CS Integration

to Enhance Disciplinary Learning

Thanks to the generous support of NSF ITEST, DRK-12, CE-21, and STEM+C programs: MIT's Making Sense of Models, award #1934126; AMNH's Decoding Urban Ecosystems, award #1934039; EDC's Computational Science Pathway Option for MA HS Students, award #1934112, and NSF DRK12 #1503383 / 1639069; NSF ITEST #0639637.

WELCOME

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MIT STEP Lab &
Distinguished Scholar
EDC

CS Integration Projects: (2003-present)

- NM Adventures in Modeling
- Project GUTS
- New Mexico CSforALL
- Teachers with GUTS
- Making Sense of Models
- DecodeNYC
- Science+C
- Developing AI Literacy
- Everyday AI for Youth

Scheller Teacher Education Program education arcade

EDC Education Development Center

150 YEARS | American Museum of Natural History

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Why Integrate CS across the Curriculum?

- To engage K-12 students in CS,
- To address CS and Disciplinary standards,
- To bypass difficulties of offering stand-alone CS classes,
- To modernize Disciplinary curricula,
- To introduce all students to CS in an equitable fashion,
- To expose students to the work of disciplinary professionals.

What's missing?

Why Integrate CS across the Curriculum?

- To engage K-12 students in CS/CT,
- To address CS and Disciplinary standards,
- To bypass difficulties of offering stand-alone CS classes,
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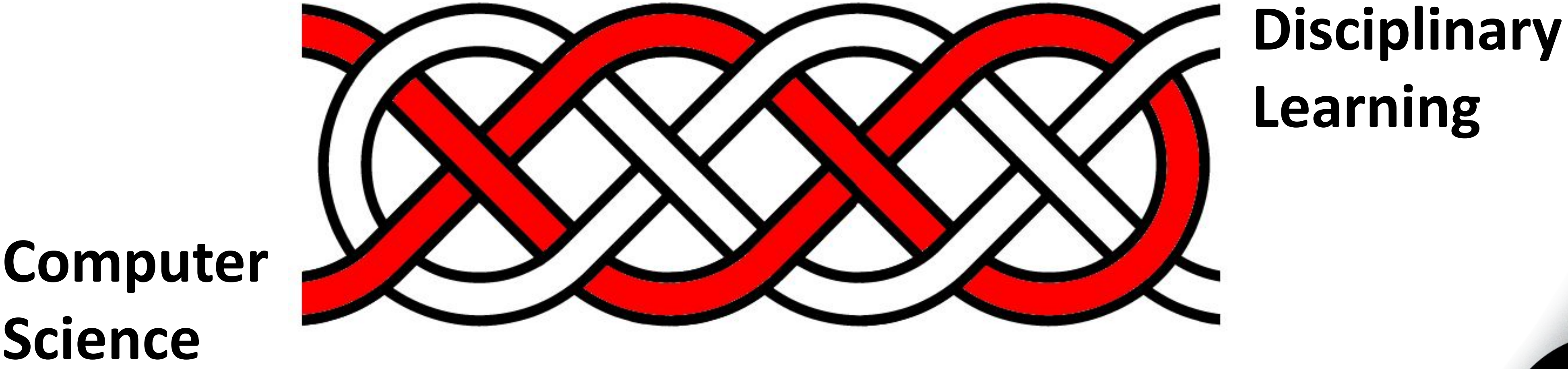
- To expose students to the work of disciplinary professionals.

What's missing?

- To **ENHANCE** disciplinary learning

WHAT is CS integration?

Definition:
CS integration is the ***interweaving*** of CS with disciplinary learning.



Reinforces - won’t untwist
Strengthens - doubles up
Extends - enables new uses…

WHAT is CS integration?

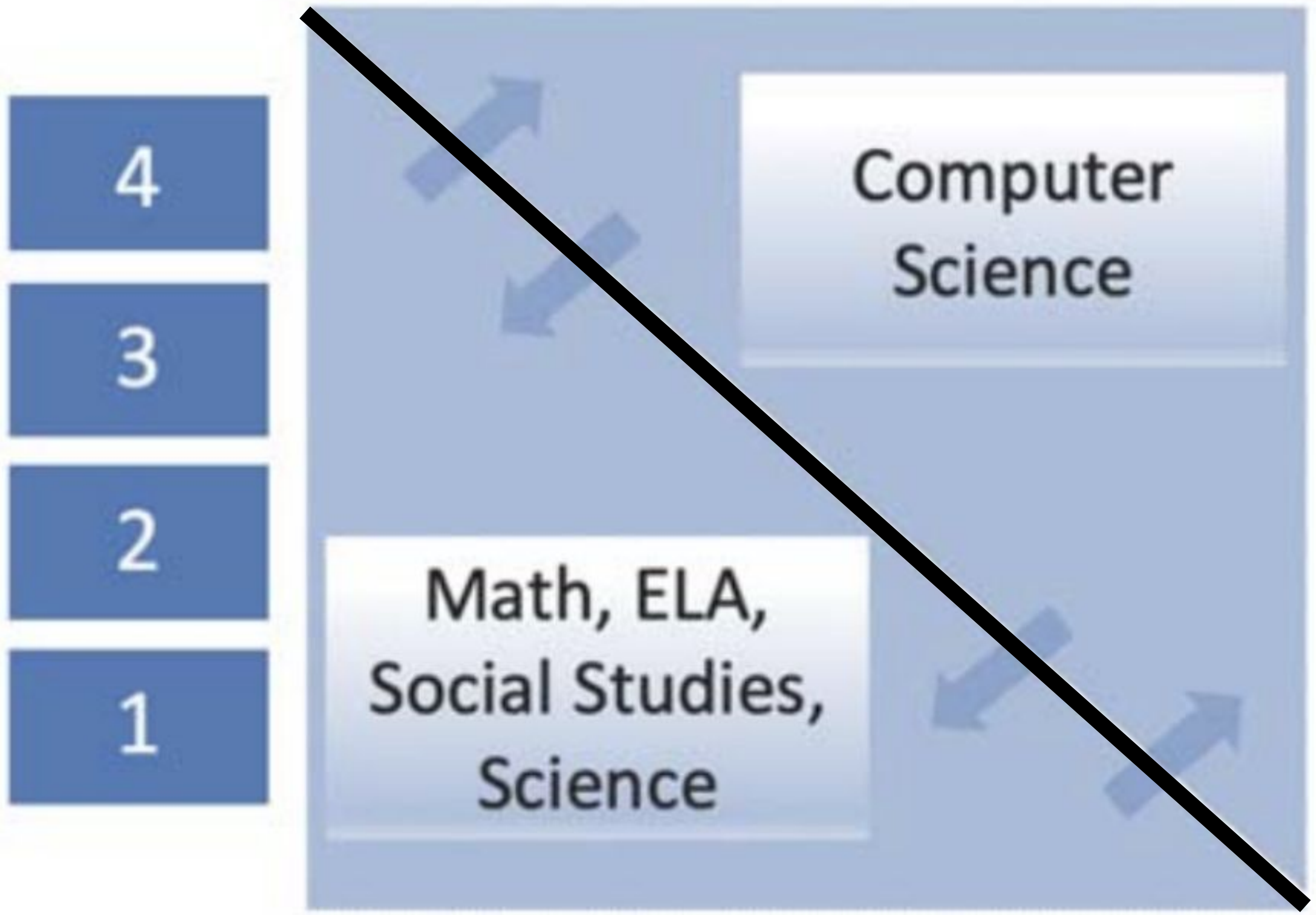
Where CS (computer science) is

> “the study of computers and algorithmic processes, including their principles, their hardware and software designs, their applications, and their impact on society.“

(Tucker et. al, 2003, p. 6 of CSTA Model Curriculum 2003)

Levels of CS integration

CodeVA's CS Integration Planning Guide Model



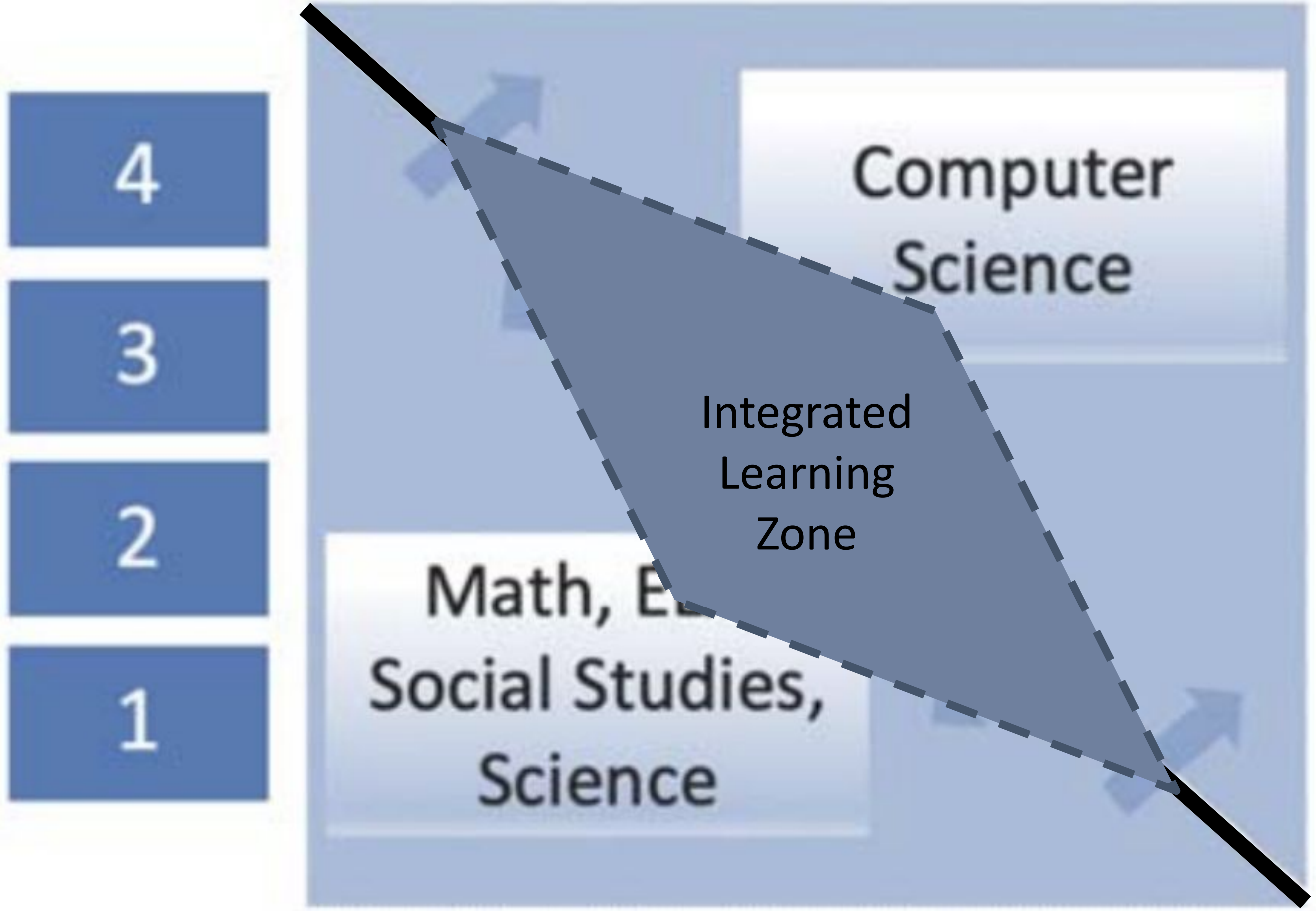
Levels of CS integration.

The optimal integration level will be different for every lesson **based on lesson objectives.**

Note:
The numbering of levels does not indicate an optimal level.

Levels of CS integration

CodeVA's *CS Integration Planning Guide Model*



Levels of CS integration.

But, perhaps, in this integrated learning zone, learning objectives in both domains can be met simultaneously.

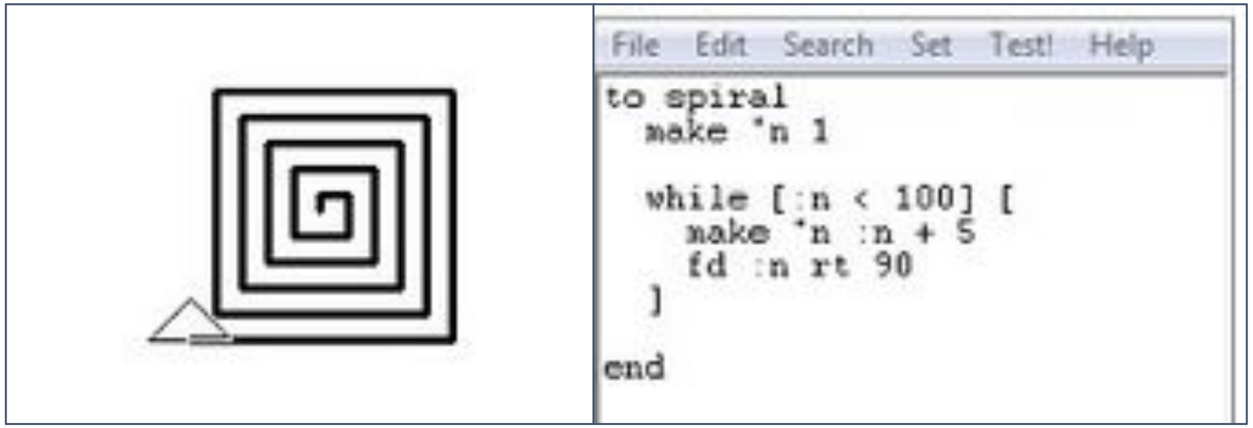
Thus creating overlapping of learning within the same lesson thereby "doubling up" on the potential learning.

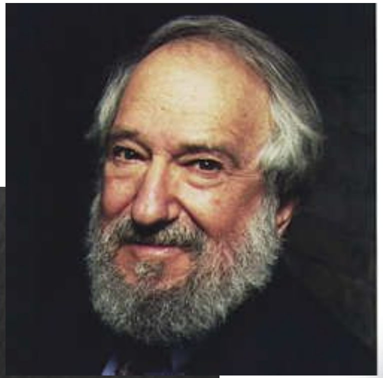
How has CS integration been achieved?
Early Examples

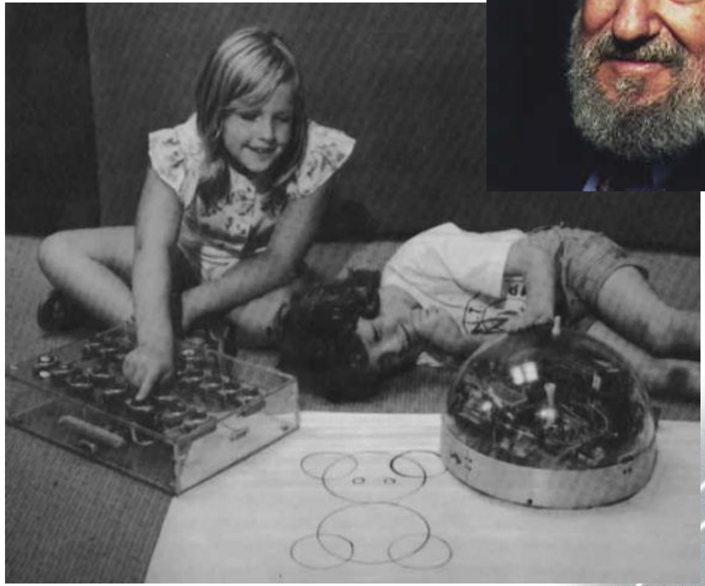
Early examples of CS Integration were primarily adding programming activities within other subjects (such as math classes).

Seymour Papert (1928-2016) Inventor of Logo language

Mindstorms (1980)







How is CS integration Achieved? 2011- present

CS integration is being addressed through **Computational Thinking:**

> "Computational thinking is the [human] thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information- processing agent [a computer]." (Wing, 2006 & 2011)

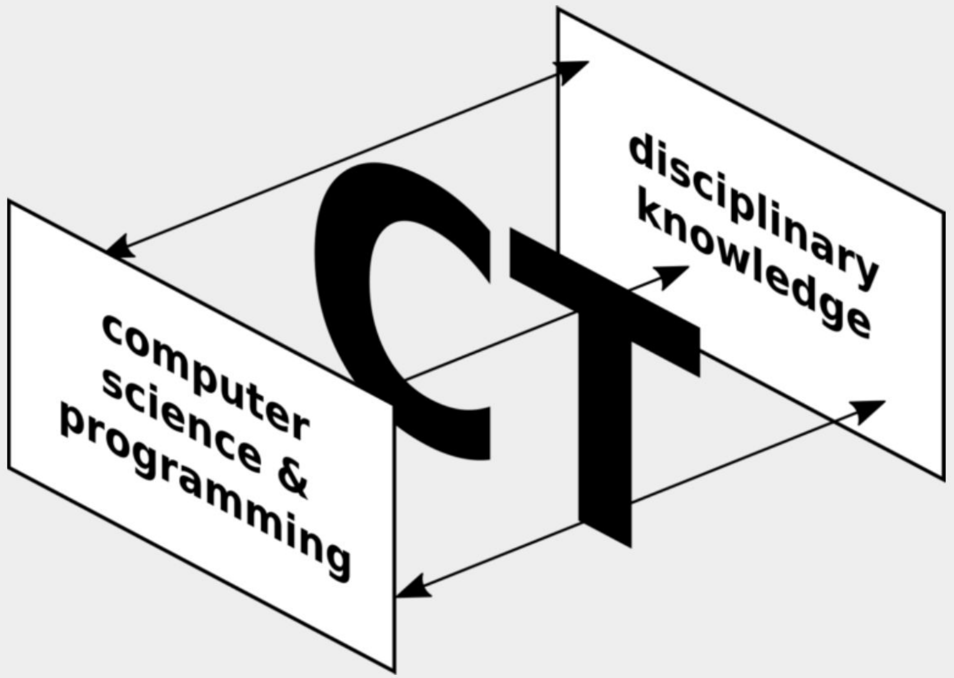
https://dl.acm.org/doi/10.1145/1118178.1118215

Computational Thinking

- **Formulating problems** in a way that enables us to use a computer to help solve the problems.
- Logically **organizing and analyzing data**
- **Representing problems through abstractions** such as in models and simulations
- **Automating solutions** through algorithmic thinking (a series of ordered steps)
- **Implementing, testing, and analyzing** potential solutions
- **Generalizing and transferring** this problem solving process to a wide variety of problems

ISTE/CSTA Operational definition of computational thinking, 2011

How is CS integration Achieved? 2011- present



— Visualization of CT as "connecting tissue" between CS/programming and disciplinary knowledge of the world

http://advocate.csteachers.org/2018/02/17/rethinking-computational-thinking/

Computational Thinking

- connects disciplinary knowledge with CS concepts & programming
- is the knowledge, skills set, and dispositions of intermediating between these two.

Levels of CT integration

Waterman, Goldsmith, and Pasquale (2020), Coenraad et al. (2021)

Exist: Elaborate on CT **that already exists** in the lesson

Enhance: Add several CT tasks to **enhance the disciplinary concept**

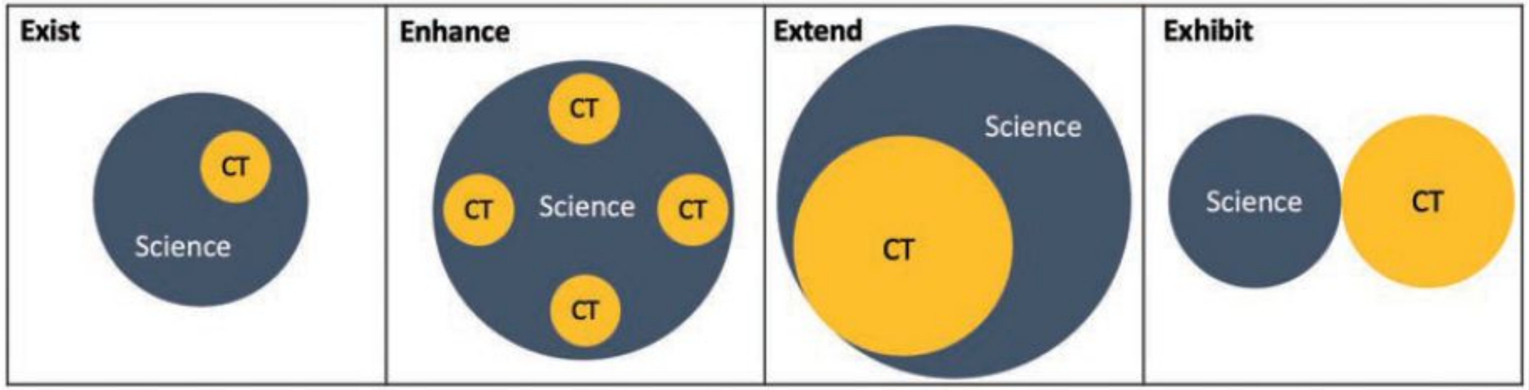
Extend: Add CT, typically programming, to **extend students' disciplinary learning**.

Waterman, Goldsmith, and Pasquale (2020)

and

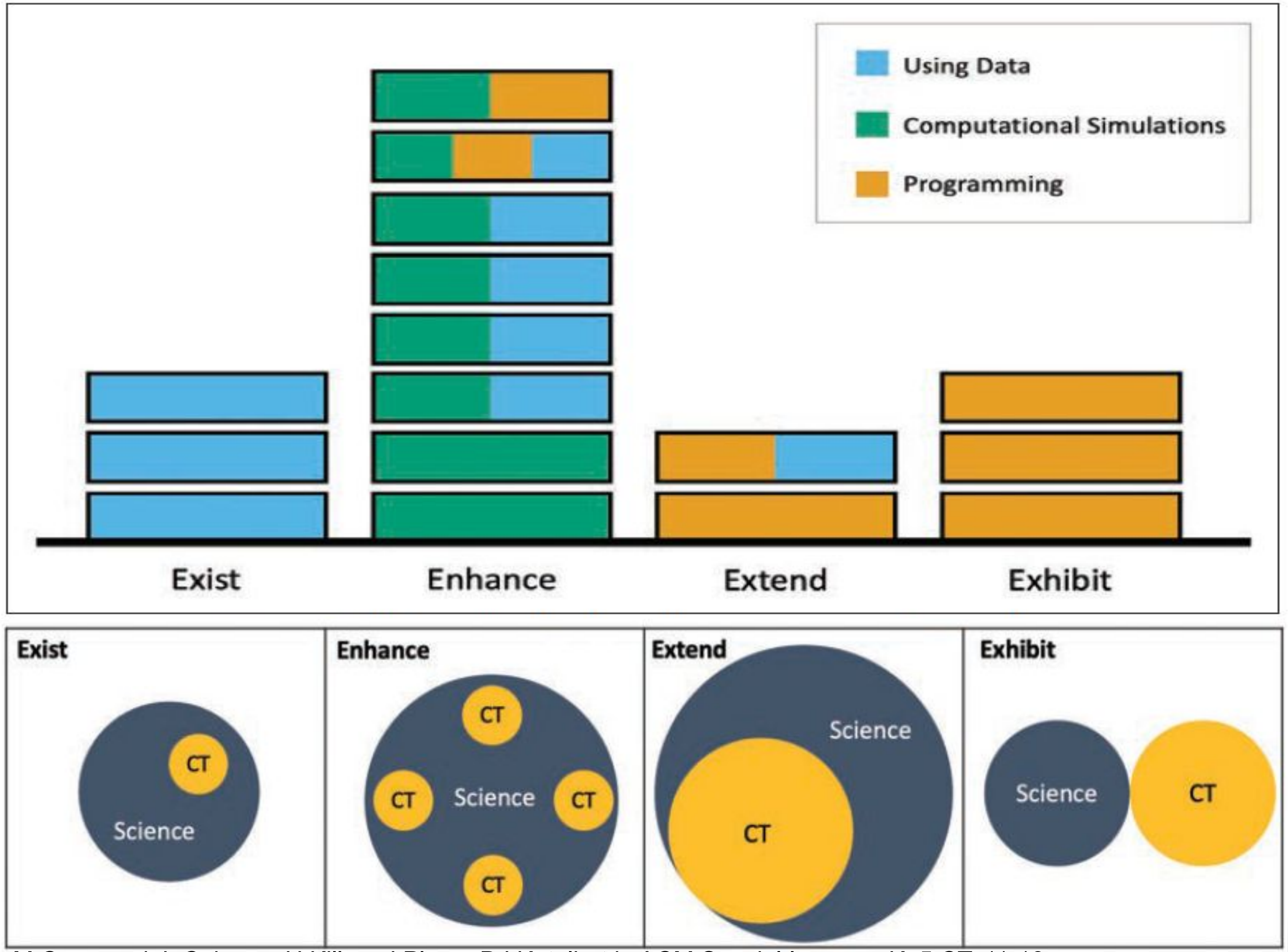
Exhibit: Add tasks to **Exhibit knowledge** gained through other means.

M Coenraad, L Cabrera, H Killen, J Plane, DJ Ketelhut in ACM Special Issue on K–5 CT, 11-18



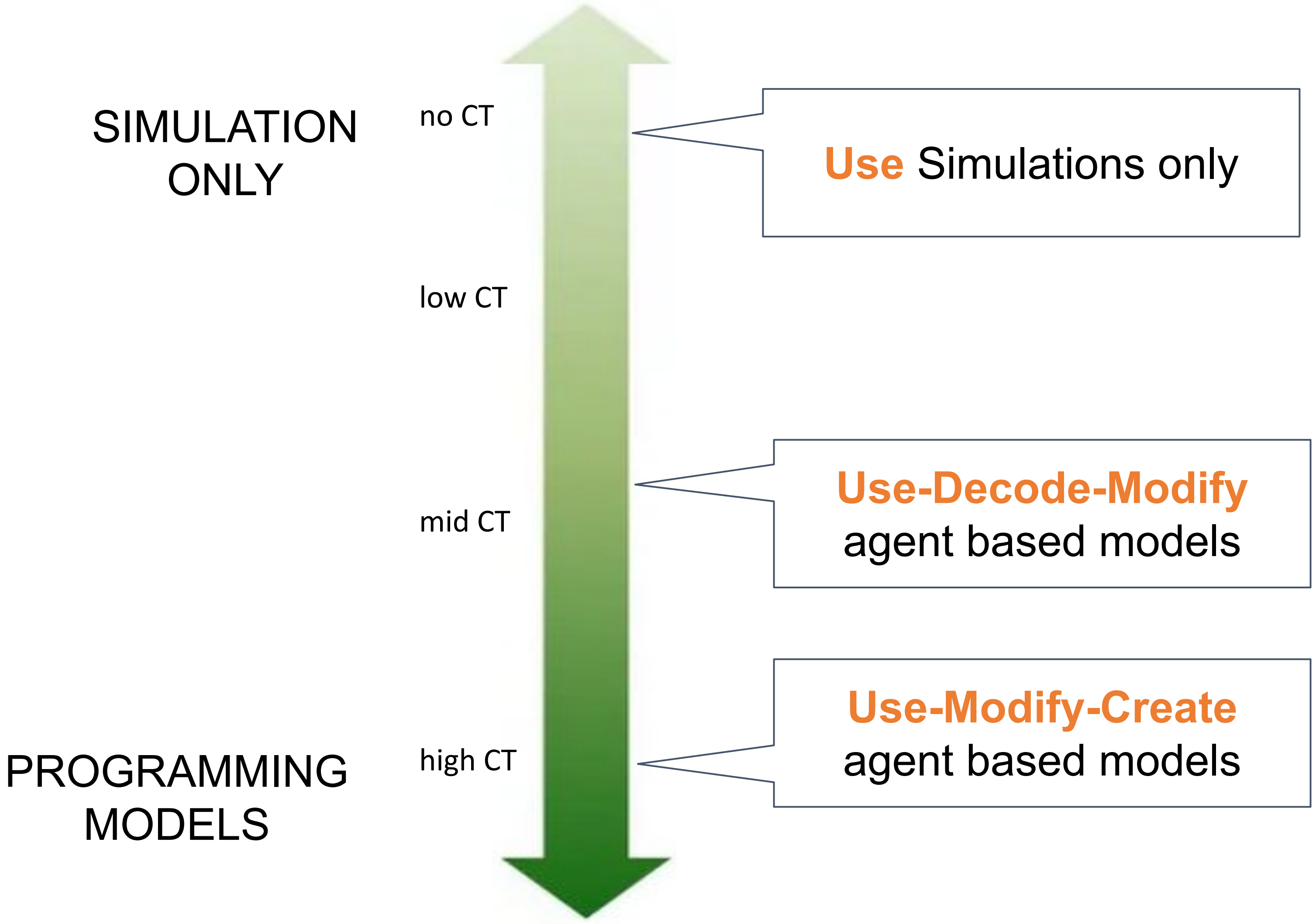
Breadth of Teachers' Integration of CT practices

Coenraad et al. (2021)



M Coenraad, L Cabrera, H Killen, J Plane, DJ Ketelhut in ACM Special Issue on K–5 CT, 11-18

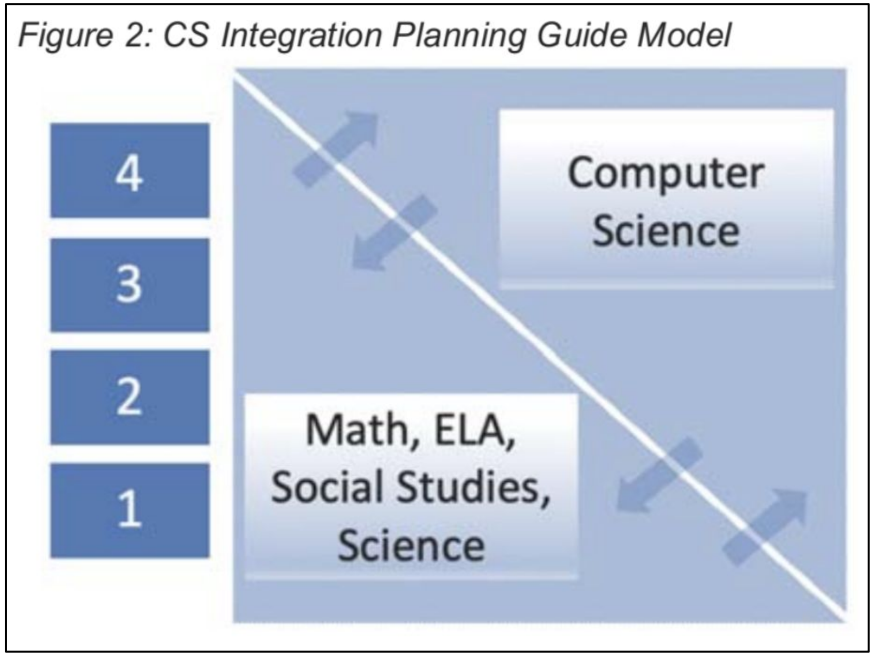
Depth of CT Integration in Modeling and Simulation



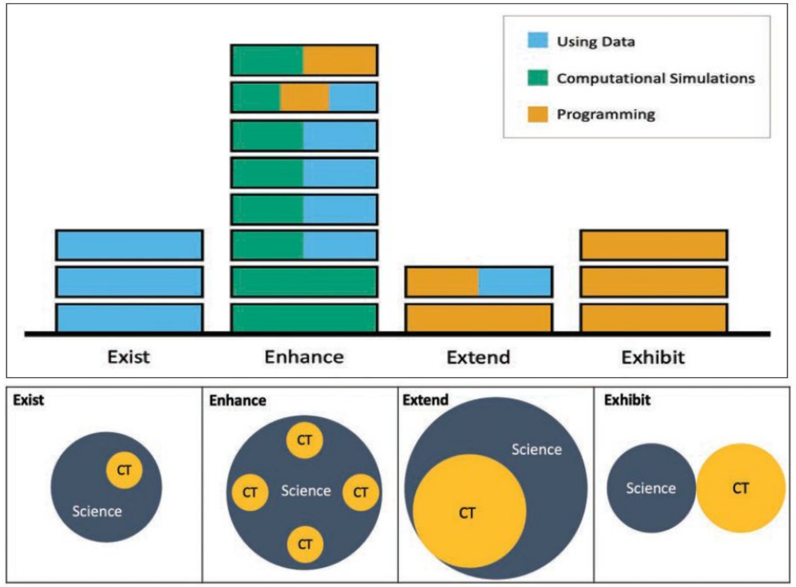
Science+C sldie

CS integration: Long, Wide, and Deep

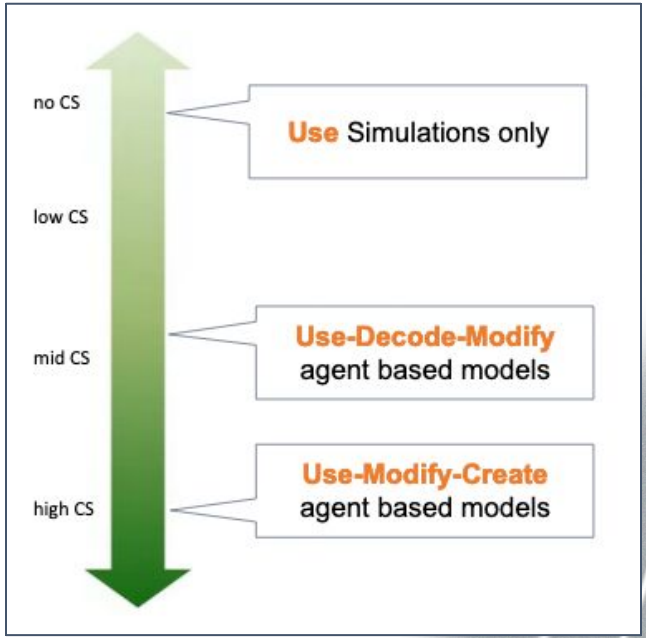
HOW LONG?



HOW WIDE?



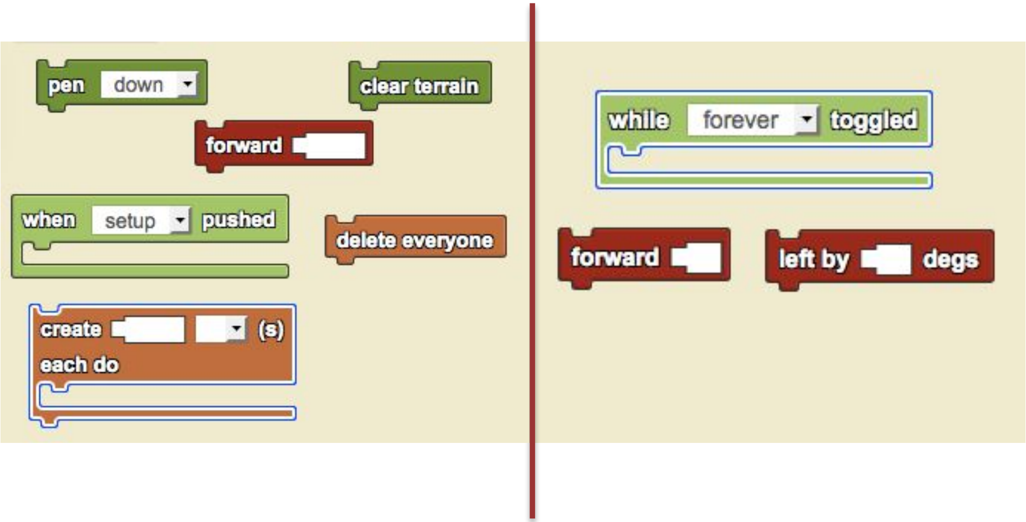
HOW DEEP?



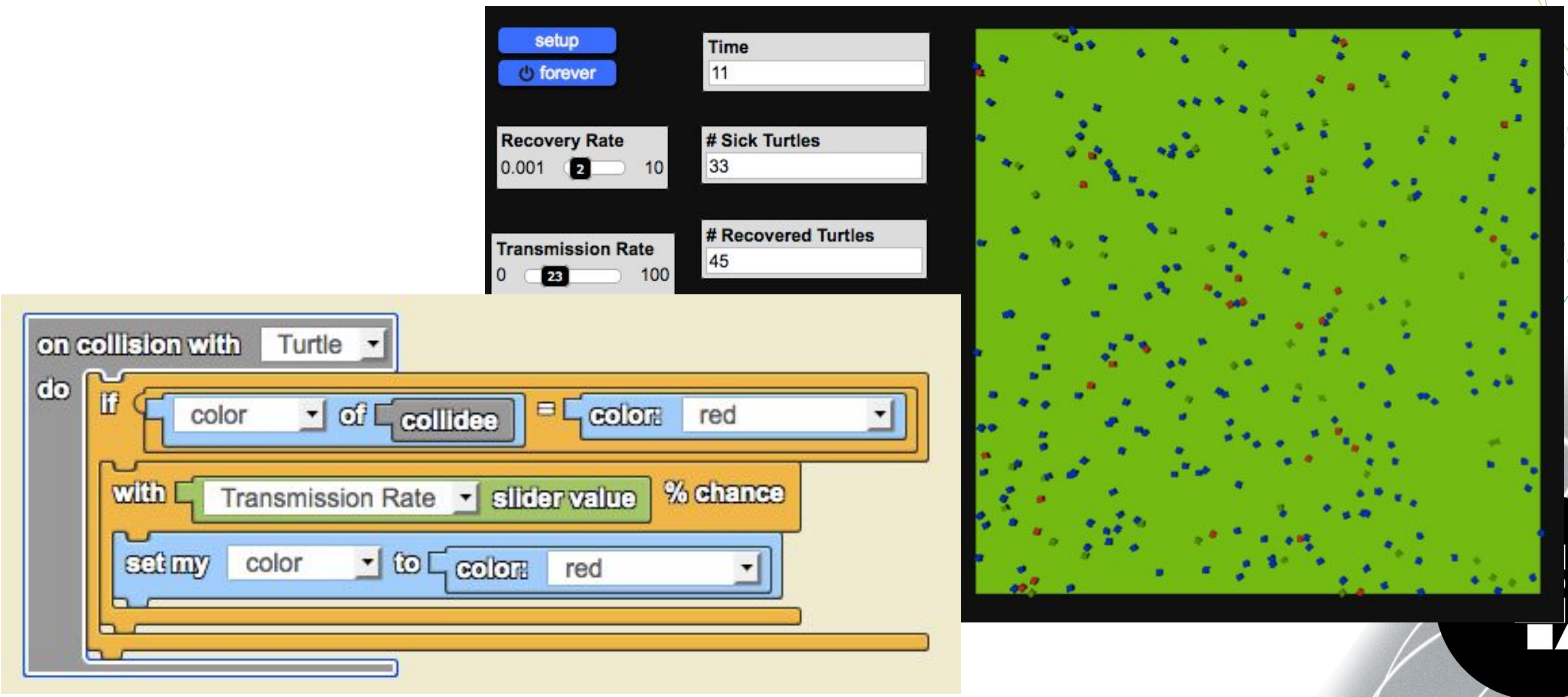
Two approaches:

1. Learn to Code, Code to Learn
2. Decoding

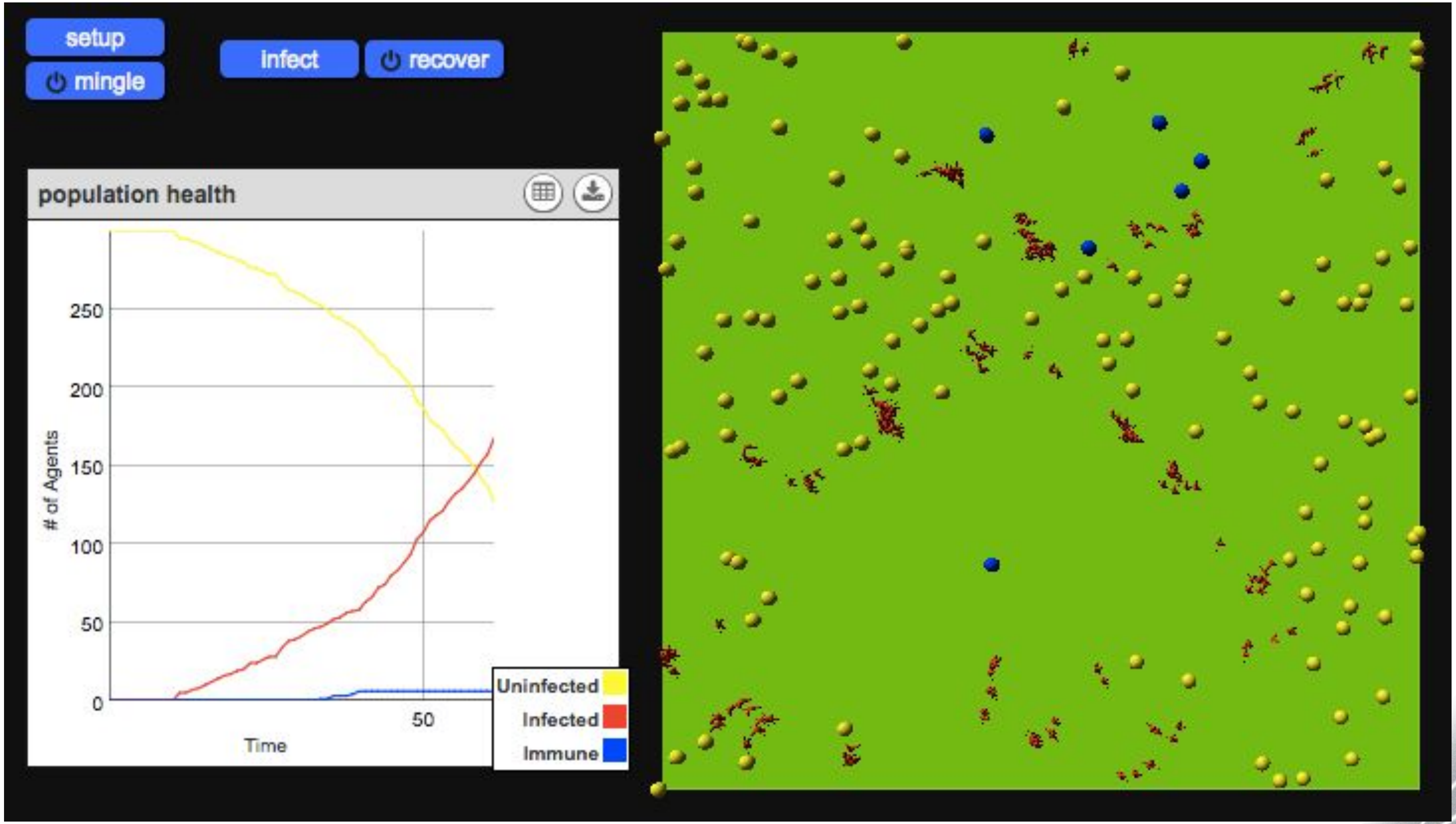
Learn to Code



Learn to Code



Learn to Code



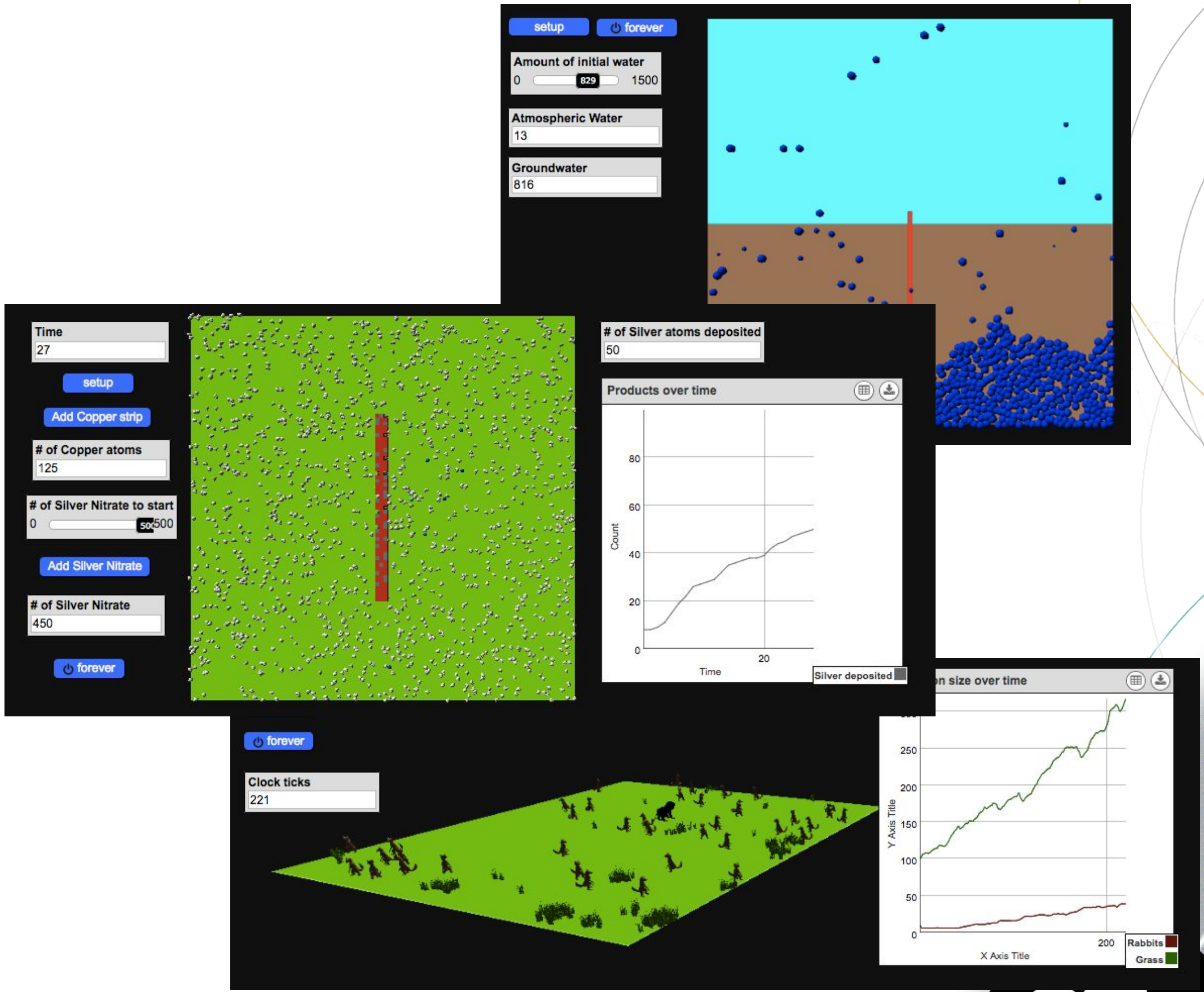
→ Code to Learn

Use models to run simulation experiments.

Modify models to answer new "what if" questions.

Run models and see the impact of the modifications made. Connect to science.

Create
Through a series of modifications what was once someone else's is now one's own.



In Project GUTS

Computer models are “objects to think with.” Resnick et al., 1996, p.449

Coding is a means to create models that can be used to understand natural processes.

FINDINGS:

Early Project GUTS findings on learning & self-efficacy (2008-2011)

CT skills: (artifact review, n=410) 82% created a working model.

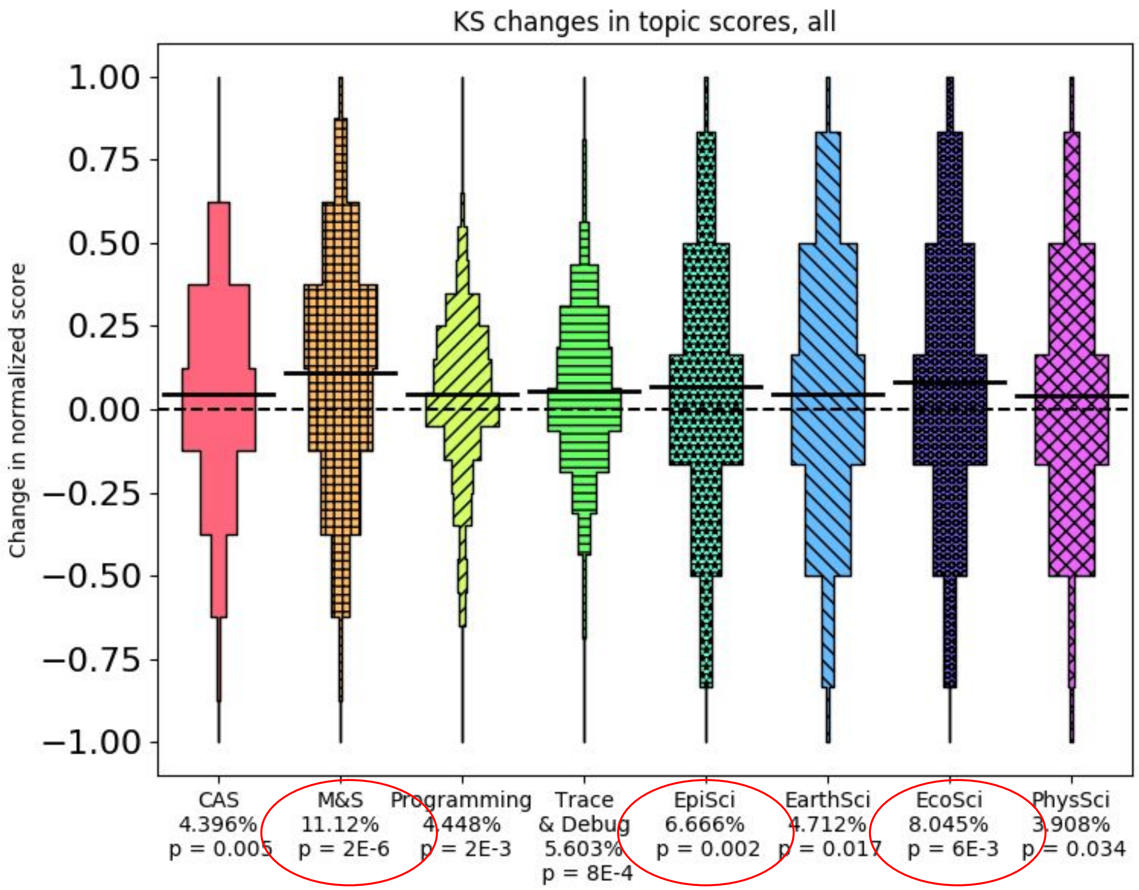
Scientific modeling and Complex Systems science knowledge and skills: (survey, n=64) when analyzing a model of a complex system.

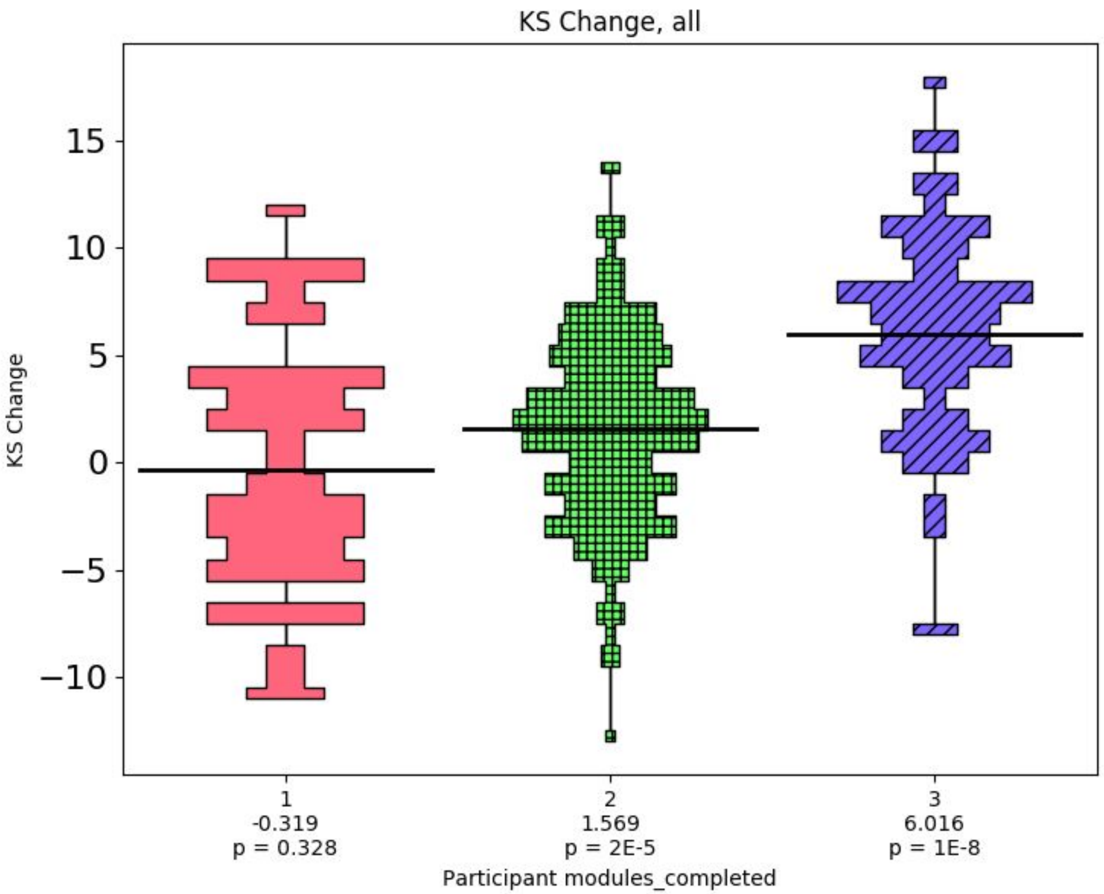
100% identified entities that were included,
91% identified simple rules / algorithms,
88% identified cause-effect interactions,
79% identified an emergent pattern, and
24% identified a feedback loop.

Self-efficacy in Programming: across tasks 46 - 63% agreement with the statement "I know how to ___"
(find the blocks I need, use the blocks to create a program, add variables to my model, and make graphs)

FINDINGS:

Teachers with GUTS PD Program (2016-2019) n=161 middle school students (with matched pre- and post-)
Change in total scores: Mean = 2.213; Sign test: p = 5E-9; Signed rank p = 1E-10
Reliability of student KS-CT: Cronbach's Alpha of .97 on pre; .976 on post





PROBLEMS OF PRACTICE

We heard from science teachers:

- Steep learning curve for programming.
- No time to teach CS and programming within core subjects.
- Teaching programming was not seen as part of their role.

What we learned:

- Teachers were comfortable with canned simulations BUT because they limit what students can do and learn about the underlying model they are not aligned with CT.
- Implementation rates in classrooms was low.
- Students didn’t always see connections between coding and disciplinary concepts.

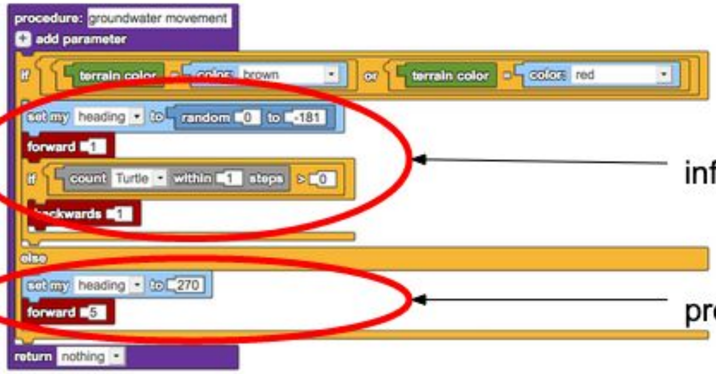
Another Approach: DECODING

Decoding is:

- An approach to integrating CS/CT within disciplinary contexts
- It features reading and interpreting code to understand how disciplinary concepts and processes are embedded in models.
- An alternative to teaching students how to code in the disciplinary classroom.

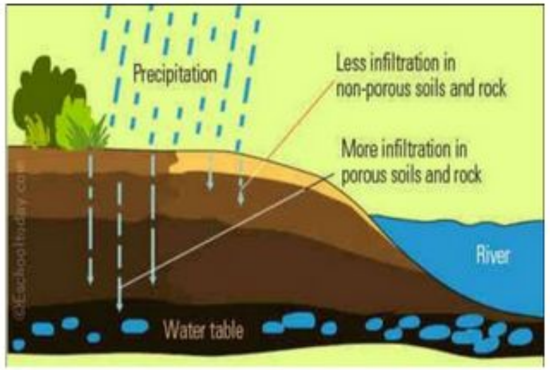
Decoding to Assess models (in Science)

Mechanism in model of phenomenon ← Correspondence between → Scientific process in real world phenomenon



infiltration

precipitation

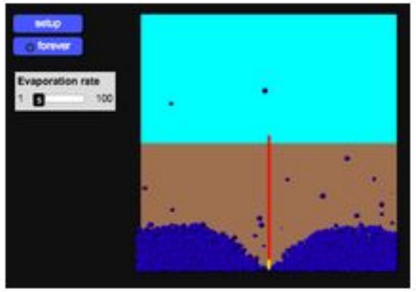


Step 1: identify and label the code segments that represent a scientific process.

Step 2: compare student knowledge of scientific process to mechanisms in code

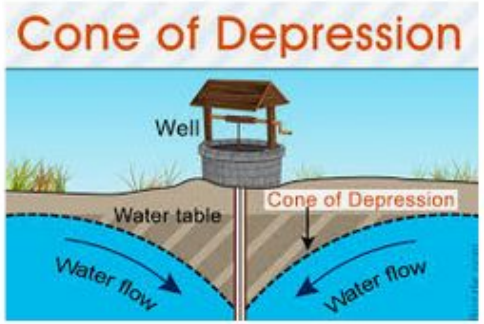
Step 3: assess whether the mechanism in code is a reasonable representation of students' understanding of scientific process. (Different porosity is missing)

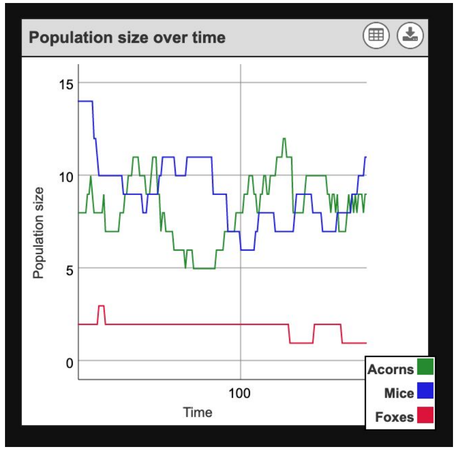
Decoding to Assess models (in Science)



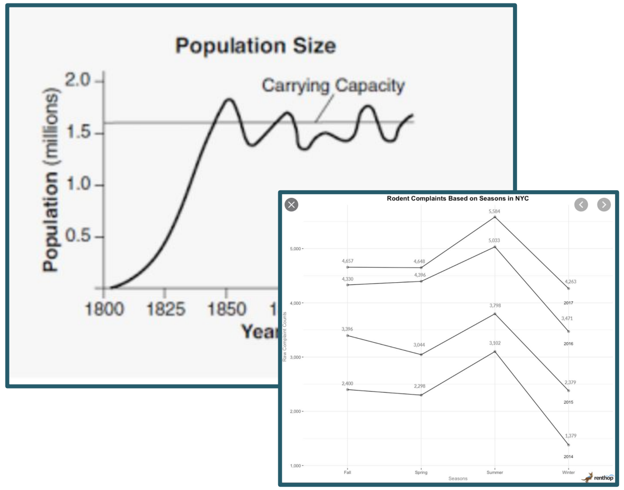
Does running the model reproduce the phenomeon? (Face validity)

Step 4: With respect to complex systems phenomenon, determine if the patterns generated by running the model (simulation) are similar to ones seen in the real world.





Do the patterns my model produced match real-world data patterns?



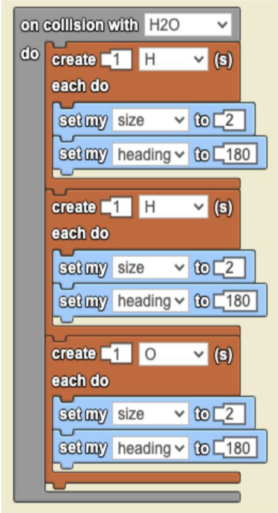
FINDINGS:

MIT's Making Sense of Models, NSF STEM+C #1934126, PI Lee / Co-PI Klopfer

Audience: 6th grade teachers & students in regular school day math and science classes.

Q: Does learning to encode processes in math class lead to the ability to decode similar processes in models within science class?

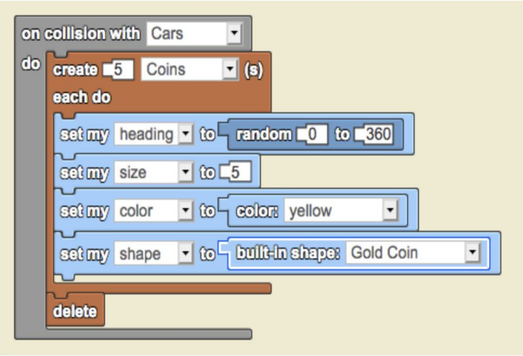
Science + CS

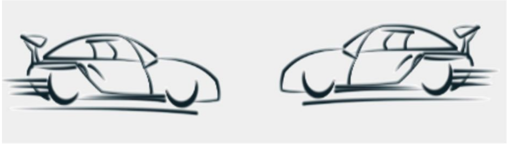


What does this code show?

1. Molecules break down into atoms when they collide
2. Water molecules can change their size under different conditions
3. Water molecules move around
4. Water molecules can change shape under different conditions

Math + CS

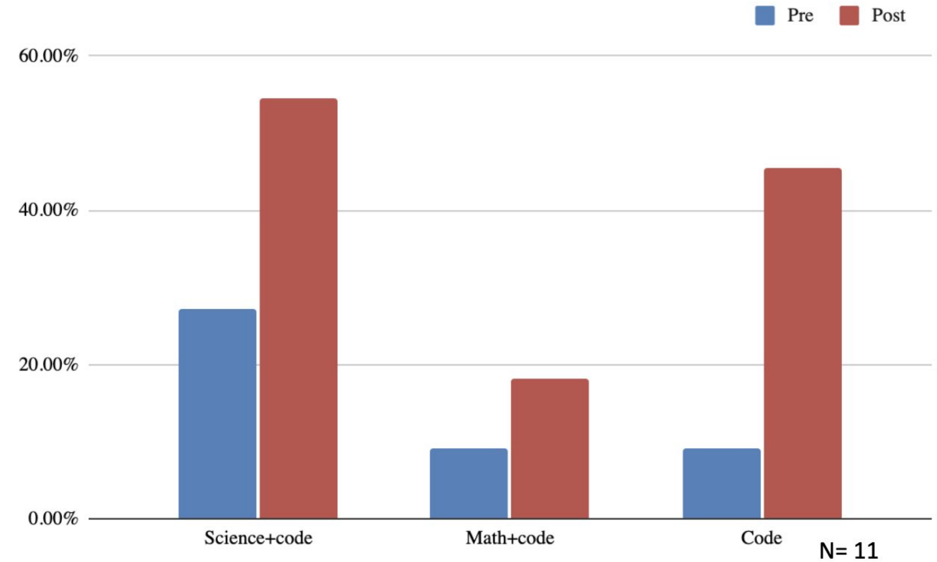




The program above is from a video game of racing cars. When 2 cars bump into each other (or "collide"), each car makes a certain number of coins.

What will the **ratio of cars to gold coins** in the game after two cars collide into each other? Explain your reasoning

Preliminary results



N= 11

FINDINGS:

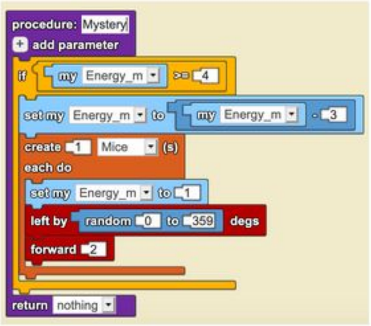
AMNH's Decoding Urban Ecosystems, NSF STEM+C #1934039, PI Gupta / Co-PI Lee

Audience: middle school students, Out of School Time programs.

Q: What is the impact of the intervention on students' learning of CT and ecosystem concepts?

Can students identify scientific processes embedded in code?
To what extent does this identification require scientific and CS understanding.

Mix: What process is represented in this code?



A) Predation
B) Reproduction
C) Death
D) Infection

Sci: During the birth of an offspring, the mother typically

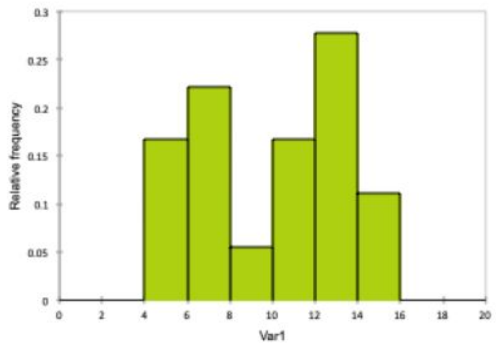
A) Gains energy.
B) Loses energy.
C) Stays the same, neither gains nor loses energy.
D) Takes energy from her offspring.

CS: What does the following code do?

Set Energy = Energy - 5

A) Sets the Energy to - 5
B) Decreases the Energy by 5
C) Increases the Energy by 5
D) Sets Energy to 5

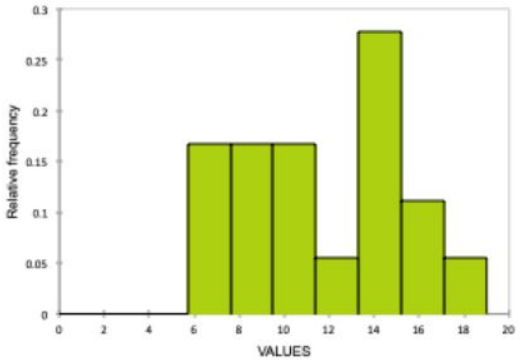
Treatment group pre-test histogram



In the treatment group pre-test: (n = 18)

i) Average raw score: 9.5 out of 19 (50%)
ii) Standard deviation: 3.417
iii) Distribution: bimodal

Treatment group post-test histogram



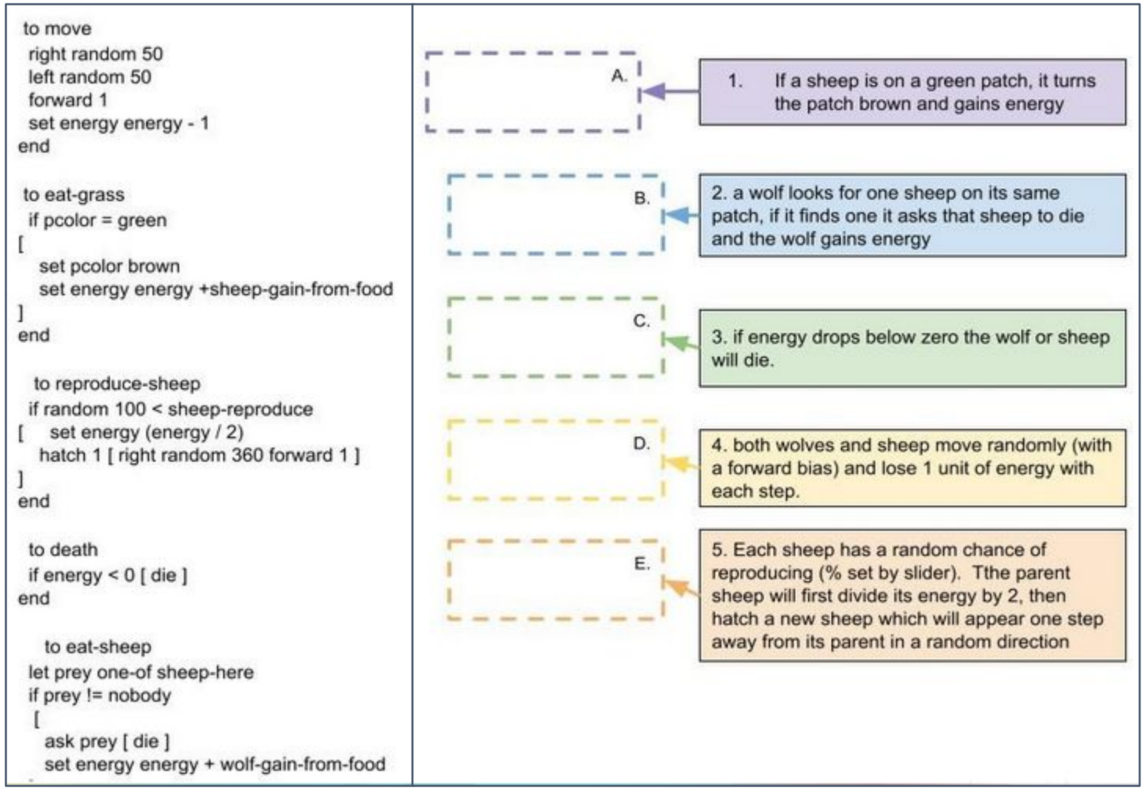
In the treatment group post-test: (n = 18)

i) Average raw score: 12 out of 19 (63%)
ii) Standard deviation: 3.911
iii) Distribution: possibly bimodal

FINDINGS:

EDC's Computational Science Pathway Option for MA HS Students, NSF STEM+C #1934112, PI Malyn-Smith, Co-PIs Lee & DeMallie. Audience: high school teachers & students in school

Q: Do students in Science+C courses demonstrate: a) higher levels of CT skills, b) higher achievement in science than those in trad. science classes?



How does CS Integration ***enhance*** disciplinary learning ?

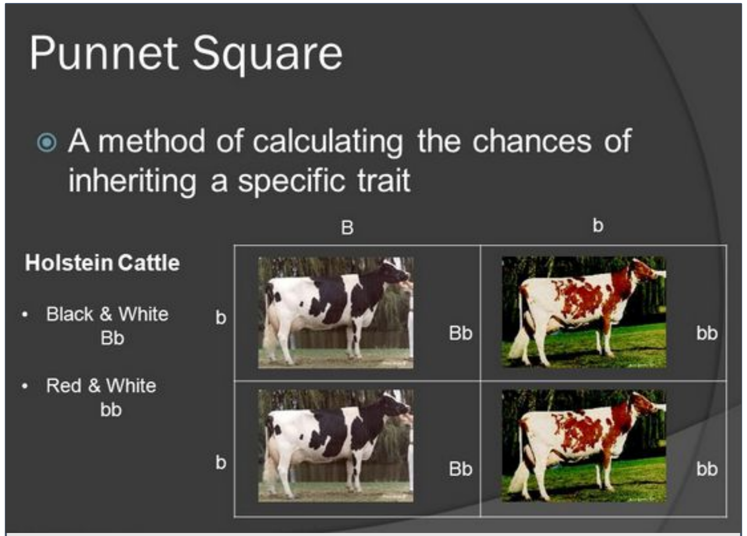
An analogy from Science.
Mechanism: A deeper way of knowing…

What it looks like

Variation exists.

https://vivadifferences.com/difference-between-holstein-friesian-and-jersey-dairy-cows/

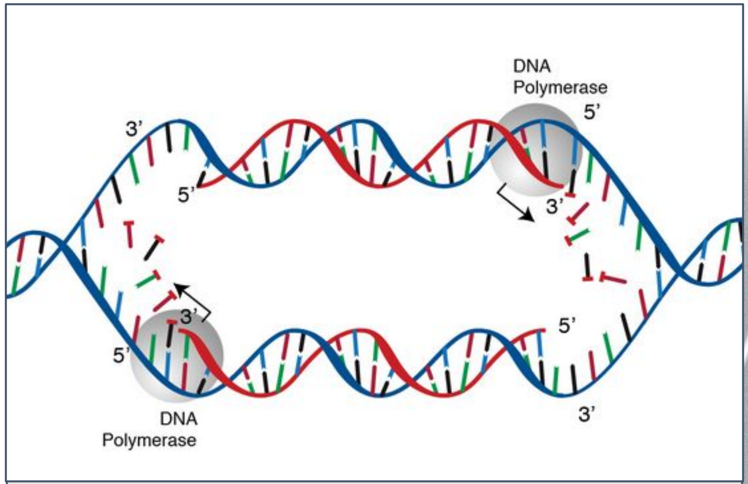
How it changes



Selective breeding experiments.

http://woodlandhighag.weebly.com/unit-3-molecular-biology.html

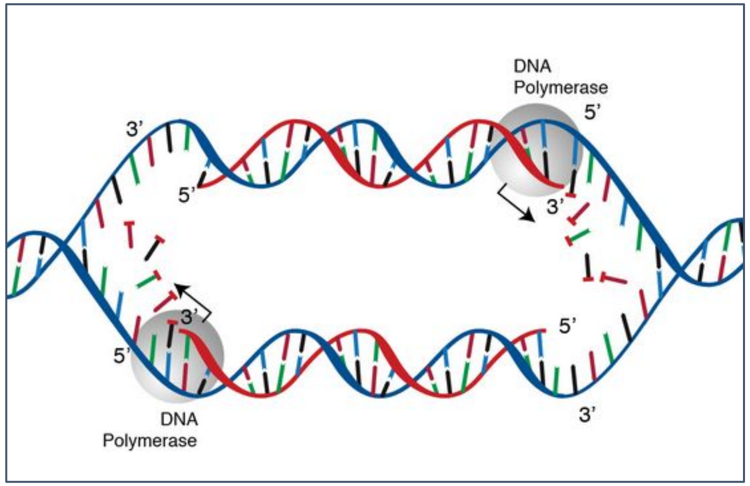
Why it works



The structure and function of DNA.
Mechanism and Process.

https://www.genome.gov/genetics-glossary/DNA-Replication

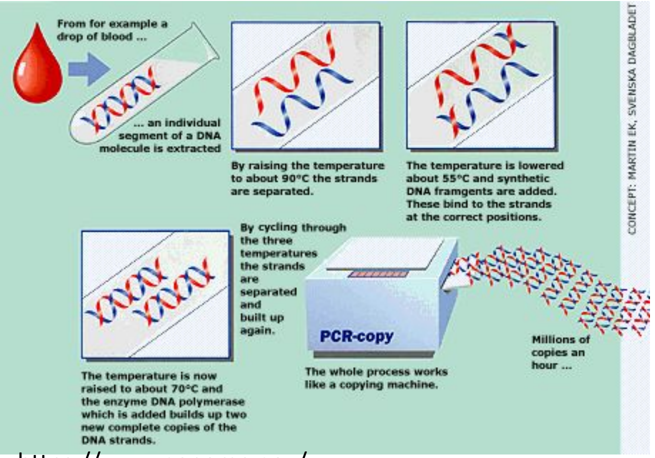
How does CS Integration ***enhance*** disciplinary learning ?



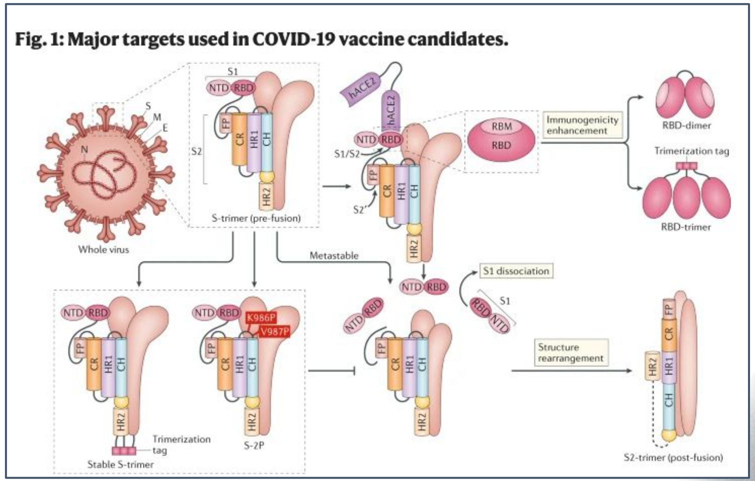
The structure and function of DNA.
Mechanism and Process.

Understanding HOW and WHY it works

Discovery & Innovation



https://www.genome.gov/



https://www.nature.com/articles/s41577-020-00480-0

How does CS Integration ***ENHANCE*** disciplinary learning ?

Integrating CS moves **learning** *in each discipline* from

a) <u>identification of pattern</u> (what it is and looks like)
to
b) <u>understanding of processes</u> that generate pattern through experiences in computing! (how, why)
to
c) the <u>generation</u> of new understandings and patterns.

Why ***ENHANCE*** disciplinary learning through CS integration?

To support discovery
To support expression
To support justice

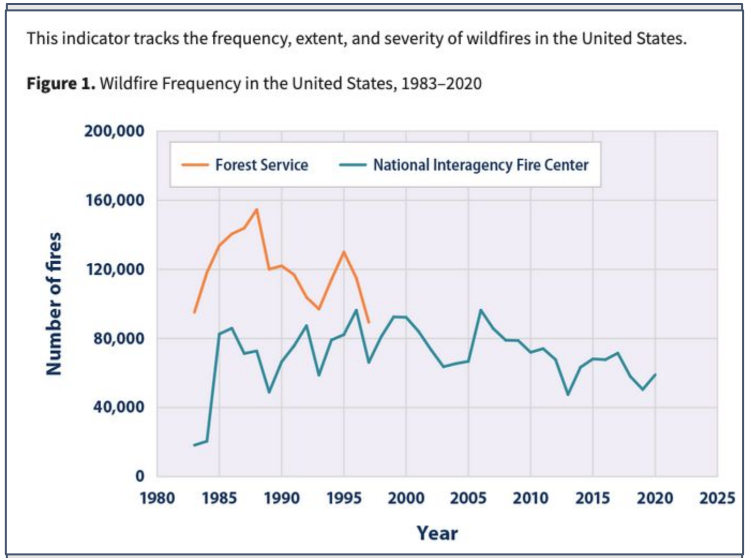
From the Liberal Arts and Sciences Computing Education Task Force at University of Michigan. See https://computinged.wordpress.com/2021/11/26/computer-science-was-always-supposed-to-be-taught-to-everyone-but-not-about-getting-a-job-a-historical-perspective/

To Support DISCOVERY: Example from Science

A student project from the Supercomputing Challenge developed new grasslands fire fighting strategies

Scientific practices with CT and CS..

Historical accounts.
What did it look like?

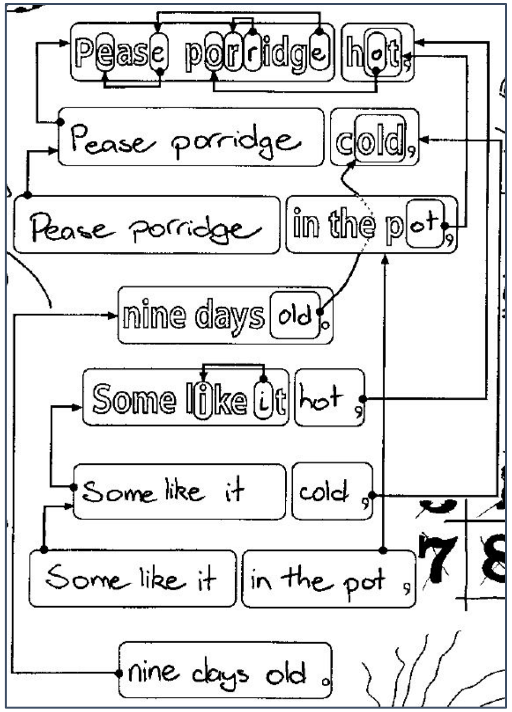


Data collection & analysis
How did it change over time?

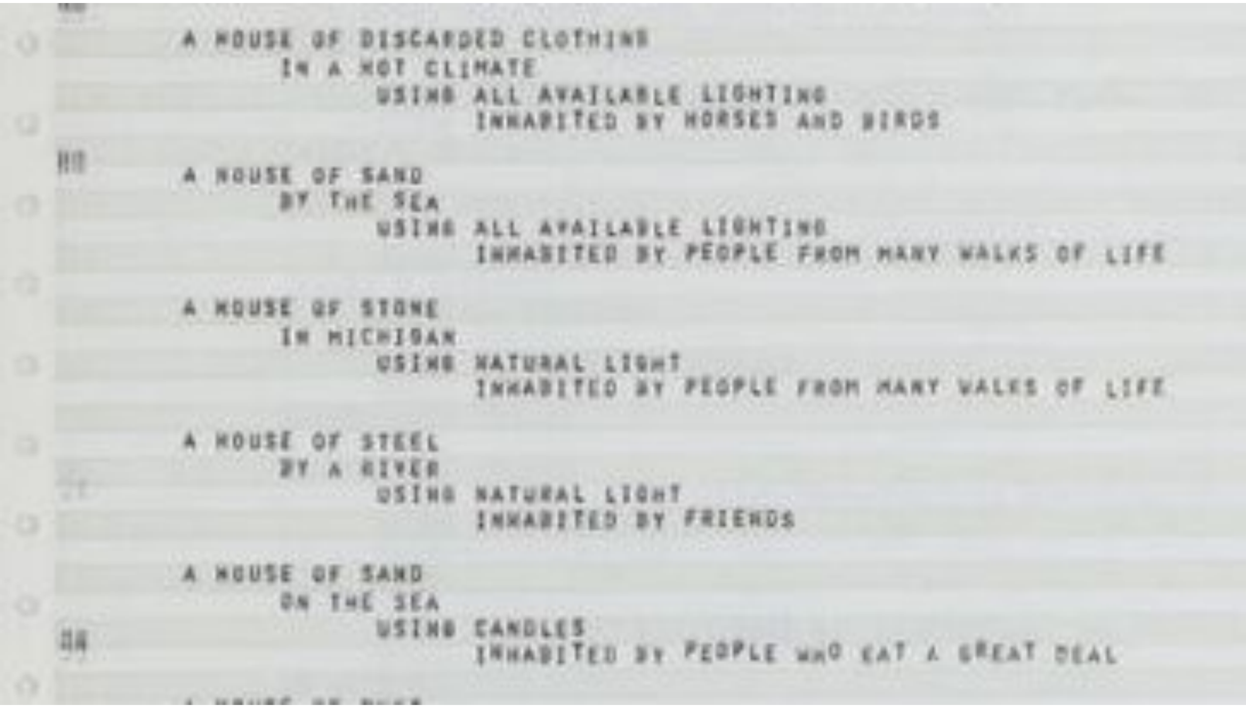
What causes fire to spread?
How can it be made less harmful?

To Support EXPRESSION
Example from English / Language Arts

What pattern exists?
How can this pattern be generated?
What new patterns can I generate?



Activity from CS unplugged



A HOUSE OF DISCARDED CLOTHING
IN A HOT CLIMATE
USING ALL AVAILABLE LIGHTING
INHABITED BY HORSES AND BIRDS

A HOUSE OF SAND
BY THE SEA
USING ALL AVAILABLE LIGHTING
INHABITED BY PEOPLE FROM MANY WALKS OF LIFE

A HOUSE OF STONE
IN MICHIGAN
USING NATURAL LIGHT
INHABITED BY PEOPLE FROM MANY WALKS OF LIFE

A HOUSE OF STEEL
BY A RIVER
USING NATURAL LIGHT
INHABITED BY FRIENDS

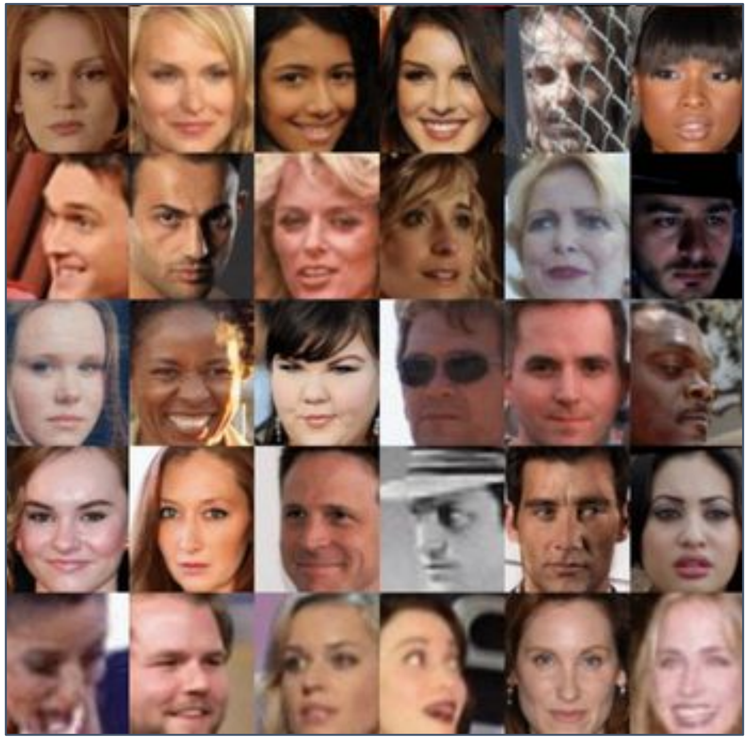
A HOUSE OF SAND
ON THE SEA
USING CANDLES
INHABITED BY PEOPLE WHO EAT A GREAT DEAL

Alison Knowles's *The House of Dust*

To Support JUSTICE
Example from Social Science

Who is represented?
How are predictions made?
How can predictions made by AI be more equitable?

https://news.sky.com/story/passport-photo-checking-service-tells-asian-man-to-open-eyes-10686376



https://www.biometricupdate.com/202102/online-tool-exposes-whether-face-biometrics-have-been-trained-with-your-photos

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IN CONCLUSION

- Integrating CS ENHANCES disciplinary learning by enabling students to tinker with and gain an understanding of processes in the discipline.

- With an understanding of processes in the discipline, students can customized and develop new processes to support DISCOVERY, EXPRESSION and JUSTICE.

THANK YOU!

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