



# Computational Thinking

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# InMside

## Inclusive Mathematics for Sustainability in a Digital Economy

### **Project Overseers of the InMside Project (APEC HRDWG 01-2018)**

Dr. Masami Isoda (Steering Meeting, Tokyo), CRICED, the University of Tsukuba, Japan

Dr. Roberto Araya (Seminar at APEC-SOM2, Valparaiso), CIAE, the University of Chile, Chile

Dr. Maitree Inprasitha (Synthesis Meeting, Khon Kaen), IEDTP, Khon Kaen University, Thailand



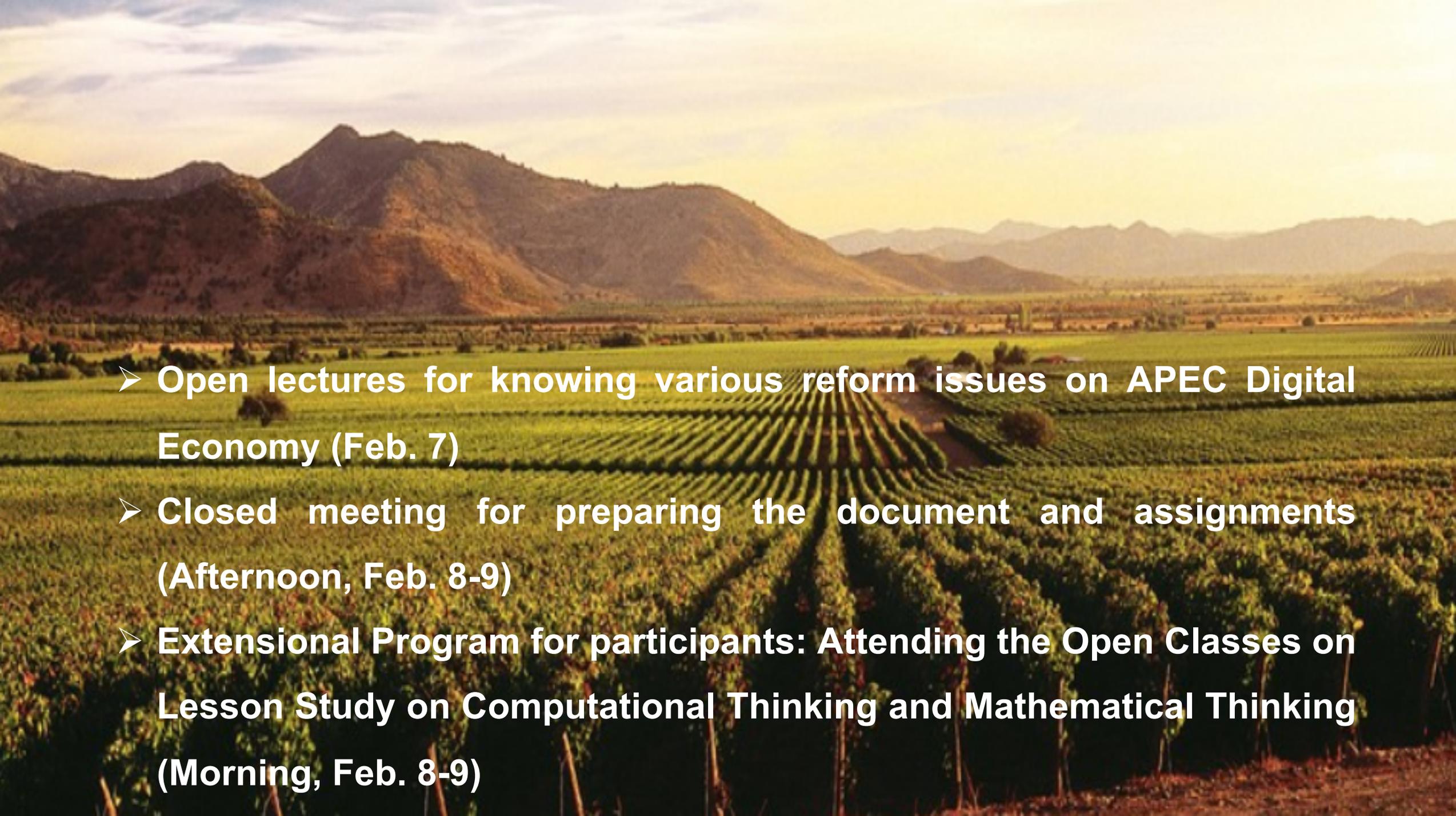
APEC Seminar on

Computational Thinking Curriculum for the Digital Economy,

May 6-8, 2019 in APEC-SOM2 at Valparaiso in Chile

14th APEC-Khon Kaen International Conference (Sep. (3-day), 2019)

Khon Kaen, Thailand

- 
- **Open lectures for knowing various reform issues on APEC Digital Economy (Feb. 7)**
  - **Closed meeting for preparing the document and assignments (Afternoon, Feb. 8-9)**
  - **Extensional Program for participants: Attending the Open Classes on Lesson Study on Computational Thinking and Mathematical Thinking (Morning, Feb. 8-9)**

# Imagine the future

*20 years from now*

# Parental expectations: 4<sup>th</sup> grade students

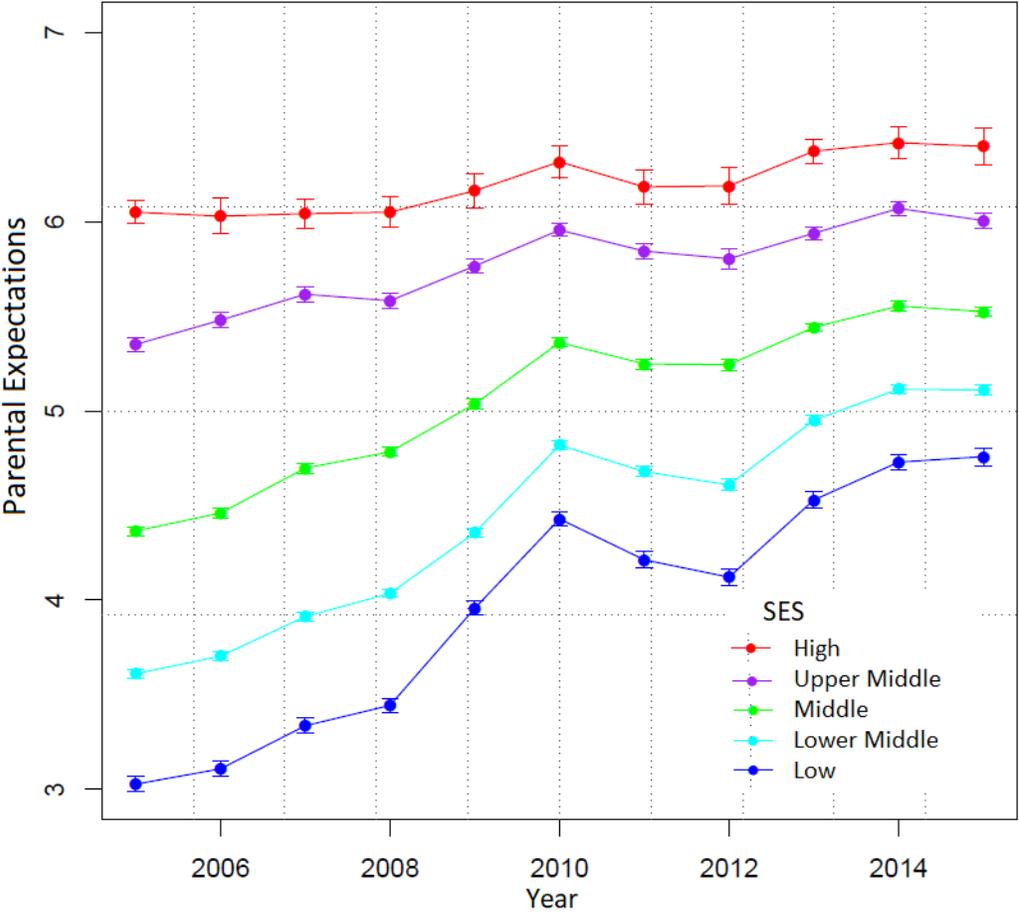
*What do you think is the highest level of education that your student will achieve in the future?*

1. *Elementary School (Incomplete)*
2. *Elementary School (Complete)*
3. *High School (Incomplete)*
4. *Vocational High School (Complete)*
5. *Regular High School (Complete)*
6. *Technical College (Complete)*
7. *University Degree*
8. *Postgraduate Degree*

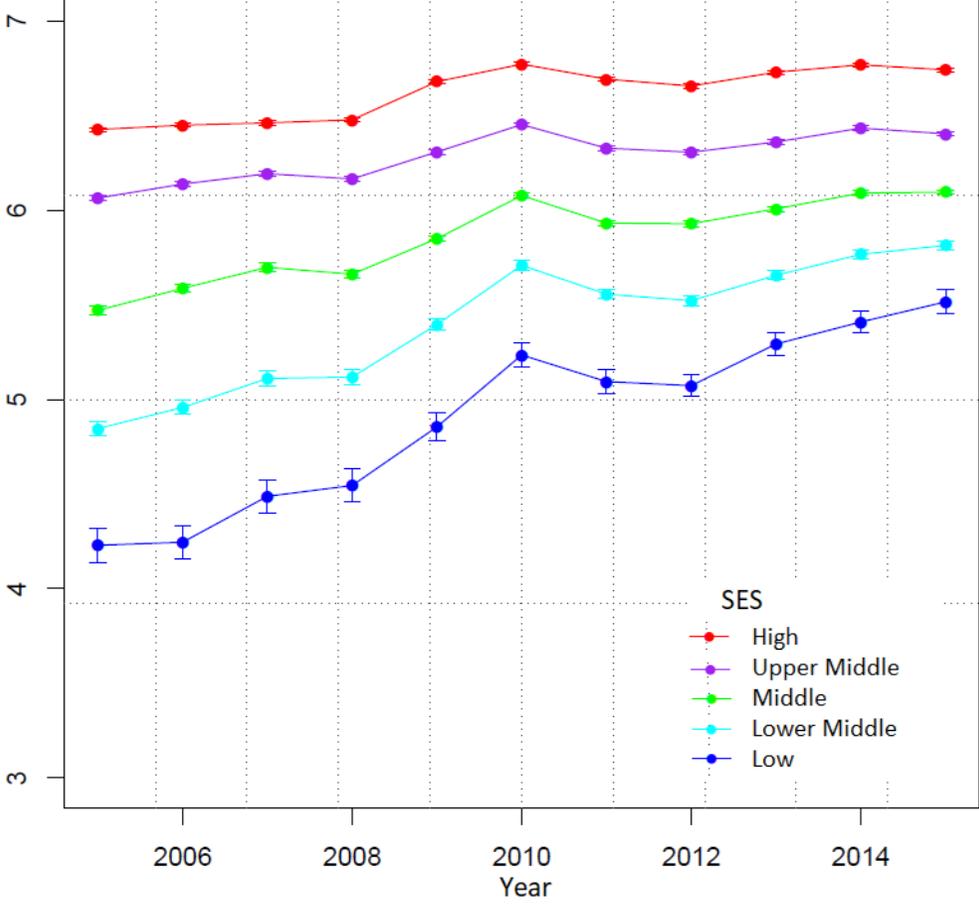
# Parental expectations: 4<sup>th</sup> grade students

Parental expectations of educational attainment of their children

Parents of students with score in the bottom 20% on the SIMCE Math Test



Parents of students in the top 20% on the SIMCE Math Test



# What to study?



**SOCIETY 1.0**

Hunter-gatherer society



**SOCIETY 2.0**

Agrarian society



**SOCIETY 3.0**

Industrial society



**SOCIETY 4.0**

Information society



**SOCIETY 5.0**

Super-smart society

Source: The Government of Japan

*Human-centered society?*





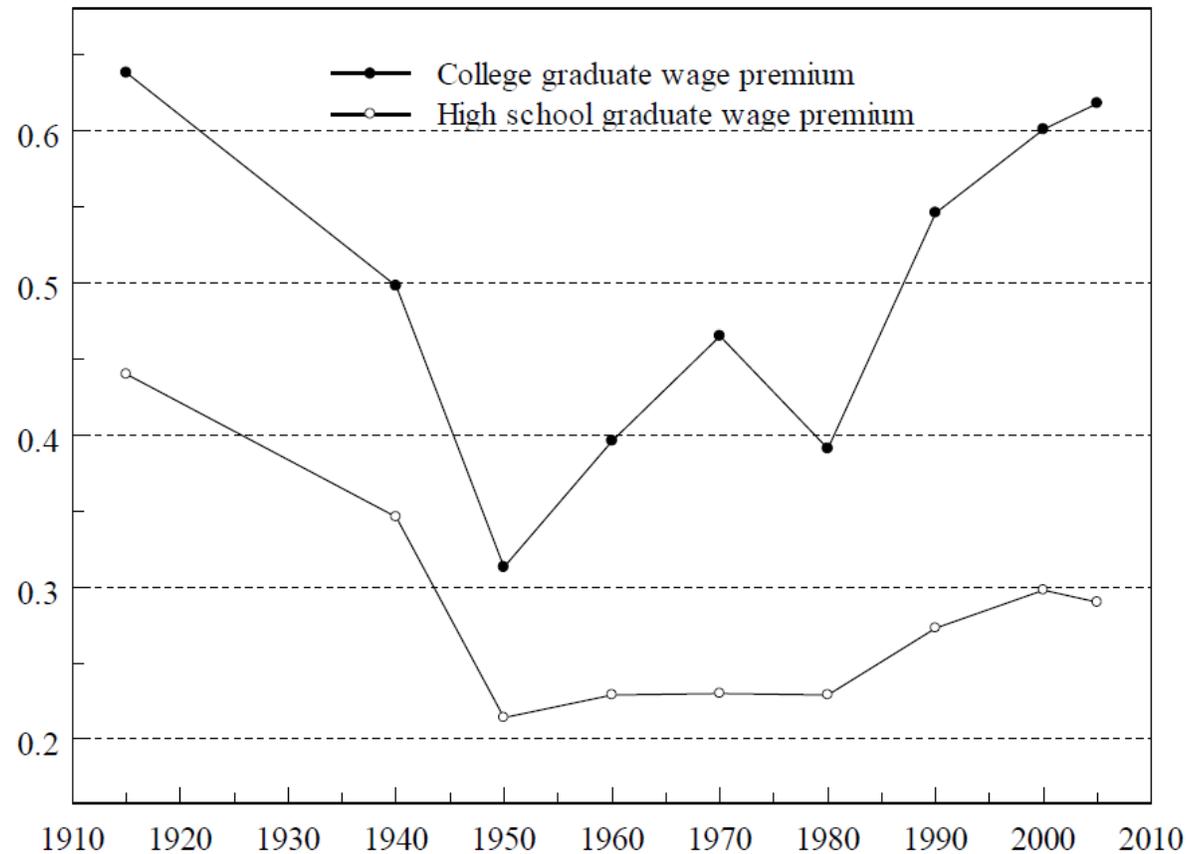
*Projectile weapons are one of the most important technologies that shaped human evolution, but they rarely get the credit they deserve. People tend to be much more preoccupied with fire.*

*... It is hard to see how this **egalitarianism** could have evolved without projectile weapons.*

- Peter Turchin, *Ultra Society: How 10,000 years of war made humans the greatest cooperators on earth*

# *The Race between Education and Technology*

-Goldin, C.; Katz, L.



*... Arms race?*

*Economist attribute this rise to the relentless increase in the skills required to work with new information-based technologies.*

*They believe that the acceleration in **skill-biased technical progress** over the past thirty years is the main engine driving **increased inequality** in earnings.*

-Angus Deaton,  
Nobel Prize Economy, 2015  
The Grate Escape

Computational Thinking?

# Computational Thinking

**Programming**

**Computational modeling**

**Machine Learning**

# Computational Thinking

**Programming**

**Computational modeling**

**Machine Learning**

# What is it CT?

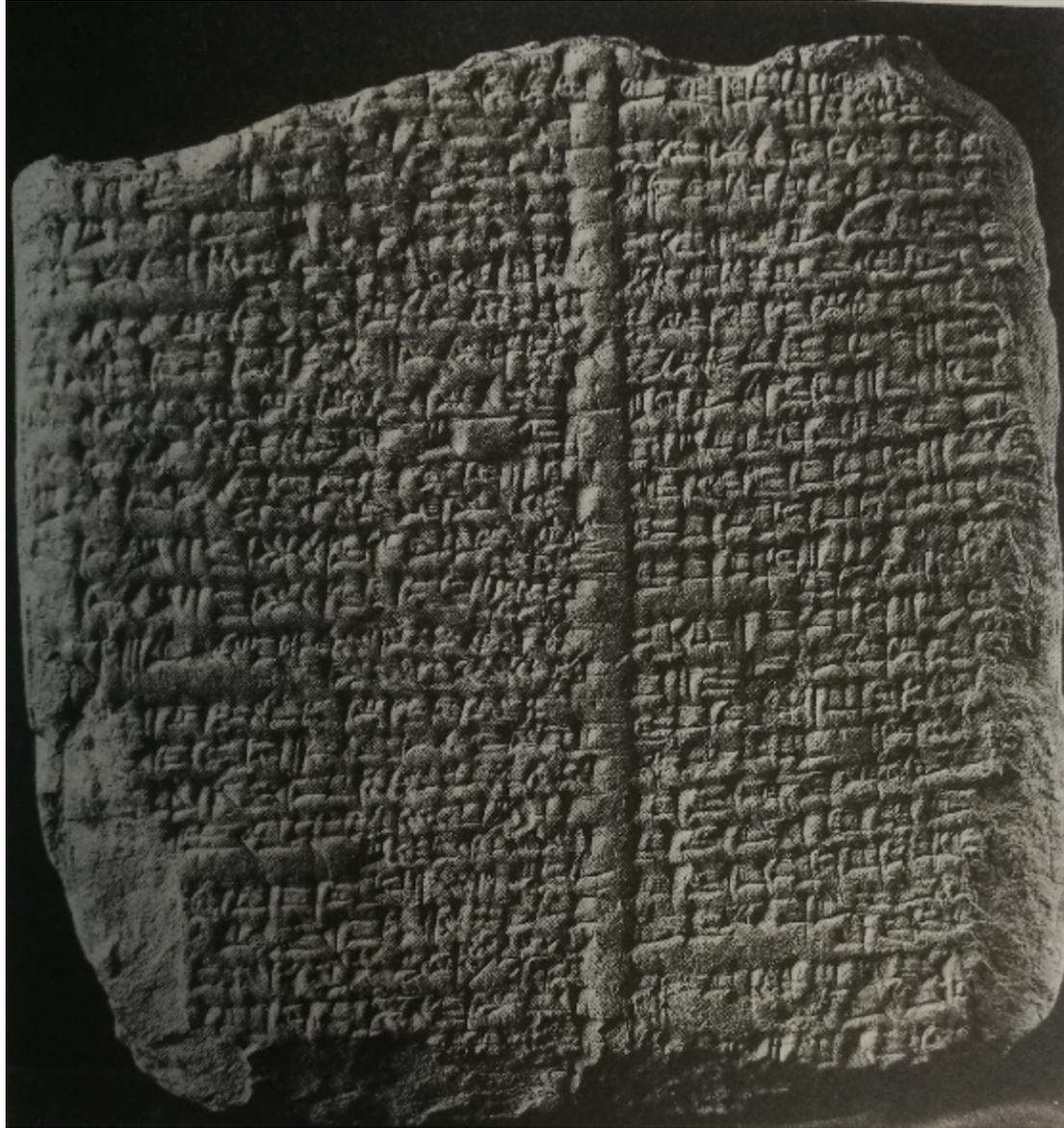
*Computational Thinking is the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer – human or machine – can effectively carry out*

- Jeannette Wing, Director of the Data Sciences Institute at Columbia University

<https://www.youtube.com/watch?v=YVEUOHw3Qb8> at min 17:15



**Algorithmic  
thinking?**



**Text to speech?**

**Speech to text?**

# Computational Thinking

*“The only way to rectify our reasonings is to make them as tangible as those of the Mathematicians, so that we can find our error at a glance, and when there are disputes among persons, we can simply say: **Let us calculate** [calculemus], without further ado, to see who is right”*

— Gottfried Wilhelm Leibniz

in a letter to Philipp Spener, The Art of Discovery 1685, Wiener 51

# Computational Thinking

**Programming**

**Computational modeling**

**Machine Learning**

*In the 1960s and 1970s we allowed, and even encouraged, the perception "CS = programming," which is now to our dismay widely accepted outside the field*

- Denning, P. (2009) Beyond Computational thinking

*Computational Thinking is much more than computer programming*

- Jeannete Wing, <https://www.youtube.com/watch?v=YVEUOHw3Qb8> at 26:02

# Computational Models

*Computational thinking emerged from within scientific fields—it was not imported from computer science.*

*Indeed, computer scientists were slow to join the movement.*

*- Peter Denning*

# What is it CT?

*Computational thinking is the thought processes in doing computational science—designing, testing, and using **computational models**.*

*Building models not only relies in abstractions like number and computation with numbers. It uses also the human ability that capture patterns and the dynamic of unfolding actions.*

# Computational Models

*Board games are not usually accorded the same primacy as numbers, but to my mind they are equally important cornerstone to the scientific endeavor. I think board games, as well as numbers, mark a watershed of human perception of the world.*

- John Holland (200x)

Emergence

# Computational Thinking

**Programming**

**Computational modeling**

**Machine Learning**

# Machine learning

*What one computational method has influenced many disciplines?  
Machine Learning*

- Wing at 35:50

*It is imperative that educators, administrators, and students begin today to consider how to best prepare for and keep pace with this datadriven era of tomorrow.*

- National Academies (2018)

# Machine learning

*Machine learning techniques mark a break with the classic algorithm.*

*In particular, as they mark the gradual transition from a programming logic to a learning logic*

- C. Villani

Fields Medal Mathematics

# Machine learning

***'The end of the code':  
in the future, we will no longer program  
computers, we will train them.***

- Wired Magazine

# Computational Thinking Unplugged

*I don't think throwing hardware and software onto the lab of nine year olds necessarily is the best way to teach computational thinking*

- Wing, <https://www.youtube.com/watch?v=YVEUOHw3Qb8> at 1:02:00

Draft of Proposed  
Framework for  
Computational Thinking

# Computational Thinking Values, Attitudes, and Habits for Human Character

Values:

Seeking

Understanding and objectivity

Attitude:

Attempting to

Compute in order to argue and reason

*(Let us compute, Leibnitz)*

Habits of Mind:

For living

Explain using computational models

*(What I cannot create, I do not understand Feynman)*

# Computational Thinking Subjects

## Key Stage 1 (1 to 4<sup>th</sup> grade)

- Mathematics
  - Arithmetic algorithms
  - Recognition of Patterns and Rules
- Language
  - Phonics (segmenting sounds)
  - Word Counting (frequency)
- Science
  - Data Analysis of Experiments (histograms)
- Social Sciences and Economics
  - Social data (numeric /categorical)
  - Population thinking
- Technology
  - Spreadsheets (tables, arithmetic)
- Arts:
  - Tools for drawing (pixels)
- Etc

## Key Stage 2 (5 to 8 th grade)

- Mathematics
  - Autonomous vehicles (navigation)
  - Programming (rules, sequencing)
- Language
  - Word clouds
  - Peer review (written arguments)
- Science
  - Experimental design (sample size, randomization)
  - Social Physics and artificial life
- Social Sciences and Economics
  - Society 5.0 (history and trends)
  - Social Networks (graphs)
- Technology
  - Simulators and board games
- Arts:
  - Tools for photography and videos (frames)
- Etc

## Key Stage 3 (9 – 12th grade)

- Mathematics
  - Machine learning (decision trees, linear classifiers)
  - Programming (Python)
- Language
  - Co occurrence
  - Text mining (topic models)
- Physics
  - Dynamical systems (boards, potential theory)
  - Computational models (propagation)
- Biology
  - Natural and sexual selection algorithms
  - Cell division and genetics
- Chemistry
  - Chemotaxis
- Social Sciences and Economics:
  - Agents and cellular automata
  - Historical Dynamics and Global History Databanks
  - Society 5.0 (super smart) Health, Education, Entertainment
- Technology
  - Sensors and Actuators
- Arts
  - Signal processing for sound
- Etc

# Exemplars

1. Quantity to position in abacus
2. Addition algorithm in abacus
3. Subtraction algorithm in abacus
4. Rules in color ties
5. Rules in boxes
6. Phonic segmentations
7. Word frequencies
8. Histograms with blocks
9. Ant and pill bug trajectories
10. Order in tables
11. Drawing with pixels

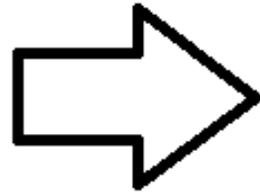
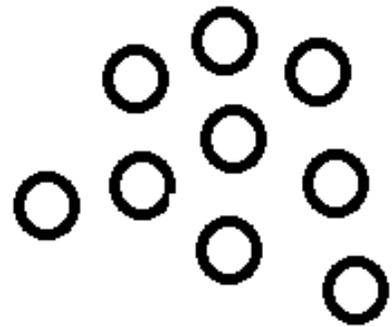
1. Simple classifiers
2. Autonomous vehicles in boards
3. Programming: rules, sequencing
4. Tic-Tac-Toe automata
5. Word Clouds
6. Peer review
7. Randomization and biases
8. Artificial life
9. Natural Selection Algorithm
10. Trends: Energy, Life Expectancy
11. Segregation models
12. Social Networks Graphs
13. Game design in concrete boards
14. Simulators Prey Predator
15. Frame rate in videos
16. Image processing

1. Classifiers (decision trees and SVM): predictive maintenance, sports
2. Python: Accumulator Dynamics
3. Word co-occurrence, concept maps
4. Topic model from corpus
5. Discrete time Newton Dynamics
6. Discrete time Potential Theory
7. Forest fire models
8. Natural Selection of Cooperation
9. Chemotaxis & Animal Tropisms
10. Embryology (Gastrulation)
11. Immunology Dynamics (virus infection)
12. Genetic algorithms
13. Cellular automata (migration)
14. Historical Dynamic simulator
15. Society 5.0: Poverty, Education, Violence, Work, Environment, Future
16. Sound processing: time and frequency domain
17. Ethical biases in machine Learning

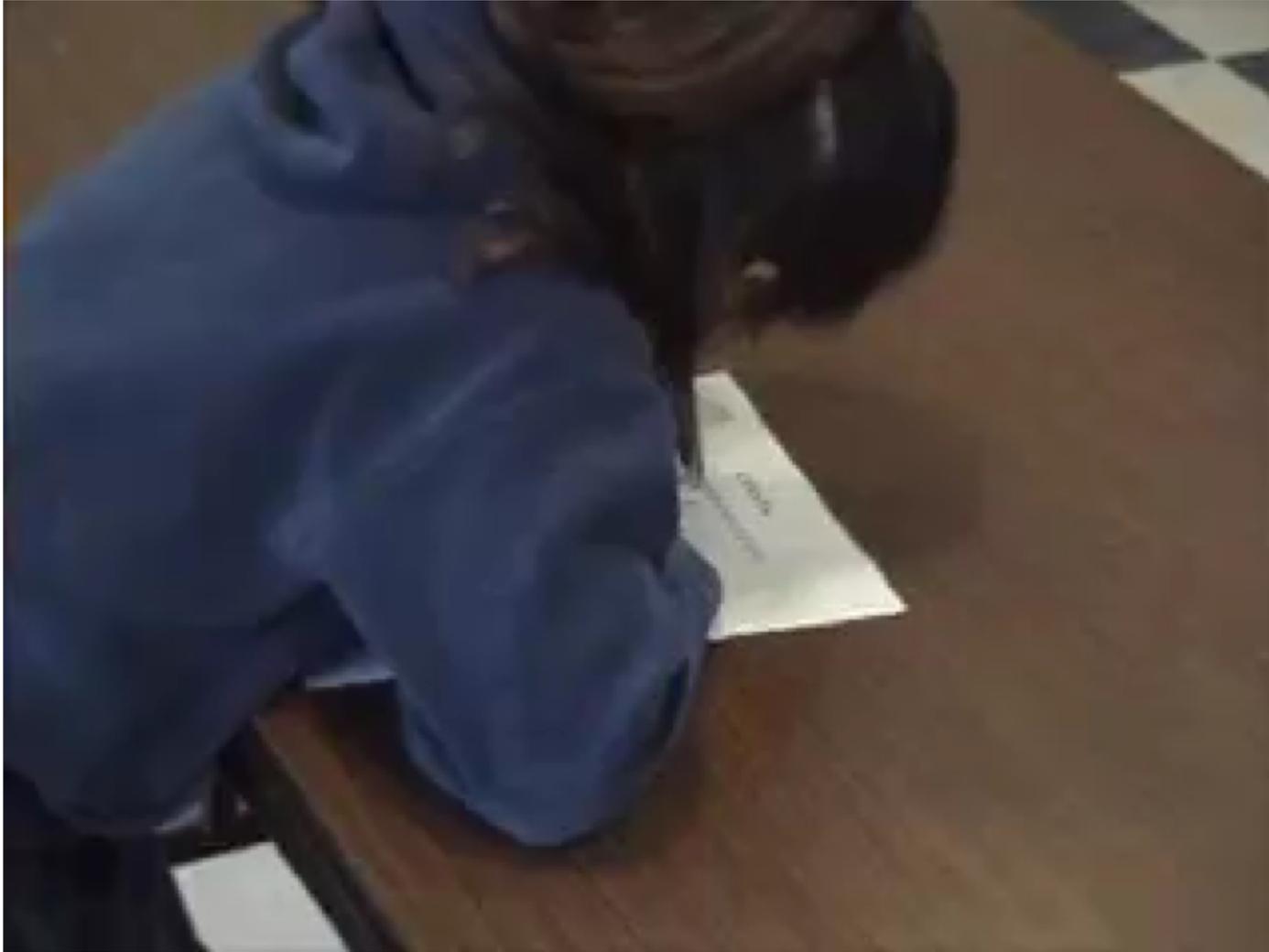
# Exemplar 1

Positional System is the most  
powerfull algorithm in Math

# Quantity to position in abacus



# Quantity to position in abacus



What would be the instructions to a peer?

Computational Thinking is the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer – human or machine – can effectively carry out.

# Exemplar 2

Machine Learning is the most  
powerfull algorithm in AI

# Rules in Boxes

Pattern detection

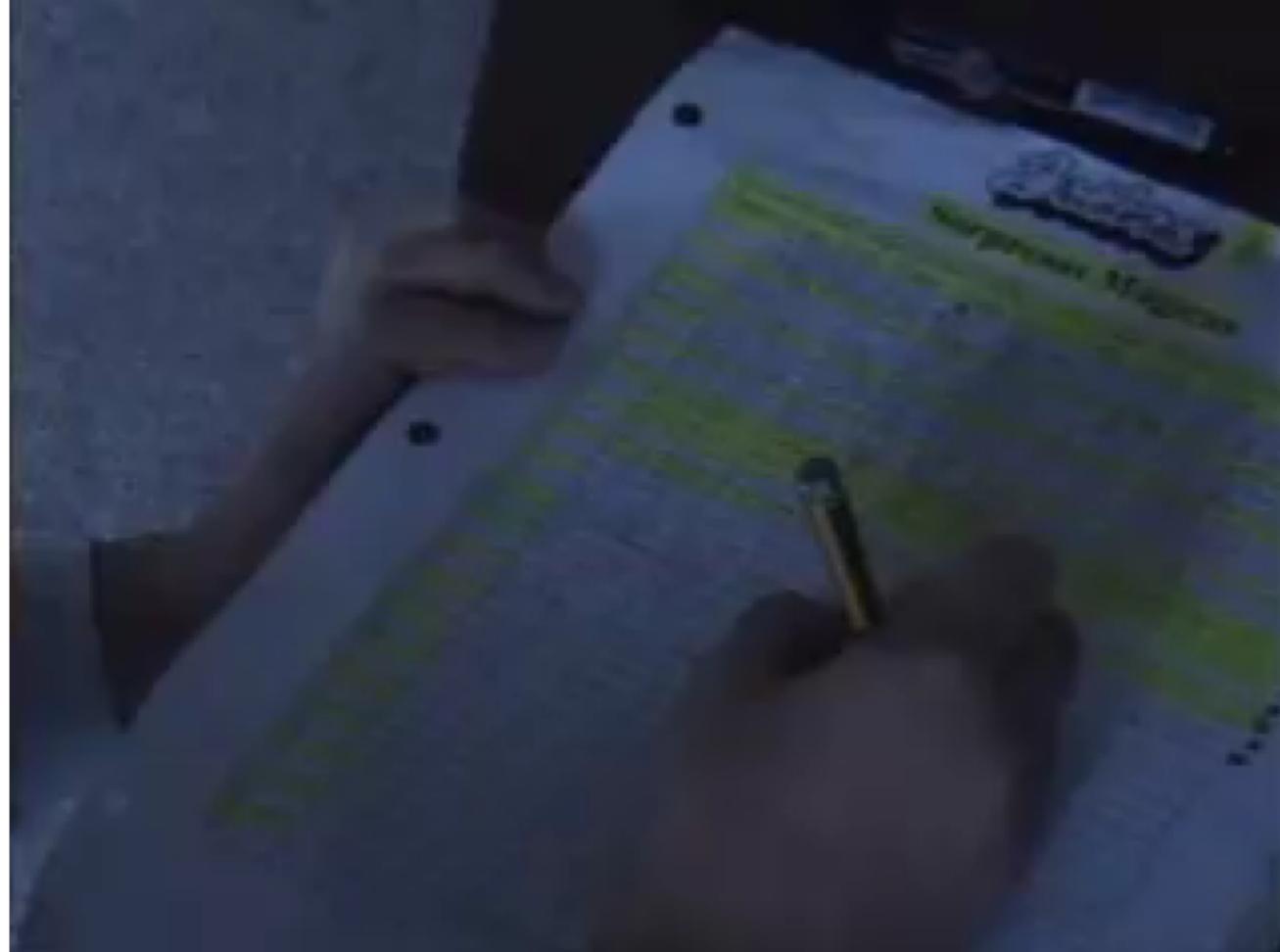
Machine Learning

Training automatas

# What color is the rabbit inside?



# Analysing the previous data



**IF**

**length + 2.5 x width > 3**

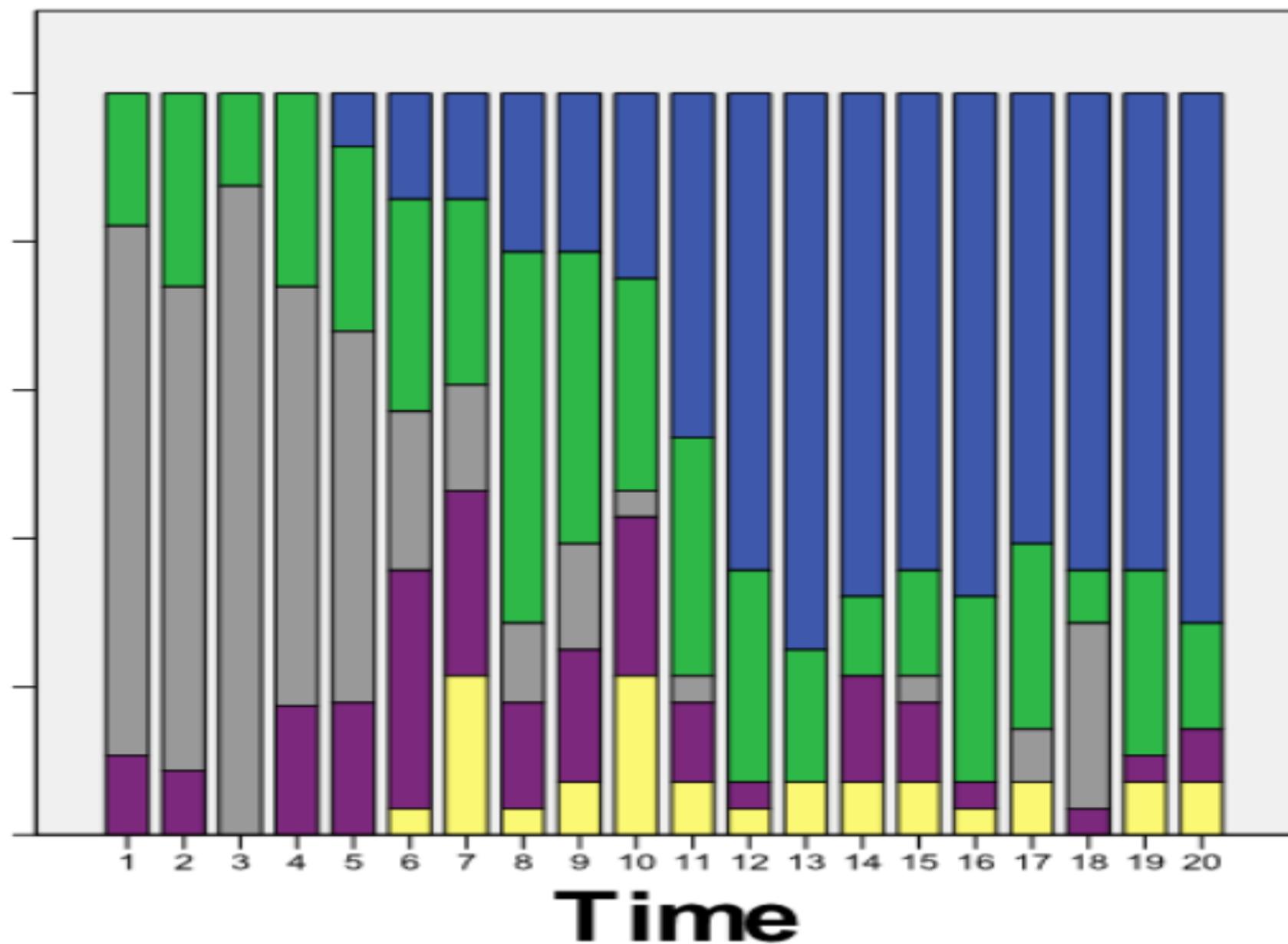
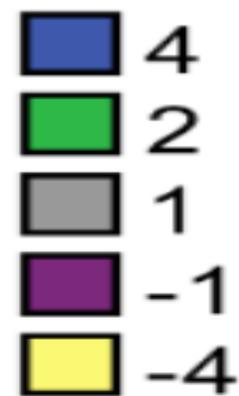
**THEN**

**color = white**

**ELSE**

**color = black.**

# Score



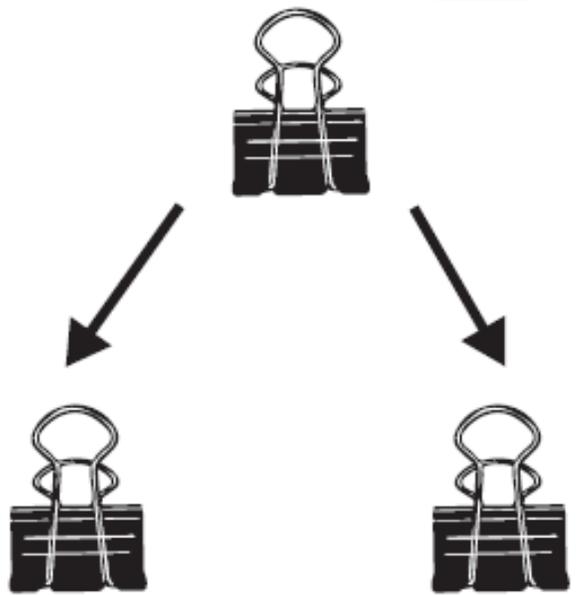
# Exemplar 3

Natural Selection is the most  
powerfull algorithm in Science

# Natural Selection Algorithms



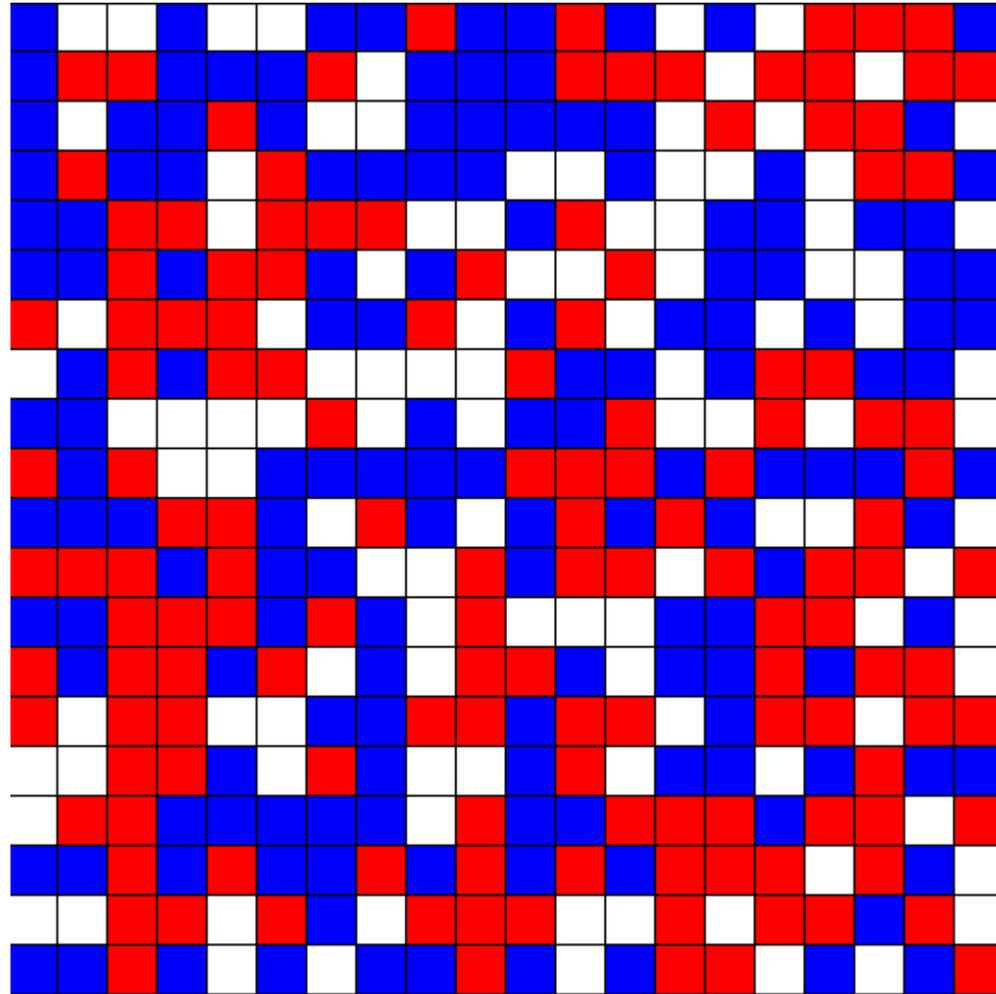
# Population thinking



# Exemplar 4

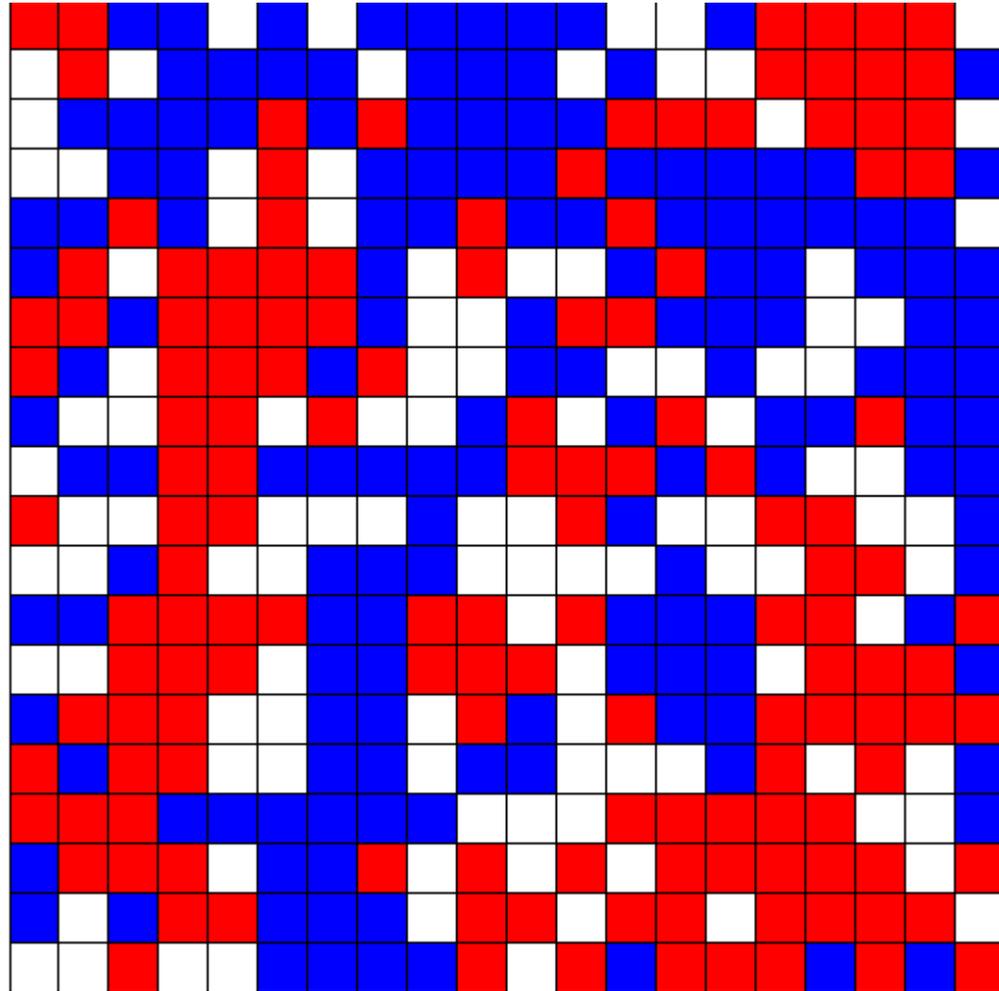
Unique social mechanism allows  
us to live together and build  
increasingly powerful civilizations

# Schelling segregation model



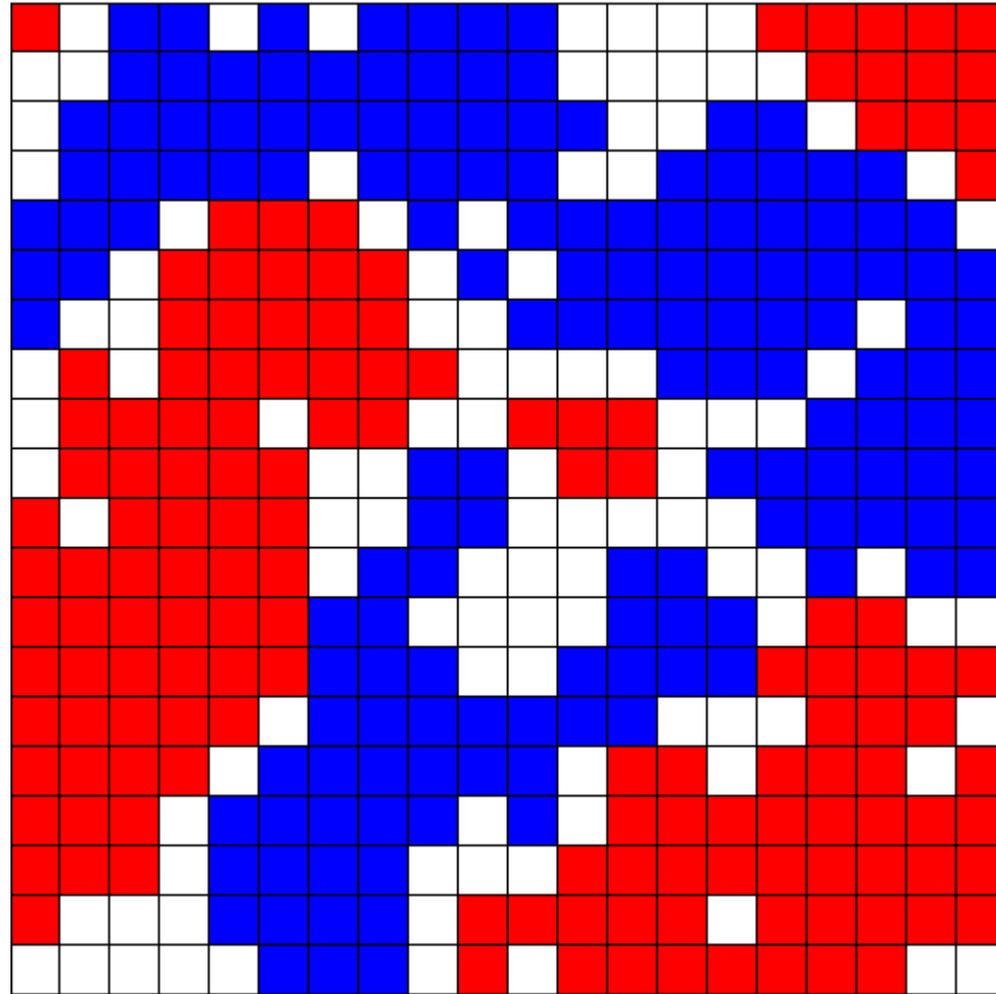
<http://nifty.stanford.edu/2014/mccown-schelling-model-segregation/>

# Schelling segregation model

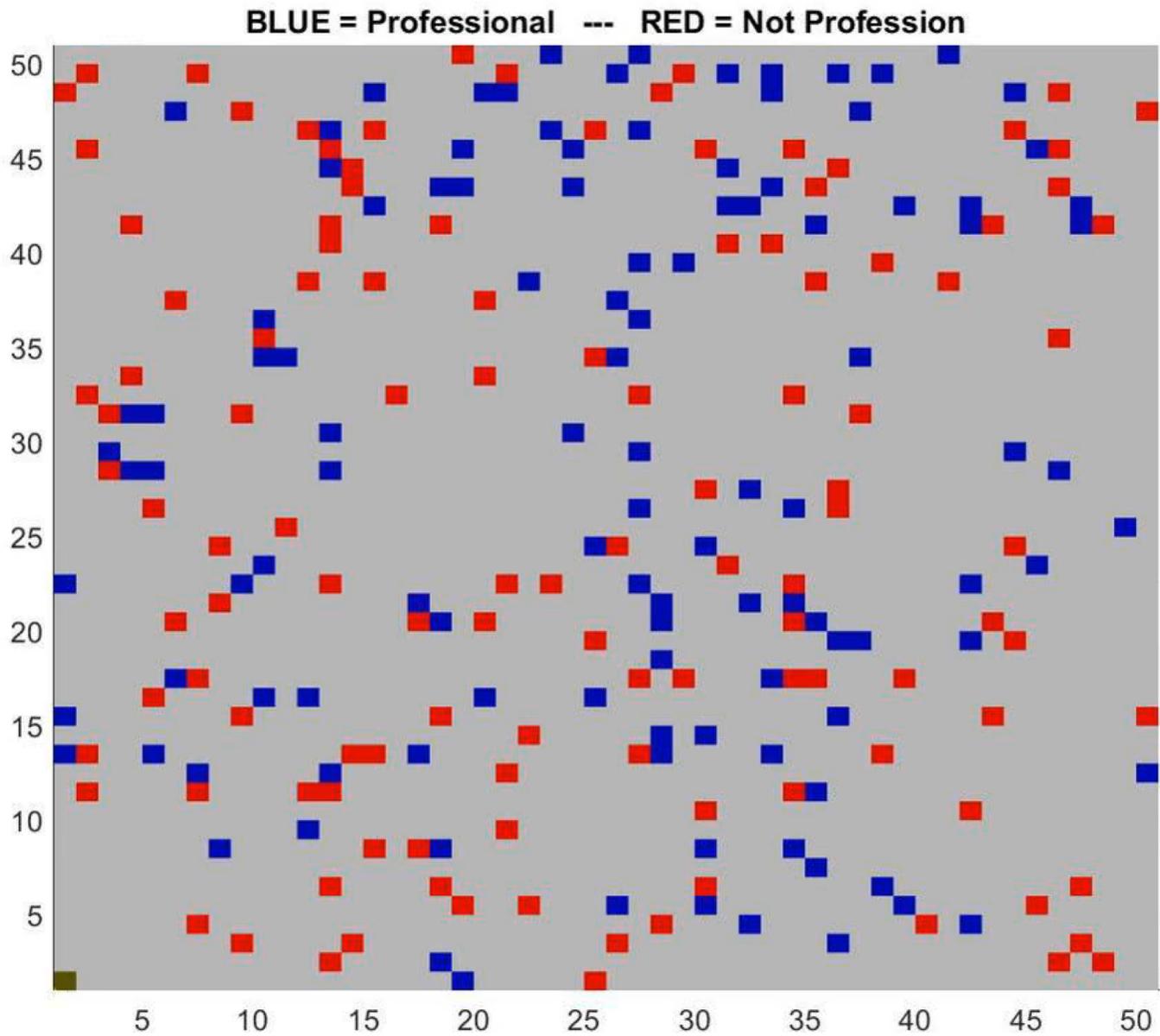


<http://nifty.stanford.edu/2014/mccown-schelling-model-segregation/>

# Schelling segregation model



<http://nifty.stanford.edu/2014/mccown-schelling-model-segregation/>



**What is going on here?**

# The new anxieties

Geographic

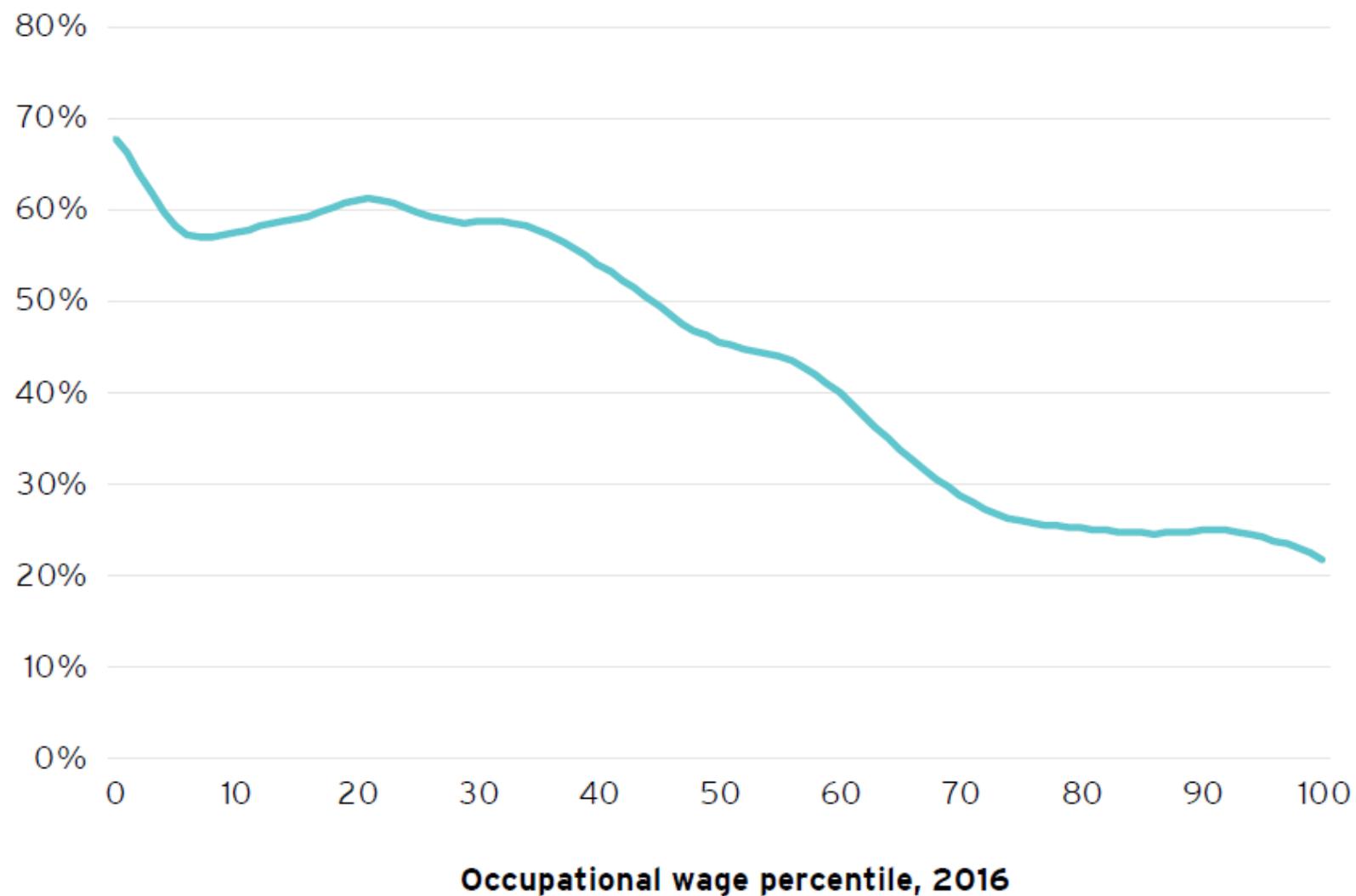
Educational

Moral

- Paul Collier

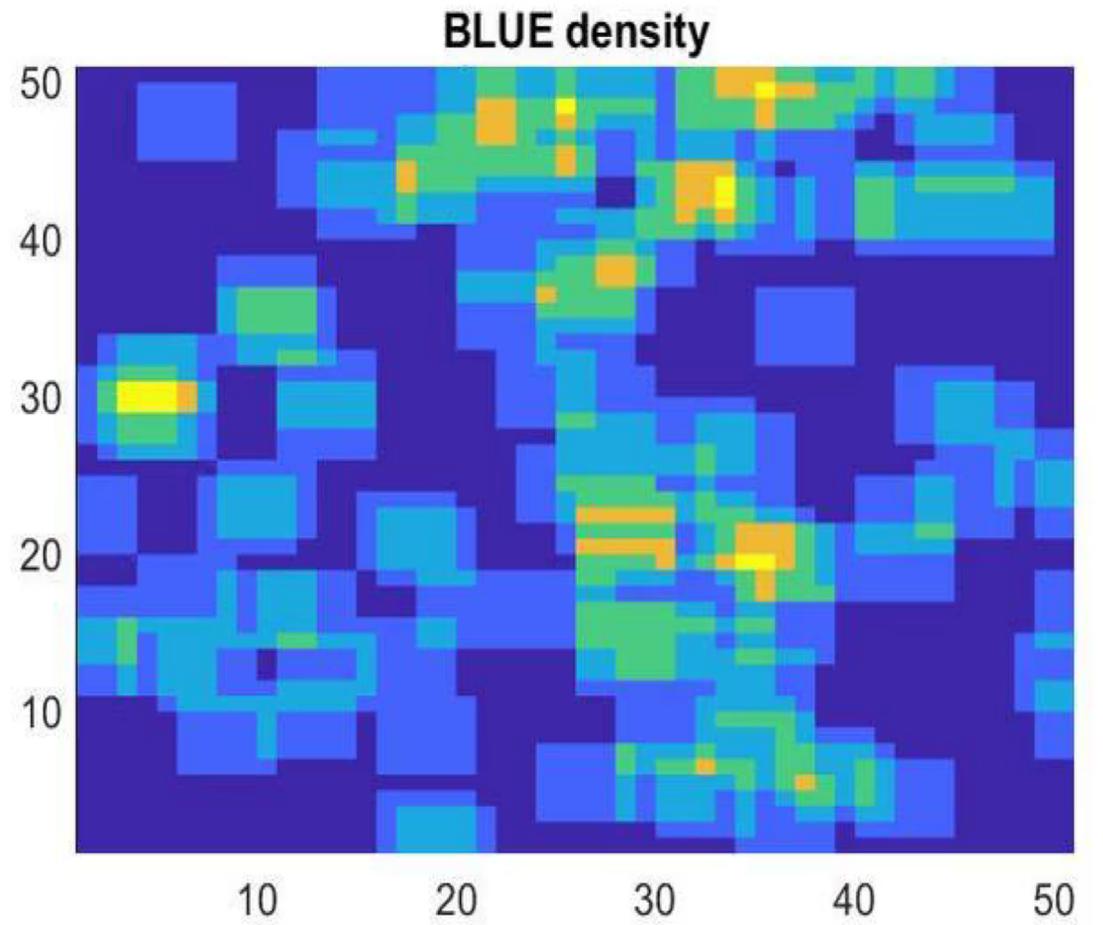
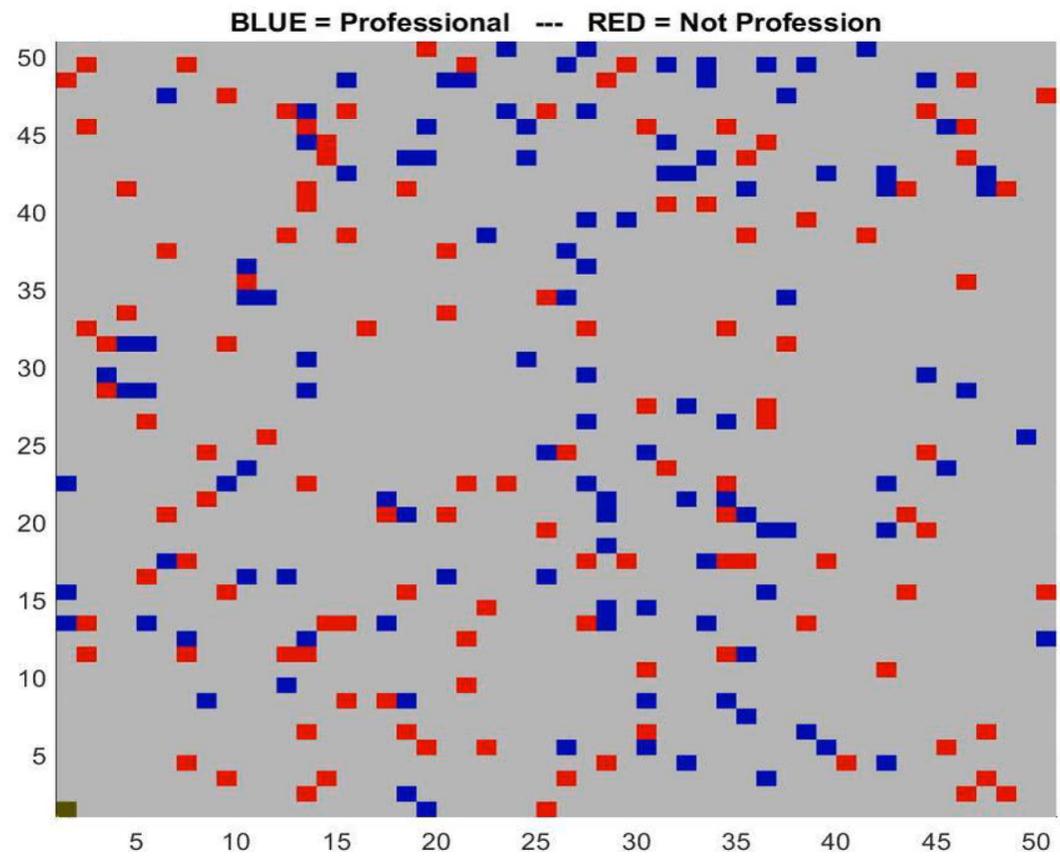
## The lowest wage jobs are the most exposed to automation

Automation potential, United States, 2016



Note: Figures have been smoothed using a LOWESS regression

Source: Brookings analysis of BLS, Census, EMSI, and McKinsey data



# The new anxieties

## Geographic

Need to belong:

Place-based identity → ← skills based identity

## Educational

Increasing complexity → higher skills

## Moral

Increasing complexity → higher skills → repercussion on identity

Instinctive morality → ← identity morality

Confirmation Bias

Us vs Them

Causal Attribution

The Tragedy of the Belief

Commons

# Debiasing Reasoning



## **SOCIETY 1.0**

Hunter-gatherer society



## **SOCIETY 2.0**

Agrarian society



## **SOCIETY 3.0**

Industrial society



## **SOCIETY 4.0**

Information society



## **SOCIETY 5.0**

Super-smart society

Source: The Government of Japan



*Computational thinking is key  
for **Society 5.0***

*Everybody ought to work  
together with increasingly  
smart systems*

***Thank you***