Science for a Complex World: How to challenge and inspire young minds

June 9, 2014 9:31 a.m.

Note: This article appeared in The Santa Fe New Mexican *on June 9, 2014.*
By Emma Wolinsky

When I begin my sophomore year at the University of California, Berkeley this fall, I will take with me experiences gained this summer as a participant in the Santa Fe Institute's Research Experiences for Undergraduates programs.

Funded by the National Science Foundation, this program lets undergraduate students work on their own research projects alongside mentors from the institute, offering insight into the career of a working scientist.

The Santa Fe Institute is the perfect place for this one-on-one interaction. The institute has helped me learn about complexity science since middle school, when I participated in its after-school program called Project GUTS, which stands for growing up thinking scientifically and teaches reasoning skills through hands-on computer modeling. I've since participated in several other institute programs that have helped me fine-tune my thinking skills and set me on my current path.

My participation in the Santa Fe Institute's education programs and its hands-on modeling exercises has influenced how I view and interact with the world. Complexity describes real-world systems in nearly every field, and its broad application and profound consequences piqued my curiosity. I began to wonder if every complex system could be simplified into programmable behaviors.

Complex systems are difficult to predict. The same set of conditions can lead to multiple outcomes; a small change in initial conditions can lead to completely different results. This is what makes them so intriguing. Studying complexity is studying the world. It exists in the self-organization of ants, economic systems, energy production, energy consumption, social interactions and the brain.

One of the key elements of many complex systems is that they are composed of networks of simpler components. We have a good understanding of the behavior of a single neuron, but when billions of them interact to form a brain, the result is a complex system we are far from understanding in its entirety. The emergence of complex behavior from simple components is crucial to developing our future understanding. This is true of many complex systems in our world, and we cannot hope to fully understand them without understanding complex systems behavior.

Computer models can be used to study complex behavior. They operate by breaking down the system into basic components. Both Project GUTS and the Santa Fe Institute's Complexity and Modeling Program, or CAMP, challenged me to develop this sort of scientific thinking by building my own computer models in middle school and high school. Programming my own simulations required me to figure out what elements were important enough to include and to formulate a way to use the simple pieces to ask testable questions and study the complex behavior.

Science has greatly influenced how we interact with the world, but we have a lot more to learn. We see this influence in the nitrogen cycle. Nitrogen is essential to all life on earth, but no animals, plants or fungi can use the nitrogen readily available in the atmosphere. The nitrogen in the atmosphere, despite being more than 75 percent of the gas present, consists of extremely strong bonds that make it impossible for our bodies to use it. We rely on nitrogen fixation, carried out by microbes that live mostly in soil, to convert the nitrogen into a form we can use.

The amount of nitrogen created by soil-dwelling microbial organisms, however, is insufficient to support food growth for the earth's current population. A little over a century ago in Europe, it was predicted there would be mass starvations due to a lack of nitrogen fertilizer for crops. Scientists had to develop an understanding of the basic components that facilitate the nitrogen cycle in order to replicate them, finally resulting in the Haber process, a method of producing ammonium (fixed nitrogen) on an industrial scale.

It is estimated that at least a third of the world's population today is dependent on food grown with the help of man-made ammonium fertilizer. This invention greatly increased the carrying capacity of the earth, but now we are beginning to face the potential threat of too much ammonium in the environment — another issue demanding a deeper understanding of system complexity.
Our existence on this planet has been fundamentally changed by science, and now we rely on understanding complexity to navigate the challenges before us. Santa Fe Institute programs have given students like me the ability to simplify and understand complex systems, which is the basis for tackling these real-world challenges. The skills I've learned through these programs have benefited me and made me excited about issues of complexity. As I begin the next iteration of my SFI education, I look forward to an even deeper exposure to these topics. I hope many other young people will get excited about science so we can begin to address the major, complex problems facing future generations.

ABOUT THE AUTHOR

Emma Wolinsky, a Santa Fe native and 2014 Research Experiences for Undergraduates participant, will be a sophomore this fall at the University of California, Berkeley. She first encountered complex systems science as an eighth-grader at Monte del Sol Charter School, where she participated in the Santa Fe Institute's Project GUTS. After her sophomore year of high school, she attended the institute's Complexity and Modeling Program at the Groton School in Groton, Mass. Her experiences have helped her focus on pursuing a career in science, and although she has not yet declared a major, she is interested in exploring the field of computational biology and a career in science.

ABOUT THE SERIES

The Santa Fe Institute is a private, not-for-profit, independent research and education center founded in 1984 where top researchers from around the world gather to study and understand the theoretical foundations and patterns underlying the complex systems that are most critical to human society – economies, ecosystems, conflict, disease, human social institutions, and the global condition. This column is part of a series written by researchers affiliated with the Santa Fe Institute and published in *The Santa Fe New Mexican*.