Center for
LifeLong
Learning
& Design

University of Colorado at Boulder

Wisdom is not the product of schooling but the lifelong attempt to acquire it.
- Albert Einstein

Distributed Intelligence: Extending the Power of the Unaided, Individual Human Mind

Gerhard Fischer
Center for LifeLong Learning & Design (L3D)
Department of Computer Science and Institute of Cognitive Science,
University of Colorado, Boulder

L3D Presentation, March 22, 2006

Overview

- Basic Message

- Beyond the Unaided, Individual Human Mind: New Media and Technologies

- Distributed Intelligence

- Conceptual Frameworks

- Socio-Technical Environments
    - CLever: Cognitive Levers
    - EDC: Envisionment and Discovery Collaboratory

- Conclusions

Basic Message

- thinking, knowing, working, and learning will further **transcend the unaided individual** human mind in the 21st century → this is not a luxury, but a necessity

- **innovative media and technologies ("socio-technical environments")** are of critical importance supporting new levels of distributed intelligence

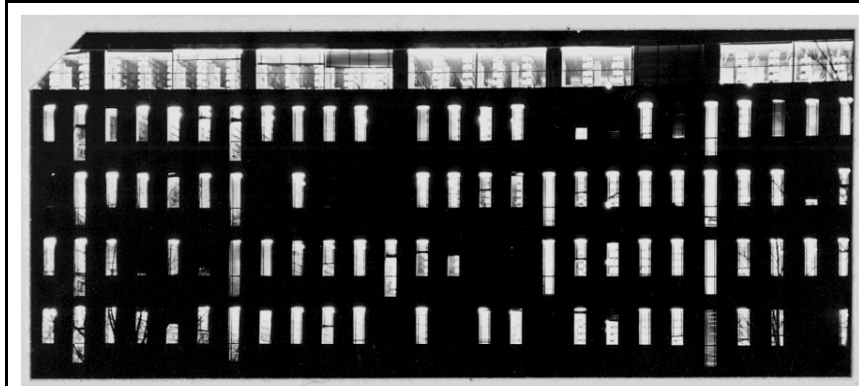# Beyond the Unaided, Individual Human Mind
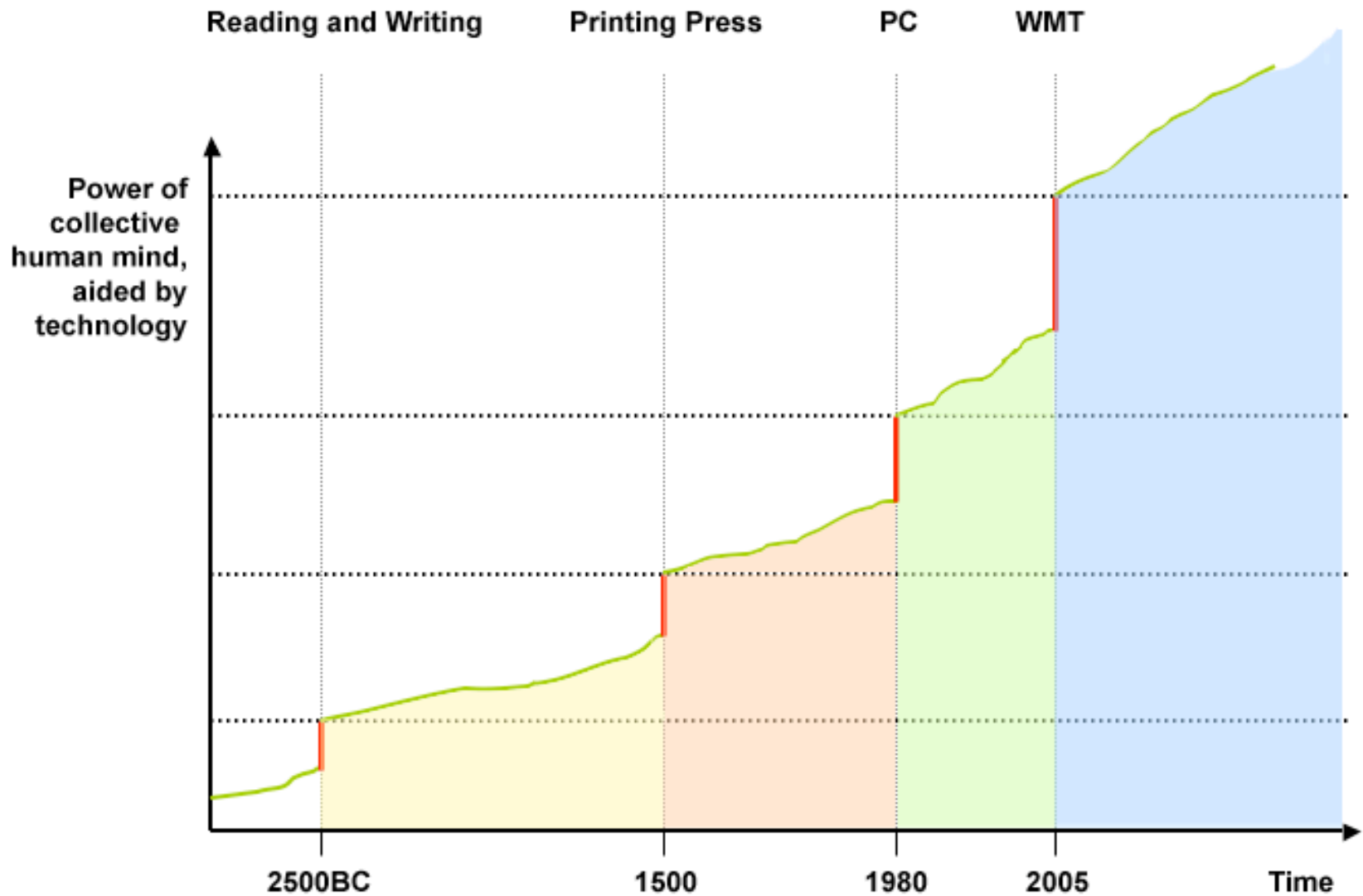
Learning = f{Media} — In "Ancient" Times: Paper, Blackboards
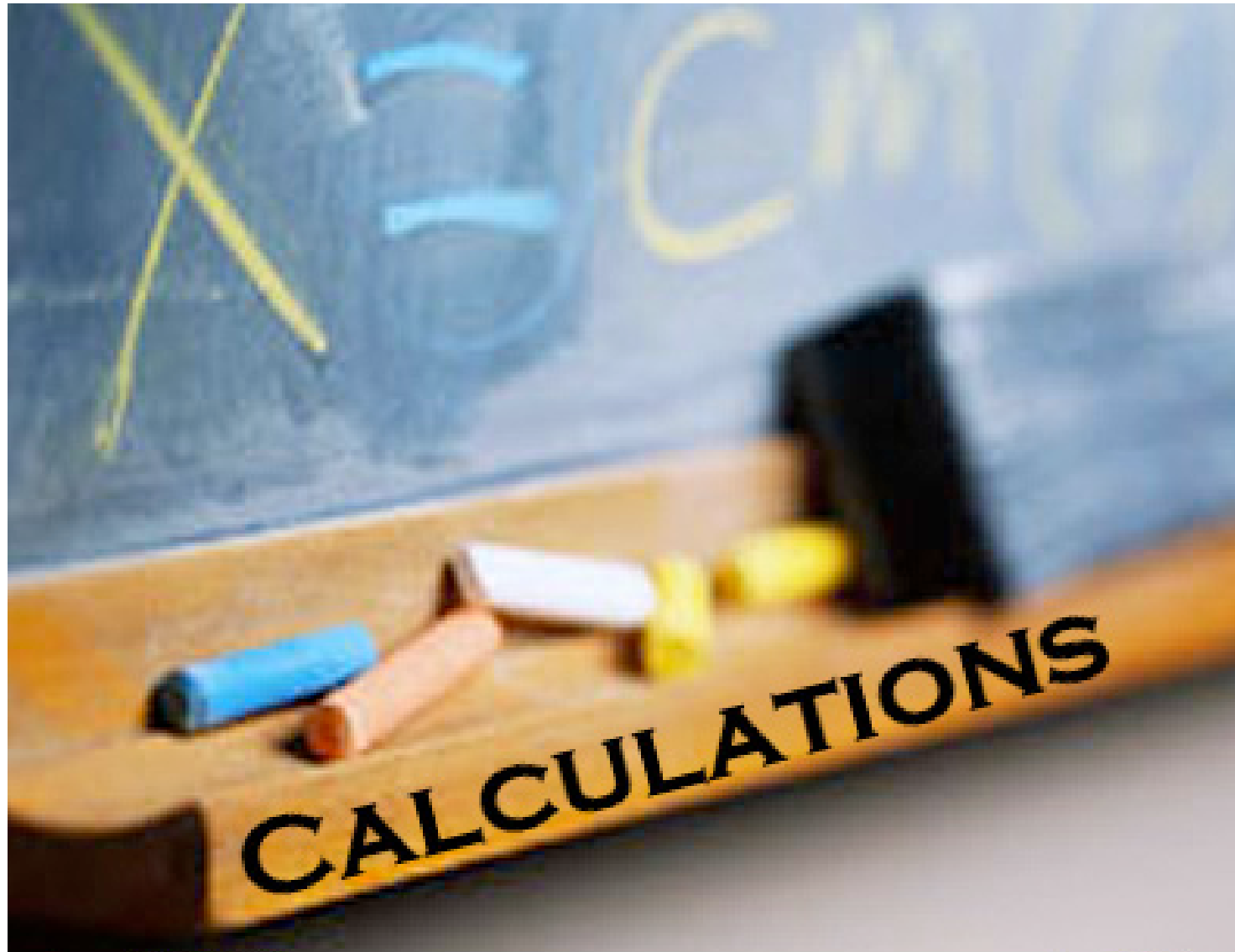
Learning = f{Media} — In the "Very Old" Days: Slide-Rules

Learning = f{Media} — In the "Old" Days: Computing with Punch Cards

Learning = f{Media} — Yesterday: The Personal Computer

Learning = f{Media} — Today: Wireless and Mobile Technologies (WMT)

Impact of New Technologies and New Media

- **claim:** all important technologies are **"Faustian bargains":** they give and take away → technological change always produces winners and loosers

- while the growth of technology is certain, the **inevitability of any particular future is not** → therefore: we can envision a number of different futures that might be

- the **visions** for possible futures (see Florida, R. (2002): "The Rise of the Creative Class")
    - **techno-utopians** romanticize the future → things will be wonderful with new technologies, technology will liberate us
    - **techno-pessimists** glorify the past → technologies will oppress us
    - **basic belief:** the deep and enduring changes of our ages are not technological but social and cultural

Media as "Faustian Bargains"

Medium	Strengths (Gains)	Weaknesses (Losses)
Reading and Writing	external memory	"books will destroy thoughts" (Sokrates)
Slide Rule	simplification of arithmetic operations	limited set of operations
Punch Cards Computing	writing programs	large overhead
PC	personal	location bound
WMT	always with us and always on; learning on demand; supporting in situated activities	disruptive

Distributed Intelligence

- ***claim:*** many scientific approaches have seen *human cognition* as existing solely "inside" a person's head, and studies on cognition have often disregarded the physical and social surroundings in which cognition takes place

- **distribution among people:**
    - all of us are knowledge in some domains and not in others ("symmetry of ignorance)
    - division of labor + specialization
    - collaborative learning and working (CSCL and CSCW)

- **distribution between humans minds and artifacts**
    - changing tasks and intelligence augmentation
    - external representations (**visualizations**)

- the two distributions can and should be **integrated** (e.g., tools for collaboration, social creativity)

Two Perspectives

- **personal point of view:** distributed intelligence **changes the nature of the tasks** which human beings have to do creating new divisions of labor

    - source: Norman, D. A. (1993) Things That Make Us Smart, Addison-Wesley Publishing Company, Reading, MA.

    - example: check-out clerk in a supermarket, pilot flying an airplane

- **system point of view:** the "person + artifact" is smarter than either alone

    - source: Engelbart, D. C. (1995) "Toward Augmenting the Human Intellect and Boosting Our Collective IQ," Communications of the ACM, 38(8), pp. 30-33.

    - Einstein: "My pencil is cleverer than I"

    - example: symbiosis in socio-technical environments for people with cognitive disabilities, cockpit of an airplane

Technologies Changing Tasks

From the Neighborhood Store to the Smart Store of the Future

- **media:** head → pencil and paper → adding machines → UPC, scanners and databases, RFID tags

- **sales clerks:** adding prices
  - in their heads
  - using pencil and paper
  - using adding machines
  - using scanners
  - no need for their services anymore

- **money:** computing the change in the head → by the machine → processing credit cards

- **customer:**
  - checking out their own groceries ("do I want to do this?")
  - walking by a RFID reader

- **overall performance of the system:** speed, reliability, visibility (total cost, partial costs)

Question: Does this Statue Convey the "Right" Image of Cognitive Activities (thinking, working, and learning)?

("The Thinker" by Auguste Rodin)

Why Distributed Intelligence?

A few Claims based on the work of Jerome Bruner

- human mental activity is **neither solo nor conducted unassisted**, even when it goes "inside the head"

- **"how the mind works"** is itself dependent on the tools at its disposal (→ "how the hand works" cannot be fully appreciated unless one takes into account whether it is equipped with a screwdriver, a pair of scissors)

- **externalizations, oeuvres, works, works-in-progress**
    - produce a record of our efforts, one that is "outside us" rather than simply in memory
    - produce situations talking back to us
    - make our thoughts and intentions more accessible to reflective efforts
    - works-in-progress produce and sustain creativity by creating shared and negotiable ways of thinking in a group

Why Distributed Intelligence?

A few Claims based on the work of Merlin Donald

- **brain-culture symbiosis:** the human brain cannot realize its potential unless it is immersed in a distribution network

- **material culture:**
  - externalizes memory and greatly amplifies the permanence and power of distributed cognition
  - new media gradually freed the symbolization process from the limitations of biological memory
  - the material culture sometimes overwhelms us with its richness

- **higher intelligence:**
  - a product of marrying the raw intellectual power of the human brain to an appropriate technology
  - think previously unthinkable thoughts
  - "mind tools": perform cognitive work, contribute symbolic technologies (musical notation, Arabic numerals)

Possible Roles for Humans and Computers in Distributed Intelligence

source: Norman, D. A. (1993) *Things That Make Us Smart*
black: human-centered view
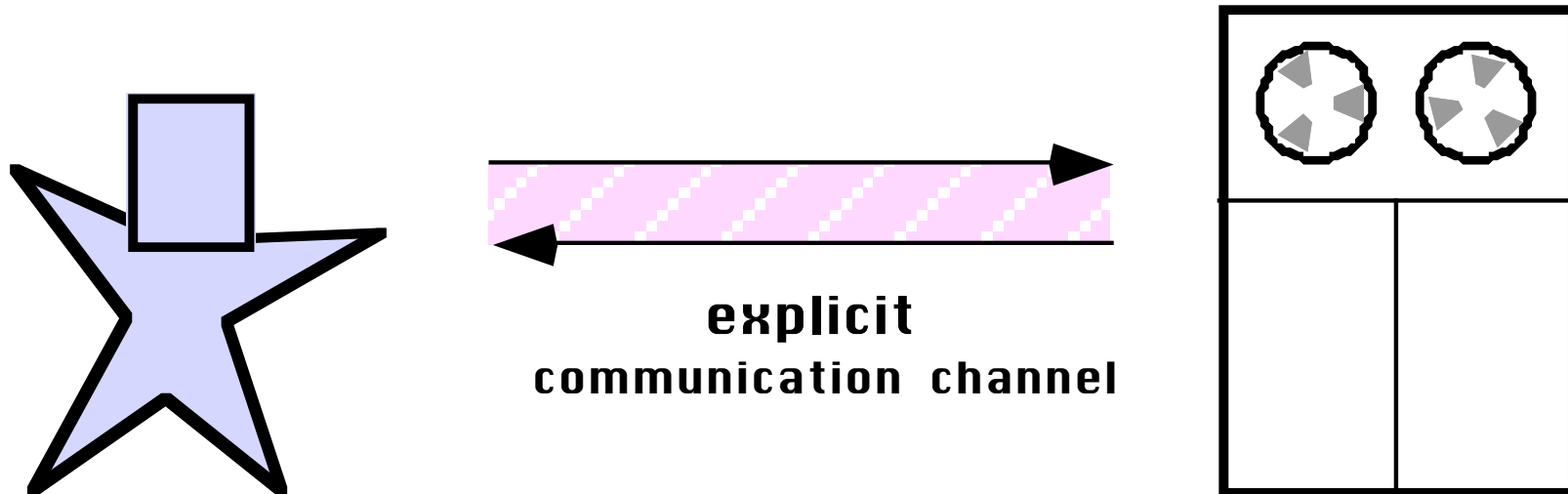*blue: computer-centered view*

Humans	Computers
creative, vague	dumb, precise
compliant, disorganized	rigid, orderly
attentive to change, distractible	insensitive to change, undistractable
resourceful, emotional	umimaginative, unemotional
flexible	consistent

Conceptual Frameworks and Socio-Technical Environments Grounded in a Distributed Intelligence Framework
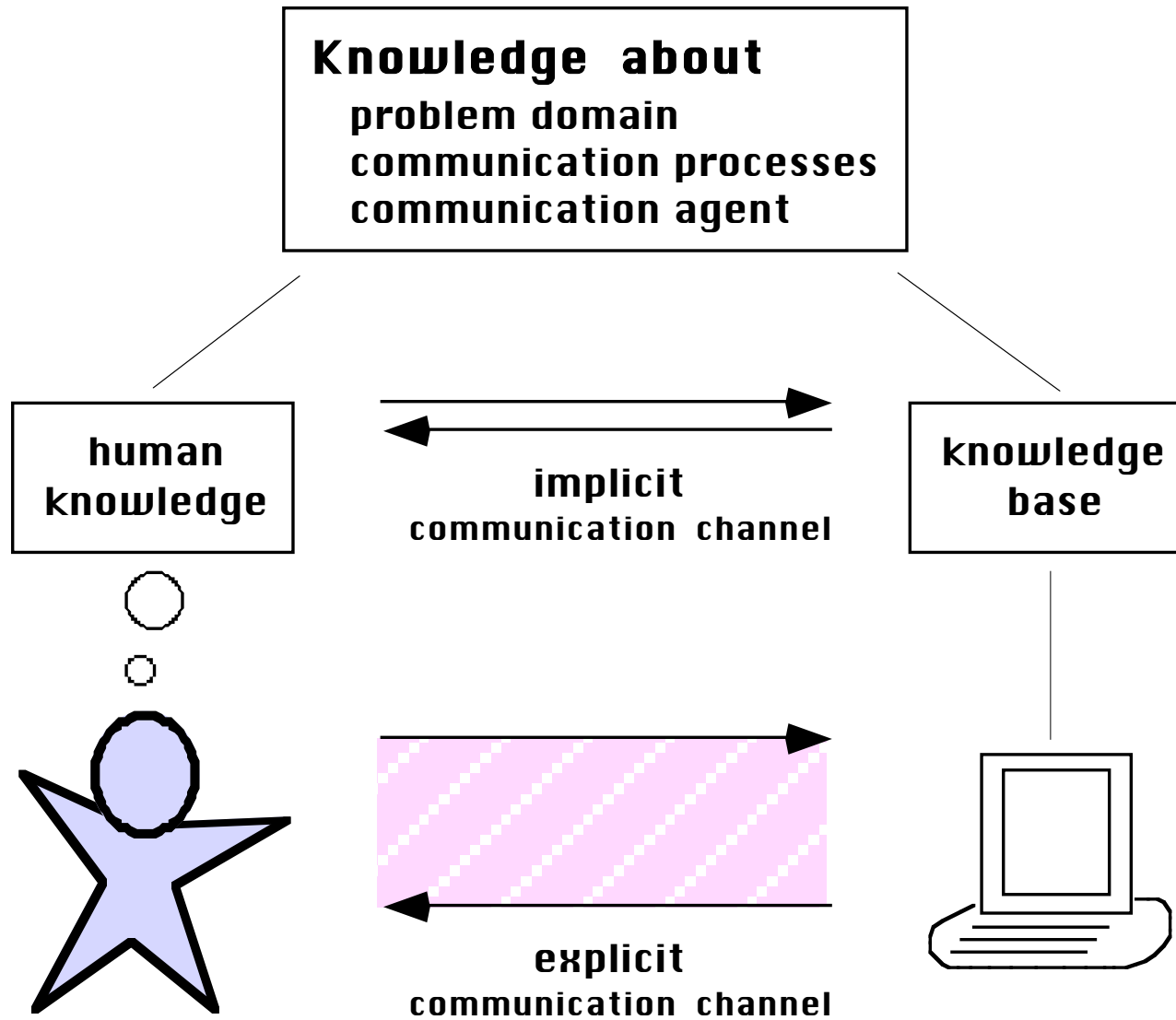
- Human Computer Interaction: Explicit and Implicit Interaction Channels

- Representations / Visualizations

- scarce resource

- examples of socio-technical environments:
    - **CLever:** Cognitive Levers — Tools for Living and Tools for Learning
    - **EDC:** Envisionment and Discovery Collaboratory — Social Creativity

The Beginning of Human-Computer Interaction (HCI)

Human and Computer connected by a narrow explicit communication channel

explicit
communication channel

Knowledge-Based Human Computer Collaboration

Knowledge about
   problem domain
   communication processes
   communication agent

human knowledge

implicit
communication channel

knowledge base

explicit
communication channel

Visualization = In Search for Powerful External Representation

source: Simon, H. A. (1996) *The Sciences of the Artificial,* third ed., The MIT Press, Cambridge, MA.

- **informational efficiency:** two representations are informationally equivalent if all of the information in the one is also inferable from the other, and vice versa. Each could be constructed from the information in the other.

- **computational efficiency:** two representations are computationally equivalent if they are informationally equivalent and, in addition, any inference that can be drawn easily and quickly from the information given explicitly in the one can also be drawn easily and quickly from the information given explicitly in the other, and vice versa

- *informational equivalence* **versus** *computational equivalence* **of representations** → *"even if two representations contain exactly the same information, it may be far cheaper, computationally, to make some of this information explicit using one representation than using the other"*

The Importance of Representations

- **critical importance of representations:**
  "Solving a problem simply means representing it so as to make the solution transparent"

- **number scrabble ("The Game of 15")**
  - two person game
  - numbers from 1 to 9
  - players alternate and take one of the numbers
  - the player who can add **exactly** three numbers in her/his possession to equal 15 will win

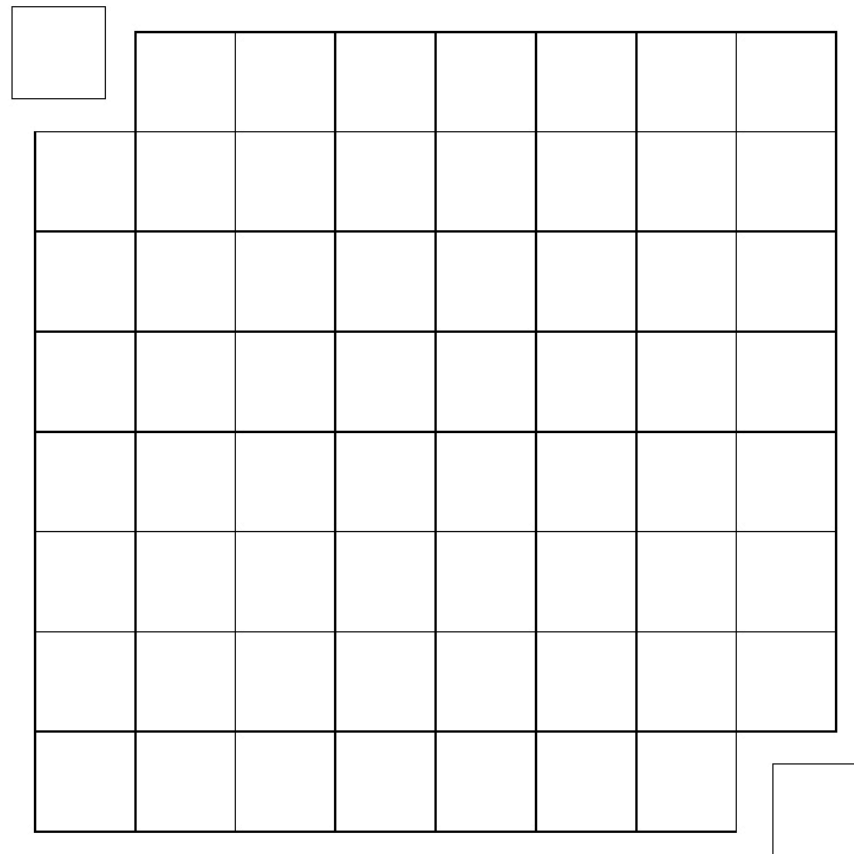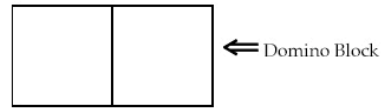# 1,2,3,4,5,6,7,8,9

Tic-Tac-Toe

		X
	O	X
O		

Number Scrabble and Tic-Tac-Toe: The "Same Game"
—
visualization makes a BIG difference (for human; for computer programs, Number Scrabble "is easier")

2	7	6
9	5	1
4	3	8

Mutilated Matrix

← Domino Block

Mutilated Chessboard
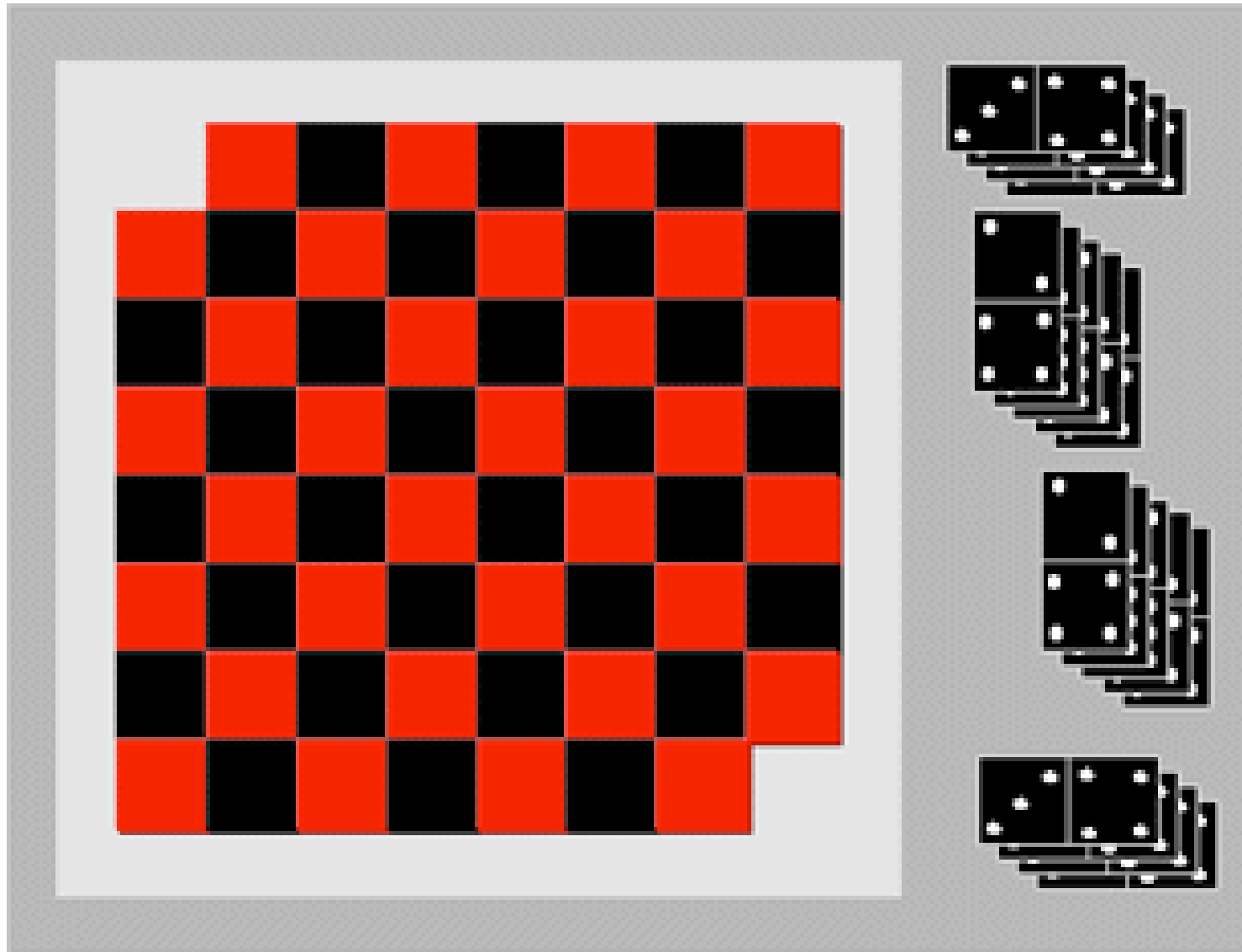
The Matchmaker Story

Many years ago, in a small but very proper village in the Midwest, there were 32 bachelors and 32 unmarried women. Through tireless efforts, the village matchmaker succeeded in arranging 32 highly satisfactory marriages. The village was proud and happy. Then one drunken Saturday night, two bachelors, in a test of strength, stab each other with knives.

Can the matchmaker, through some quick arrangements, come up with 31 satisfactory marriages among the 62 survivors?

Constraints: good catholic environment — no same-sex marriages are allowed!

Existence of Powerful Tools is Not Good Enough
—
The Rationale for Critiquing Systems

- **color** →Travis, D. (1991) *Effective Color Displays—Theory and Practice,* Academic Press, London:

  "but when color is used inappropriately it can be very counter productive and few software designers have much experience with the use of color; the aim of this book is to synthesize our current knowledge in the area and specify guidelines so that programmers, engineers, and psychologist can use color."

- **graphs** → Kosslyn, S. M. (1994) Elements of Graph Design, W.H. Freeman and Company, New York

  "one reason for the abundance of bad graphs is the proliferation of low-cost microcomputers and 'business graphics' packages which often seduce the user into producing flashy but muddled displays; many graphs are designed without consideration of principles of human perception and cognition"

The Scarce Resource: Human Attention, not Information

- **claim:** a design representation suitable to a world in which the scarce factor is information may be exactly the wrong one for a world in which the scarce factor is attention → for example: a "good" representation captures the essential elements of an event, deliberately leaving out the rest

- **Herbert Simon:** *"What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate efficiently among the overabundance of information sources that might consume it."*

- **a Faustian Bargain:**
always on (WMT) ←----------**X**--------------------**X**-------------→ Rodin's Thinker

Beyond Anywhere, Anytime, Anyone
→
The 'Right' Information at the 'Right' Time, in the 'Right Place', in the 'Right Way', to the 'Right' Person

- **'right' information:** relevant to the task at hand → task modeling

- **'right' time**: intrusiveness (pull versus push), interruptions

- **'right' place:** location-aware cell phone (noisy environment versus movie theatre), smart tour guides

- **'right' way:** multimodal presentation (textual, visual, auditory, tactile)

- **'right' person:** taking background knowledge and interests of specific users into account → user modeling, "who do I ask and who do I tell"

Quality of External Representations
Supporting Distributed Intelligence

- long lasting (not ephemeral)

- easily produced, modified, and reproduced

- communicable over distance

- computational capabilities (e.g., multi-model, dependent on user, task, and context)

- exploiting the strength of the human system → sometimes visualization make a big difference (Number Scrabble and Tic-Tac Toe) and sometimes they do not (Mutilated Matrix, Chessboard, and Match Maker Story)

Two Examples of Socio-Technical Environments

- **CLever: Cognitive Levers — Helping People Help Themselves**
  - to support people with cognitive disability by increasing their independence
  - new insight into distributed intelligence
  - application areas: **human-centered public transportation systems**, smart care, life histories
  - more info: http://l3d.cs.colorado.edu/clever/index.html

- **EDC: Envisionment and Discovery Collaboratory**
  - support for formal and informal learning
  - social creativity ("learning when the answer is not known") and knowledge sharing **in everyday life** (e.g.: urban planning and emergency management)
  - allow all stakeholders to act as informed participants and active contributors

Tools for Living and Tools for Learning

- **tools for living:** grounded in a "distributed intelligence" perspective, in which intelligence is mediated by tools for achieving activities that would be error prone, challenging, or impossible to achieve

- **tools for learning:** grounded in a "scaffolding with fading" perspective leading to autonomous performance by people without tools

- **the fundamental question:** what does it mean to learn in the 21st century in which powerful tools are available for many intellectual activities—allowing people to have instant access to facts, assisting people in spelling, doing arithmetic, and performing numerous other intellectual activities

- a potential danger → **over-reliance on tools for living**: does an over-reliance on tools for living lead to learned helplessness and deskilling, ruining humans' native abilities by making them dependent on tools?

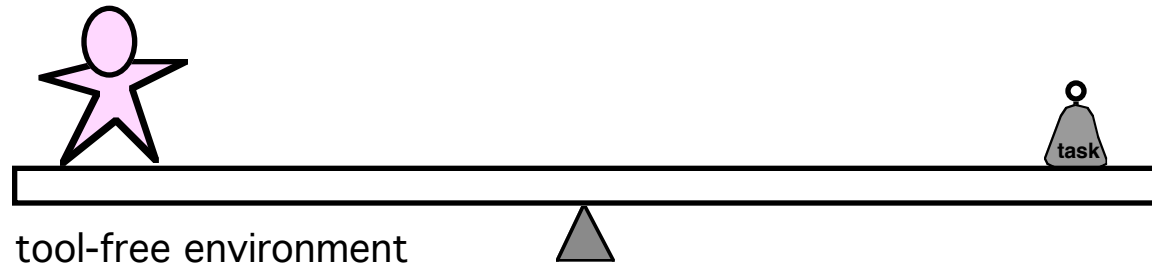# Over-Reliance on Tools for Living

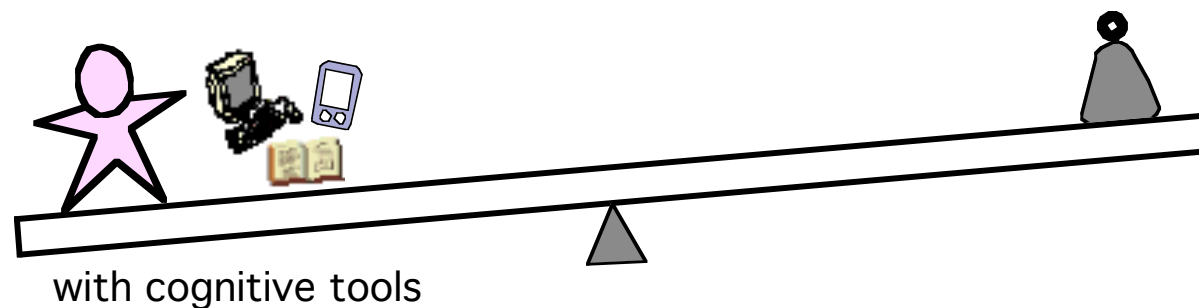# Over-Reliance on Tools for Living

"Nurse, get on the internet, go to SURGERY.COM, scroll down and click on the 'Are you totally lost?' icon."

Empowering Humans with Media and Technologies
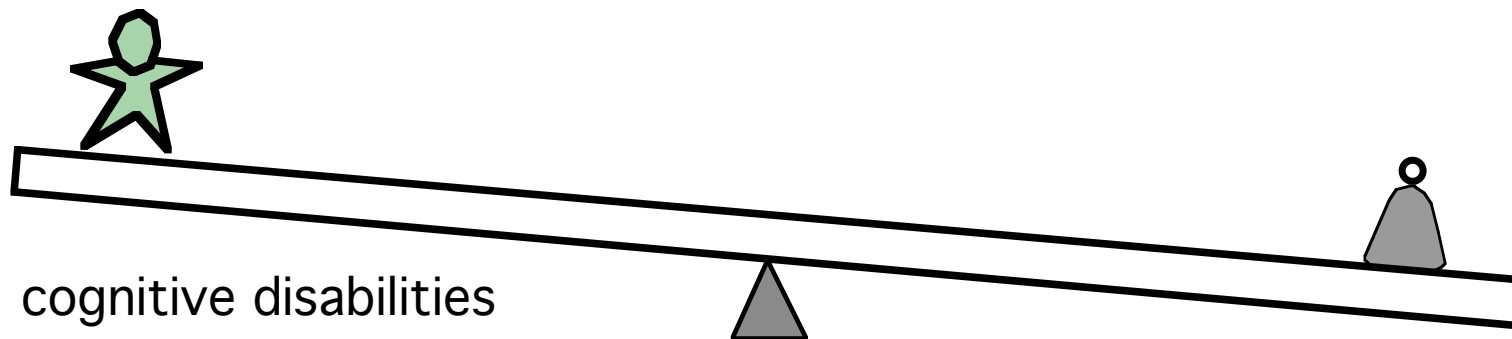
- the unaided, individual human mind

tool-free environment

- with tools/media, humans have more power
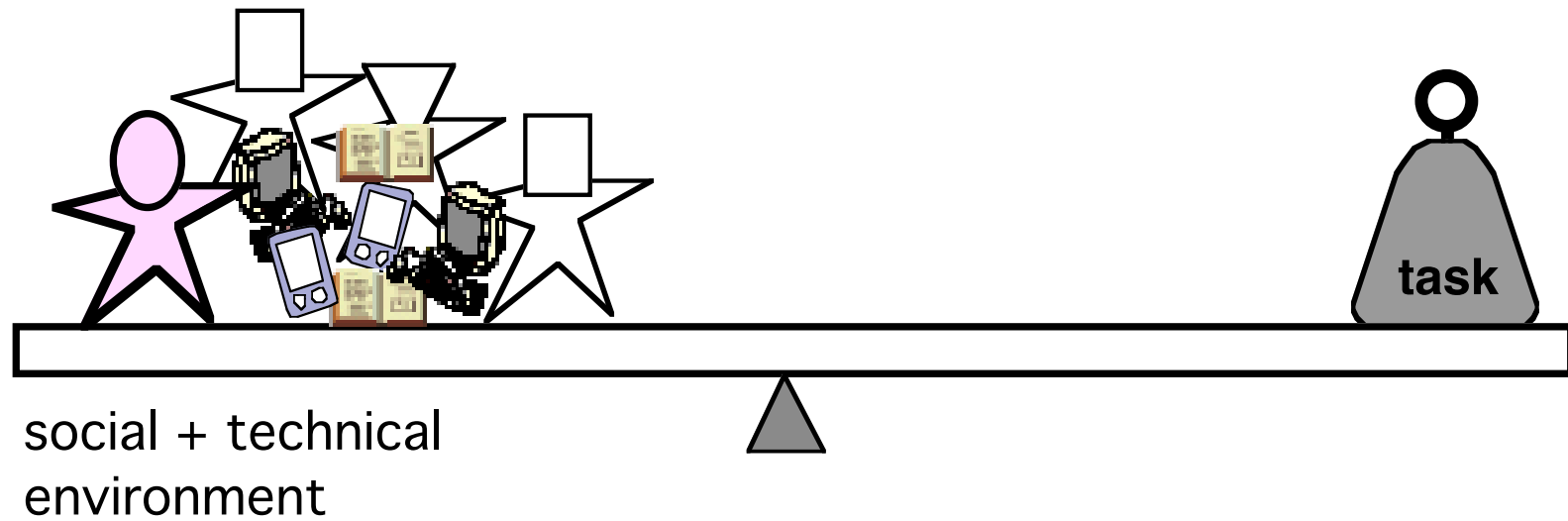

with cognitive tools

Cognitive Disabilities — Without Tools: Severe Limitations Exist

- some simple tasks are hard to achieve (e.g., simple plans can not be achieved, internal scripts are weak)

cognitive disabilities

Collaborative Minds with Rich Tool Sets

social + technical environment

task

Mismatch between Needs and Support Tools

- in the past: technology needed to fit **people's body**

- today: distributed intelligence needs to fit **people's mind and activities**


mismatch

task
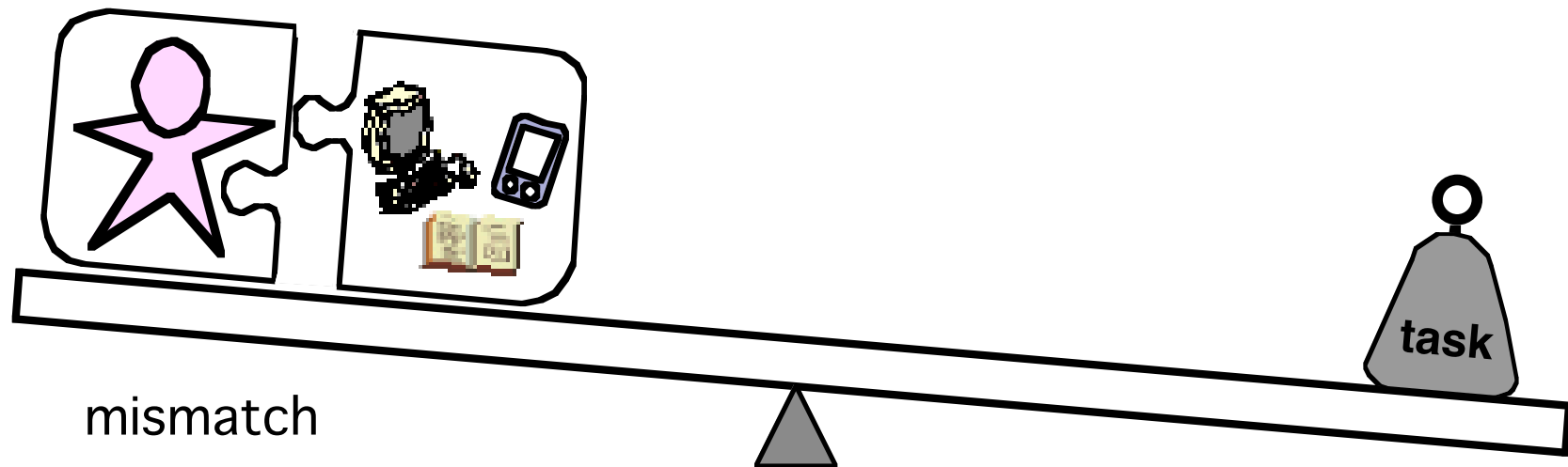
Envisionment and Discovery Collaboratory (EDC)

- **the EDC supports:**
  - collaborative design
  - integration of problem framing and problem solving
  - social creativity
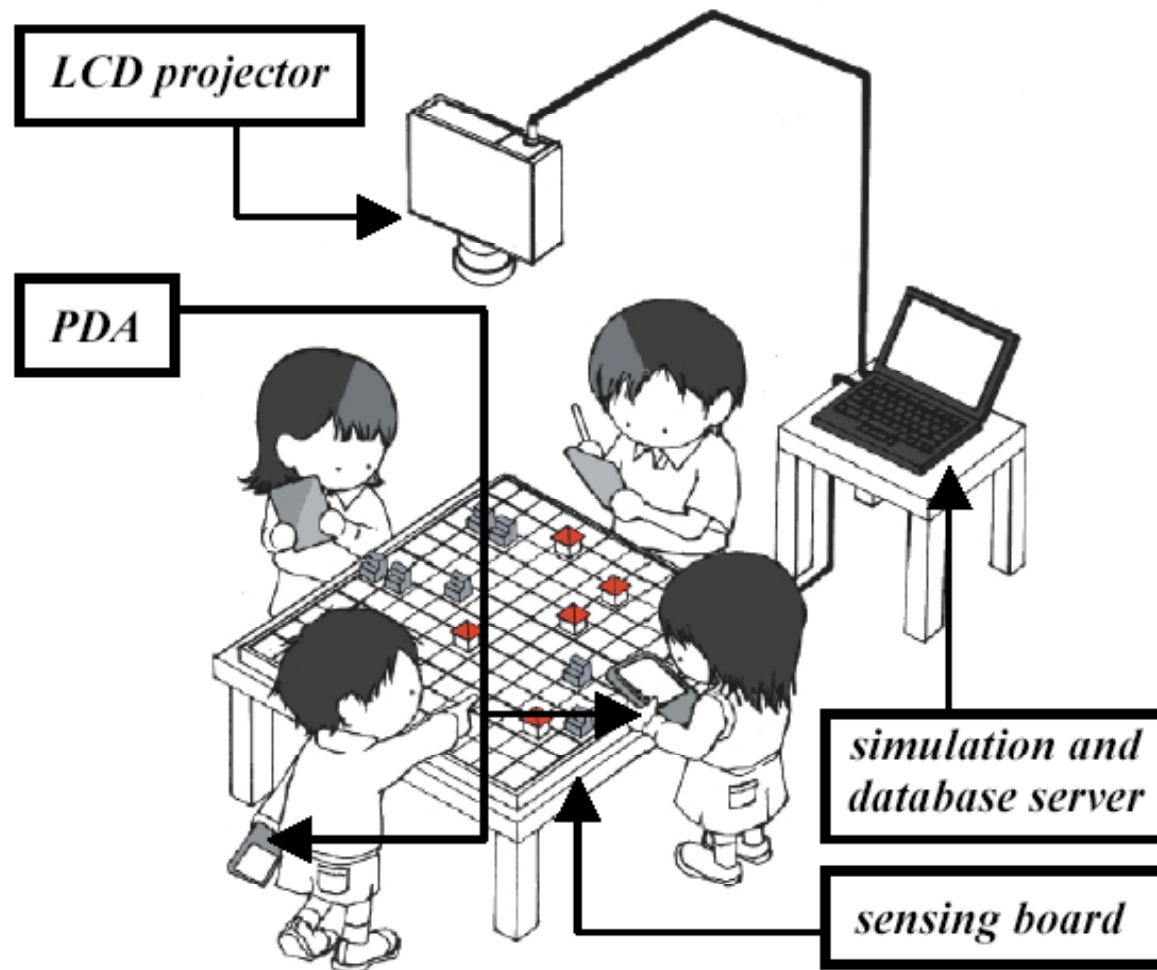 - meta-design

- **the EDC is based on:**
  - reflection-in-action
  - creating shared understanding in communities of interest

- **the EDC has been applied to:**
  - urban planning
  - emergency management

Buildings Sketched into a Google-Earth Client
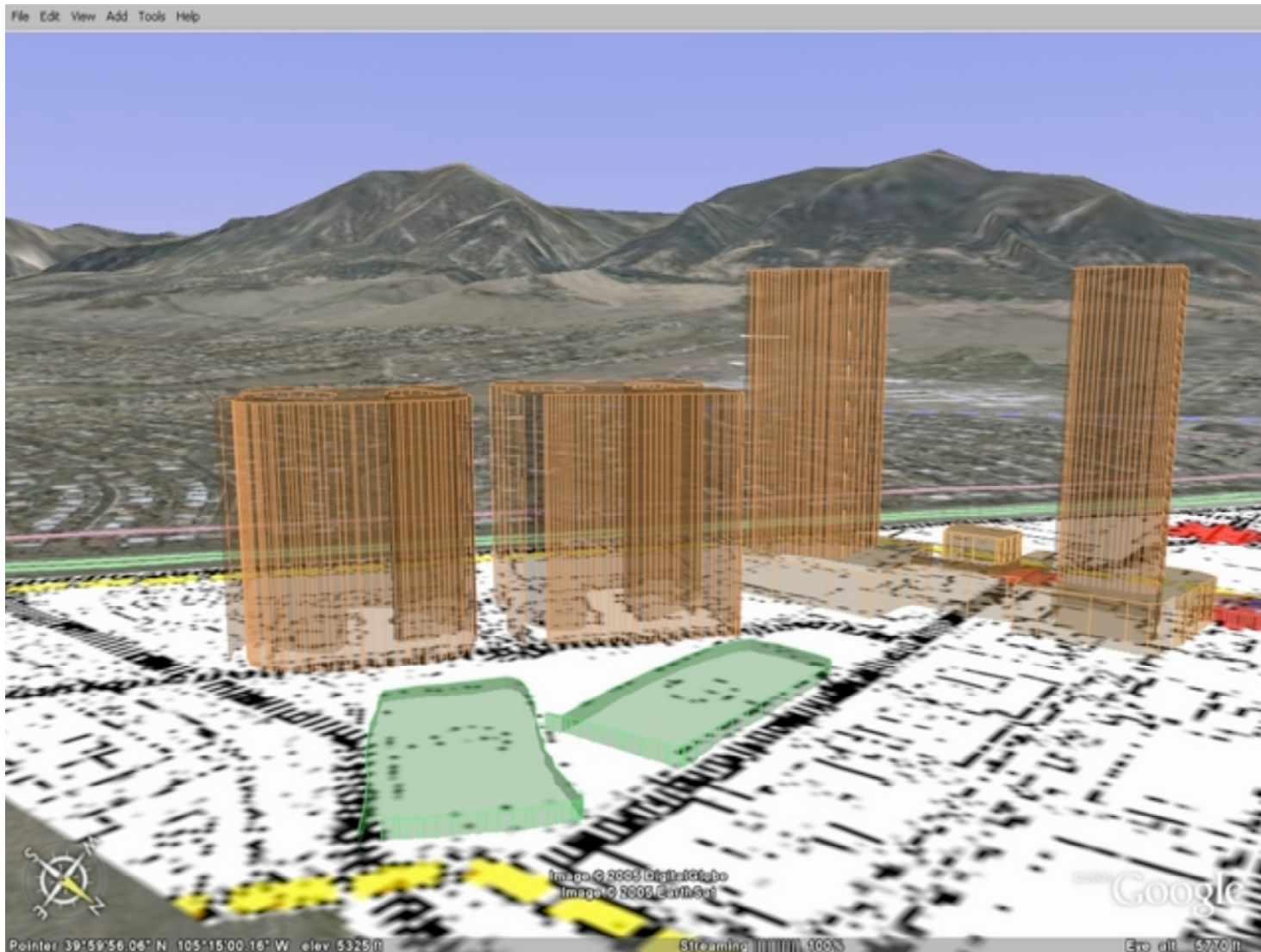
Integrating Individual and Social Creativity: Caretta
(collaboration with Masanori Sugimoto, University of Tokyo)

Looking 10 Years in the Future

- **1992** ←--→ **2006**
  first AVI conference   GUI
                                                  WWW
                                                  extensive computational power

- **2006** ←--→ **2016**
  lots of contents, digital libraries,   new levels of
  powerful search engines   distributed intelligence
  wireless and mobile technologies

Conclusions

- we need new **conceptual frameworks** and **socio-technical environments** to support **distributed intelligence**

- the future is not out there to be discovered — it has to be **invented and designed**

- looking ahead: **predicting the future**

  > *"This is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning."* —Winston Churchill