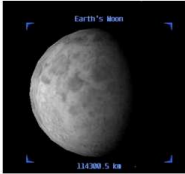
e) What do you think is causing the phases of the Moon? Does your observation from the evidence fit with your thoughts? If not, what did you find out from this exercise that you did not know before?

The parts of the Moon facing the Sun. Yes, my observations from the evidence fit with my thoughts

Figure 1. Joanna’s Initial Phases Drawing and Parts of Astronomicon Exercise Assignment

i) Phases of the Moon are caused by the shadows from the Earth on the Moon

False. Look at the first picture and the next one. See the difference?

ii) Lunar phases are caused by the changing position of the Moon with respect to the Sun.

True. As the Moon changes position, the phases of the Moon changes either because of the Earth's shadow is being cast on it or a part of the Moon blocks the Sunlight.

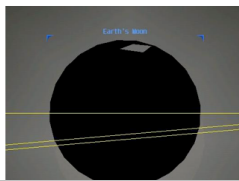


Figure 2. Joanna and Sandy’s Presentation Slides (Comparing Theories on Lunar Phases)

References

- Belcher, J. W., & Olbert, S. (2003). Field line motion in classical electromagnetism. *American Journal of Physics*, 71, 220.
- Bereiter, C., & Scardamalia, M. (1987). *The psychology of written composition*. Hillsdale, NJ
- Bransford, J. D., Brown, A. L., Cocking, R. R., & Donovan, S. (2000). *How people learn: Brain, mind, experience, and school (expanded edition)*. Washington, DC: National Academy Press.
- Buckley, B. C., Gobert, J. D., & Horwitz, P. (2006). *Using log files to track students’ model-based inquiry*. Paper presented at the International Conference of the Learning Sciences, Bloomington, IN.
- Buckley, B. C., Gobert, J. D., Kindfield, A. C. H., Horwitz, P., Tinker, R. F., Gerlits, B., et al. (2004). Model-based teaching and learning with BioLogica™: What do they learn? How do they learn? How do we know? *Journal of Science Education and Technology*, 13(1), 23-41.

- Chi, M. T. H., Slotta, J. D. & de Leeuw, N. (1994). From things to processes: A theory of conceptual change for learning science concepts. *Learning and Instruction*, 4, 27-43.
- Clement, J. (2000). Model based learning as a key research area for science education. *International Journal of Science Education*, 22(9), 1041-1053.
- Collins, A. (1996). Design Issues for Learning Environments. In S. Vosniadou, E. De Corte, R. Glaser, & H. Mandl (Eds.) *International perspectives on the psychological foundations of technology-based learning environments*. Hillsdale NJ: Lawrence Erlbaum Associates (pp. 347-361).
- Comins, N. F. (2001). *Heavenly errors*. An accompaniment of "Heavenly errors: Misconceptions about the real nature of the universe," Columbia University Press Retrieved November, 2007 from <http://www.physics.umaine.edu/ncomins/>
- Duschl, R. A., & Gitomer, D. H. (1997). Strategies and Challenges to Changing the Focus of Assessment and Instruction in Science Classrooms. *Educational Assessment*, 4(1), 37-73.
- Eylon, B.-S., & Ganiel, U. (1990). Macro-micro relationships: The missing link between electrostatics and electrodynamics in student reasoning. *International Journal of Science Education*, 12 (1), 79-94.
- Gutwill, Joshua, Frederiksen, John & Ranney, Michael (1996). Seeking the causal connection in electricity: shifting among mechanistic perspectives. *International Journal of Science Education*, 18 (2), 950-693.
- Hansen, J., Barnett, M., MaKinster, J., & Keating, D. P. (2004). The impact of 3-D computational modeling on student understanding of astronomical concepts. *International Journal of Science Education*, 26(13), 1555-1575.
- Hay, K. E., Kim, B., & Roy, T. C. (2004). *Virtual reality modeling-based inquiry: Conceptual coherence and alternative theories trials*. Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA.
- Hay, K. E., Shaw, J. S., & Hauschildt, P. H. (2000). The Virtual Solar System Project: Students building virtual models for scientific understanding. In D. G. Brown (Ed.), *Teaching with Technology* (pp. 66-68). Bolton, MA: Anker Publishing.
- Hufnagel, B., Slater, T., Deming, G., Adams, J., Adrian, R. L., Brick, C., & Zeilik, M. (2000). Pre-course results from the Astronomy Diagnostic Test. *Publications Astronomical Society of Australia*, 17(2), 152-155.
- Kim, B., & Hay, K. E. (2004). *Creating universe with computer: Charting the structure of distribution between learner and a cognitive tool*. Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA.
- Latour, B. (1990). Visualization and cognition: Drawing things together. In M. Lynch & S. Woolgar (Eds.), *Representation in scientific activity* (pp. 19-68). Cambridge, MA: MIT Press.
- Philips, W. C. (1991). Earth science misconceptions. *The Science Teacher*, 58(2), 21-23.
- Pollatsek, A., & Well, A. D. (1995). On the use of counterbalanced designs in cognitive research: A suggestion for a better and more powerful analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 21(3), 785-794.
- Sadler, P. M. (1998). Psychometric models of student conceptions in science: Reconciling qualitative studies and distractor-driven assessment instruments. *J. of Research in Science Teaching*, 35(3), 265-296.
- Schneps, M., & Sadler, P. M. (1989). A private universe [18 minute video]. Santa Monica, CA: Pyramid Films.
- Schoenfeld, A. H. (1985). *Mathematical problem solving*. New York: Academic Press.
- Sengupta, P., & Wilensky, U. (2005). *N.I.E.L.S: An emergent multi-agent based modeling environment for learning physics*. Paper presented at the 4th International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS 2005), Utrecht, Netherlands.
- Sengupta, P., & Wilensky, U. (2006). *NIELS: An agent-based modeling environment for learning electromagnetism*. Paper presented at the annual meeting of the American Educational Research Association (AERA 2007), San Francisco, CA.
- Smith, J. P., diSessa, A. A., & Roschelle, J. (1993). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Sciences*, 3(2), 115-163.
- Sneider, C. I., & Ohadi, M. M. (1998). Unraveling students' misconceptions about the earth's shape and gravity. *Science Education*, 82(2), 265-284.
- Stewart, J. H. (1982). Difficulties experienced by high school students when learning basic Mendelian genetics. *The American Biology Teacher*, 44, 80-84, 89.
- Tsui, C.-Y., & Treagust, D. F. (2007). Understanding genetics: Analysis of secondary students' conceptual status. *Journal of Research in Science Teaching*, 44(2), 205-235.
- White, B., & Frederiksen, J. (1987). "Qualitative Models and Intelligent Learning Environments." In R. Lawler & M. Yazdani (Eds.), *AI and Education* (pp. 281-305). Ablex Publishing Corporation.
- White, B., & Frederiksen, J. (1998). "Inquiry, Modeling, and Metacognition: Making Science Accessible to All Students." *Cognition and Instruction*, 16(1), 3-118.
- diSessa, A. (1993). Towards an epistemology of physics. *Cognition and Instruction*, 10, 105-225.