COMPUTATIONAL THINKING

A PROBLEM-SOLVING TOOL FOR EVERY CLASSROOM

By: Pat Phillips
What is computational thinking?

Computational thinking is integrating the power of human thinking with the capabilities of computers.

The essence of computational thinking is thinking about data and ideas, and using and combining these resources to solve problems. Teachers can encourage students to “think computationally” by moving technology projects beyond “using” tools and information toward “creating” tools and information.

The creation of tools and new information requires thought processes about manipulating data, using abstractions, and lots of computer science concepts. To encourage computational thinking in the classroom teachers must ask different questions related to problem solving and the use of technology. They must ask:

- What are the power and limit of human and computer intelligence?
- How difficult is the problem?
- How can it be solved?
- How can technology be applied to the problem?
- What computational strategies might be employed?

Because simulations can encourage students to think about data and ideas, and about using and combining data and ideas to solve problems, simulations are helpful to engage students in computational thinking. Simulations that encourage students to think computationally often require a mathematical representation of the problem—like a story problem, and mental modeling with the symbols and processes of other disciplines. Computational thinking is a required skill for 21st Century success which teachers can foster using subject-specific simulations and modeling. Learning activities that allow students to discover and explain scientific relationships, predict events, and learn procedural skills will enable them to better understand these subjects, to predict behavior, and to build computational thinking skills.

NOTE: The following pages of this document were originally printed and cut into individual cards for each discipline. Computer science and technology teachers at the CS & IT Symposium 2008 were urged to distribute the cards to fellow teachers who taught mathematics, science, computer science, social studies, language arts, and the fine arts, and to encourage the use simulations and modeling as a way to develop computational thinking skills across the disciplines.
COMPUTATIONAL THINKING IN COMPUTER SCIENCE

AGENTSHEETS
A computational science authoring tool
scalablegamedesign.cs.colorado.edu

ALICE
Programming language based on Standard ML
www.ps.uni-sb.de/alice/

BEGINNER DEVELOPER LEARNING CENTER FROM MICROSOFT®
msdn.microsoft.com/vstudio/express/beginner/

COMPUTER SCIENCE 4 FUN
www.cs4fn.org/

COMPUTER SCIENCE-IN-A-BOX
Teach computational concepts without a computer
www.ncwit.org/unplugged

COMPUTER SCIENCE TEACHERS ASSOCIATION
The primary resource for all CS teachers
csta.acm.org/

COMPUTER SCIENCE UNPLUGGED
csunplugged.com/

INTRODUCTION TO MEDIA COMPUTATION
A media-based path into computer science
coweb.cc.gatech.edu/mediaComp-plan

PHROGRAM
A programming environment for kids
phrogram.com/

PRE-COLLEGIATE FACULTY CONNECTION FROM MICROSOFT®
www.microsoft.com/education/facultyconnection/precollegiate

SCRATCH FROM LIFELONG KINDERGARTEN
Easy to learn programming for children
scratch.mit.edu/

THE INTEGRATED CIRCUIT
http://nobelprize.org/educational_games/physics/

COMPUTATIONAL THINKING IN PHYSICAL SCIENCES

CONCORD CONSORTIUM
Free software for analyzing and manipulating data
www.concord.org/resources/browse/172/

GALILEO’S EXPERIMENTS
www.pbs.org/wgbh/nova/galileo/

GEOLOGY LABS AND EARTHQUAKE SIMULATIONS
nemo.sciencecourseware.org/

LASER CHALLENGE
nobelprize.org/educational_games/physics/laser/

MICROSOFT® FLIGHT SIMULATOR X
Free trial with 2 airports, 2 missions, and 3 aircraft
www.microsoft.com/games/pc/flightsimulatorx.aspx

Information for educators
www.fsinside.com/product/Pages/InfoEducators.aspx

NATIONAL COMPUTATIONAL SCIENCE INSTITUTE
Resources for teachers and students
computationalscience.org

NETLOGO USER COMMUNITY MODELS
A wide variety of simulations
cc.lnorthwestern.edu/netlogo/models/community/

ONLINE MATH APPLICATIONS FOR SCIENCE
library.thinkquest.org/4116/Science/science.htm

SCIENCE ANIMATIONS, MOVIES, AND INTERACTIVE TUTORIALS
An extensive list from dozens of sources
nhscience.lonestar.edu/biol/animation.htm

UNDERSTANDING SCIENCE THROUGH COMPUTING
A Web site from the U.S. Department of Energy
ascr-discovery.science.doe.gov/
COMPUTATIONAL THINKING IN MATHEMATICS

CONCORD CONSORTIUM
Free Software for analyzing and manipulating data
www.concord.org/resources/browse/172/

eNLVM INTERACTIVE ONLINE MATH LESSONS
Lessons with teacher-supplied plans
enlvm.usu.edu/ma/nav/bb_school.jsp?sid=emready&coid=all

EXPLORATION OF PROJECTILE MOTION AND AIR RESISTANCE
csip.cornell.edu/curriculum_resources/

INTERACTIVE MATHEMATICS
www.cut-the-knot.org/index.shtml

MATH FORUM
A wealth of problems and puzzles, team problem-solving, collaborations, and professional development
mathforum.org/

MATH STANDARDS
By grade level with modeling activities
standards.nctm.org/document/eexamples/index.htm

MATHEMATICS GIZMOS
www.explorelearning.com/

NATIONAL LIBRARY OF VIRTUAL MANIPULATIVES
By grade level aligned to standards
nlvm.usu.edu/en/nav/topic_t_1.html

ONLINE MATH APPLICATIONS
library.thinkquest.org/4116/Science/science.htm

TOPOLOGY AND GEOMETRY SOFTWARE
www.geometrygames.org/

COMPUTATIONAL THINKING IN SOCIAL STUDIES

ATLAS OF U.S. PRESIDENTIAL ELECTIONS
uselectionatlas.org/

CONCORD CONSORTIUM
Community Planner
www.concord.org/resources/browse/251/

CORNROW HAIR BRAIDING
The history, culture, and transformational geometry with interactive software
www.ccd.rpi.edu/Eglash/csdt/african/CORNROW_CURVES/cornrow_homepage.html

DISCOVERY CHANNEL INTERACTIVES
Your Digital Footprint and many more
dsc.discovery.com/games/games-tab-04.html

JUNK CHARTS
Analyzing data representations
junkcharts.typepad.com/

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS (NCTM)
Census data analysis with spreadsheets
standards.nctm.org/document/eexamples/chap5/5.4/index.htm

ONLINE MATH APPLICATIONS: INVESTING
library.thinkquest.org/4116/Investing/investin.htm

POLLING GIZMOS
Inferences and predictions
www.explorelearning.com/

PROJECTS FROM LIFELONG KINDERGARTEN
llk.media.mit.edu/projects.php
COMPUTATIONAL THINKING IN LANGUAGE ARTS

A SIDE OF SIMS
Suggestions for the Classroom
A sampling of simulations for elementary, middle, and high school
www.edutopia.org/node/3343

BLOGMARKS
A collection of many language arts tools and simulations
blogmarks.net/marks/tag/sms%253Alanguage%2Barts

CONCORD CONSORTIUM
Video Paper Builder (English and Spanish)
www.concord.org/resources/browse/172/

DIGITAL LITERACY
Skills for the 21st Century
“We have to get used to thinking of images, sounds and movement as raw material for construction...Students have to learn to think about the purposes for which they want to use different media when they are authoring a multimedia text.”
www.edc.org/CCT/dig_lit/web/index.html

JUNK CHARTS
Analyzing data representations
junkcharts.typepad.com/

STAGECAST
Students build and script their own simulations
www.stagecast.com/index.html

COMPUTATIONAL THINKING IN FINE ARTS

COLORJACK
A powerful color wheel simulation
www.colorjack.com/

CRAFT TECH
Software to design and construct crafts such as mechanical toys and paper sculpture
l3d.cs.colorado.edu/~ctg

CRICKETS
Create musical sculptures, interactive jewelry, and artistic inventions while learning math, science, and engineering
www.picocricket.com/

DIGITAL LITERACY
Explorations with graphics and sounds
www.edc.org/CCT/dig_lit/web/index.html

INTRODUCTION TO MEDIA COMPUTATION
A media-based path into computer science
coweb.cc.gatech.edu/mediaComp-plan

ONLINE MATH APPLICATIONS: MUSIC
library.thinkquest.org/4116/Music/music.htm

PERFECT PITCH FROM THE KENNEDY CENTER
Create an orchestra and experiment with instruments and compositions
www.artsedge.kennedy-center.org/perfectpitch/

THE PERCEPTION DECEPTION
www.cs4fn.org/illusions/
COMPUTATIONAL THINKING IN LIFE SCIENCES

BIOLOGY LABS ONLINE
nemo.sciencecourseware.org/BLOL/

CONCORD CONSORTIUM
www.concord.org/resources/browse/172/

DISCOVERY CHANNEL INTERACTIVES
Ice Map, Earth Live and more
dsc.discovery.com/games/games-tab-04.html

ONLINE MATH APPLICATIONS: SCIENCE
library.thinkquest.org/4116/Science/science.htm

PHASE CONTRAST MICROSCOPE SIMULATION
nobelprize.org/educational_games/physics/imaginglife/index.html

PhET INTERACTIVE SIMULATIONS
A wide variety of science simulations
phet.colorado.edu/index.php

SCIENCE ANIMATIONS, MOVIES & INTERACTIVE TUTORIALS
nhscience.lonestar.edu/biol/animatio.htm

SMITHSONIAN MUSEUM OF NATURAL HISTORY
www.mnh.si.edu/education/classroom_resources/studentactivities/index.html

FURTHER READING

BEGINNER DEVELOPER LEARNING CENTER FROM MICROSOFT®
Bits & Bytes and Kid’s Corner
msdn.microsoft.com/en-us/beginner/default.aspx

CENTER FOR COMPUTATIONAL THINKING
Sponsored by Microsoft® Research
www.cs.cmu.edu/~CompThink/

COMPUTATIONAL THINKING
Jeannette M. Wing, CMU
www.cs.cmu.edu/afs/cs/usr/wing/www/publications/Wing06.pdf

COMPUTATIONAL THINKING
IAE-pedia - A free education-oriented encyclopedia
iae-pedia.org/Computational_Thinking

COMPUTATIONAL THINKING PATTERNS
See the possibility of computational representation in situations
scalablegamedesign.cs.colorado.edu/wiki/Computational_thinking

GREAT PRINCIPLES OF COMPUTING
Peter J. Denning, Naval Postgraduate School
cs.gmu.edu/cne/pjd/GP/gp_overview.html