Week-3-Wendy-Huang-Daniel-Wendel-540p

WENDY HUANG: Hi, I'm Wendy Huang.

DANIEL WENDEL: And I'm Daniel Wendel. We are staff members in the MIT Scheller Teacher Education Program.

WENDY HUANG: This week, we'll be talking about modeling.

DANIEL WENDEL: This week's lesson has five parts.

WENDY HUANG: In the first part, we'll talk about why modeling is important in education. By the end of our lecture, you'll be able to define what a model is, explain how models are useful, and begin thinking about how to use models in the classroom . You will then watch a seven-minute video showing examples of a category of models known as agent-based models, which are often used to model complex systems.

DANIEL WENDEL: Next, we will demonstrate our model using Toolblox, which is an online agent-based modeling program. You will use this model to investigate fundamental genetics and evolution concepts in this week's assignment. We will summarize the key points of this video and then explain this week's assignment.

WENDY HUANG: Why model? The truth is that everyone is always creating mental models of how the world works. These are usually implicit, which means that we may not even be conscious of them. When you say you understand something, it usually means you have an implicit mental model of that thing. You can think of your implicit models as being in a box that no one can see inside.

So rather than ask, why model, because our minds can't help but model, a better question might be, what kind of model are we making? Why are we teaching you to model if your mind already makes models all the time? Learning to model allows us to make our implicit models explicit. Explicit means that we realize that the model is a model.

So we can think about it as its own thing and maybe write it down or program it into a computer. Making explicit models forces us to confront our assumptions and makes us think about what we're attempting to model. Also, bringing our implicit models out of our minds and into the world by making that explicit means we can now compare that with other people's models and test them against real world data.

We can also use models to test different scenarios to reveal trade-offs, uncertainties, and sensitivities, and to discover new questions and lines of investigation. A society that is literate in modeling can have disciplined and informed public discussions about options and would be less prone to being swayed by personal preferences, the power of special interests, or tradition.

DANIEL WENDEL: The real world is complicated. Models are not meant to capture all of these complications. If they did, they would be just as complicated as the real world. So essentially all models are wrong, because they are simplification of the real thing. But the best models are useful because they are simple. "Art is a lie that helps us see the truth," said Picasso. And models are similar to art in this sense.

Although models are lies, they are illuminating abstractions that purposely focus on certain important features to help us understand, make predictions, or generate new ideas.

WENDY HUANG: When you think of models, you might think of weather forecasting, where models are very commonly used to predict the weather in the future. But models do more than predict. Models can explain phenomena, such as epidemic dynamics, wealth distributions, and how energy flows through a food chain. They can also guide data collection. In science, you often need a theory before you know what data to collect.

For example, Maxwell's electromagnetic theory deduced the existence of radio waves, which people then looked for and found. Models can help us think about what data to look for.

DANIEL WENDEL: Model suggest analogies, which allow us to see connections between seemingly unrelated processes. For example, an epidemic is similar to other phenomena, such as the spread of ideas, revolution, religions, adoption of innovations, or even a forest fire. Models also raise new questions. Doing well on school exams can show that you are able to answer someone else's questions, but perhaps a more important goal of education is, can you ask a new question?

Only new questions can produce new discoveries and new knowledge. Models help us generate new questions, because they naturally lead us to ask, what if?

WENDY HUANG: Modeling enforces a scientific habit of mind. All scientific knowledge is uncertain, contingent, and subject to revision. And this becomes evident in the process of modeling. A person with a scientific mind does not base beliefs on authority, but on evidence. He or she is always doubting, which means gathering evidence. And if the evidence conflicts with a mental model, adjusting the model to make it more correct.

Intellectuals have a solemn duty to doubt and to teach doubt of this kind. Education is not just about gaining a marketable skill set. It is more fundamentally about gaining freedom from inherited prejudice and argument by authority.

DANIEL WENDEL: There are many ways to model. We will focus on one type of model, known as agent-based modeling. In agent-based modeling, you create the models by specifying the rules for agents and then letting them interact with each other. For example, you could create an agent-based model of an ecosystem by creating some predator agents and prey agents. Or you could create an agent-based model of an epidemic by making many agents to represent the population.

And when a sick agent touches a healthy agent, the healthy agent become sick, too. Agent-based models can be very sophisticated and can even model complex systems, even with simple rules for the agents. To make agent-based computer modeling easy for beginners, we have built a computer tool called Toolblox that helps with creating agents and giving them rules to follow.

This way, you don't need advanced mathematics to work with interesting, powerful models. We will show you how to use Toolblox later in this lesson. The next seven minutes will introduce you to the basics of agent-based modeling and how it is particularly useful for modeling complex systems. This video will tell you what a complex system is and explain how agent-based models can be used to study one.

ILANA SCHOENFELD: Have you ever wondered how thousands of birds move in amazing patterns like this? Ever watched fish schooling and wondered how they coordinate their movements? When you're looking at a flock of birds or a school of fish, you're watching the behavior of a system of many interacting parts. In this case, individual birds or individual fish are the parts.

Systems where unexpected patterns emerge as a result of many individual parts interacting are called complex systems. The study of complex systems has recently been recognized as a new type of science. The living world is a great place to find examples of complex systems, where the actions of individuals turn into the behaviors of a group.

This bird flock is an example of a complex system in action. To understand how any complex system works, it's important to answer two basic questions. How do each of the parts of the system behave? For example, how does each bird in a flock behave?

And how do the parts act together to form the behavior of the whole system? For example, how do individual birds in a flock act together to form beautiful flying patterns? Let's look at the first question, how does each bird in the flock behave? Believe it or not, every bird in the flock is following the same three simple rules.

Stay close to but don't bump into the birds around me, fly as fast as the birds near me, and move towards the center of the group. Now, for the second question, how do the individual birds in a flock act together to form these beautiful flying patterns? You might think there is one leader bird who is somehow sending messages to tell other birds in the flock where to fly. But really, it's much less complicated than that.

When hundreds or thousands of birds each follow the same three rules, amazing flocking patterns emerge. Sometimes even if you can figure out how each individual in a complex system behaves, it's really hard to predict how a system as a whole will behave or what types of patterns will emerge when many individuals are all acting at the same time. This is where the power of computer simulations comes in.

Agent-based computer models and simulations are great tools to visualize and explore group behaviors. For example, in this simulation of fish interacting with algae in a pond, every yellow fish you see is programmed to follow the same simple rules for movement, getting energy by eating algae, reproduction, and death. The algae is also programmed to follow simple rules for reproduction and death.

Once the behavior of these two types of individuals and the interactions between them has been programmed, the simulation can then populate a virtual world with tens, hundreds, or even thousands of fish and algae all following their assigned rules at the same time. Using computer models like this helps people observe what happens at the level of the system, or in this case, the simulated ecosystem.

Eric Klopfer is a professor and the director of the Scheller Teacher Education Program and the Education Arcade at MIT. His research focuses on developing and using computer games and simulations to build understanding of science, technology, engineering, and math.

ERIC KLOPFER: In agent-based models, you describe rules for individuals in this system. And then you see how the system-level behaviors emerge from this collection of individual interactions. We know that systems are a really important way of understanding science, technology, and engineering, because that's the way we do prediction, that's the way we understand systems, that's the way we think about projections and modifications of systems.

But oftentimes if we try to describe the system as a whole, it's a complicated set of equations or aggregate distributions. And even conceptually, it's difficult for people to understand those. In agent-based models, since we're describing the rules for individuals almost as behaviors that we imagine whether they're real behaviors for a person or an animal or an insect or anything else inside of a system, or even a molecule, it's a way of understanding how that individual behaves in a system. And it's intuitive to think about yourself as one of those agents in a system.

And then you can from there understand what's happening in the system as a whole.

ILANA SCHOENFELD: So other than the fact that they're really cool, why is understanding complex systems important? Biologists, physicists, engineers, mathematicians, and social scientists are finding that the rules the create ordered systems from individual behaviors are showing up in many fields and at many different scales, from molecules in our bodies, to bird flocks to human interactions, like crowds and traffic jams. They are also finding that understanding the way individual parts work together may be just as important as understanding the way that they work alone.

Sabine Hauert is a scientist using her understanding of how insects swarm and birds flock to research ways to treat cancer tumors in humans using tiny objects called nanoparticles. She also designs flying robots that mimic the way animals in nature organize themselves in large groups. Her field of research, called swarm engineering, looks for ways to make simple agents cooperate to achieve organized behaviors.

SABINE HAUERT: I'm really interested in swarm intelligence. So how can we make very simple agents that work in very large numbers to accomplish real world tasks? So whether they're flying robots that work together in rescue scenarios or whether they're nanoparticles that can work together to deliver drugs to tumors, that's the type of system I'm interested in. Designing swarm systems is actually a really difficult task, because if you look at an individual ant or if you look at an individual bird, that won't really tell you how they're able to do some of these amazing group behaviors.

And so designing these group behaviors is really difficult if you don't have a good example. And that's what we have the nature. And that's why we study these natural systems. And so things like in a flock of birds, there's no leader. There's no one telling the different birds where they need to go. If you remove one of the birds from the flock, the flock is not going to fall from the sky. They're still going to be able to fly.

And if you add more birds to the flock, it's also going to be able to flock. So these are a lot of really cool rules that you can apply to applications. Now, we're really interested in swarming nanosystems because, nanoparticles, when you inject them, you inject 10 to the power of 13 nanoparticles in a system. And that's a huge number.

And nanoparticles are very small, they're very simple. So you can't get complex behaviors with individual particles. So we're really trying to find ways in which we can make these very large numbers of very simple nanoparticles work together, or hopefully swarm, to be more efficient in treating cancer.

ILANA SCHOENFELD: By looking at patterns that are common to systems studied in many different fields, from physics and biology, to the social sciences, experts that may not have shared ideas in the past are now sharing the results of their research. We've seen how understanding swarming behaviors in nature can lead to new ways to treat cancer in humans. This is just one example of how complex systems thinking is changing our world.

What's next? The possibilities are endless.

WENDY HUANG: When integrating models into classroom practice, we find it helpful to think about the classroom activities in terms of using, modifying, and creating models. As students move from Use to Modify to Create, they follow a progression from easier but less powerful learning to harder but more powerful learning.

DANIEL WENDEL: When using a model, students are given a completed model. They may run the model using different parameters, make observations, collect data, and try to infer the rules of the model. This type of activity takes less time to implement in the classroom than a Modify or Create activity. But teachers do need preparation time to select or modify an existing model or create their own model, and to design the activity for the students to interact with that model.

When modifying a model, students can look at the rules of the model and change the rules or add new ones. This is a little harder and takes more classroom time to help students understand the model's rules. Because computer models built in Toolblox allow students to see the rules behind them, students can uncover the assumptions of the person who made the model, understand that rules can be changed, and see how these changes may affect how the model works.

WENDY HUANG: When creating a model, students design the model and determine its rules. This is the hardest activity along the progression, because they need to teach students how to design and program. But it also has the most potential for powerful, deep learning. Students are able to fully participate in the process of making their mental models explicit, share and compare their models with others, and have ownership of their ideas.

DANIEL WENDEL: As part of this week's assignment, you will use Toolblox, an online agent-based modeling program to learn about evolution and ecology using a pre-built model. The model is a virtual pond that has some fish and algae. And the fish eat the algae to gain energy, so they can live and reproduce.

The model is linked from this week's lesson, and you will be following a worksheet that is linked from this week's lesson as well. When you click on the link, Toolblox will begin to open the model. At first, you'll just see a blank screen, then some text like this. And finally, you should see something that looks like this. With a green square in the middle of the screen, this is the 3D display where you can see the model as it runs.

Follow the instructions on the worksheet to set up and run the model by clicking the buttons on the screen. For example, one of the steps on the worksheet is to set up a pond with multi-colored fish and then to run. To do that, I will first click on Setup, which will make a bunch of green cubes appear. These cubes represent the algae that the fish will eat.

Next, I click Create Multicolored Fish. And the pond is filled with many fish of different colors. If I want to see the pond from a different angle, I can click and drag with my mouse to move the view, or I can hold Alt while dragging to rotate the view. I can also scroll with my mouse's scroll wheel to zoom in and out or use the buttons on the side.

Now that I have adjusted the view of my model, I will run it by clicking the Run button. Watch the fish as they swim around and eat the algae. After a while, some of the colors of fish will die out, leaving only one or two colors. Try setting up and running the model again.

Do you always find the same color surviving the longest? The worksheet will ask more questions like this to help you learn about what causes some traits to become more or less common in a population over time.

WENDY HUANG: In summary, models are illuminating abstractions. They're useful because they're simple.

DANIEL WENDEL: You watched a video segment showing how agent-based modeling is used to model complex systems.

WENDY HUANG: You saw a demonstration of a model running in Toolblox, a computer programming tool that can be used to build agent-based models.

DANIEL WENDEL: We used the Use, Modify, Create progression to help you think about how modeling activities fit into the classroom. And this week, we're focusing on using models. For this week's assignment, you'll read the essay titled Why Model, which we used to make our key points about the importance of modeling. After reading the essay, please respond to the question in this week's online discussion forum.

"How would you convince a teacher to try modeling in his or her classroom?" "How would you advise him or her to start?" For the second part of the assignment, you will use Toolblox to investigate the EvoFish model that we demonstrated. Follow the directions on the activity sheet provided, answer the questions, and submit your completed activity sheet as an attachment to your reflection about the activity in the appropriate online course forum.

WENDY HUANG: Thanks for watching, and we look forward to seeing your responses in the course website.

DANIEL WENDEL: Here's our contact information.