MANY PATHS TO COMPUTATIONAL THINKING

TACCLE 3 CODING // FINAL CONFERENCE

MATTI TEDRE
MATTI.TEDRE@UEF.FI

45 MINUTES ON ONE SLIDE

WHAT?
WHY?
SO WHAT?

WHAT?

MASSIVE DISRUPTIONS IN LABOR AND SOCIETY

WORK IS CHANGING

RETAIL

RETAIL

WAREHOUSING

FAST FOOD

RENTAL—FROM MOVIES TO CARS AND BEYOND

BANKING

DESIGN

DESIGN

MEDICAL DIAGNOSIS

CUSTOMER SERVICE

HOTELS

JOURNALISM

COMPANY ANNUAL REPORTS

FUTURE: TRANSPORTATION

“I THINK THAT MY JOB IS SAFE FROM CHANGES”

—

YOU ARE PROBABLY WRONG

“I THINK THAT MY JOB WILL BE MUCH BETTER IN THE FUTURE”

—

YOU ARE PROBABLY RIGHT

WHY?

AUTOMATION OF KNOWLEDGE WORK

THE SCIENTIFIC REVOLUTION

TWIN PILLARS OF SCIENCE: THEORY AND EXPERIMENT

THEORY **EXPERIMENT**

THE NEW SCIENTIFIC REVOLUTION

COMPUTATIONAL SCIENCE

TWO STAGES

1) NEW TOOL WITH UNPRECEDENTED POWER

2) A NEW WAY TO THEORIZE

STAGE 1: TOOLS OF UNPRECEDENTED POWER

COMPUTER SIMULATION
SUPERCOMPUTERS
COMPUTATIONAL SCIENCES

COMPUTER SIMULATION

“WHAT IF THE WORLD WORKED LIKE THIS”

THEORY EXPERIMENT

?

BEFORE AFTER

CHEMISTRY LAB

BEFORE AFTER

PHYSICS LAB

BEFORE AFTER

CELL BIOLOGY LAB

BEFORE AFTER

COSMOLOGY LAB

BEFORE AFTER

CHEMICAL TECHNOLOGY LAB

BEFORE AFTER

MEDICINE RESEARCH LAB

BEFORE AFTER

MATERIAL TECHNOLOGY LAB

"BIG DATA" ALL AROUND

THEORY EXPERIMENT COMPUTATION

A DRAMATIC CHANGE IN "KNOWLEDGE": MAKING COMPUTER MODELS

"PROBABLY APPROXIMATELY CORRECT"

DATA, ASSUMPTIONS, ESTIMATES, HOT FIXES, METAPHORS, INTUITION

MODEL IS NOT EVEN A KIND OF THING THAT CAN BE "TRUE" OR "UNTRUE"

GLOBAL WARMING: MODEL 1

GLOBAL WARMING: MODEL 2

PHASE 2: A NEW WAY TO PERCEIVE THE WORLD

INFORMATION PARADIGM OF SCIENCE
INFORMATION ONTOLOGY
NATURALLY OCCURRING INFORMATION PROCESSES

BIOLOGY AS INFORMATION

DAVID BALTIMORE, 1980S

DNA AS A STORAGE OF GENETIC INFORMATION

TRANSFORMATION OF GENETIC INFORMATION

PHYSICS: A STUDY OF INFORMATION FLOWS

KEN WILSON, 1980S

DIGITAL HUMANITIES

LEARNING ANALYTICS

DATA MINING FROM LEARNING PROCESSES

COMPUTATIONAL EXPLANATIONS OF THE WORLD

INFO-COMPUTATIONAL THEORY OF SCIENCE

AUTOMATION OF KNOWLEDGE WORK

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SCIENTIFIC REVOLUTION

PAVED THE WAY FOR INDUSTRIAL REVOLUTION

INDUSTRIAL REVOLUTION

AUTOMATION OF MANUAL WORK

AUTOMATION DEVELOPS

200 YEARS OF "YEAH BUT MY JOB IS SPECIAL BECAUSE IT REQUIRES HUMAN INTUITION"

2ND SCIENTIFIC REVOLUTION + DATA DELUGE + MOORE'S LAW

FOUNDATIONS FOR THE SECOND INDUSTRIAL REVOLUTION

THE SECOND INDUSTRIAL REVOLUTION

AUTOMATION OF KNOWLEDGE WORK

WHAT COMPUTERS REALLY CAN'T DO

HISTORICAL OVERVIEW

WHAT COMPUTERS REALLY CAN'T DO

CALCULATE FASTER THAN THE BEST PEOPLE

WHAT COMPUTERS REALLY CAN'T DO

DO LOGICAL INFERENCES

WHAT COMPUTERS REALLY CAN'T DO

SOLVE DIFFICULT MATHEMATICAL PROBLEMS

WHAT COMPUTERS REALLY CAN'T DO

BEAT A HUMAN IN CHESS

WHAT COMPUTERS REALLY CAN'T DO

BEAT A HUMAN IN GO

WHAT COMPUTERS REALLY CAN'T DO

ENGAGE IN CREATIVE ARTS (MUSIC / PAINTING / ETC)

T

WHAT COMPUTERS REALLY CAN'T DO

RECOGNIZE AND TRANSLATE SPOKEN / WRITTEN LANGUAGE

WHAT COMPUTERS REALLY CAN'T DO

RETRIEVE RELEVANT DOCUMENTS FOR THE USER

WHAT COMPUTERS REALLY CAN'T DO

DESCRIBE THE CONTENTS OF A PICTURE

WHAT COMPUTERS REALLY CAN'T DO

IDENTIFY EMOTIONS / ETC.

WHAT COMPUTERS REALLY CAN'T DO

IDENTIFY SARCASM, IRONY, HUMOR, ETC.

WHAT COMPUTERS REALLY CAN'T DO

FLY AN AIRPLANE

WHAT COMPUTERS REALLY CAN'T DO

DRIVE A CAR

WHAT COMPUTERS REALLY CAN'T DO

DO RELIABLE MEDICAL DIAGNOSES

T

WHAT COMPUTERS REALLY CAN'T DO

WRITE NEWSREPORTS

WHAT COMPUTERS REALLY CAN'T DO

BEAT A HUMAN IN DIFFICULT COGNITIVE TASKS GIVEN IN NATURAL LANGUAGE

T

MOVING GOAL POSTS

EVERY TIME SOMETHING IS ROUTINELY SOLVED BY MACHINES, WE DON'T SEE IT AS REQUIRING INTUITION

NONE OF THIS WAS SUPPOSED TO HAPPEN THIS FAST

1990S SCIENCE FICTION IS REALITY TODAY

THE PACE OF DEVELOPMENT IS ACCELERATING

WE NEVER USED TO KEEP THE PROMISES ON TIME. TODAY WE ARE MUCH AHEAD OF THE PROMISES.

SO WHAT?

NOW WE HAVE:

- NEW MEANS OF KNOWLEDGE PRODUCTION
- NEW EPISTEMOLOGY OF SCIENCE
- RAPID DIGITALIZATION OF SOCIETAL STRUCTURES AND PROCESSES
- NEW WAYS OF AUTOMATING KNOWLEDGE WORK

… BUT HOW DO YOU LEARN TO COPE WITH DIGITALIZATION?

- COMPUTER SCIENCE'S RESPONSE: COMPUTATIONAL THINKING

COMPUTATIONAL THINKING

AN ATTEMPT TO CAPTURE COMPUTING'S DISCIPLINARY WAYS OF THINKING AND PRACTICING

COMPUTATIONAL THINKING

- SKILLS TO INTERPRET PHENOMENA AS COMPUTATIONS
- ABILITY TO HARNESS COMPUTATIONS FOR SOLVING PROBLEMS
- ABILITY TO DESIGN AND CONTROL AUTOMATION TASKS

OPEN QUESTION

HOW DO YOU TEACH COMPUTATIONAL THINKING?

WE'VE LEARNED COMPUTATIONAL THINKING THROUGH…

MODELING THE WORLD NUMERICALLY

ELIMINATING INTUITION FROM OUR MODELS

AUTOMATING MANUAL CALCULATION

BUILDING AND CONTROLLING MACHINERY

PROCESSING SYMBOLS

MECHANIZING REASONING

DEVELOPING PROGRAMMING METHODOLOGY

DESIGNING SYSTEMS FOR HUMANS

PERHAPS WE SHOULD ALSO TEACH COMPUTATIONAL THINKING THROUGH…

MODELING THE WORLD NUMERICALLY

ELIMINATING INTUITION FROM OUR MODELS

AUTOMATING MANUAL CALCULATION

BUILDING AND CONTROLLING MACHINERY

PROCESSING SYMBOLS

MECHANIZING REASONING

DEVELOPING PROGRAMMING METHODOLOGY

DESIGNING SYSTEMS FOR HUMANS

CHALLENGES

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CHALLENGE 1: AMBITION

- EPISTEMOLOGICAL REVOLUTION
- PEDAGOGICAL REVOLUTION
- SCIENTIFIC REVOLUTION

CHALLENGE 2: PLURALISM

- HISTORY OF EPISTEMOLOGICAL PLURALISTS (PAPERT, TURKLE)
- AVOID "COMPUTATIONAL CHAUVINISM" (TEDRE, DENNING & YONGPRADIT)

CHALLENGE 3: DIRECTION OF FIT

- THE DRIVER OF PROGRAMMING SKILL OR
- THE OUTCOME OF PROGRAMMING PRACTICE?

CHALLENGE 4: BUILD AN EVIDENCE BASE

- TESTING CLAIMS BEFORE OVERSELLING CT

CHALLENGE 5: RICHNESS OF COMPUTING

- CT ≠ "CODING"

CHALLENGE 6: THE ROLE OF FORMULATION

- DO WE REALLY "FORMULATE PROBLEMS"?

CHALLENGE 7: MACHINES OR HUMANS?

IS CT ABOUT…

- "HOW HUMANS THINK"
- "HOW TO CONTROL COMPUTING MACHINERY"
- "HOW TO MODEL & INTERPRET PHENOMENA"

CHALLENGE 8: RENEWING WITH THE FIELD

- COMMODIFICATION OF MACHINE LEARNING
- AUTOMATION OF CODING
- THE RISE OF DESIGN

CHALLENGE 9: COMPUTATIONAL WORLD VIEW

WEAK CT:
COMPUTING IS A GREAT TOOL FOR STUDYING HOW THE WORLD WORKS

STRONG CT:
THE WORLD COMPUTES

Epistemological challenges

- Science isn't what it used to be
  - New modes of production
  - New limits and assumptions ("probably approximately correct")
  - New ways of applying
- How do we teach "*disciplinary ways of thinking and practicing"* if we lack a consensus over what they are?

Pedagogical challenges

- New science, new ways of teaching it
  - How ready are our learning environments for the new era of science?
  - How can we support empirical, simulation based modes of inquiry?
  - How do we prepare students for the *next 30 years* instead of the previous 30 years?

SUMMARY

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Summary:

- We're in midst of an **epistemic revolution** that was
  - …**initiated by** computing pioneers,
  - …**adopted by** researchers and practitioners field after another,
  - …and this far almost completely **overlooked by educators**.
- And it's our job to make sense of all this.

Summary:

- Perhaps the best way to **teach** computational thinking is the same way we **learned** it:
  - Modeling things
  - Automating and mechanizing things
  - Building and controlling machinery
  - Creating information processing systems
  - Designing systems

Pitfalls to avoid

- Computational thinking is not a **silver bullet**
- Computational thinking is not **reducible** to one or few skills
- Computational thinking is not **ahistorical**
- Computational thinking cannot be **separated from automation** and machinery
- There's **no consensus** over computational thinking even among computer scientists

THANKS!

QUESTIONS, COMMENTS?

MATTI.TEDRE@UEF.FI
WWW.TEDRE.NAME