Engineering problem-solving

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Definition of the engineering method

Engineering is a problem-solving, goal-directed, and needs-fulfillment activity.

Characteristics of an engineering problem:

- Change - required
- Resources - limited
- Best – as far as possible
- Uncertainty – in a context.

Steps in engineering

1. Being prepared.
2. Define the problem.
3. Explore.
4. Plan.
5. Implement.
6. Evaluate, check.

Or:

CDIO (Conceiving — Designing — Implementing — Operating real-world systems and products)

The engineering method

- The engineering method is the use of heuristics to cause
  the **best change**
  in a **poorly understood** situation
  within **available resources**.

- **State of the art**:
  the best practice at a certain time.

Heuristics

- A heuristic is a mental shortcut that allows people to solve problems and make judgments quickly and efficiently.
- Heuristics are
  - "rules of thumb",
  - educated guesses,
  - intuitive judgments,
  - working bases,
  - guiding principles, or
  - simply common sense.
    (”common sense is not so common”)

Heuristics and the scientific method

- In more precise terms, heuristics stand for strategies using readily accessible, though loosely applicable, information to control problem solving in human beings and machines.

The scientific method: use of logic

- Deduction
- Induction, abduction, statistical reasoning
- Philosophical logic: Aristotelian logic, syllogisms.
- Mathematical logic, Boolean algebra
- Logic in information technology

Example of a syllogism

GIVEN: If it is raining then the roof is wet.
SUPPOSE: The roof is wet.
THEN:
(a) It must be the case that it is raining.
(b) Maybe it is raining and maybe it isn't.
(c) It must be the case that it is not raining.

Heuristics

A heuristic has four definite signatures:

1. A heuristic does not guarantee a solution,
2. It may contradict other heuristics,
3. It reduces the search time for solving a problem,
4. Its acceptance depends on the immediate context instead of an absolute standard.

A heuristic is anything that provides a plausible aid or direction in the solution of a problem but is in the final analysis unjustified, incapable of justification, and potentially fallible.

Problem-solving

- Problem recognition,
- problem definition and
- problem representation.

"In order to see a solution, you must see the problem first."

"In the field of observation, fortune favors only the prepared mind."

"The best way to get a good idea is to get lots of ideas."

Problem-solving

Requires

- divergent thinking
- openness to ideas
- tolerance of ambiguity
- intrinsic motivation
- attention to all aspects and details

Intelligence and expert performance

The acquisition of expert performance as problem solving

- Even the most talented individuals in a domain must spend over ten years actively engaging in particular practice activities (deliberate practice) that lead to gradual improvements in skill and adaptation that increase performance.
- The acquisition of expert performance can be described as a sequence of mastered challenges with increasing levels of difficulty
- The mental representations of experts appear to be qualitatively different from those of less skilled individuals. It is not simple difference in accumulated knowledge about past experience.
- Expert – novice differences appear to reflect differential ability to react to representative tasks and situations that have never been previously encountered.

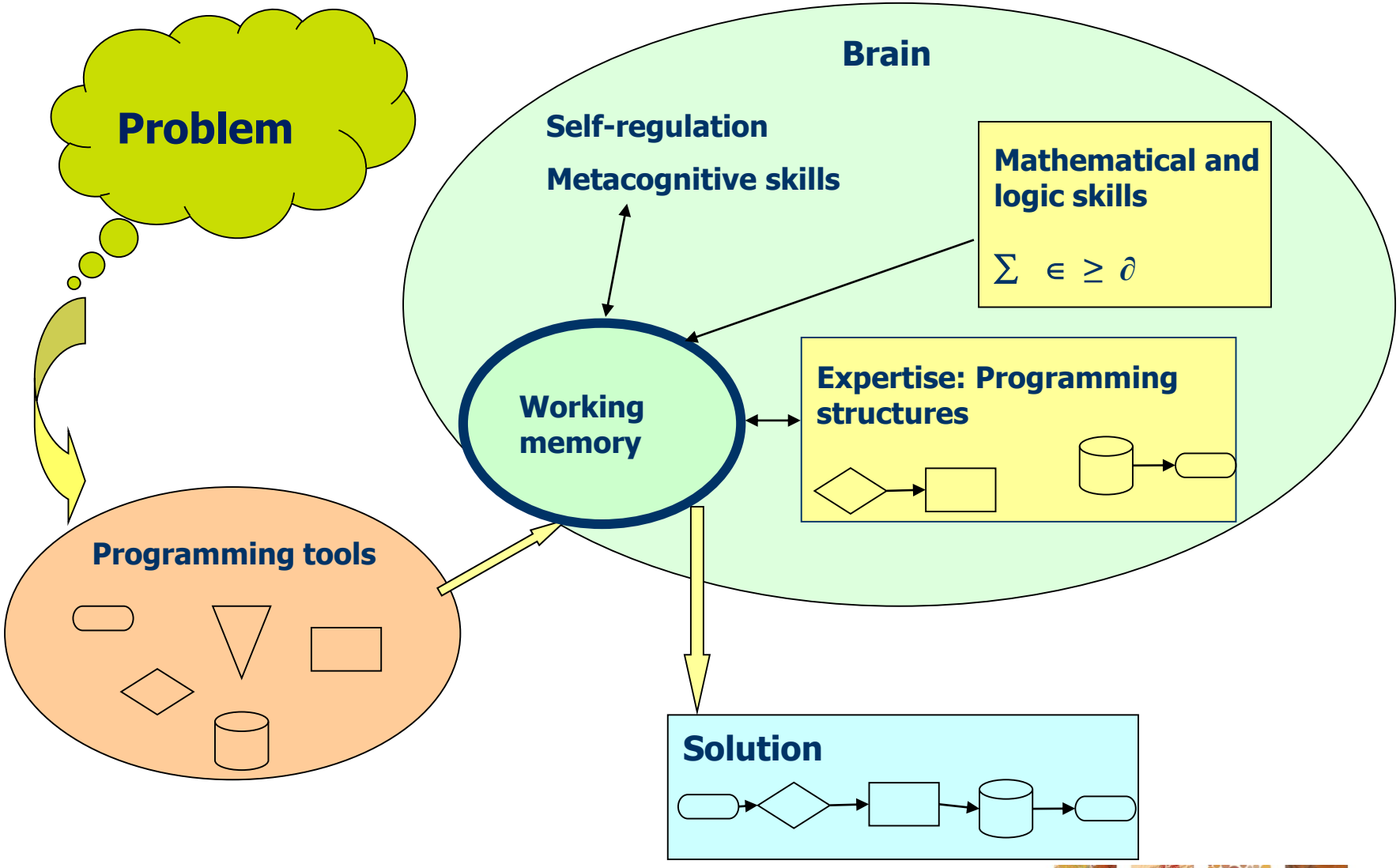
The acquisition of expert performance

- Comparison of several groups of professional musicians representing different levels of achievement:
- the most accomplished had spent more time in activities classified as deliberate practice:
  by the age of 20, the best musicians had spent over 10,000 hours practicing, which is 2,500 and 5,000 hours more than two less accomplished groups, respectively, and 8,000 hours more than amateur pianists of the same age.
- elite performers report a very high level of focus and concentration during deliberate practice. Practice sessions were limited to around one hour at a time; maximal level of deliberate practice was found to be 4-5 hours when sustained daily for months and years.

Problem solving by experts and novices

- Experts possessed greater domain-specific knowledge about a task that novices. Experts excelled mainly in their own domains and did not have greater knowledge or general problem-solving abilities.
- Experts perceived meaningful patterns, redefined and classified problems according to underlying principals. They organize their knowledge more hierarchically than novices.
- Experts performed quickly because they took strategic shortcuts.
- Experts spent more time in analyzing and planning.
- Experts redefined and reinterpreted the task.
- Experts monitored their performance more carefully. Good self-regulation.
- High levels of motivation.

Programming



Expertise is a team function

- High-tech environments depend on shared cognition
  - an operating theatre in a hospital, where the expertise of the operating team depends on seamless and synchronized contribution of all team members.
  - expertise is a characteristic of a working team instead of an individual, embodied in the functioning of the experts.

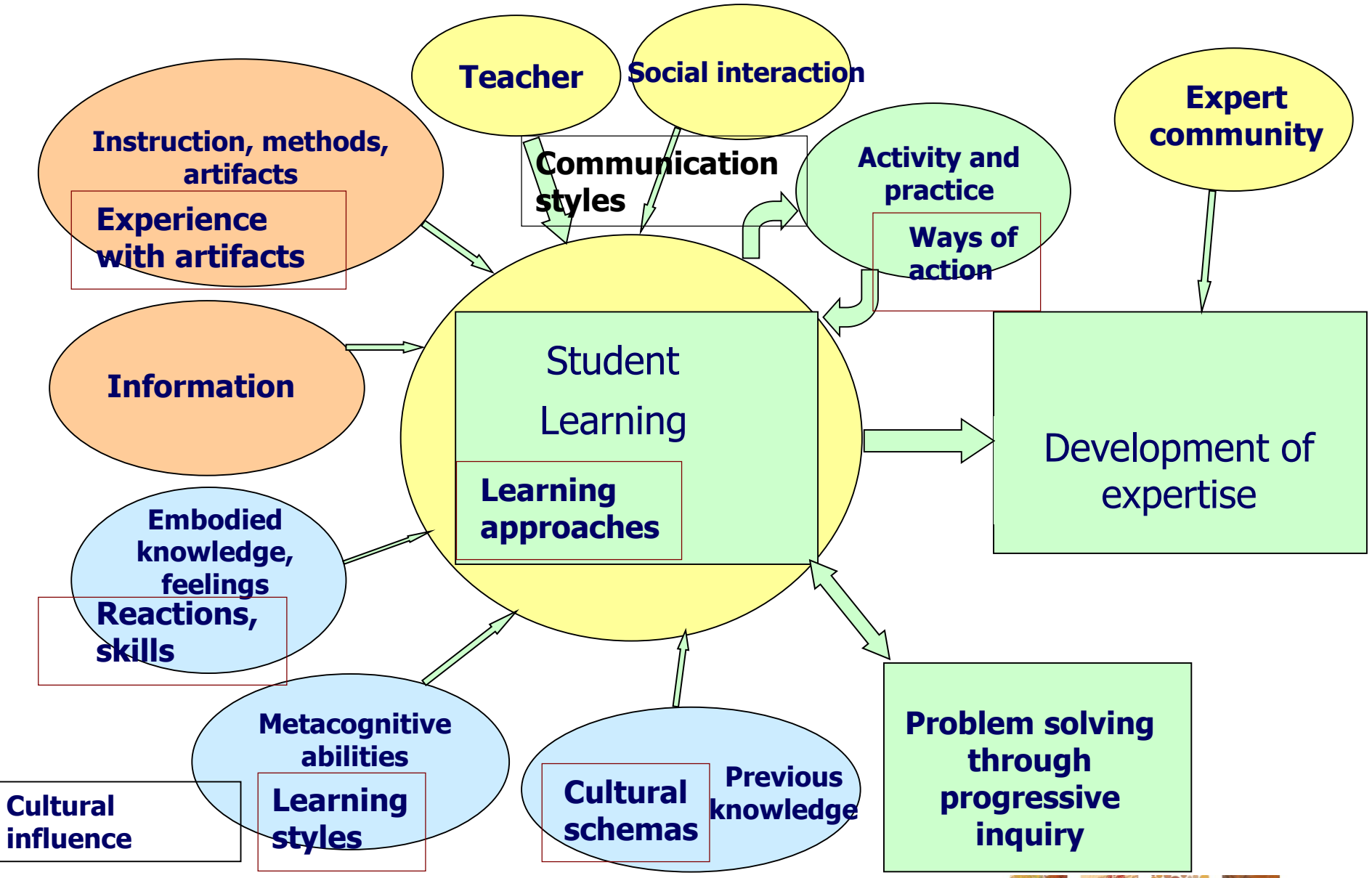
Cognition and emotion

- Happiness and positive mood increases flexibility in problem solving.
- Affect, cognition, and motivation influence one another.

- Meaningful and emotional information is retained better in memory than purely factual information.
  - It does not necessarily indicate, however, that the memories would be accurate in relation to factual events, especially if they are connected to strong feelings.
  - Memories do change.

Valuation

- Positive or negative impressions are formed in a mere "blink".
- People evaluate everything as good or bad.
- We feel before we analyze.
- Decisions made too quickly are not the best:
  - facing with complex decisions involving many factors, the best advice is to take your time - to await the intuitive result of unconscious processing


Teacher
Social interaction
Instruction, methods, artifacts
Experience with artifacts
Communication styles
Activity and practice
Ways of action
Expert community
Information
Student Learning
Learning approaches
Development of expertise
Embodied knowledge, feelings
Reactions, skills
Metacognitive abilities
Learning styles
Cultural influence
Cultural schemas
Previous knowledge
Problem solving through progressive inquiry