Maggie Mars: Theatrical Modeling and the Phenomenological Understanding of Solar Systems

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Abstract: In this manuscript we report on initial findings from the first implementation of a four-cycle design study that seeks to synergize computational modeling and narrative theater to support students' phenomenological understanding of solar systems. We develop the notion of the theatrical model as a low-overhead, high-expressivity alternative to typical computational modeling approaches. We then analyze the lifespan of one theatrical model as a case study to show how its collaborative creation and interpretation both reflect characteristic computational modeling practices and suggest new resources for modeling.

Introduction

Embodiment is supports the development of computational thinking through syntonic links between human learner and computational agent (Papert, 1980). Recently, learning environment designers have used this syntonicity to support students' construction and use of embodied computational models to study dynamic, complex systems (Colella, 2000; Wilensky & Reisman, 2006; Brady, Holbert, Soylu, Novak, & Wilensky, 2015). Outside the classroom, embodiment is an important modeling tool for structural biologists, who conduct "body experiments" to understand the dynamics of protein folding (Myers, 2012). In this paper, we present a kind of modeling activity—theatrical modeling—that leverages the power of syntonicity by combining theater and multi-agent computation in the context of solar systems modeling. We believe that theatrical modeling is especially useful for the study of perspectival aspects of solar systems using what Bollen and van Joolingen (2013) call a "*phenomenological* way of modeling" (p. 213, italics in original).

Theoretical framework

We ask: how might theater and computational modeling be coordinated in a collaborative learning environment to promote students' development as scientific modelers of solar systems? To answer this question, we build on work in computational modeling to develop the concept of the *theatrical model.* We believe embodiment is conducive to computational thinking because of human-agent *syntonicity* (Papert, 1980). We also draw from Wilensky and Reisman (2006), who analyzed how students construct embodied computational models of complex systems, like firefly populations, to understand emergent phenomena such as the synchronization of the fireflies' flashes. These works highlight syntonicity as an embodied, perceptual resonance between a single learner in physical space and a single agent in representational space (e.g., the LOGO turtle or the NetLogo firefly). There is a related body of research considering how computationally enriched embodied activities (e.g., participatory simulations) enable groups to model emergent phenomena in complex systems (Wilensky & Stroup, 1999; Brady, Weintrop, Anton, & Wilensky, 2016; Colella, 2000; Brady, Holbert, Soylu, Novak, & Wilensky, 2015). This work extends the idea of syntonicity to groups of learners modeling complex systems.

We believe, however, that there is a categorical difference between the complex systems modeling (e.g., of a firefly population) and phenomenological modeling (e.g., of a solar system). This important difference is in *how* the target phenomenon emerges. For the firefly population, synchronization emerges as a global aggregation of local, single-agent behaviors. This contrasts with solar systems, where phenomena such as day and night emerge through the interaction of only *some* of the many bodies. In this case, we believe that embodied perspective taking is an even more crucial "phenomenological connector" for enabling students to model perspectival aspects of solar systems (cf. Soylu, Holbert, Brady, and Wilensky, 2017).

With this background, theatrical modeling was conceived as a low-overhead modeling environment that could blend science with art to support both quantitative scientific modeling and qualitative narrative expression. Theatrical models involve a script, a performance, and a recording all geared toward a modeling question. We construe the *script* as a modeling artifact that mediates between the computational and the theatrical: it defines the stage as a performative and co-ordinate space and assigns roles and behaviors to actors using codified stage directions and narrative lines. Throughout the modeling process, the development of the script parallels the development of the group's epistemological and affective stances toward the phenomenon. In these ways the script both organizes and is shaped by each group performance in much the same way that a computational model evolves over time. Theatrical models are similar to what Myers (2012) calls "body experiments," which

> are part of the daily and mundane work of learning and conducting inquiry in science…. As improvised articulations they can be reenacted, revised and refuted mid-gesture. They can be repeated, but always with a difference. What's crucial here is that these animations do not fix the temporal flow of a process: their temporality is elastic. (p. 171)

In much the same way, theatrical modelers and their onlookers can use the performance as a temporally elastic tool for exploring and communicating ideas about solar systems and their experience as *part of* the model. In a theatrical model, human bodies become celestial bodies, human eyes become perspectival sensors, and human experiences become scientific evidence.

Methods and data

We developed a three-week unit on solar systems, emphasizing a phenomenological understanding of patterns (like day/night cycles). The 15-day sequence of lessons culminated in students working in groups of three to video record a theatrical model of an imagined solar system that addressed two questions: (1) How do planets move through the solar system? and (2) What are some consequences or implications of that motion? Students first wrote a narrative script to be read aloud as the group enacted the model. They then used a head-mounted GoPro camera to record their enactment. In total, 7 models were recorded. On the last day of the unit, Ms. Rogan facilitated an activity in which students viewed two of the videos, reenacted each of them to address questions that arose in discussion.

We collected student artifacts (e.g., written scripts and video recordings) as well as video and audio recordings of the whole classroom. First, we prepared a detailed transcript of the whole-class video and audio data using Inqscribe. We then used NVivo to code the transcript and students' scripted theatrical models. We were looking specifically for instances of students using theater as modeling: these included making claims related to both quantitative and qualitative aspects of the model, bids to re-run or change the parameters of the model, taking the perspective of actors within the model, and using the model to generate new questions. The research team met weekly to discuss the analytic process and review data at length while simultaneously developing a theoretical framing for the argument presented here. As themes began to emerge in our discussion and analysis, we twice brought selections from the video record before an interdisciplinary group of researchers to conduct interaction analysis sessions (Jordan & Henderson, 1995), which both refined and opened new avenues for our inquiry.

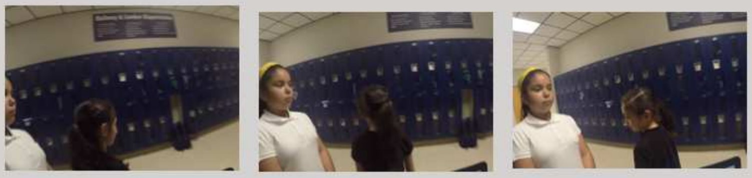
Analysis

We present here an analysis of the lifespan of a single model: *Maggie Mars*. This model was the first video watched in the final discussion, and was both reenacted by new actors and built on to construct new theatrical models in real time. First we introduce the video as a model by describing its components and discussing the decisions made in its creation. We then narrate its lifespan in the course of the final discussion as it was viewed and reenacted, framing students' interpretive discourse as characteristic of scientific modeling (cf. Lehrer & Schauble, 2015).

Maggie Mars

Maggie, Amanda, and Britney created *Maggie Mars* to explore Mars' perspective on the Earth-Sun relationship. They wrote it as a script before they performed and recorded it in private, knowing that it might be presented to the whole class for interpretation and questioning (see Figure 1).

Each model, including *Maggie Mars*, reflected a unique combination of modeling decisions that we categorize as literary, filmic, and computational. Literary decisions concern narrative aspects of the model, including story and point of view. Filmic decisions concern cinematic aspects of the model, including camera position and perspective. Computational decisions concern metric qualities of the model, including timing and actor motion. Literarily, the story is told from *Maggie Mars*' point of view as she recounts her own experience as *Amanda Earth*'s next-door neighbor. In this model, the filmic perspective is the same as the literary perspective: Maggie wore the camera in addition to being the story's narrator. She positioned the camera to maintain a consistent view of *Amanda Earth*, with *Britney Sun* usually at the left edge of the image. Computationally, "orbit" means *to traverse a circular path* and "rotate" means *to spin in place*—both of which were definitions used by the whole class.



A: [left to right] Amanda (dark shirt) orbits and rotates by walking around Britney.

B: Hi I'm Maggie mars. I have been watching the Amanda earth and how it orbits and rotates the Britney sun. The Amanda earth is a wonderful planet, very talkative and happy. The Amanda earth has told me that my days are longer than hers! I don't completely know how that is, but the Amanda earth has told me that this happens because I rotate slower than her, I can see why because when I watch her spin it takes 2 seconds! My day takes about 4 seconds. Amanda Earth is a very good friend of the Britney sun, but that might be because I have a longer way to walk so I am very tired and not as energetic as Amanda earth is. Britney stays still while Amanda rotates in a circle while orbiting the sun. That is what I, Maggie mars have to say about how Amanda earth rotates and orbits the Britney sun.

Figure 1A. Series of still frames from *Maggie Mars*. 1B. A copy of the script of *Maggie Mars*.

In both the script and video, *Amanda Earth* orbits *Ashley Sun* and rotates about her own axis every 2 seconds, producing a complex pattern of doubly circular walking. *Maggie Mars* follows in an orbit slightly outside of and behind *Amanda Earth's*, but does not rotate (in disagreement with the script, which is of consequence to our later analysis). *Britney Sun* holds her position at the center of both orbits. Here the use of "orbit" and "rotate" to denote different kinds of walking motion parallels the uses of functions in computational modeling. Considering the script alone, it would be possible to translate it into a computer-based model, which reinforces the validity of the script as an artifact of scientific modeling. What would be lost in the process, however, would be the perspectival understanding embedded in Maggie's cinematic choices and the nuanced phenomenological understandings embedded in the model's literary choices.

Viewing the model

The final class began with a viewing of *Morgan Mars*. Ms. Rogan paused the video midway through to facilitate a brief discussion about the basics of the model, establishing a shared understanding of each actor's role and the goal of the model. Then, Ms. Rogan instructed the students: "pretend you live on Amanda's nose." This was a bid to inhabit the model as a world, much like when Papert (1980) suggested that students "play turtle." Ms. Rogan asked the students to clap when they'd "seen a full day," then replayed the video. Students clapped in approximate unison each time Amanda completed a full rotation, suggesting that they used their embodied in-model perspective to infer when day and night would occur. This routine continued without teacher prompting, serving as the theatrical equivalent of a model-clock or tick-counter. Further discussion interrogated the literary and filmic perspective of *Maggie Mars*, from which students inferred that *Maggie Mars* was orbiting, but not rotating. Ms. Rogan built on this realization by asking what life would be like on *Maggie Mars*, garnering a chorus of claims about how either day or night would be everlasting depending on your location. In the language of planetary motion, *Maggie Mars* was tidally locked to the *Britney Sun* (like the moon is to Earth). The theatrical model not only supported students in realizing this fact, but also enabled them to imagine the experiential implications of tidal locking in a phenomenological way.

Re-enacting the model

Ms. Rogan expressed her own confusion at students' claims about everlasting day or night: "Could we demonstrate this for a second? Because you guys are talking but it's hard for me to see it in my head." After selecting actors and clearing a stage at the front of the room, the re-enactive demonstration began. Esteban played *Britney Sun*, Brian played *Maggie Mars*, and Kyle played *Amanda Earth*. The trio began their performance, portraying the motions of all three original actors with an impressive degree of accuracy given that they had never read the script. As the performance continued a researcher asked the class where daytime was on Brian, which also met a chorus of claims about which parts of Brian's body directly faced Esteban. Macey pointed out that Brian was "actually moving," by which she meant not that he was simply moving, but that he was moving differently relative to how Maggie had moved in the video. This insight reflected a remarkable understanding of the reenactment as a model of motion in comparison to the video as a model of motion, and suggests that Macey was thinking deeply about the computational and filmic qualities of both the video and reenactment. When the class faced the question of where daytime was on Kyle, Ms. Rogan "froze" the performance to allow for closer inspection of Kyle's orientation without him continuing to rotate. Over the course of the reenactment, the performance came to be frozen, played in discrete steps, replayed, and slowed down to support finer-grained quantitative investigation by the students into the perspectival relations embedded in the model. This kind of flexible executability and repeatability is an affordance of computational modeling environments, as it supports both intuition-building and experimentation (Brady et al., 2015).

Conclusion

We believe that the findings from this initial study show promise for the future iterations of this work and for the learning design community at large. Particularly given the constraints of this particular setting (i.e., 26-minute class periods), it is remarkable how richly these students were able to engage in both collaborative construction and interpretation of theatrical models of solar systems. These findings suggest that theatrical modeling enables students to explore both quantitative and qualitative aspects of solar systems in a bootstrapping kind of way. For example, we consider the intellectual work done by a student in imagining the stage from another student's perspective to be similar to the work done by a physicist when transposing frames of reference or considering relative motion. If composing and inhabiting models in which the physical world is blended with human experience is a quintessential scientific practice (cf. Ochs, Gonzales, & Jacoby, 1996), then we believe further research into the intersection of modeling and expression at the classroom level could offer significant insight to educators and other designers of learning environments. We have continued to explore and improve the theatrical modeling framework in subsequent implementations. Extended analyses of these data are pursuing an adaptation of the *liminal blends* framework (Enyedy, Danish, & DeLiema, 2015) to analyze theatrical modeling. Future work will explore a tighter coupling of theatrical modeling with agent-based computation, perhaps through the use of programmable robots.

References

Bollen, L., & van Joolingen, W. R. (2013). SimSketch: Multiagent Simulations Based on Learner-Created Sketches for Early Science Education. IEEE Transactions on Learning Technologies, 6(3), 208–216.

Brady, C., Holbert, N., Soylu, F., Novak, M., & Wilensky, U. (2015). Sandboxes for model-based inquiry. *Journal of Science Education and Technology*, 24(2-3), 265-286.

Brady, C., Weintrop, D., Anton, G., & Wilensky, U. (2016). Constructionist learning at the group level with programmable badges. In *Proc. Constructionism Conf* (pp. 61-68).

Colella, V. (2000). Participatory simulations: Building collaborative understanding through immersive dynamic modeling. *The journal of the Learning Sciences,* 9(4), 471-500.

Enyedy, N., Danish, J. A., & DeLiema, D. (2015). Constructing liminal blends in a collaborative augmented-reality learning environment. *International Journal of Computer-Supported Collaborative Learning*, *10*(1), 7–34.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The journal of the learning sciences*, 4(1), 39-103.

Lehrer, R., & Schauble, L. (2015). The development of scientific thinking. *Handbook of child psychology and developmental science*, *2*(7), 671-714.

Myers, N. (2012). Dance Your PhD: Embodied Animations, Body Experiments, and the Affective Entanglements of Life Science Research. Body & Society, 18(1), 151–189.

Ochs, E., Gonzales, P., & Jacoby, S. (1996). "When I come down I'm in the domain state": grammar and graphic representation in the interpretive activity of physicists. *Studies in Interactional Sociolinguistics*, 13, 328-369.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc..

Soylu, F., Holbert, N., Brady, C., & Wilensky, U. (2017). Embodied Perspective Taking in Learning about Complex Systems. Journal of Interactive Learning Research, 28(3), 269–303.

Wilensky, U., & Reisman, K. (2006). Thinking like a wolf, a sheep, or a firefly: Learning biology through constructing and testing computational theories—an embodied modeling approach. *Cognition and instruction*, 24(2), 171-209.

Wilensky, U., & Stroup, W. (1999, December). Learning through participatory simulations: Network-based design for systems learning in classrooms. In *Proceedings of the 1999 conference on Computer support for collaborative learning* (p. 80). International Society of the Learning Sciences.

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