Computational Literacy in the Classroom

Introduction and STEM Ed. Possibilities

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STEM (SCIENCE, TECHNOLOGY, ENGINEERING, MATH) EDUCATION

Agenda

- Computational Literacy?
- Standards for Mathematics, Science, Engineering
- Examples of using Computational Literacy
  - Teaching to the standards (content)
  - Best practices (principles)
- Next steps

Computational Literacy, Computational Thinking

- If a true computational literacy comes to exist, it will be infrastructural in the same way current literacy is in current schools. Students will be learning and using it constantly through their schooling careers, and beyond, in diverse scientific, humanistic, and expressive pursuits.
- Computational literacy will allow civilization to think and do things that will be new to us in the same way that the modern literate society would be almost incomprehensible to preliterate cultures.

Clearly by computational literacy I do not mean "a casual familiarity with a machine that computes"

\- Andrea diSessa, Changing Minds: Computers, Learning, and Literacy

- Computational Thinking is the study and development of human capabilities and processes for solving problems, designing systems, and understanding human behavior, in order to magnify and enhance those human aspects. It has roots in mathematics, engineering, technology, and science, and draws on concepts and methodologies fundamental to the sciences in general and computer science and technology in particular.

\- inspired by the National Academies workshop on Computational Thinking

Common Core State Standards for Mathematics

The Standards for Mathematical Practice describe varieties of expertise that mathematics educators at all levels should seek to develop in their students.

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

National Framework for K-12 Science & Engineering

Scientific and Engineering Practices

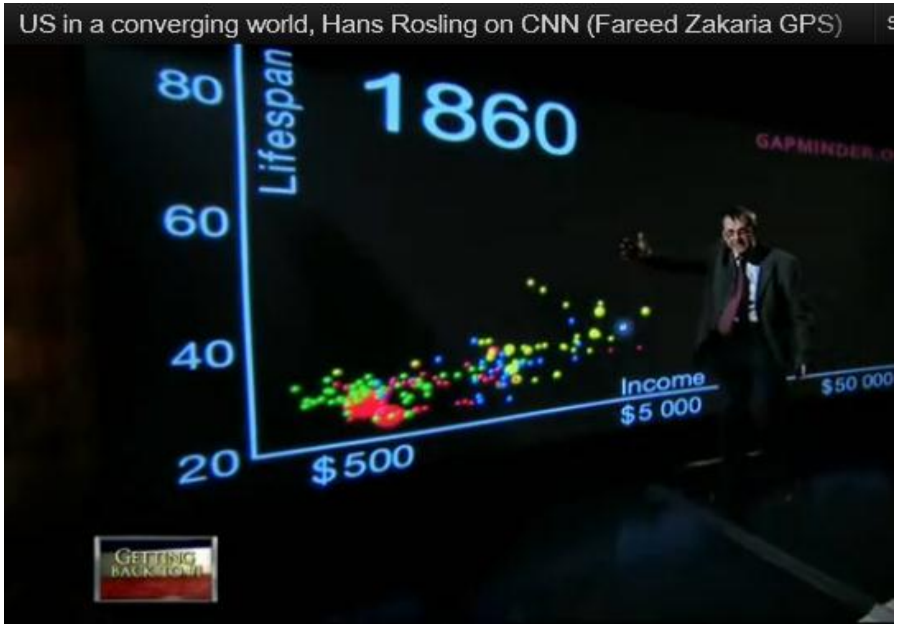
- 1. Asking questions (for science) and defining problems (for engineering)
- 2. Developing and using models
- 3. Planning and carrying out investigations
- 4. Analyzing and interpreting data
- 5. Using mathematics and computational thinking
- 6. Constructing explanations (for science) and designing solutions (for engineering)
- 7. Engaging in argument from evidence
- 8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

- 1. Patterns
- 2. Cause and effect: Mechanism and explanation
- 3. Scale, proportion, and quantity
- 4. Systems and system models
- 5. Energy and matter: Flows, cycles, and conservation
- 6. Structure and function
- 7. Stability and change

Example of Computational Literacy in Action

- GapMinder * – Hans Rosling
  - Dynamic models, relationships, statistics, information coding, meaning
  - Launch



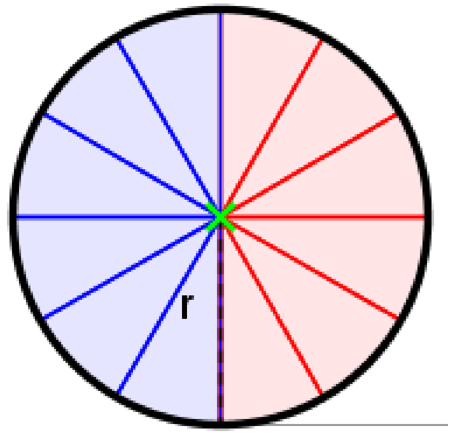
- **Common Core Standards: 8.F, 4**
  - Use functions to understand and model relationships between quantities.
  - Interpret components of the relationship in terms of the situation (real-world).

* http://www.gapminder.org/

Geometry - Circle Area

- **Common Core Standards: 7.G, 4**
  - Know the formulas for the area and circumference of a circle and use them to solve problems; give an informal derivation of the relationship between the circumference and area of a circle.

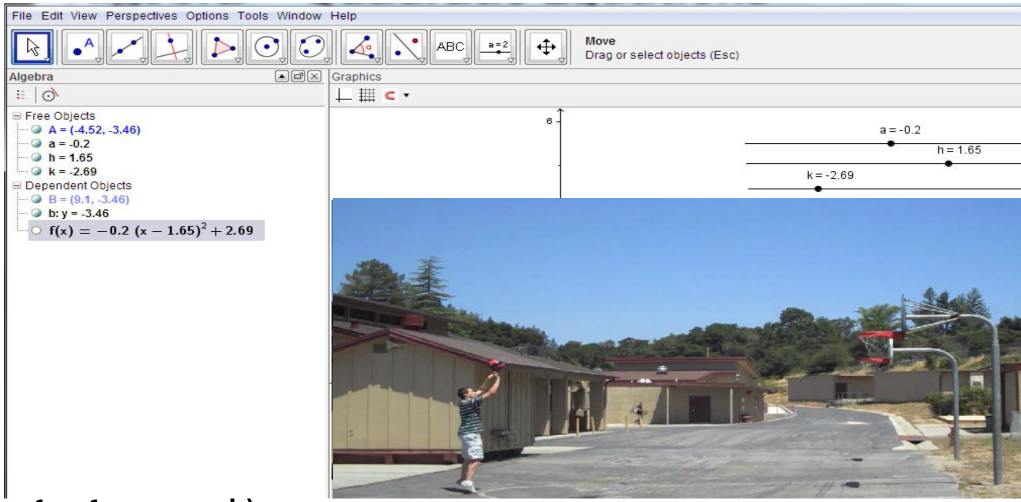
- **GeoGebra Animation**
  - Demo, exploration
  - Launch



- **Some Best Practices**
  - Build on prior knowledge (connections)
  - Make it visual, concrete, interactive
  - Raise follow-up questions
  - Plant seeds for the future (calculus)

Algebra – Quadratic Equations

- **Common Core Standards: 8.F, 5**
  - Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear).
- **Video + GeoGebra**
  - Demo [1], exploration
  - The Shot (video)
  - Prediction (GeoGebra)
  - Conclusion (video)

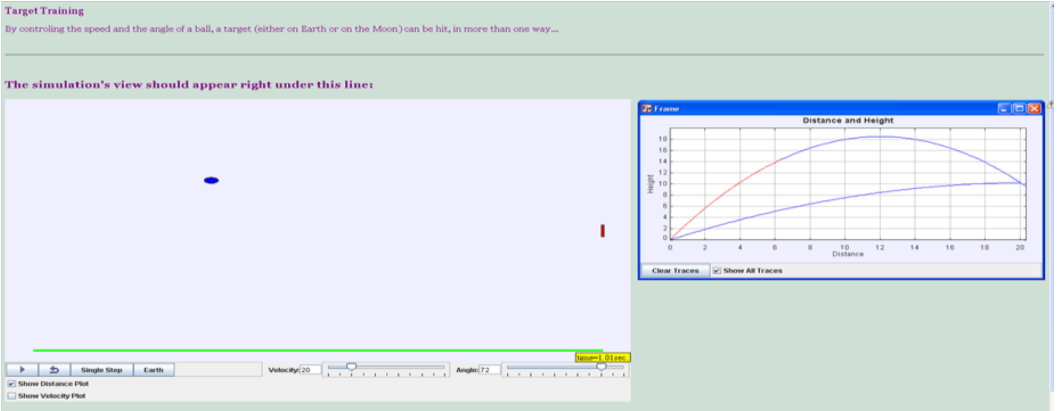


- **Some Best Practices**
  - Start with a "burning question" (engagement)
  - Show Math as a predictor (explore, verify)
  - Make connections (math + physics)
  - Make it interactive, provide immediate feedback
  - Finish (answer the question) decisively
  -

[1] – based on Dan Meyer

Physics/Math – Projectile Motion

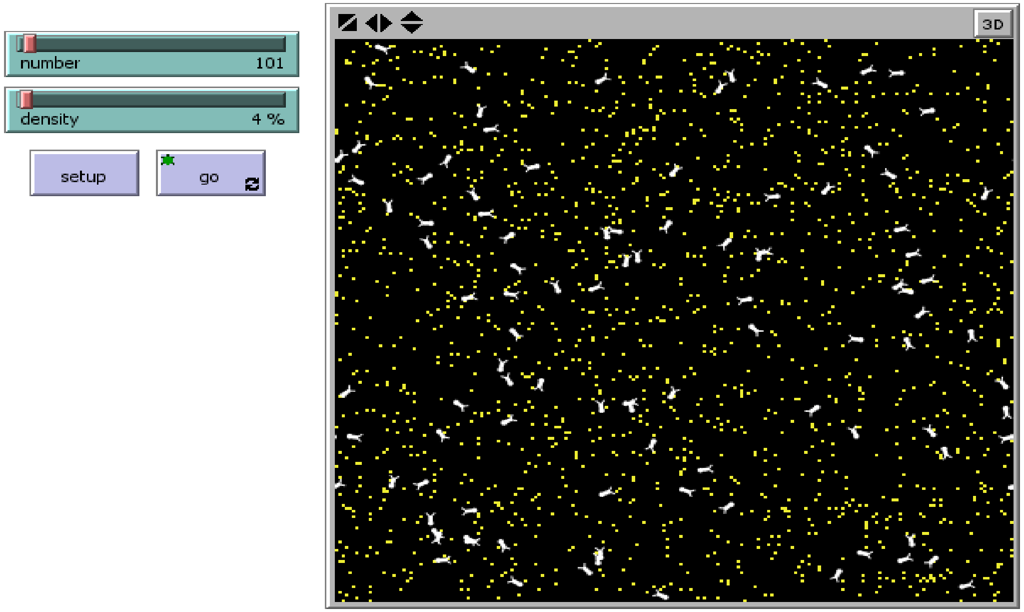
- **EJS simulation**
  - Demo, exploration
  - Target Training (balistics)
  - Motion (free fall)



- **Some Best Practices**
  - Start in the middle (using it before getting it)
  - Build hypotheses (student “skin in the game”)
  - Make connections (math + physics)
  - Create visual and immediate feedback
  - Enable rich exploration and what-if scenarios (e.g. Earth, Moon)

Biology/Science – Termites

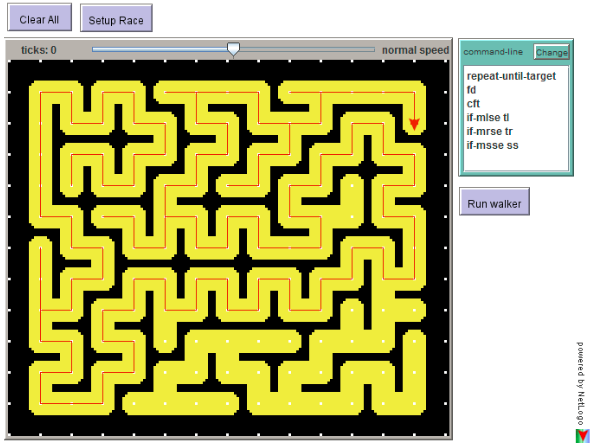
- **NetLogo simulation**
  - Explore, hypothesize
  - Launch

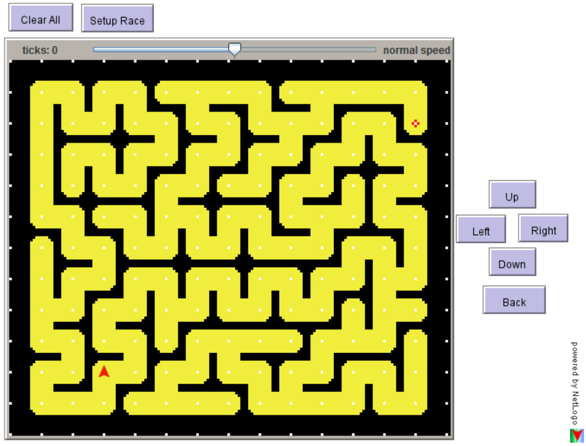


- **Some Best Practices**
  - "Systems Thinking"
  - Leverage unexpected behavior (emergent behavior/phenomena)
  - Build hypotheses ("skin in the game")
  - Explore and test hypotheses
  - Make connections (variable control, emergent behavior)

Math/Programming – Amazing Mazes

- **Common Core Standards: 6.NS , 8**
  - Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane.





- **NetLogo game**
  - Play, explore
  - Launch

- **Some Best Practices**
  - Use teamwork and competitions (games)
  - Make connections (math + programming)
  - Start in the middle; let students use it before they get it
  - Open exploration, Immediate feedback

Questions and Next Steps

- **What's your goal?**
  - Tie to standards and objectives (introductions, demos, transitions)
  - Student activities (exploration, discovery)
  - Student activities (drill & practice, skill gaps)
  - Connections to other subjects/topics

- **What would you like to do?**
  - Use existing materials as-is
  - Modify and fit
  - Create your own

- **When?**
  - Ready to explore right now
  - In 3-6 months
  - Next year
  - Never, thank you.

APPENDIX

Useful Links

- Haggai's educational web app examples
  - http://employees.org/~hmark/math/index.html
- Haggai's Ed wiki
  - http://employees.org/~hmark/wiki.html#Education
- Dan Meyer's blog
  - http://blog.mrmeyer.com/
- Hans Rosling 's GapMinder
  - On TED: http://www.ted.com/talks/hans_rosling_shows_the_best_stats_you_ve_ever_seen.html
  - GapMinder: http://www.gapminder.org/
- The National Science Digital Library
  - http://nsdl.org/
- Open Source Physics
  - http://www.compadre.org/osp/

Some Additional Best Practices

- **Make it compelling for students**
  - Introduce a conflict/question/perplexity;
  - start in the middle;
  - conclude with a "spectacular resolution"

    - Dan Meyer (dy/dan)

- **Make multiple, interdisciplinary connections**
  - Connect to prior knowledge and to actual experiences/life
  - Promotes understanding, curiosity, remembering

    - Neil Gershenfeld – MIT (Center for Bits and Atoms)

- **Upside-down mentality**
  - Using it before getting it;
  - project before problem;
  - new media = new content;
  - object before operation;
  - dynamics before statics

    - Symour Papert – MIT (Media Lab)

Guidelines/Suggestions for creating/using effective simulation-based learning activities

Define specific learning goals

The learning goals need to be specific and measurable. Many of the sims are complex and students can become overwhelmed; align the lesson with your goals.

Encourage students to use sense-making and reasoning

The activity should be geared towards encouraging the student to operate in learning mode not performance mode. What can they discover about the physics? What connections do they find? How does it make sense? How do they explain what they discover?

Connect and build on students' prior knowledge & understanding

Ask questions to elicit their ideas. Guide students' use of the sims to test their ideas and confirm their ideas or confront any misconceptions. Provide ways for them to resolve their understanding.

Connect to and make sense of real-world experiences

Students will learn more if they can see that the knowledge is relevant to their everyday life. The sims use images from everyday life, but the lesson should explicitly help them relate to their lives. As you write the questions and examples, consider their interests, age, gender, and ethnicity.

Design collaborative activities

The sims provide a common language for students to construct their understanding together. More learning happens when they communicate their ideas and reasoning to each other.

Give only minimal directions on sim use

The sims are designed and tested to encourage students to explore and make-sense. Recipe-type directions can suppress their active thinking.

Require reasoning/sense-making in words and diagrams

The sims are designed to help students develop and test their understanding and reasoning about things. Lessons are most effective when students are asked to explain their reasoning in a variety of ways.

Help students monitor their understanding

Provide opportunities for students to check their own understanding. One way is to ask them to predict something based on their new knowledge and then check the prediction with the simulation.

Simulation design principles

Good simulations:

- Use accurate, dynamic visual representations
- Show the invisible
- Provide real-time, animated feedback as learners play
- Allow actions that would be difficult or impossible in the real world
- Create a game-like environment
- Make simulations highly interactive
- Implicitly scaffold inquiry through design of controls and representations
- Provide an intuitive interface, usable without instructions

Additional web resources

- http://phet.colorado.edu
- http://nsdl.org
- http://www.teachersdomain.org
- http://www.ThePhysicsFront.org
- http://compadre.org
- http://www.tomorrow.org/speakup/
- http://paer.rutgers.edu/ScientificAbilities/The+Abilities/default.aspx
- http://edtechteacher.org/index.php/teaching-technology/tech-tools

Center for History and New Media

Classroom 2.0

Edutopia

Discovery Education: Kathy Schrock "Guide for Educators"

PBS Teachers: Media Infusion

Thinkfinity

Strategic use of tools and technology - I

- Mathematically proficient students consider the available tools when solving a mathematical problem.
- Proficient students are sufficiently familiar with tools appropriate for their grade or course to make sound decisions about when each of these tools might be helpful, recognizing both the insight to be gained and their limitations.
- They detect possible errors by strategically using estimation and other mathematical knowledge.
- When making mathematical models, they know that technology can enable them to visualize the results of varying assumptions, explore consequences, and compare predictions with data.
- They are able to use technological tools to explore and deepen their understanding of concepts.

- from the intro to the **Common Core State Standards for Mathematics**

Strategic use of Tools and Technology - II

- Both scientists and engineers use their models—including sketches, diagrams, mathematical relationships, simulations, and physical models—to make predictions about the likely behavior of a system, and they then collect data to evaluate the predictions and possibly revise the models as a result.
- Science often involves the construction and use of a wide variety of models and simulations to help develop explanations about natural phenomena. Models make it possible to go beyond observables and imagine a world not yet seen.
- Engineering makes use of models and simulations to analyze existing systems so as to see where flaws might occur or to test possible solutions to a new problem. Engineers also call on models of various sorts to test proposed systems and to recognize the strengths and limitations of their designs.
- In science, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks, such as constructing simulations, statistically analyzing data, and recognizing, expressing, and applying quantitative relationships.
- In engineering, mathematical and computational representations of established relationships and principles are an integral part of design. Moreover, simulations of designs provide an effective test bed for the development of designs and their improvement.

- from the **Framework for K-12 Science Education**

Some explicit Common Math Core Standards examples

- **6.NS , 8**
  - Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane.
- **6.EE, 9**
  - Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.
- **7.SP , 8**
  - Find probabilities of compound events using organized lists, tables, tree diagrams, and simulation
- **8.EE, 8**
  - Analyze and solve pairs of simultaneous linear equations.
- **HS.G-CO**
  - Experiment with transformations in the plane… using geometry software
  - Make geometric constructions (bisecting angle, segment; perpendiculars, parallels, etc.)