Computing
Computational Thinking

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Computational Thinking Tools

- **Not the usual suspects:** inner city, remote rural, Native American Alaska, California, Wyoming, South Dakota, Colorado, Texas, ...

- **Users**

- **Projects**
  - Programming for everyone
  - Collective simulations

- **Funding**
  - NSF
  - National Institutes of Health
  - European Union
  - Google
  - Apple

- **Platforms**
  - AgentCubes
  - AgentSheets
  - Mr Vetro
  - Inflatable Icons

- **CS curriculum from elementary to graduate school**

**SCALABLE GAME DESIGN**
**goal:** get computer science into public schools
- inner city, remote rural, Native American schools

**approach:**
1. Reinventing computer science in public schools by motivating & educating all students including women and underrepresented communities to learn about computer science through game design starting at the **middle school level**
2. Start with **game design**, move on to **science simulation building** and explore **transfer**
3. Broaden participation through getting game/simulation design into **required courses** if possible (neighborhood: keyboarding, powerpoint)

**funding:** NSF ITEST + Google, starting: CE21 Type II
Computational Thinking definition

Good news: we have come a long way

- **2009**
  - CT ≠ Programming
  - example: “grandma backing a cake”

- **2011: CSTA, ISTE, NSF:** Computational thinking (CT) is a problem-solving process that includes (but is not limited to) the following characteristics:
  - Formulating problems in a way that enables us to use a computer and other tools to help solve them.
  - Logically organizing and analyzing data
  - Representing data through abstractions such as models and simulations
  - Automating solutions through algorithmic thinking
  - Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources
  - Generalizing and transferring this problem solving process to a wide variety of problems
computational thinking tools
synthesize human abilities with computer affordances

start with question: how does a mudslide work?

visualize consequence of thinking

revise model

run model

express ideas computationally

human abilities

computer affordances
results

What kind of pedagogy should be used to broaden participation of women and minorities?
**findings**

- **Reach**: already > 4000 students in year 2 of three-year project (Alaska, Colorado, Ohio, Oregon, South Dakota, Tennessee, Texas, and Wyoming)
  - some schools: 600 students/year/school
  - starting internationally, e.g., Brazil site.

- **Broadening participation**: 45% girls, 55% boys; 44% white, 56% racial minorities

- **Motivation**: 61% of the girls, 71% of boys; 71% of white students, 69% racial minority students want to continue with similar courses

- **Learning outcomes**: Computational Thinking Pattern Analysis: every game submitted (one every 14 seconds during class) gets analyzed
motivation versus scaffolding

Towards a theory of broadening participation
Project First Pedagogy
Zones of Proximal Development

Zones of Proximal Flow

Csíkszentmihályi meets Vygotsky

projects

City Traffic
the Sims
Bridge Builder
Pac Man
Forest Fire
Space Invaders

STEM simulations

games

challenges

anxiety

ZPD

Flow

boredom

skills

0%

computational thinking patterns

100%

computational thinking patterns

then project

principles first

first project then
computing computational thinking

what can we compute and what does it mean?
computational thinking

expectation

I want to be able to walk into a classroom with game design and ask a student: “...now that you can make space invaders, can you also make a science simulation?”

– Len Scrogan, Director of Instructional Technology, Boulder Valley School District
the trouble with transfer

- good news: transfer connects well to CSTA, ISTE, NSF operational CT definition
- but:

This idea--that programming will provide exercise for the highest mental faculties, and that the cognitive development thus assured for programming will generalize or transfer to other content areas in the child's life--is a great hope. Many elegant analyses offer reasons for this hope, although there is an important sense in which the arguments ring like the overzealous prescriptions for studying Latin in Victorian times.

- Roy Pea, in Logo Programming and Problem Solving, 1987
challenges for transfer 2.0

- need to find realistic expectations
- need to find the right level representations, e.g., computational thinking patterns
  - need to make CT patterns computable
  - need to make CT patterns recognizable by people
the “right” level of representation for transfer

game

science simulation

froger

avalanche

Michotte: “Perception of Causality”

launch:

loop, if, then, else, print, ...

collision, push, pull, diffusion, hill climbing, ...

phenomena

program
computational thinking inventory
basic computational thinking patterns

- **Collision**: Frogger: Frog meets Truck
- **Push**: Sokoban: person pushes boxes
- **Transport**: Frogger: logs transport frogs
- **Generate**: Space Invaders: defenders shoot rockets
- **Absorb**: Bridge Builder: tunnel absorbs cars
- **Choreography**: Space Invaders: mother ship makes attack alien ships move left and right and descend
- **Polling / Counting**: Pacman: game over when all the dots are eaten
advanced patterns

- **Diffusion**: Electricity, Heat, rumors, toys: spread of information
- **Seeking**: Sims: people finding food
- **Collaborative Diffusion**: Soccer: players collaborate and compete
- **Multiple Needs**: Maslow’s hierarchy of needs
STEM in games

\[ u_{0,t+1} = u_{0,t} + D \sum_{i=1}^{n} (u_{i,t} - u_{0,t}) \]

sophisticated visualizations

game world

advanced math (diffusion)
transition to computational science models
computing computational thinking

Latent Semantic Analysis inspired similarity
Computational Thinking Pattern Analysis

Scalable Game Design Arcade

**Probot**

Program the robot so it can get through the maze to the flag. The commands that you can use are “forward”, “turn left”, “turn right” and “change to red” (you need to be red to cross the lava.) use the drawing tool to place the commands into the boxes. Once you have placed the commands into the boxes, press spacebar to have the robot start. R resets everything. To win you must finish the game in 12 move or less, remember, commands on the same line all happen at the same time.

**Similarity Score to Four Tutorial Games**

This score shows how much your game structure is similar to the tutorial games. Max value is 1

This game’s similarity score to Frogger: 0.624
This game’s similarity score to Sokoban: 0.715
This game’s similarity score to Space Invaders: 0.644
This game’s similarity score to Sims: 0.082

**Similarity Score Matrix**

Below Matrix shows other AgentSheets projects sharing similar programming structure.

This Matrix updates itself every 2 and half hours. It may have random projects right after your submission.
transfer?

“Now that you can make ‘Space Invaders’, can you also program a science simulation?”
ONE STUDENT MADE DIFFERENT GAMES

Game #1
- Sokoban

Game #2
- Sims
Science Simulation based on Chaos theory
Transfer
From Game Design to Science Simulation Design

Game #1 and #2

Science simulation
learning trajectories, divergence, ownership and creativity

what else can we compute?
middle school vs. college
divergence

difference between *Your* game and *Tutorial* game

Divergence Score \((u, v)\) is given by:

\[
\sqrt{\frac{\sum_{i=1}^{n} (u_i - v_i)^2}{n}}
\]
divergence in Sandy’s classes
questions

- divergence $\Rightarrow$ ownership?
- divergence $\Rightarrow$ creativity?
- ownership $\Rightarrow$ creativity?
- what is social divergence/ownership/creativity?
conclusions

- we can compute computational thinking
- there are early indicators for transfer between game design and science simulation design. But need to be careful:
  - do not confuse correlation with causation
  - investigate role of teacher to scaffold concepts to be transferred.
thank YOU!

scalable
game design

http://scalablegamedesign.cs.colorado.edu