The Center for Polymer Studies at Boston University

On Growth & Form:

Learning Probability Concepts By ``Doing Science''

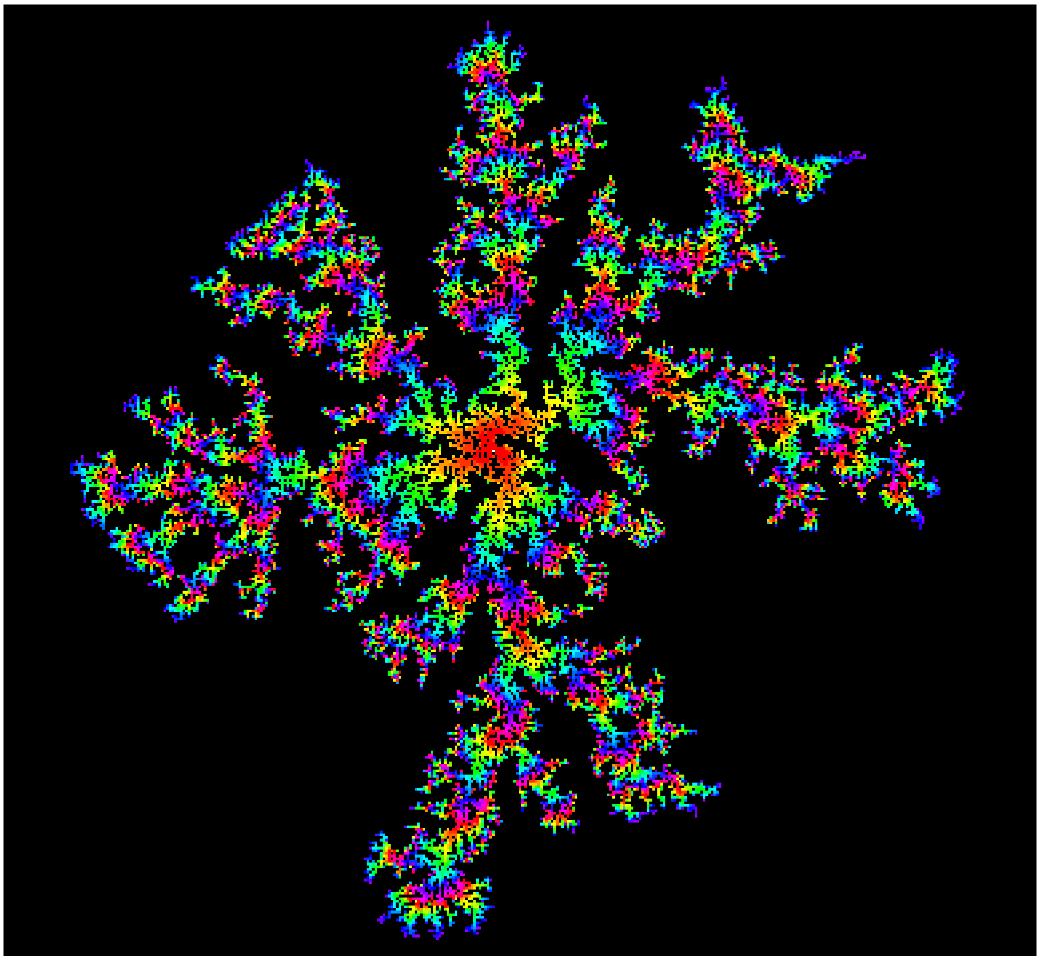

Figure 1: The Aggregation Kit

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On Growth and Form: Learning Concepts of Probability and Fractals by "Doing Science" (OGAF), assists students in analyzing fractal patterns in nature. In each module, students typically start with a hands-on activity in which they flip coins or roll dice to mimic the randomness involved in forming structures such as lightning bolts, coastlines, neurons, termite tunnels, bacterial colonies, root systems, forest growth, soil cracking, galactic distributions, mountain ranges, deltas, tides, clouds, DNA nucleotide sequencing, coral formations, and body organs. As repetitive coin flipping becomes tedious, students turn to computer simulations that use similar randomness to build very much larger structures of interest in current research. Students then carry out laboratory experiments closely coupled with these computer simulations. By varying experimental conditions and adjusting computer parameters, students test their own speculations about the fundamental processes at work.

We have tested several such student modules and have verified that using them can help restructure the classroom so that the student gradually grows into investigator, while the teacher takes on the role of mentor and advisor.

The materials developed through this AAT funding form the basis of addition projects form the basis of additional projects on materials development (**The Random Universe**), teacher enhancement (**Patterns in Nature**), and informal science (**The Dance of Chance**). These carry-on initiatives are all aimed at scaling up our approach to impact large audiences.

An example of our approach: This description of a classroom module on pattern formation by electrochemical deposition puts the high school student in nearly the same position as a graduate student. Many of the physical effects that a student sees and speculates about remain on the current agendas of research scientists. Publication of scientific papers on these phenomena continue, reporting experiments with equipment little more sophisticated than that described below.

The electrodeposition experiment uses simple equipment costing about $2.00 beyond what is usually on hand in the high school science laboratory. Development of student understanding is aided by an interactive visual computer display that models a growth process similar to the one observed in the experiment. Students manipulate computer parameters to compare results on the computer with results of the experiment.

- *Electrodeposition experiment:* A current is passed through a plastic box with copper sulfate solution. A spidery, many-branched aggregate grows between the positive and negative terminals immersed in the solution. Students record data on the deposit's radius and the electric current during the growth.
- *Data analysis:* Students scan their electrodeposition aggregate into the computer and compute its fractal dimension using Fractal Dimension programmed by the On Growth and Form project.
- *Hypothesizing:* Student teams engaged in a modeling exercise speculate on the mechanisms for the growth of the aggregate: How do the ions travel to the deposit? How do they attach? Why does the object have the branching geometry? Such speculation replicates what research scientists do at this stage of an investigation.
- *Modeling:* Student speculation on the mechanisms for the experimental results is aided by the computer program Aggregation Kit. By adjusting the program according to their hypotheses, students generate images that resemble their experimental results. To test their hypotheses, students capture the resulting modeled image and import it into the Fractal Dimension program for quantitative comparison with aggregates generated and scanned from the experiment.
- *Model testing:* Like research scientists, students test their models of aggregation dynamics by devising and performing additional experiments with different parameters (different concentrations of electrolyte, different electrolytes, different current through the cell, etc.) to determine whether results are consistent with their proposed model, as reflected in similar structures grown with the computer simulation.
- *Reporting results:* Student teams who worked on variations of the experiment and computer models meet in a "research conference" to report their findings and to propose hypothetical mechanisms that account for their results.

In the electrodeposition learning module, the experiment is carefully designed and pilot tested and the computer model of the phenomenon is provided to the student. In contrast, a graduate student studying the same subject would design or revise the experiment for him or herself and similarly design or revise the corresponding computer modeling program. However, both experiences share the common activities of growing a set of unique structures that no one has ever seen before, speculating about causal mechanisms, modeling these mechanisms, testing the model, and reporting results. Both rely on the growth of personal initiative over time. And, both approach the limits of what is currently known.

See also the final report for this project.

A number of activities, experiments, and simulation programs developed under this applications of advanced technologies project.
