TEACHING THEORY OF SCIENCE TO COMPUTER SCIENCE STUDENTS

Information Technology Interfaces
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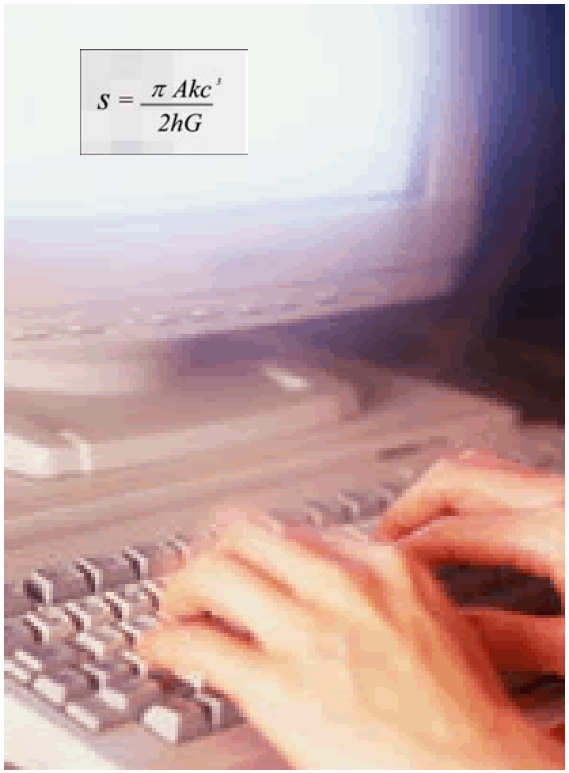

(The black hole entropy formula on the screen)

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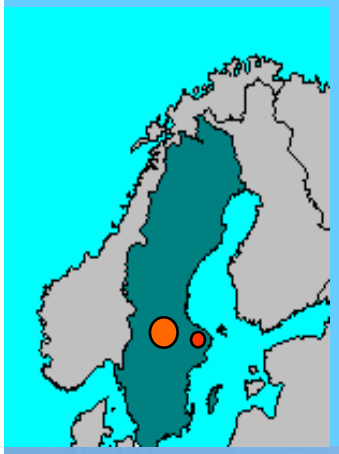
Mälardalen University (MdH)

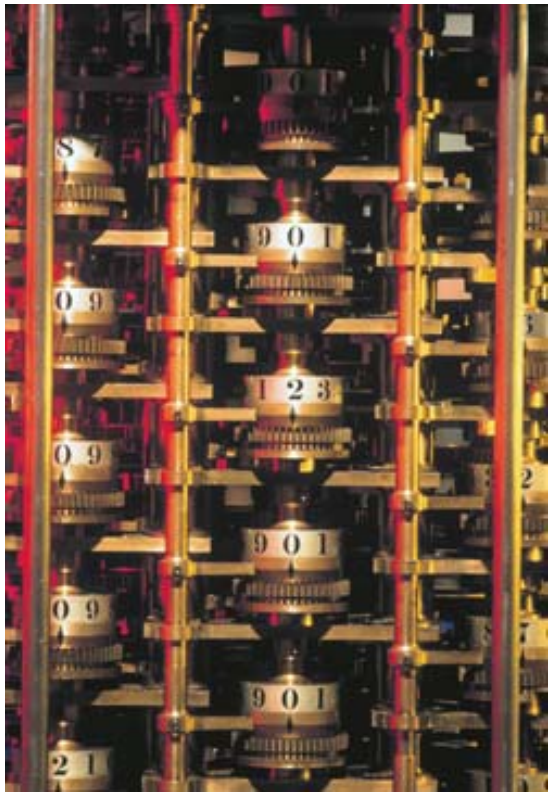


Mälardalen University, Vasteras (Västerås)

12 000 Students
~ 15 Institutions/departments

Department of Computer Science and Engineering

TEACHING THEORY OF SCIENCE TO COMPUTER SCIENCE STUDENTS



Babbage's Difference Engine No 1, 1832. Front detail.

Science Museum London

I. Computer Science Context

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VI. Mälardalen University Theory of Science Courses

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I. Computer Science Context

Institute for Electrical and Electronic Engineers

Computing Curricula 2001

STEELMAN DRAFT

(August 1, 2001)

Association for Computing Machinery

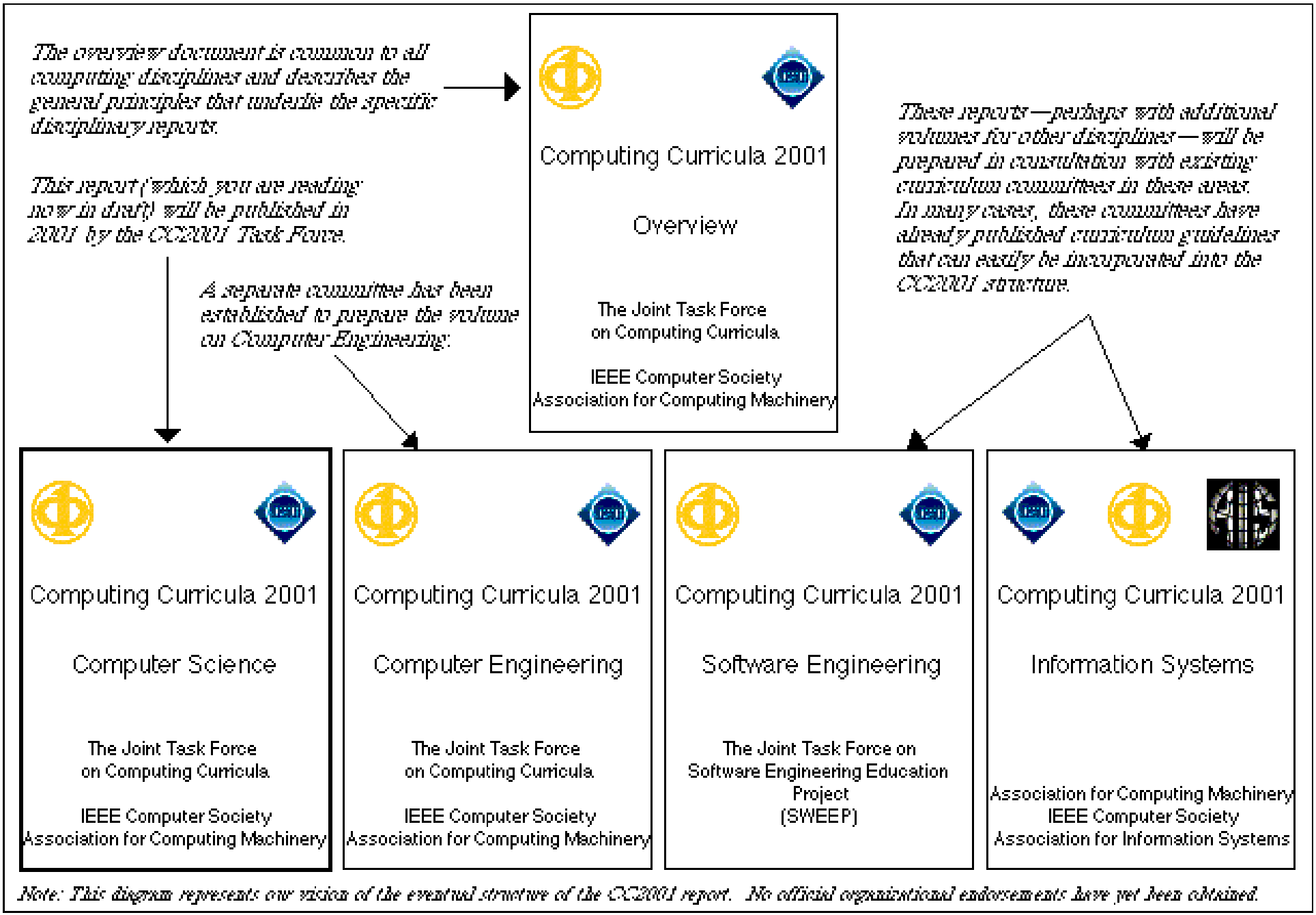
http://www.computer.org/education/cc2001/steelman/cc2001

successor of:

Allen B. Tucker, et al.
Computing Curricula '91.
ACM &Computer Society of the IEEE, 1991.

similar to the familiar:

***Computing: as a Discipline*,**
Denning, P.J. et al. Commun. ACM 32, 1 (1989), 9


The overview document is common to all computing disciplines and describes the general principles that underlie the specific disciplinary reports.
This report (which you are reading now in draft) will be published in 2001 by the CC2001 Task Force.
A separate committee has been established to prepare the volume on Computer Engineering.
These reports—perhaps with additional volumes for other disciplines—will be prepared in consultation with existing curriculum committees in these areas. In many cases, these committees have already published curriculum guidelines that can easily be incorporated into the CC2001 structure.
Computing Curricula 2001
Overview
The Joint Task Force on Computing Curricula
IEEE Computer Society
Association for Computing Machinery
Computing Curricula 2001
Computer Science
The Joint Task Force on Computing Curricula
IEEE Computer Society
Association for Computing Machinery
Computing Curricula 2001
Computer Engineering
The Joint Task Force on Computing Curricula
IEEE Computer Society
Association for Computing Machinery
Computing Curricula 2001
Software Engineering
The Joint Task Force on Software Engineering Education Project (SWEEP)
Computing Curricula 2001
Information Systems
Association for Computing Machinery
IEEE Computer Society
Association for Information Systems
Note: This diagram represents our vision of the eventual structure of the CC2001 report. No official organizational endorsements have yet been obtained.

TERMINOLOGY: COMPUTING → INFORMATICS

Observe that what is called "COMPUTING" in Steelman Report corresponds to term "INFORMATICS" in German and Franch speaking countries, where following systematization is made:

- Theoretical Informatics (Complexity, Formal Languages, Semantics, Algorithms..)
- Practical Informatics (Software Engineering, System Architecture, Information Systems, Program Languages, Parallel Computing, Distributed Systems...)
- Technical Informatics (Networks, Computer Architecture, Integrated Circuits..)
- Applied Informatics (System Analysis, CAD/CAM, Integated Systems..)
- Artificial Intelligence (Automatic Theorem Proving, Expert Systems, Robotics..)
- Informatical Didactics
- Corporate Informatics

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WHAT IS COMPUTER SCIENCE?

- **C**omputer Science is the study of processes and machines which describe and transform information.

- The fundamental question underlying all of computing is, "What can be efficiently automated?"

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- The discipline was born in the early 1940s with the joining together of algorithm theory, mathematical logic, and the invention of the stored-program electronic computer.

- The roots of the discipline extend deeply into mathematics and engineering. Mathematics contributes analysis methods to the field and engineering contributes design methods.

CS Body of Knowledge

Discrete Structures (DS)

Programming Fundamentals (PF)

Algorithms and Complexity (AL)

Programming Languages (PL)

Architecture and Organization (AR)

Operating Systems (OS)

Net-Centric Computing (NC)

CS Body of Knowledge (continued)

Human-Computer Interaction (HC)

Graphics and Visual Computing (GV)

Intelligent Systems (IS)

Information Management (IM)

Software Engineering (SE)

Social and Professional Issues (SP)

Computational Science and Numerical Methods (CN)

IS. Intelligent Systems (10 core hours)

IS1. Fundamental issues in intelligent systems (1)
IS2. Search and constraint satisfaction (5)
IS3. Knowledge representation and reasoning (4)
IS4. Advanced search
IS5. Advanced knowledge representation and reasoning
IS6. Agents
IS7. Natural language processing
IS8. Machine learning and neural networks
IS9. AI planning systems
IS10. Robotics

SE. Software Engineering (31 core hours)

SE1. Software design (8)
SE2. Using APIs (5)
SE3. Software tools and environments (3)
SE4. Software processes (2)
SE5. Software requirements and specifications (4)
SE6. Software validation (3)
SE7. Software evolution (3)
SE8. Software project management (3)
SE9. Component-based computing
SE10. Formal methods
SE11. Software reliability
SE12. Specialized systems development

SP. Social and Professional Issues (16 core hours)

SP1. History of computing (1)
SP2. Social context of computing (3)
SP3. Methods and tools of analysis (2)
SP4. Professional and ethical responsibilities (3)
SP5. Risks and liabilities of computer-based systems (2)
SP6. Intellectual property (3)
SP7. Privacy and civil liberties (2)
SP8. Computer crime
SP9. Economic issues in computing
SP10. Philosophical frameworks

WHAT SORT OF SCIENCE IS IMPORTANT FOR COMPUTING PROFESSIONALS?

"PROFESSION" IS A VERY HETEROGENEOUS GROUP OF PEOPLE:

- SCIENTISTS → A SMALL GROUP
- ENGINEERS → GROUP
- INTERNET USERS → VIRTUALLY EVERYBODY

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WHAT SORT OF KNOWLEDGE IS NECESSARY?

PRACTICES (SKILLS/TACIT KNOWLEDGE)
(knowing *how* to do something)

THEORY (PROPOSITIONAL/ DESCRIPTIVE/FORMAL KNOWLEDGE)
(knowing *what* and *why* is the case)

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II. Scientific Methods of Computer Science – The Traditional View

SCIENTIFIC METHODS OF COMPUTER SCIENCE

- *Theoretical Computer Science*
- *Experimental Computer Science*
- *Computer Simulation*

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SCIENTIFIC METHODS OF CS

THEORY: (**WHAT *IS* IT?)**
COMPUTER AS AN **FRAMEWORK/OBJECT** OF INVESTIGATION.
(MATHEMATICAL LOGIC, MATHEMATICS, FORMAL METHODS)

EXPERIMENT: (**WHAT/HOW *DOES* IT?)**

COMPUTER AS A **TOOL** OF INVESTIGATION.

(SEARCH, AUTOMATIC THEOREM PROVING, PLANNING, VISION, NEURAL NETS, GAMES, MACHINE LEARNING)

SIMULATION: REPRESENTATION OF PHENOMENA
WHAT IT DOES (MODEL) ≡ **WHAT IT IS** (PHENOMENON)
Computer simulation considered essentially equivalent to real world experiment.
(GRAPHICAL REPRESENTATION OF SPACE/TIME BEHAVIOR, E.G.)

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THEORETICAL COMPUTER SCIENCE

- Conceptual and formal models (including data models, algorithms and complexity)
- Computer is the object of research

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MAIN METHODOLOGICAL THEMES IN THEORETICAL CS (INHERITED FROM MATHEMATICS)

- *Iteration.* Performs a sequence of operations repeatedly using an iterative construct such as *for-* or *while-* statement.

- *Recursion*. Recursive procedures call themselves either directly or indirectly.

- *Induction*. Inductive definitions and proofs use basis and inductive step to encompass all possible cases.

EXPERIMENTAL COMPUTER SCIENCE

- Experiments are used for:
- Theory testing
- Exploration

EXPERIMENTAL COMPUTER SCIENCE

Experiments are made in many different fields of CS such as

- automatic theorem proving,
- natural language,
- vision,
- neural nets/connectionism,
- machine learning,….

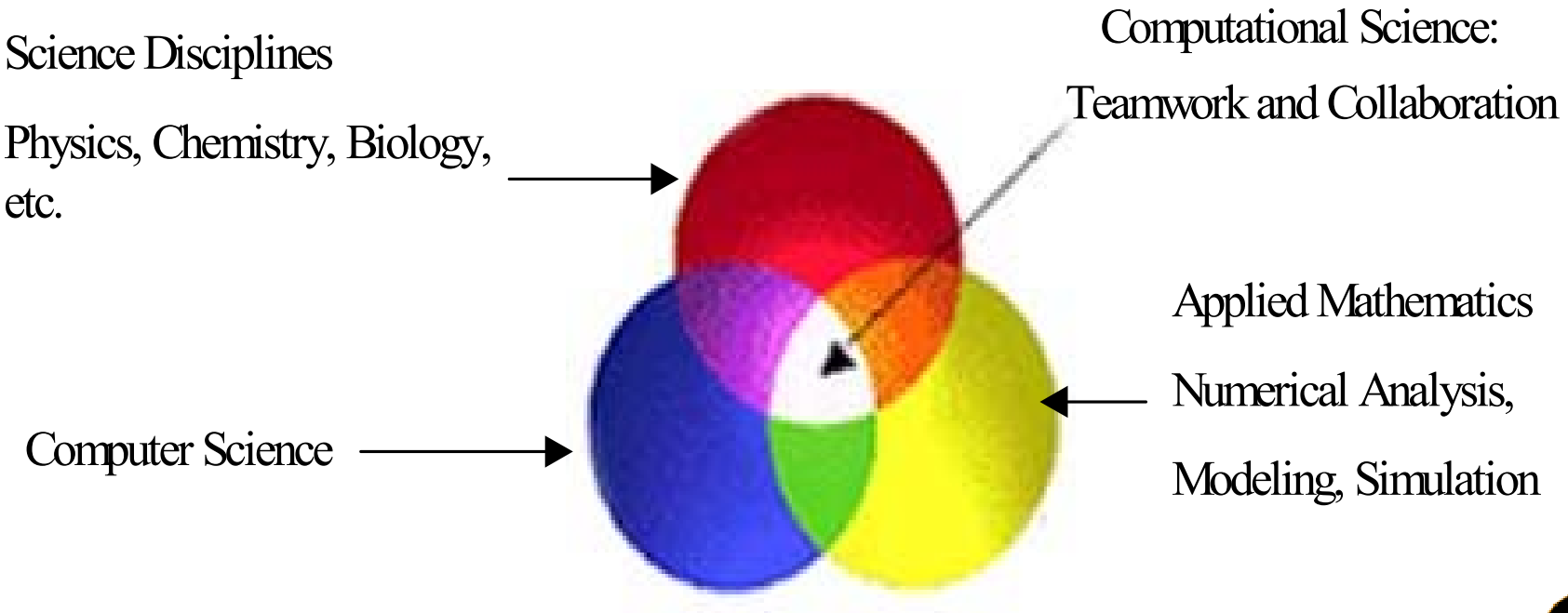
CS THEORIES THAT HAVEN'T BEEN TESTED YET

Functional programming, object-oriented programming, and formal methods are all means to improve *programmer productivity* and *program quality*, or both.

Yet, none of these obviously important claims have ever been tested systematically.

COMPUTER SIMULATION

In recent years, computation (computer-based modeling and simulation), has become the third research methodology within CS, complementing theory and experiment.



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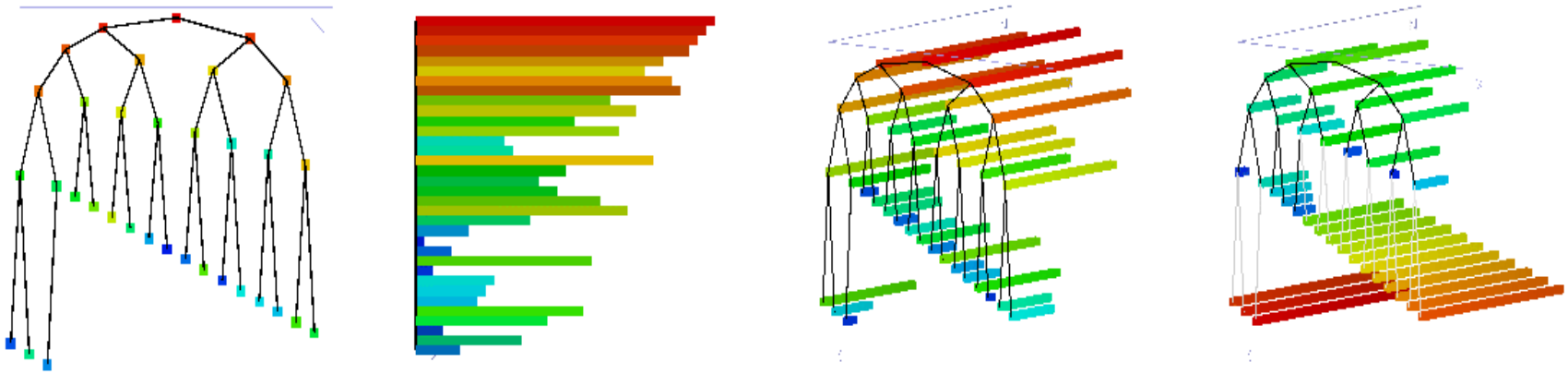
3D VIEW OF HEAPSORT ALGORITHM



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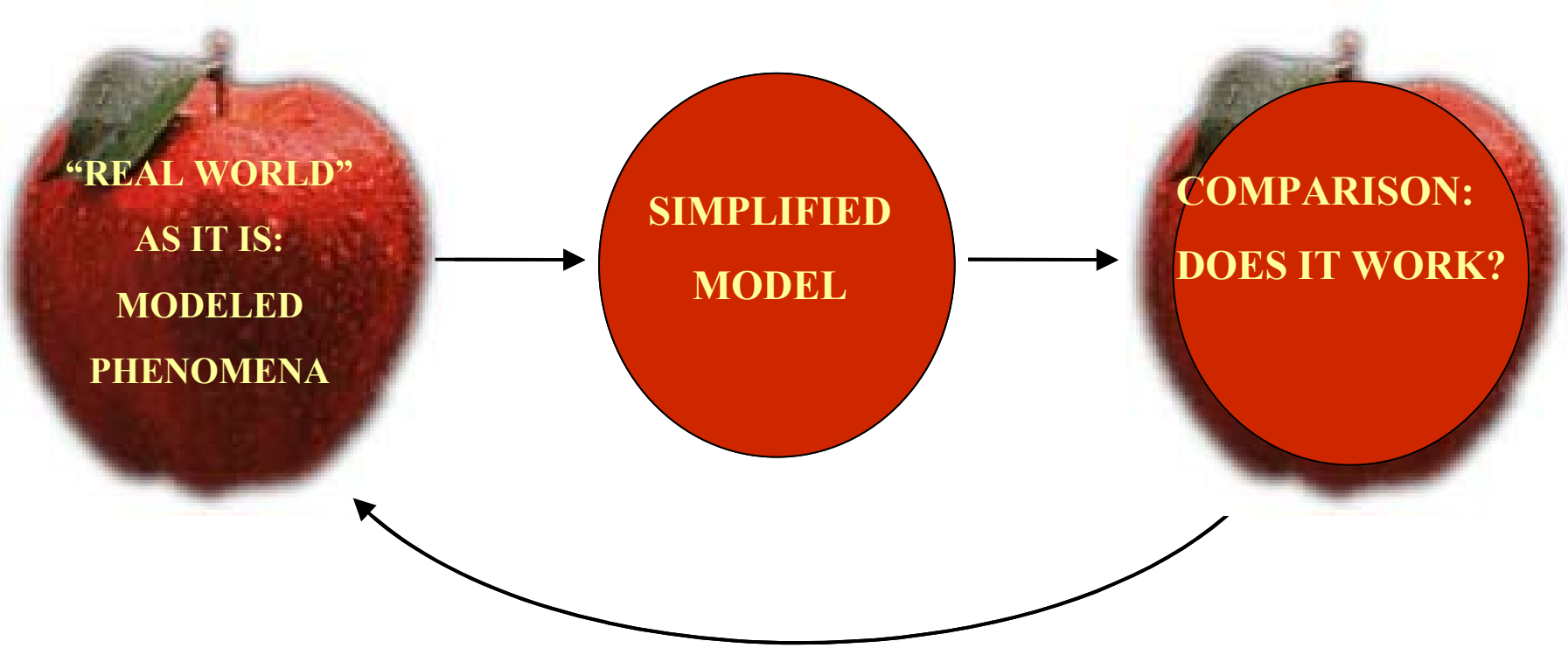
MODELLING



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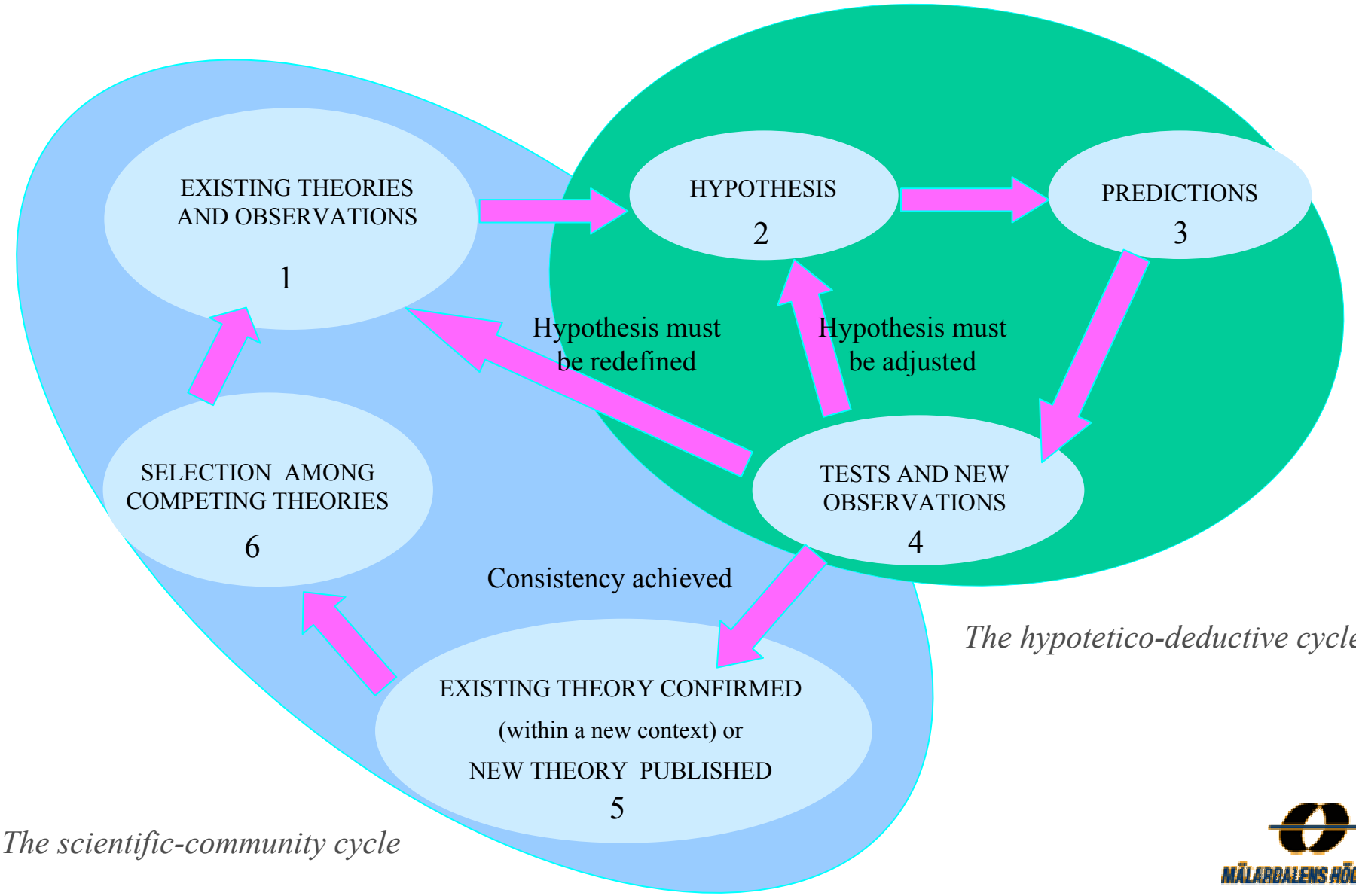
THE SCIENTIFIC METHOD



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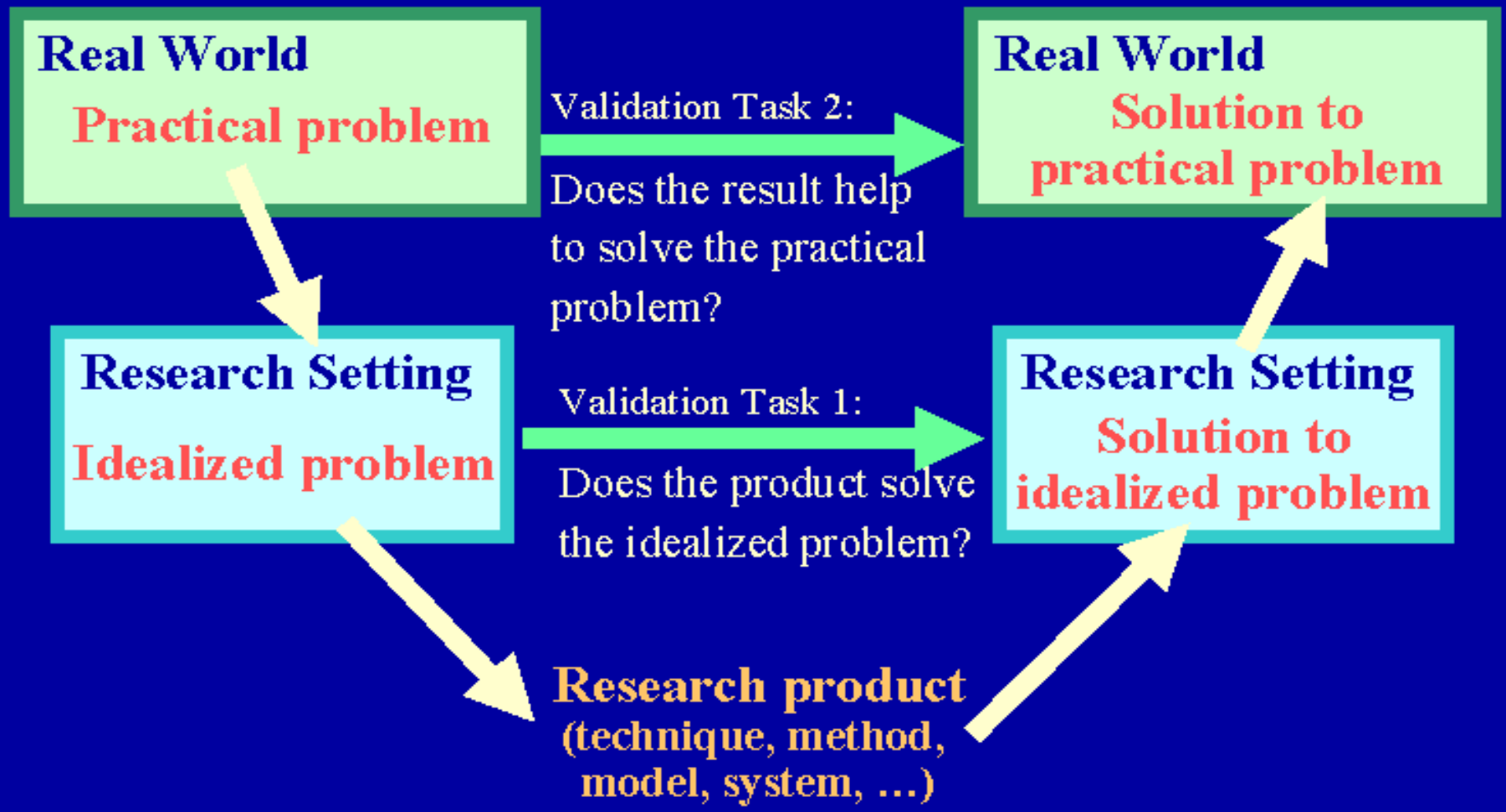
SE Research Methods



Building Blocks for Research

Question	Strategy/Result	Validation

UNIVERSE AS AN REFLECTION OF OUR OWN VALUE SYSTEM: A MODEL ESSENTIALLY EQUIVALENT TO REAL WORLD OBJECT

A late thirteenth-century illustration of the venous system within the body. According to Galen the venous system was distinct from the arterial, and the blood ebbed and flowed through the body.

Post-mortem examinations were rare well into the Middle Ages, largely due to religious and intellectual scruples.

http://www.princeton.edu/~his291/Mondino.html

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III. Bird's Eye View of Science

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Bird's Eye View of Science

SCIENCES

Typus Arithmeticae, 1535. From the book of Arithmetic, part of the Margarita Philosophica by Gregorius Reisch.

First printed in 1503, Margarita Philosophica is divided into twelve 'books', with each one dealing with the **'Sciences' of Grammar, Dialectic, Rhetoric, Arithmetic, Music, Geometry, Astronomy, Principles of Natural Philosophy, Origin of Natural Objects, Psychology, Logic and Ethics.** Hand-coloured wood-cut.
Science Museum London

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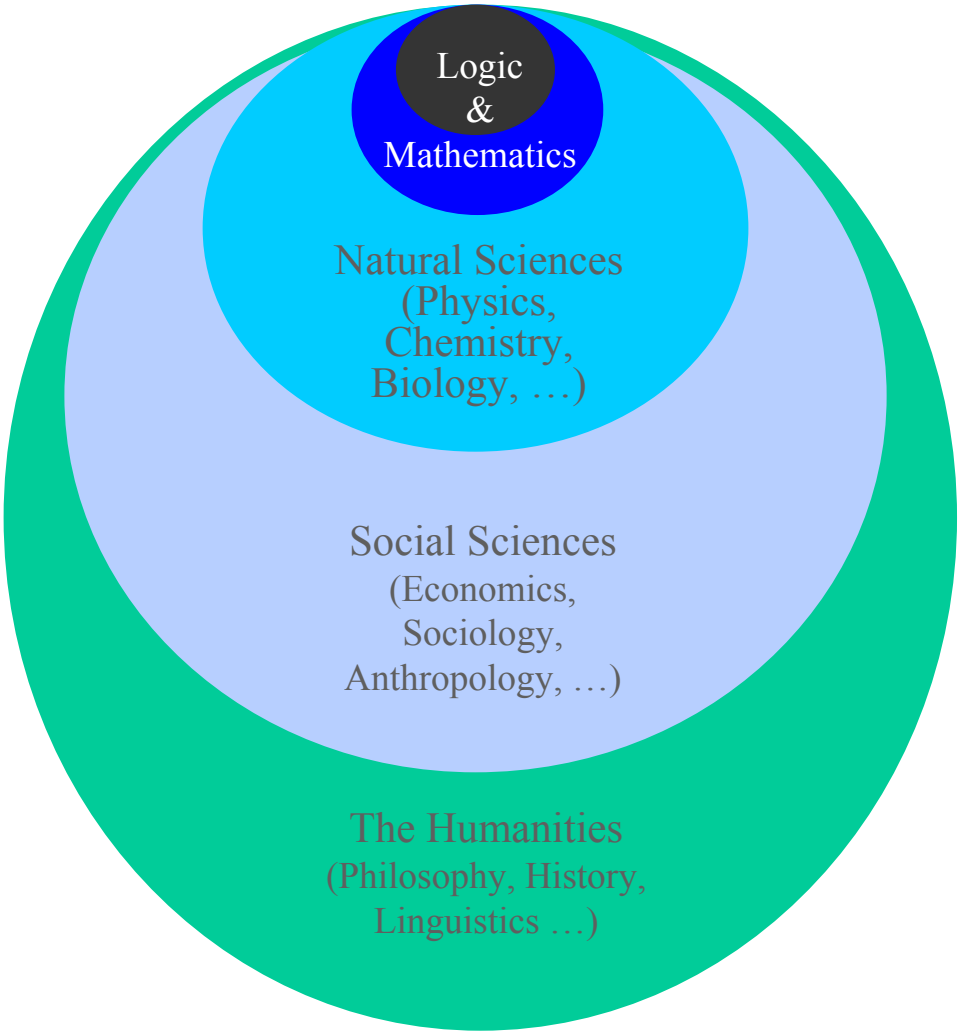
WHAT IS THIS THING CALLED SCIENCE?
A possible classification: a formalism of its language



Culture
(Religion, Art, …)

The whole is more
than the sum of its parts.

Aristotle, Metaphysica

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IV. Science and Technology

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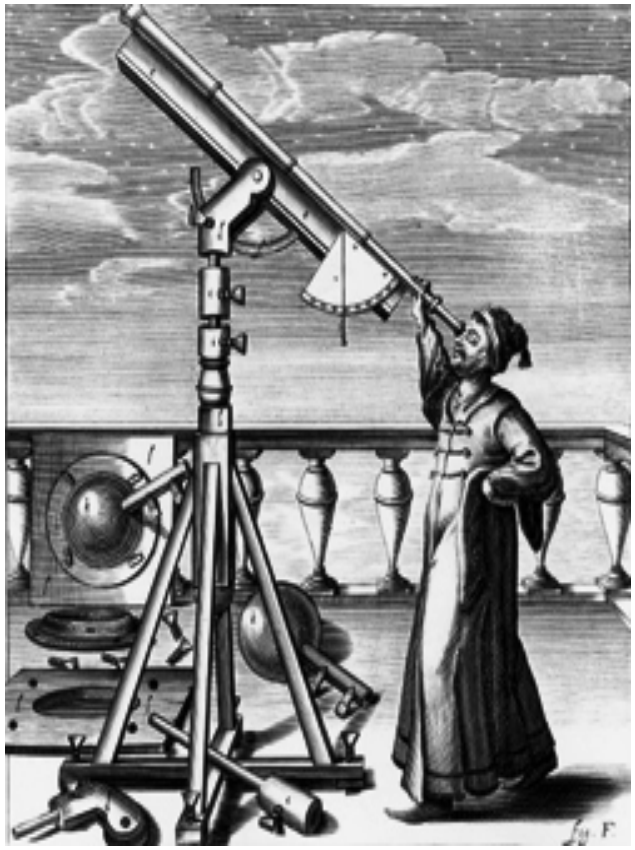

Science and Technology

Astronomical telescope with observer, 1647.
Plate taken from 'Selenographia'(1647) by Johannes Hevelius (1611-1687).
Hevelius was an early German astronomer, who established the foremost observatory in Danzig in 1641, and rebuilt it after a fire in 1679.

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TECHNOLOGY EXPANDS OUR WAYS OF THINKING ABOUT THINGS, EXPANDS OUR WAYS OF DOING THINGS.

Herbert A. Simon

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SCIENCE VS TECHNOLOGY

The invention of gunpowder', c 14th century.

Allegorical interpretation of the invention of gunpowder, showing the devil on the shoulder of a monk involved in an experiment. It is thought that the artist intended the monk in the picture to be Berthold Schwarz, a semi-legendary German Franciscan monk.

Schwarz was a nickname (German for 'black') due to Berthold's chemical experiments. The picture is an alchemical engraving.

Science Museum London/ Science & Society Picture Library

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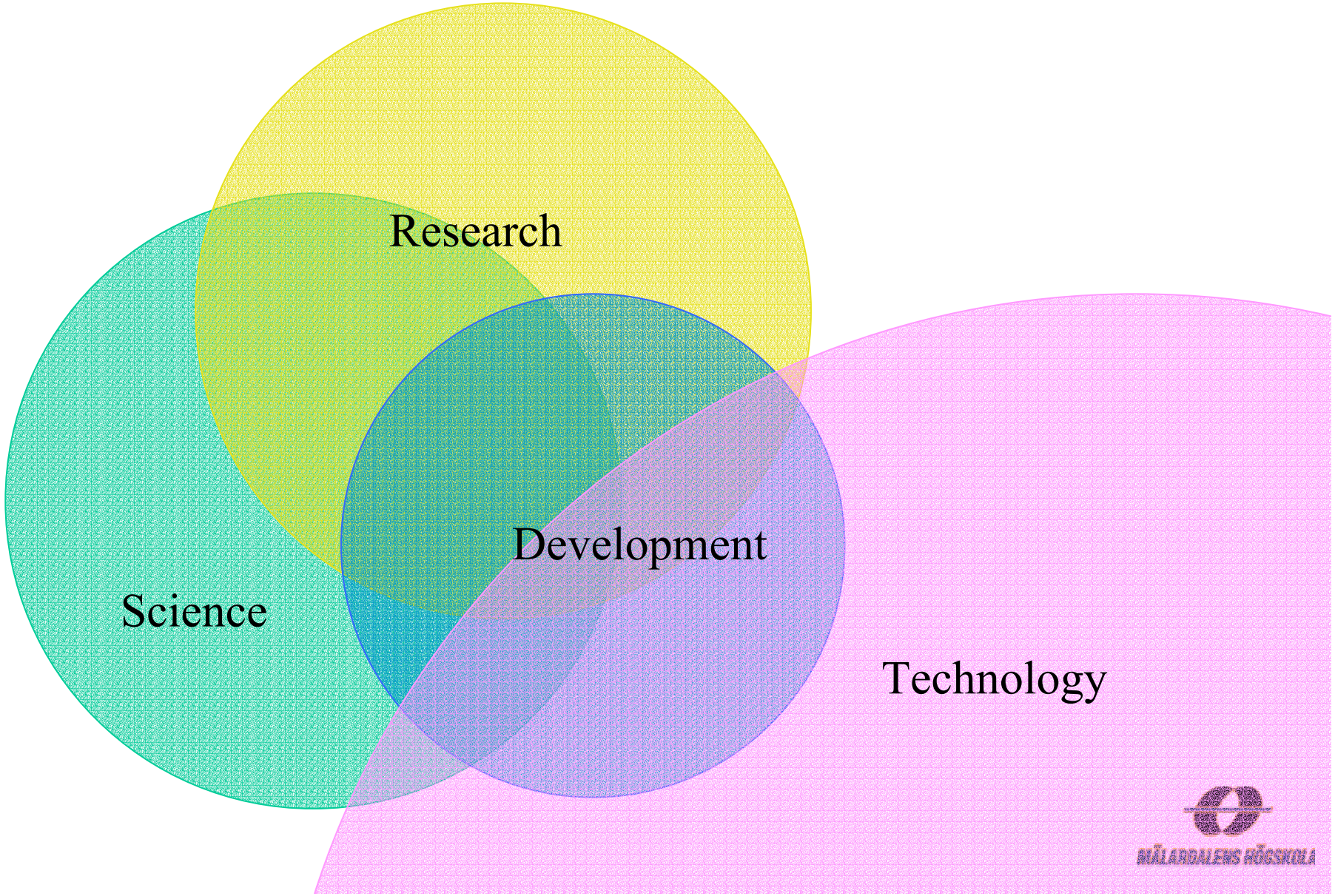
SCIENCE, RESEARCH, DEVELOPMENT AND TECHNOLOGY



V. Problem with the Traditional View: In what way is CS a Science?

AI example

AI is a branch of Computer Science with two distinct facets: Science and Engineering:

- *The scientific facet of AI* attempts to understand intelligence in humans, other animals, information processing machines and robots.
- *The engineering facet of AI* attempts to apply such knowledge in designing new kinds of machines.

Sub-fields of AI	Related Fields
Perception, (vision, auditory, tactile perception, and more recently taste and smell).	Philosophy, Cognition, Psychology, Mathematics, Biology, Medicine, Behavioral Sciences, Brain Sciences
Natural language processing: production and interpretation of spoken and written language.	Linguistics, Psychology, Philosophy, Logic, Mathematics, Behavioral Sciences, Brain Sciences
Learning and development symbolic learning processes (e.g. rule induction), the use of evolutionary algorithms, self-debugging systems, self-organization.	Logic, Philosophy, Mathematics, Biology, Medicine, Behavioral Sciences, Brain Sciences

Sub-fields of AI	Related Fields
Robotics: is sometimes studied for the purpose of producing new kinds of machines, and sometimes because designing complete working robots provides a test bed for integrating theories and techniques from various sub-areas of AI, e.g. perception, learning, memory, motor control, planning, etc. I.e. it is a context for exploring ideas about complete systems.	Philosophy, Cognition, Psychology, Mathematics, Biology, Medicine, Behavioral Sciences, Brain Sciences

AI is generally associated with Computer Science, but it has many important links with other fields such as Mathematics, Psychology, Cognition, Biology, Linguistics and Philosophy, Neuroscience, Social Science, Behavioral and Brain Sciences among many others.

Similar with other CS disciplines

Example:

Human-Computer Interaction

Software Engineering *have to take into consideration humans* (users, programmers) in their models of the investigated phenomena.

The consequence of widening the problem domain to include humans is introduction of a “soft” empirical approach more characteristic for Humanities and Social Sciences, with methodological tools such as *interviews* and *case studies*.

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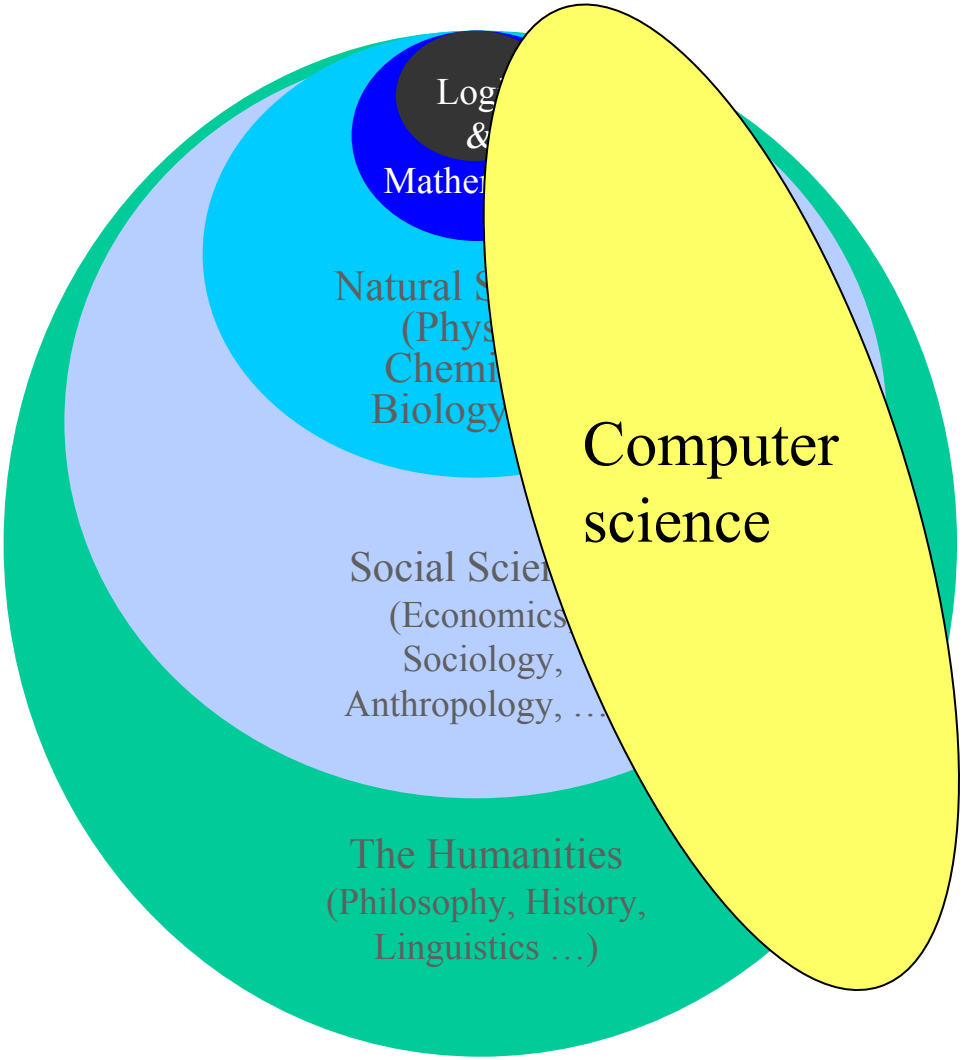
WHAT IS THIS THING CALLED SCIENCE?



Culture
(Religion, Art, …)

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Sciences Belonging to Several Fields

We should, by the way, be prepared for some radical, and perhaps surprising, transformations of the disciplinary structure of Science (Technology included) as information processing pervades it. In particular, as we become more aware of the detailed information processes that go on in doing Science, the Sciences will find themselves increasingly taking a meta-position, in which doing Science (observing, experimenting, theorizing, testing, archiving,) will involve understanding these information processes, and building systems that do the object-level Science. Then the boundaries between the enterprise of Science as a whole (the acquisition and organization of knowledge of the world) and AI (the understanding of how knowledge is acquired and organized) will become increasingly fuzzy.

Allen Newell, Artif. Intell. 25 (1985) 3.

PHILOSOPHY OF SCIENCE – A NEW PARADIGM

Computers give us the potential to bring again together (Natural) Sciences and Humanities in a number of common projects.

It means that it is necessary, indeed essential to educate Computers Science students not only in Theory of Science including classical sciences, but also give the insights in values and methods of Humanities.

VI. Mälardalen University Theory of Science Courses

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MÄLARDALEN UNIVERSITY COURSES (1)

Science Methodology for Computer Science and Engineering CD5420 (second year course)

- Theory of Science
- History of Science. History of Computer Science
- Information Search
- Reading and discussing texts
- Writing and Presentation of Report
- Review and Opposition of Papers

Teaching forms

- Lectures, assignments and seminars.

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MÄLARDALEN UNIVERSITY COURSES (2)

Research Methodology for Computer Science and Engineering (graduate course)

- Theory of Science, History of Science.
- History of Computer Science
- Research Methodology within
  - Computer Science
  - Software Engineering
  - Real Time Systems
  - Basic Theory of Measurement

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Teaching forms

- Lectures and seminars
- Reading and discussing texts and scientific papers
- Writing and Presentation of Scientific Paper
  - Peer Review of Papers
  - Mini-Conference

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VII. Conclusions & questions

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- Should all students study Theory of Science?
  - To which extent?
- Should students from other sciences study Computer Science?
  - To which extent?
    - Data structure and algorithms
    - Programming language(s)
    - Software Design
    - Numerical methods
    - Different tools
    - Database
    - ……

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- Should teaching of computer science replace some other disciplines (physics,,…)?