Paper Title The Model Gallery: Supporting Idea Diffusion in Computational Modeling Activities

Author(s) Nathan Holbert, Teachers College, Columbia University; Corey Brady, Northwestern University; Firat Soylu, The University of Alabama; Michael Novak, Northwestern University; Uri J. Wilensky, Northwestern University

Session Title Advanced Technologies for Learning Poster Session

Session Type Poster Presentation

Presentation Date 4/17/2015

Presentation Location Chicago, Illinois

Descriptors Collaboration, Computers and Learning, Science Education

Methodology Qualitative

Unit SIG-Advanced Technologies for Learning

The Model Gallery: Supporting Idea Diffusion in Computational Modeling Activities

Abstract

We proposed that to facilitate the sharing of ideas in computational modeling activities models should first be easily sharable, and a tool for viewing, running, and critiquing models should be made available to students**.** In this paper we describe an innovation we call the "model gallery" for allowing students to present, discuss, and share both full computational artifacts as well as component features and ideas. Using data from one classroom using the models library we present evidence of non-standard ideas becoming commonplace across a classroom and argue that the regularity of these unique designs, their increased usage over time, and the presence of student critiques iterating these designs suggest the models gallery may be responsible for idea diffusion.

Purpose

While many scholars have highlighted the potential of engaging students in agent-based modeling (ABM) for facilitating reasoning about complex scientific phenomena, most of this work has focused on individual student thinking. Because open-ended computational modeling necessarily leads to a diverse set of explorations and unique constructions, sharing knowledge among a class full of students has proven challenging. In this paper we describe an innovation we call the "model gallery" for allowing students to present, discuss, and share both full computational artifacts as well as component features and ideas. Using data from one classroom we illustrate the ways in which this tool facilitated the thinking and reasoning about complex scientific phenomena at the classroom scale.

Agent-based Modeling

Agent-based modeling (ABM) refers to a variety of computer-based tools for exploring and creating models of scientific phenomena. Elements of a system are represented by computational entities whose simulated interactions result in emergent, whole-system behaviors. ABMs have become a critical tool for research in many fields (Gilbert & Troitzsch, 2005; Railsback, Lytinen, & Jackson, 2006), enabling scientists to capture system behavior by "growing it" from the behavior of the system elements (Epstein & Axtell, 1996). In other words, by identifying individual "agents" and endowing them with computational behaviors that govern their interactions, scientists can model and understand complex, real-world phenomena.

Though ABM is a cutting-edge professional practice, agent-based learning environments can paradoxically be significantly *more* accessible for younger students than those using traditional approaches. For instance, core phenomena of ecology—such as predator-prey interactions or the emergence of competition—can all be modeled and understood without differential equations or advanced algebra, but rather through simple "local" computational rules such as "wolf-eats-sheep" or "sheep-eats-grass" (Wilensky & Novak, 2010; Wilensky & Reisman, 2006; Yoon, 2008). Once they are endowed with these local rules, the computational agents can be *run* collectively to simulate the system that they comprise. Furthermore, because models are composed of individual agents, each with perceivable states and easily describable behaviors, modelers are able to put themselves in the place of the agent, bringing valuable intuitions about

the world into the modeling process to imagine how they might act under the same conditions (Wilensky & Papert, 2010; Wilensky & Reisman, 2006; Wilensky, 1991).

Sharing

One challenge using ABMs in educational contexts has been developing techniques to scale this thinking and reasoning beyond the individual. Because creating and exploring ABMs necessarily allows individuals to dictate the direction of the modeling process, in a given classroom there are often many different lines of exploration being followed. As complex phenomena are composed of many interdependent interactions, lessons learned by one student would ideally be shared with others whether they are exploring a tangential topic or a different one altogether. In other words, ABM curricula often struggle to distribute knowledge at the class level.

Typically the onus of achieving this classroom-level scaling has fallen to the teacher. Expert teachers can skillfully identify interesting lines of exploration and important features or ideas illuminated by these explorations and then lead rich consensus building discussions with the whole class. However, much has been written about the challenge of both teaching students to engage in the argumentation process (Berland & Reiser, 2011; Berland, 2011) and in training teachers to lead these consensus building discussions (Berland & Hammer, 2012; Meyer & Woodruff, 1997). For these reasons, even the most carefully designed ABM curriculum often relies heavily on teacher experience and expertise.

While we certainly are not advocating for designing around the teacher, we do believe there are possible tools that might be developed to support this classroom-level scaling process. We have identified two possible leverage points: 1) developing tools that simplify sharing and integrate it throughout the construction process and 2) developing models that are intrinsically conducive to sharing. Tools are needed that allow students to easily "go public" with *both* works-in-progress as well as more "final" products. By sharing artifacts more frequently and widely, learners are able to share ideas and knowledge-in-process. This allows the publishing student to use feedback and critiques from others as they debug their model and their thinking and can provide reviewers new ideas and potentially new directions for in-process explorations.

However, this sharing process is only valuable if the models themselves are sharable. Observers should be able to determine the states and rules of model components they themselves did not create without needing to delve into the model code. Likewise, the path to implement similar behaviors or components should be immediately clear to the observer. Elsewhere (Authors, 2014) we have described a class of models called Emergent Systems Sandboxes (ESSs) and shown how this class of model is specifically designed to be sharable in this sense.

In the following sections we describe an innovation we call the "model gallery" that facilitates this sharing process. This innovation was created in the context of ModelSim—a four-year NSF funded project with the principle goal of investigating the scalability of model-based science inquiry activities, structured around ABMs. The ModelSim project is best characterized as design-based implementation research, or DBIR (Penuel & Fishman, 2012), involving the design and large-scale implementation of four units (Population Biology, Evolution, the Particulate Nature of Matter, & Electricity) each of which include 5-7 activities that revolve around

exploring or creating ABMs. ModelSim units have been used in more than 100 classrooms, across three states.

The Model Gallery

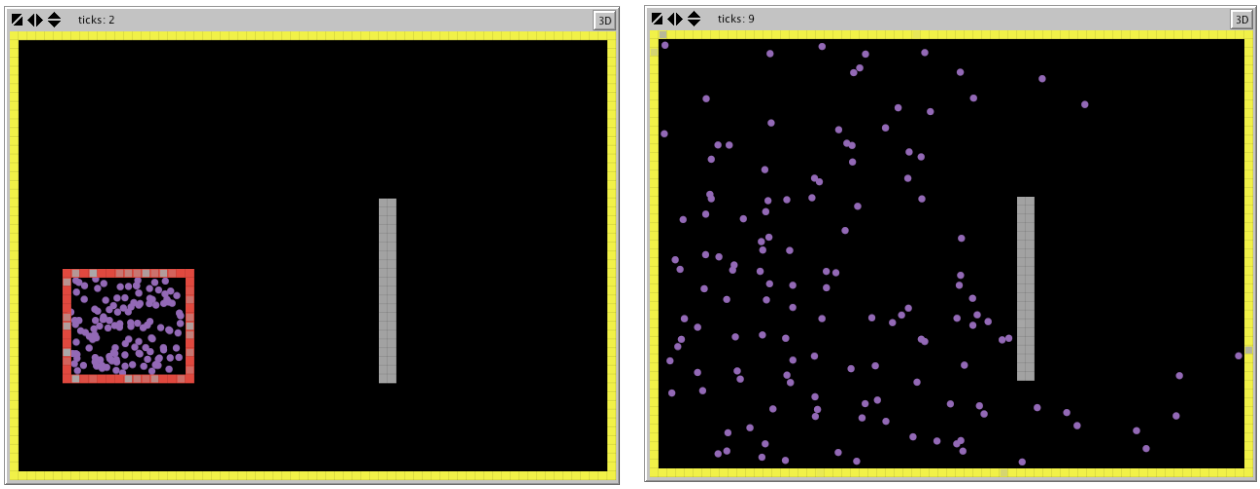
At its core the model gallery is composed of a shared database and a web interface. While creating or working with ModelSim models using the ABM modeling environment NetLogo (Wilensky, 1999), students can "post" these models to the shared database simply by pressing a button and adding a description of the artifact to be posted. Posted models include the actual artifact, the student-written description, an image of the artifact, and identifying information (the class, activity number, etc). In the web interface, students can then view posted artifacts made by classmates (or their own posted artifacts), leave comments for the author, and even download and run posted models (Error: Reference source not found). Downloaded models are opened in NetLogo, allowing the downloader to view and explore the artifact, make modifications to the model, and even repost modified models.

Fig. In the web interface of the model gallery, students can view models, download models, and leave comments.

Methods and Data

The model gallery was a core part of our Particulate Nature of Matter ModelSim unit. In this unit students interacted with specialized NetLogo models we call Emergent System Sandboxes (ESS) which allow students to design systems or experiments by "painting" agents or objects into a blank space that encodes the predefined rules (see Authors, 2014). In the particular activity important to the data presented here, students explored the phenomenon of diffusion. After taking part in a classroom demonstration where the teacher released an odor at two locations in the room (one heated, one at room temperature), students attempt to explain their observations of the odor movement by constructing a virtual model of particle dynamics. The ESS model used allowed students to add obstacles such as walls and particles (which followed the rules outlined in the Kinetic Molecular Theory) and to modify the state of these objects (such as "heating" particles). To do this, they select the object or action they intend to perform from the "draw" tool, and simply click and draw to add the object into the model view. For example, many students created a small container that "held" the odor. This was done by selecting the "wall" tool, "drawing" four walls, then selecting the "purple particles," and clicking and holding to place a large collection of particles inside (Error: Reference source not founda). When the walls are

removed the contained particles begin to diffuse throughout the room, bouncing off one another and any other walls present (Error: Reference source not foundb).



(a) (b)

Fig. A model showing particles that follow the rules of the Kinetic Molecular Theory trapped in a container (a). When the container is "opened" the particles are free to diffuse throughout the model, bouncing off of walls and each other (b).

As students created models of the diffusion process they posted both "works-in-progress" as well as "final" experiments. In our analysis of these data, posted models were first coded for relevant or interesting features such as the inclusion of air particles, the use of walls to represent "desks," etc. Then, by examining the timestamps of posted models and comments left by classmates, we looked for patterns of objects or experiments as well as how ideas moved throughout the classroom over time. The data presented here is meant to be an illustrative example of idea diffusion using the model gallery and come from one sophomore chemistry classroom at a public school in a large Midwestern city.

Results & Discussion

Many students attempted to directly replicate the diffusion demonstration by constructing a literal depiction of their classroom. For these models, students typically recreated the room layout using the "wall" tool, used removable walls to create two containers placed at different locations, and then filled these containers with different colored particles (Error: Reference source not found). Once the experiment was "set up," students would open the containers and observe how particles moved through the room.

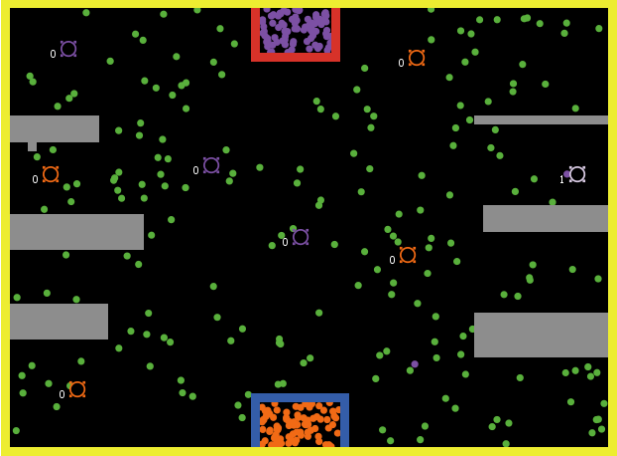


Fig. Students frequently attempted to draw the physical layout of the classroom, which used "walls" for desks, when modeling the diffusion experience.

To better understand how the gallery and model design facilitated a classroom-level shared understanding, it is important to note both the features common in all student constructions as well as distinctive innovations introduced by students that were later adopted by the classroom group over time. Nearly all models included "air," represented by green particles throughout the construction space. Similarly, students often used the "wall" tool to represent desks present in the room. While these practices were common, neither is explicitly suggested by model tools. Rather, the shared assumptions of the class and the intuitive nature of the model tools likely lead students to implement these features whether or not they are appropriate.

Evidence of non-standard or even strange ideas becoming commonplace across a classroom is a robust measure of the effect of the gallery on the classroom-level sharing of ideas and construction elements. While students commonly create two containers to hold the odor, in this class one group chose to place these containers "inside" one of the many "desks" added to their model (Error: Reference source not found). Despite this logical attempt to represent the placement of the container *on top* of the teacher's desk, this was the first such case observed in any ModelSim implementation.

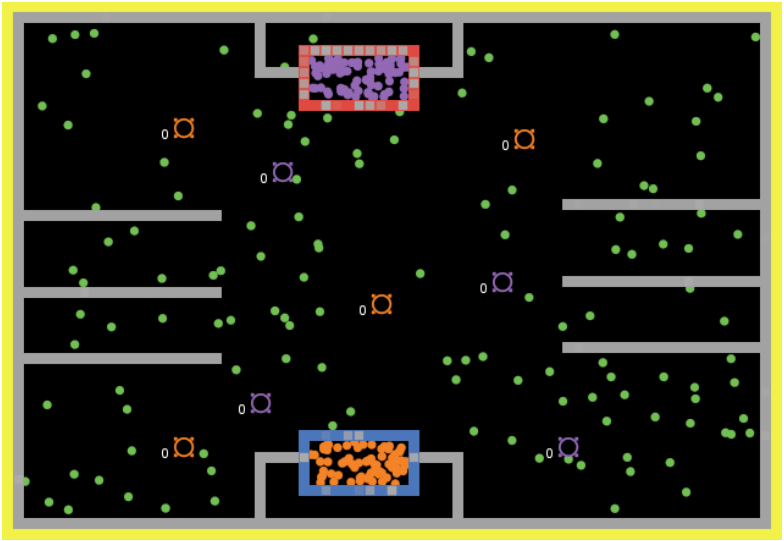
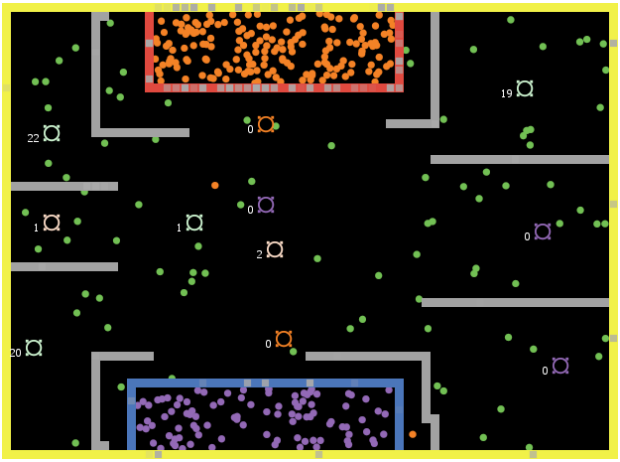
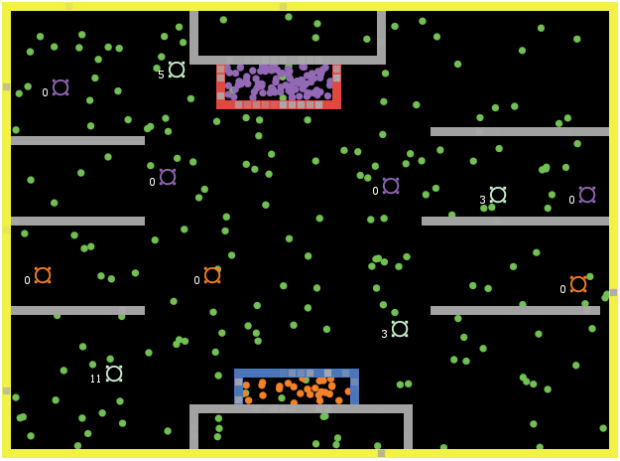


Fig. Attempting to replicate the odor container being placed on top of a desk for the diffusion experience, some groups drew their container inside of a desk in the model.

Soon after this model was posted to the model gallery, the design became commonplace throughout the class. Some groups directly replicated the container placement, some moved the container more completely 'inside' of the desk (Error: Reference source not founda), while others, realizing some particles become caught inside of the desk after the container is removed, moved the container to the front of the desk (Error: Reference source not foundb). As the activity progressed students began to offer suggestions and criticism about the container placement. Regarding Fig. a, one student suggests, "The experiment layout is really good but I think you should not put the whole red and blue box into the gray desk." Likewise, the design in Fig. led one student to comment, "I liked your idea of not adding the red and blue box to the gray wall but making it apart of it because it shows that the molecules are not just going to disperse forward but instead in every direction." Much of the class adopted this feature with seven of the twelve groups incorporating it in some way throughout the design process and five of the eight groups using it in their "final" experiment posts. The regularity of this unique design, its increased usage over time, and the presence of student critiques iterating the design suggests the models gallery may be responsible for the idea's diffusion.





(a) (b)

Fig. As the container-desk representation became more common, some groups attempted to place the container more completely inside of the desk (a) while others moved the container to the front of the desk (b).

Conclusion

In this paper we have outlined the design of the model gallery, a tool for facilitating the sharing of models and scientific reasoning at the classroom scale. We proposed that to facilitate the sharing of ideas around ABMs, models should first be easily sharable, and a tool for viewing, running, and critiquing models should be made available to students.

This work indicates tools can be created to facilitate classroom-level sharing of ideas for highly open-ended modeling activities. Furthermore, these tools can encourage idea diffusion (both good and bad ideas) without direct teacher intervention. When an expert teacher deploys such tools, idea diffusion can be amplified and classroom discussions can be encouraged to critique unique constructions and to develop consensus around a highly diverse set of constructions.

Bibliography

Authors. (2014).

Berland, L. K. (2011). Explaining Variation in How Classroom Communities Adapt the Practice of Scientific Argumentation. *Journal of the Learning Sciences*, *20*(4), 625–664. doi:10.1080/10508406.2011.591718

Berland, L. K., & Hammer, D. (2012). Framing for scientific argumentation. *Journal of Research in Science Teaching*, *49*(1), 68–94. doi:10.1002/tea.20446

Berland, L. K., & Reiser, B. J. (2011). Classroom communities' adaptations of the practice of scientific argumentation. *Science Education*, *95*(2), 191–216. doi:10.1002/sce.20420

Epstein, J. M., & Axtell, R. (1996). *Growing artificial societies: social science from the bottom up*. Brookings Institution Press.

Gilbert, N., & Troitzsch, K. (2005). *Simulation for the social scientist*. McGraw-Hill International.

Meyer, K., & Woodruff, E. (1997). Consensually driven explanation in science teaching. *Science Education*, *81*(2), 173–192.

Penuel, W. R., & Fishman, B. J. (2012). Large-scale science education intervention research we can use. *Journal of Research in Science Teaching*, *49*(3), 281–304. doi:10.1002/tea.21001

Railsback, S. F., Lytinen, S. L., & Jackson, S. K. (2006). Agent-based Simulation Platforms: Review and Development Recommendations. *SIMULATION*, *82*(9), 609–623. doi:10.1177/0037549706073695

Wilensky, U. (1991). Abstract meditations on the concrete and concrete implications for mathematics education. In I. Harel & S. Papert (Eds.), *Constructionism*. Norwood, N.J.: Ablex Publishing Corp.

Wilensky, U. (1999). *NetLogo*. Evanston, IL: Center for Connected Learning and Computer-Based Modeling, Northwestern University. http://ccl.northwestern.edu/netlogo/.

Wilensky, U., & Novak, M. (2010). Understanding evolution as an emergent process: Learning with agent-based models of evolutionary dynamics. In *Epistemology and Science Education: Understanding the Evolution vs. Intelligent Design Controversy*. New York: Routledge.

Wilensky, U., & Papert, S. (2010). Restructurations: Reformulating knowledge disciplines through new representational forms. In *Proceedings of Constructionism 2010*. Paris, France.

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

Yoon, S. A. (2008). An Evolutionary Approach to Harnessing Complex Systems Thinking in the Science and Technology Classroom. *International Journal of Science Education*, *30*(1), 1–32. doi:10.1080/09500690601101672