## Research News

# SIGACT trying to get children excited about CS

By Michael R. Fellows
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As an emerging discipline, computer science has a serious communication problem. The public generally is ignorant of what computer science is and what computer scientists do. They tend to hear the word "computer" and assume that we are some kind of technicians. Is it any wonder then that computer science is represented in many schools by either computer games or some antiquated approach to programming, which at worst concentrates on a litany of syntax and at best emphasizes expediency over effectiveness and efficiency? But computer science is *not* about computers—it is about computation.

What would we like our children—the general public of the future—to learn about computer science in schools? We need to do away with the myth that computer science is about computers. Computer science is no more about computers than astronomy is about telescopes, biology is about microscopes or chemistry is about beakers and test tubes. Science is not about tools, it is about how we use them and what we find out when we do.

It may come as a surprise to some that computer science is full of activities that children still find exciting even without the use of computers. Take theoretical computer science, for example, which may seem an unlikely candidate. If computer science is underrepresented in schools, then theoretical computer science is doubly so.

Theoretical computer science is built on the foundation of discrete mathematics, which generally is ignored in schools in favor of continuous mathematics such as geometry, algebra and calculus. While the reasons for studying these subjects have been valid for centuries, and are still valid, an argument can be made that the citizen of the future who lives in the "information age" might benefit from at least a passing knowledge of the type of mathematics that underlies computer science and the ubiquitous computer.

### Problems for children

Children come with built-in abstraction abilities that seem to get lost before they become adults. They have no trouble imagining that a block of wood is a house and a piece of driftwood is a boat. Experience has shown that children can imagine that a dot on a piece of paper is a house, that lines connecting them are streets and that numbers labeling the streets represent distances. With these representations in mind, the children are ready for the "Muddy City Problem."

The children are given a map of Muddy City and told the story of its woes—residents sink in mud up to their elbows when it rains. The mayor insists that some of the streets must be paved, and poses the following problem: Enough streets must be paved so it is possible for a resident to travel from their house to anyone else's house by a route consisting only of paved roads. But as little paving material should be used as possible so there will be funds remaining to build the town swimming pool. This, of course, is the familiar minimum-cost spanning tree problem.

The children can work on the problem, usually in small groups, with the immediate objective of finding the best possible solution. This is recorded in a place that everyone can see. Students are asked to describe their strategies and ideas, both as they work and in a concluding discussion. In classrooms where the students keep mathematics journals, they write descriptions of the problem and of their ideas on how to solve it.

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This simple (and fundamental) problem has excited children whenever it has been posed. The problem exercises children's problem-solving skills, gets them to think and write about the way they tackle problems, and incidentally, provides them with a meaningful opportunity to use their basic arithmetic skills (adding a list of numbers is needed to determine the cost of a solution).

This kind of meaningful, multileveled problem-solving experience is exactly the sort of thing called for by the new National Council of Teachers of Mathematics (NCTM) curriculum standards for school mathematics. Problems such as these can show children that science and mathematics are exciting frontiers, not dry, boring topics in which everything is known in advance and nothing is left to discover.

The minimum dominating set is another mathematically rich problem, and it illustrates the idea of computational complexity. A *dominating set* in a graph is a chosen set of vertices such that every vertex is either chosen, or has a neighboring vertex that is chosen. The problem is to choose such a set that is as small as possible. The stories told for this problem generally run to the theme of *facilities location*.

For example, in Tourist Town, we want to place ice-cream stands at corners so that no matter which corner you stand on, you need only walk one block at most to get ice cream. We allow some time for the children to puzzle over the map of Tourist Town, and they gradually produce more efficient solutions. Often, no one is able to find the optimal solution.

The children usually get an intuitive sense that Tourist Town is harder than Muddy City; the former does not seem to lend itself to solution by a quick and simple algorithm. The contrast between these two problems—one solvable in polynomial time and the other apparently intractable—provides a concrete introduction to the notion of computational complexity.

One-way functions are another fundamental topic of modern computer science accessible to children. After explaining that no one knows a good algorithm for Tourist Town, one can show that there is, however, a simple algorithm for "working backwards," i.e., starting with a set of vertices V' that is to become an efficient solution, and constructing a Tourist Town $G=(V, E)$ around it. First, one forms a number of "stars" made up of "rays" (edges) emanating from the vertices in V'. (Two rays from different vertices in V' are allowed to have a common endpoint.) This graph clearly has V' as a solution.

The second step is to "disguise" this easy-to-solve graph by adding more edges. This does not increase the number of vertices required in a dominating set, but it does make the original built-in solution harder to see. This is a nice example of the idea of a one-way function. The children may look forward to trying out on their parents the process of creating a graph for which they secretly know a difficult-to-match solution. (One-way functions such as these are the basis of modern cryptography.)

### Collective efforts

The Association for Computing Machinery Special Interest Group on Algorithms and Computation Theory (SIGACT) has formed a committee with the idea of compiling a compendium of theoretical computer science topics for children. The SIGACT compendium project was initiated at the business meeting at ACM's Symposium on the Theory of Computing last May. This project is a collective effort at science popularization, by one of the modern branches of mathematical science.

The SIGACT project joins a number of recent initiatives by professional science organizations to bring "live" science more directly to children. The Center for Discrete Mathematics and Theoretical Computer Science, located at Rutgers University, now publishes the newsletter *In Discrete Mathematics*, which contains articles on topics in discrete mathematics intended to be useful to teachers introducing discrete mathematics to their classes. The newsletter also serves as a networking service and clearinghouse for ideas and materials related to discrete mathematics in education in the lower grades. For more information, contact Joe Rosenstein at E-mail: joer@math.rutgers.edu.

The goal of the Los Alamos National Laboratories Megamath Project is to influence classroom practice by making schoolwork more like the experience one has in a good science museum. That is, the goal is to make mathematical science something in which students can actively participate.

The Megamath Project is exploring such things as (1) finding mathematics research problems that are accessible to children, (2) possible forums for children to present the results of their mathematical investigations, (3) extended projects for classroom investigation, (4) the classroom use of personal mathematics journals and (5) opportunities for children to communicate with larger mathematical communities.

The three aforementioned initiatives in discrete mathematics and computer science join other efforts involving research scientists in elementary education. These include the Mathematicians and Education Reform Network sponsored by the American Mathematical Society and the National Science Foundation, and the Scientists in the Schools programs of the national research laboratories. Many scientists are looking for more direct ways to work with children and stimulate grade-school educational reform. This seems to be an idea whose time has come.

Topics in theoretical computer science provide some ideal material for using the National Council of Teachers of Mathematics' new curriculum standards. These standards stress the importance of mathematical thinking, problem-solving, communication and connections between mathematics and the world, and represent an ambitious program for fundamental reform in mathematics education.

The idea of presenting the mathematics of computers without machines has attracted the attention of several organizations interested in promoting opportunities for women and minorities in science and technology, particularly in situations where funds for education are severely limited.

One of the sponsoring organizations of the Los Alamos Megamath Project is the American Association of Historically Black Colleges. The Kovalevskaia Fund, a foundation for women in science in developing countries, has organized lectures and demonstrations on discrete mathematics in the classroom at a number of universities in the Third World.

We believe that the computer science community has an important role in the ambitious curriculum reform projects articulated by NCTM and other organizations. Theoretical computer science includes a tremendous wealth of vivid, accessible, applicable, engaging and active mathematics in its treasury of ideas. The involvement of computer scientists in elementary education can have several effects—first and foremost in helping to clarify what computer science is really about.

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