

encircling a region of the classroom with paper from three-foot roll of butcher paper. Some students held up the “walls” of this container while other students were the “molecules” placed in the container (Figure 7).

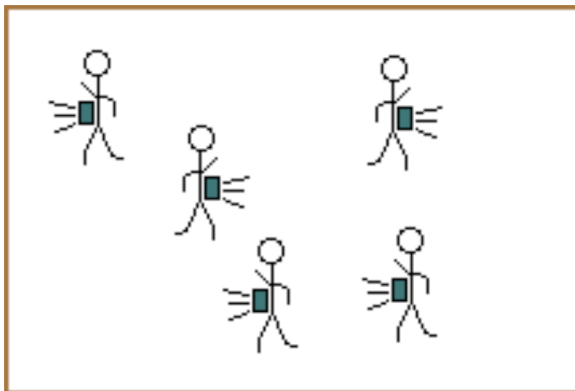


Figure 7: Students moving around and enclosed space as if they are molecules.

Each student molecule carried a calculator connected to a motion detector (Texas Instruments’ Calculator Based Ranger [CBR]). As these students moved around in this space their speeds varied. Motion detectors and calculators sampled and recorded each student’s speeds out over a fifteen-second time interval. In this way data was collected for each "molecule" (student) in this "people-molecules" gas (collection of students). At the end of the time interval, each calculator was programmed to display an individual histogram of sampled speeds. These individual histograms were then compared. While students were able to identify some similarities in the shapes of the distribution (e.g. “few out on the end” [few samples of relatively high speed]), for the most part they tended to see the distributions as mostly different. Often this sense of difference was judged relative to comparatively minor variances. Consistent with the sense that students often see any variance as meaning there can be “no pattern” overall, the results from individual calculators seemed to be too “rough” to highlight, in a significant way, any top-level consistency. The students were generally quick to express the sense that the changes in speed came from interacting with each other or the “wall.” Yet any sense of a consistent global distribution of speeds was not seen as significant relative to the variance.

It was when the results were combined to get the distribution of speeds for the whole people-gas that consistent patterns between trials became more noticeable. The students did notice an overall asymmetric shape that built up toward the middle and then trailed off near the end. Two examples of aggregate results are show in Figure 8.

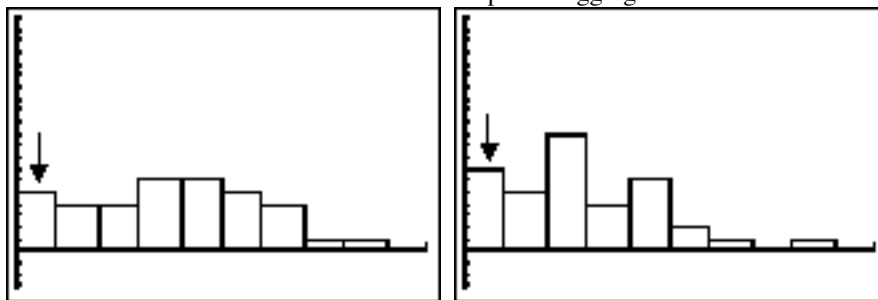


Figure 8: Histograms of “molecule” speeds for two trials of the PeopleMolecules activity.

As has been true for nearly every time we have run this simulation, the aggregate histograms have local maxima near the lowest values of speed (e.g. the regions indicated by the arrows in Figure xx). Students’ account of why there are these relatively high incidences of the lowest speeds is that the molecules “slow down” before “hitting” and/or changing directions. People have social conventions for “collisions” that even middle-schoolers observe and these include slowing down. The students themselves advanced the explanation that this local, individual behavior would manifest itself in the collective results as a local maximum for low speeds.

In a later class these PeopleMolecules results were then compared to results from a NetLogo model of an ideal gas. In this NetLogo model the rules for elastic collisions of an ideal gas are programmed in for the interaction of thousands of computational agents simulating the motion of gas molecules (Wilensky, 1999, 2000).

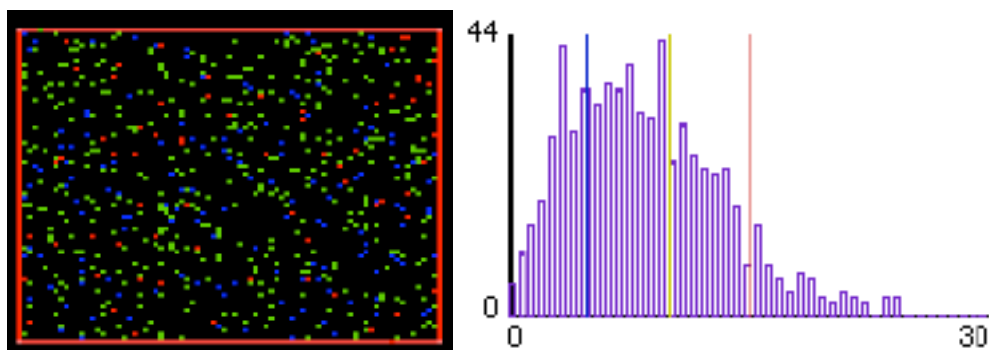


Figure 9: GasLab model of an ideal gas with histogram of speeds closely matching the Maxwell-Boltzman distribution.

This use of NetLogo highlights the sense in which the language is both a powerful environment for agent-based modeling and an environment for authoring network-based participatory simulations, like the Gridlock PSA discussed earlier. The NetLogo model of an ideal gas was introduced to the students as being like a billiard table with lots of “very hard” billiard balls colliding (Figure 9). To highlight the issue of how local rules for collisions (elastic collisions for momentum and energy being conserved) both create variation in the speeds of the molecules and a stable, top-level a distribution all the molecules in the model start off moving at the same speed (with arbitrary headings). This is like having all the balls on the idealized billiard table start off moving at the same speed. There is a significant literature related to using this model alone in learning about gases (Wilensky, 1999, in press). What is new in the context of this paper is the way the results from running the PeopleMolecules participatory simulation interacts with and deepens the student understanding of the NetLogo model and of the Maxwell-Boltzman distribution of an ideal gas.

Before using our simulations with learners we were quite concerned with the limitations of some of them in terms of their fidelity to the systems they represent. We clearly don’t want students learning falsehoods. With PeopleMolecules, for example, we clearly didn’t want students learning that there was a local maximum of slow moving molecules in real gases. When we ran the simulations like PeopleMolecules we were very pleasantly surprised to find that student understanding was *enhanced* by the contrasts between the simulations and more traditional depictions. While it *is* important to have the participatory simulations be like the system being rendered in at least *some* significant ways and that these ways be closely associated with the learning goals of the activity, it is also the case that many of the most important insights from students come from leveraging the ways in which the simulation is *not* exactly like the “real” thing. The consequence of a simulation not being entirely like the thing rendered turned out to be generative at two levels: (1) The contrasts often highlight significant aspects of the standard scientific models in ways that did, in fact, deepen the understanding of the standard model, and (2) the contrasts also invited the students to develop a sense of agency relative to both the particular models presented and the activity of modeling – the rendering of experience in enactive ways – itself. For PeopleMolecules, the absence of a relative minimum in the Maxwell-Boltzman distribution was noticed and assumed a significance it wouldn’t have had if the students hadn’t just examined the distribution from the PeopleMolecules activity. Moreover, the contrast or “gap” between the simulation results and the distribution for an idea gas catalyzed an examination of the different ways of running the simulation (e.g. “What if we all tried to move slower?”) and the GasLab model (e.g. “What if we they all started moving at a slower speed).

We are continuing to run the PeopleMolecules in schools as there is still much more to learned about the interaction of simulation experiences, understanding of scientific models, and students being able to generate and take ownership of the design and implementation of both simulations and models. A new capability for the PeopleMolecules activity we are beginning to explore in these on-going investigations is the ability to replay the motion data from each student in the NetLogo environment.

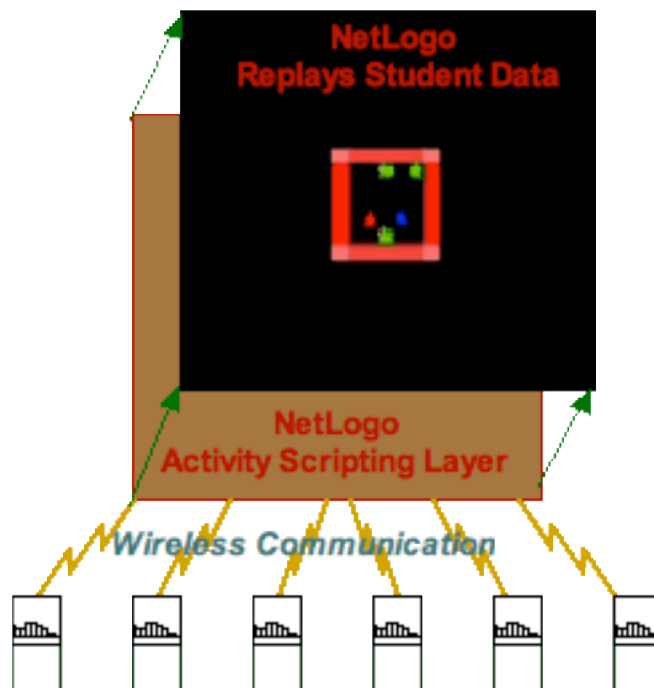


Figure 10: NetLogo Activity Scripting Layer can Import Student Data to be Replayed in NetLogo Modeling Layer

For the replay, the data from each student can be imported into an agent (see colored agents in Figure 10). These agents then would be confined to move in a container where their speeds would come from the student motion data and the directions would be randomly assigned. Agents would also “bounce” off the walls in the model. The sense is that this re-enactment in the NetLogo environment would provide additional scaffolding between the embodied student experience and the interpretation of the GasLab model of an ideal gas. Although the students would not be controlling the NetLogo agents in real-time like they do in the Gridlock simulation, there would still be the sense in which their embodied movements with the motion detectors were controlling cybernetic agents. There would be a succession of kinds of embodiment from moving around in a room, to having that motion be rendered in a computer model, to having students explore the embodied rules for agents that animate the NetLogo model of an ideal gas. At the level of aggregate analysis there is also a movement from a histogram of motion in a room, to an evolving histogram in NetLogo of the “replay” of their motions, to making sense of the histograms associated with the GasLab model and, by extension, real gas molecules in the classroom.

Future Directions

As indicated above, the HubNet architecture is in a preliminary stage. Significant project resources are allocated to developing HubNet and completing the fully networked architecture. Alongside this iterative design research, we will continue to conduct both implementation and curricular research with successive versions of HubNet. We have begun to design and test a set of PSA using ClassLogo that make use of sophisticated new content domains. This fundamental research is being carried out in economically challenged inner-city schools. Significant resources from the PSP Project are going toward site-based support and innovation. We are working alongside the teachers in targeting and implementing network-based participatory simulations that can transform students’ understanding of core concepts of the current curriculum (e.g. the concept of function) even as fundamentally new systems-understandings and content areas are introduced.

In this context, we seek to gain a better understanding of how a PSA can significantly advance student understanding of the unfolding dynamics of systems. We hope to shed light on how learners’ intuitive understandings and ways of responding interact with rule-based, embodied (e.g., StarLogoT, NetLogo) and aggregate (e.g., STELLA) modeling environments. Through this design, implementation and curricular research, we hope to further the goal of advancing systems related understanding for *all* students.

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