# Consider the Gypsy Moth: An Example of System Dynamics for Carlisle

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As we begin to consider applying systems thinking and system dynamics in the Carlisle schools, it might help us to understand and explain just how system dynamics would ”look” in our curriculum if we had a concrete example of its application. One good place to start using this tool might be in Jim Trierweiler’s current science curriculum, in the insects unit in particular. Here is an example for you.

Consider the gypsy moth caterpillar! Everyone in Carlisle knows and cares a lot about this pest, but we want to know more. For example, why is it that for many years we see hardly any evidence of gypsy moth caterpillars, and then, in other years, we are hit with such massive destruction of our oak trees? Once we are suddenly rid of them, why do they come back again? And, is there anything we can do about them?

This problem lends itself very well to system dynamics modeling. It appears that at least three important “levels” are involved. Levels describe the condition of the system at any point in time; they are accumulations that rise and fall over time depending on actions (called “rates”) which flow into and out of them. Levels and rates are the building blocks of dynamic feedback systems. These levels and rates must be identified and then quantified in equations using the STELLA software. You are forced to be very specific in stating your assumptions about the relationships between the variables.

Our first level would be the gypsy moth population itself; we have all observed that it increases and decreases over time. A rate flowing into the level of the gypsy moth population would be gypsy moth births; flowing out would be deaths. Of course, this does not tell the whole story because other factors also exert their influence on these variables. Deaths could be due to various causes and at different points in their life cycle.

Another level would be food supply for the caterpillars, in this case oak leaves, which can also rise and fall depending on its rates. For example, the more the caterpillars eat, the less food remains; without enough food, more caterpillars die, eventually leaving more food for the survivors who then eat more, and so on.

A third level would probably be the size of the predator population. In this case, I am not sure what the predator is since gypsy moths are an introduced species. Maybe disease and starvation play a more important role. We’d do some research to find out. The dynamics of disease spread are somewhat different from predation, but they are both limiting factors on the population growth.

All of these levels and rates are interdependent and class discussion would certainly bring out that idea. Students would have to learn about gypsy moths, their reproduction rates, life cycles, and predators in order to accurately build this model. They could draw much of their information from their own observations and experience, but they would also have to hunt for some pieces either through research or asking an expert. It is a bit trial and error, but you can see how it would be an engaging activity for kids in cooperative groups.

Once the model is built, it is simulated, or computed over small intervals of time, to see how our system behaves over time. (“Dynamics” means changes over time.) Then, to validate the model, we would fine-tune it to make the simulation replicate the real world behavior of the system that we see in Carlisle: gypsy moths seem to suddenly disappear and always come back again!

Probably the following scenario would unfold in our finished model. (The results are “read” as graphs showing how the variables change over time in relation to one another.) At first there would be only a few caterpillars, so they would thrive with plenty of food. They would reproduce at their normal rate, but because their initial population is so small, we wouldn’t notice them or their consumption of oak leaves. However, even a small population that grows at a constant rate exhibits exponential growth (a characteristic curve that kids would soon recognize). For example, if you double a small number, it is still relatively small; as the new number grows larger, doubling it makes a big jump, then an even bigger jump. After a few years of not much noticeable growth, the population would seem to blossom causing people to moan that the caterpillars have returned.

Meanwhile, while the population has surged in the last two years, the other two levels also have been changing. Initially, there was plenty of food. However, as the growing population devours all the oak leaves in your yard, more and more caterpillars go hungry. Many of the weaker oak trees do not survive the onslaught, and die, further reducing the food supply. In the final year of the population explosion, many caterpillars die of starvation, while others die of illness from eating other foods like pine needles. To add to the drama, the predators are gaining ground too. In the early phase of the cycle, their numbers slowly grow as their food supply grows. At the peak of the caterpillar growth, they have almost reached their peak; they can feast on the overabundance of food and multiply.

The resulting impact of the decline in food and the increase in predators (both initially spurred by the growth in the gypsy moth population) results in the dramatic collapse in the gypsy moth population. They seem to be wiped out. The following year, the continuing large population of predators almost finished the job, but it too declines rapidly because it has little food left. And now we are right back where we started, ready to go again. It is a natural cycle.

Once the model seems to run correctly, (that is, it accurately represents past behavior of the system) you can begin to play with it. You can perform experiments on the simulated system without the risks, expense, or uncertainties of experimenting on the real thing. Does trying to kill the caterpillars on your trees, as the population becomes a nuisance, really have any impact or does it just delay the inevitable by providing more food for the rest? How about cutting down some or all of the oak trees? Is that a realistic policy? What about the predators? What leverage can we apply to the system there? Are the wild swings in gypsy moth population related to the fact that it is an introduced species? We could simulate all of these conditions and see what happens. And there are, of course, broader questions that arise. Can or should we try to tamper with natural system cycles? What similarity does this system have with other systems in our experience?

You can see that kids would find this engaging. It is a big puzzle that they construct based on their own knowledge and experience. As they play with it, they are learning a lot about insects, ecology, cycles, and systems all around us.

In our sixth grade, the students would not yet have the skill to build the model. We would have to build it first and get it to run properly. But, we could lead them through the process, so that it becomes their model to play with. (STELLA provides a special authoring software which makes this easier.) In the long run, we might expect our students to begin to conceive their own models. We would need a lot of preliminary units, starting early, to get there.

This isn’t the only model we could do, nor do we have to do this one if Jim Trierweiler thinks others would fit his curriculum better. It is just an example. The appeal of this one is that it is familiar, very concrete, and part of the curriculum. Everyone in Carlisle would resonate to it! (My kids hate standing in the slimy green droppings at the bus stop, or finding caterpillars in the mailbox!)

This gypsy moth model is a relatively simple one, but that is not to say that building it is easy. It is a challenge to begin to think in this way and to take a multi-disciplinary approach to learning. It is a skill that takes practice. Working together, we’ll all get there. (Not surprisingly, kids take to this naturally. Our compartmentalized, fact-oriented education must have taught it out of us!)

Also, this model applies to the science curriculum, but we should try to broaden our aim as soon as we are competent and confident with using system dynamics as a curriculum tool. With the gypsy moths we can almost predict the behavior of the system, because it is small and easily defined and observed. However, once you get into bigger models of more complicated systems, you cannot predict the outcomes. Cause and effect may be distant in time and space; our mental models cannot encompass them. This would apply to systems like human population growth, the development and decay of a city, the causes leading up to the Civil War or the American Revolution, our intervention in Somalia or Haiti, and so on. The tools for building these models would be the same as those for the gypsy moth (and so would be the underlying system structures). However, we would save the more abstract models, like social studies, for later, when our modeling skills are more sophisticated and when we have gained more confidence in tackling bigger ideas and controversies using the tool of system dynamics. This is the arena for teaching the critical thinking skills so necessary for the future, as described by Jay Forrester. It will be a growing process for us all.

I hope this makes sense. It is just a start. It will be exciting for us all to take it further, one step at a time.