Growing Up Thinking Scientifically
SFI EDUCATION PROGRAM SPREADS ITS WINGS

BY IRENE LEE

America's competitive edge in the global economy is measured by the skill and versatility of its labor force, and its capacity to nourish research and innovation. The Bureau of Labor Statistics projects that between 2006 and 2016, more jobs will be created in science, technology, engineering, and mathematics (STEM) than in any other field. The ability to fill these positions depends on an education system capable of producing a steady supply of young people prepared in science and math. Unfortunately, current reports show that the U.S. has a dearth of such students; fewer than one-third of 4th grade and 8th grade students perform at or above a level called "proficient" in mathematics, and 12th graders perform below the international average for 21 countries on a test of general knowledge in mathematics and science.

The SFI education programs recognize that an understanding of complexity science and computational thinking will be an important part of all sciences in the 21st century. In order to address the defining problems of this century, such as climate change, loss of biodiversity, energy

consumption, and spread of virulent disease, scientists and researchers will need an understanding of the interrelatedness of systems and of underlying patterns that transcend single disciplines. Future scientists and researchers will need to know how to harness computational resources to model and understand these daunting problems.

The Santa Fe Institute's Project GUTS: Growing Up Thinking Scientifically, aims to address this situation and produce students who can apply computational methods and analysis to complex systems issues. Thus the program has introduced complexity science and agent-based modeling to middle-school students (ages 12–14). Project GUTS provides diverse groups of students the opportunity to learn by using engaging materials and technology tools to investigate complex systems topics of interest to their local communities. The aim is to recruit the next generation of scientists and engineers, especially from previously underrepresented populations such as women and minorities.

Project GUTS was implemented as a 20-week series of after-school club meetings and two-week summer workshops. Each after-school club consisted of between 5 and 24 students, a school teacher serving as a club leader, and a Project GUTS facilitator. Following a four-week introduction to complex systems and agent-based modeling in the computer language StarLogo TNG, clubs followed six-week units on topics in complex systems: opinion dynamics, shared resource management, and social networks. Within each unit, students were introduced to the topic, participated in hands-on activities, and ran experiments on computational models. At the conclusion of each unit students created their own models of a community-relevant application of the topic. For example, as part of the opinion dynamics unit, students investigated the relative impacts of having a strong opinion leader versus having eager adopters of new opinions in a school setting.

Project GUTS has three goals for its students: to attract diverse participants through targeted recruitment and by providing relevant content, a comfortable context, and a flexible program; to prepare students for careers in STEM fields by developing fluency with the concepts of complex systems and computational tools and techniques; and to retain students in STEM disciplines by supporting them from middle to high school as young scientists.

How is the program doing? In the second year of working with students, Project GUTS reached 344 students in 24 after-school clubs; two-fifths were 7th-graders, with the remainder split almost equally between the sixth and eighth grades. Twelve clubs were established in Santa Fe and 12 new clubs were spawned in other areas of New Mexico including Taos, Peñasco, Albuquerque, Chaparral, Carlsbad, and Los Alamos. Attendance was generally high, with two-thirds of participating students attending at least 75 percent of club meetings. In addition to addressing student needs, the project has engaged teachers in its clubs, exposing them to complexity science, technology tools, and pedagogy. Twenty-four teachers who served as Project GUTS club leaders attended 20 hours of professional development sessions over the course of the school year.

Preparation for the future of the STEM program was measured by students' fluency with the

Students learn about sharing resources while playing with the Rabbit Farm model in Starlogo The Next Generation (TNG). Starlogo is an agent-based simulation language that can be used to model behavior of decentralized systems.

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concepts of complex systems and their ability to use computational tools to experiment, manipulate, visualize, and interpret data. Students rated themselves high in their ability to select real-world problems to model, write their own computer models, use computer models to test hypotheses, and interpret data from computer models. However, their understanding of complex systems was limited. "Complex" and "complicated" systems were often confused, and there was a lack of discernment of different levels of dynamics (individual versus aggregate), pointing toward a need to refine the curriculum to address these misunderstandings.

The program has met up with a few roadblocks, and there is much to improve. Notably, Project GUTS has not yet developed metrics and instruments to assess students' gain in understanding of complex systems. Project GUTS also seeks to improve its outreach and recruitment of young women and retention of young Hispanic males. The program will continue to seek ways to engage such students in STEM through a combination of efforts. The project has applied for future funding that will bring it to a wider audience both regionally and nationally. A proposal has been submitted to the National Sci-

ence Foundation's (NSF) Innovative Technology Experiences for Students and Teachers Program for a girl-focused version of Project GUTS; and another has been submitted for funding through NSF's Broadening Participation in Computing program to develop near-peer mentoring.

It is clear that the project is succeeding in attracting students, and that the core concept—integrating community-relevant investigations with an engaging modeling tool in which to conduct inquiry—is valid. Additionally, Project GUTS has succeeded in providing program-level and curricular support that enables distal club leaders to run clubs without a GUTS facilitator present. Most importantly, Project GUTS has created a community of teachers, students, and researchers who are interested in and committed to continuing with the program, and thus to better addressing the needs of the U.S. in this century. ◀

Irene Lee is the principal investigator of Santa Fe Institute's Project GUTS: Growing Up Thinking Scientifically. Her research interest is in exploring the use of new technologies and computational methods, from agent-based modeling to network visualization, as tools to teach and learn about complex adaptive systems.

In this Rabbit Farm model in StarLogo TNG, students supervise a farmer, grass, and rabbits, gaining an understanding of the complexity of resources management. Students also deconstruct the model and build their own based on management of a local resource.

94%

NO

"Is what you learn in Project GUTS similar to the science you learn in school?"

6%

YES