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.

Practice problem-solving

- Warm-up problems
- Which strategies did you use?

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."

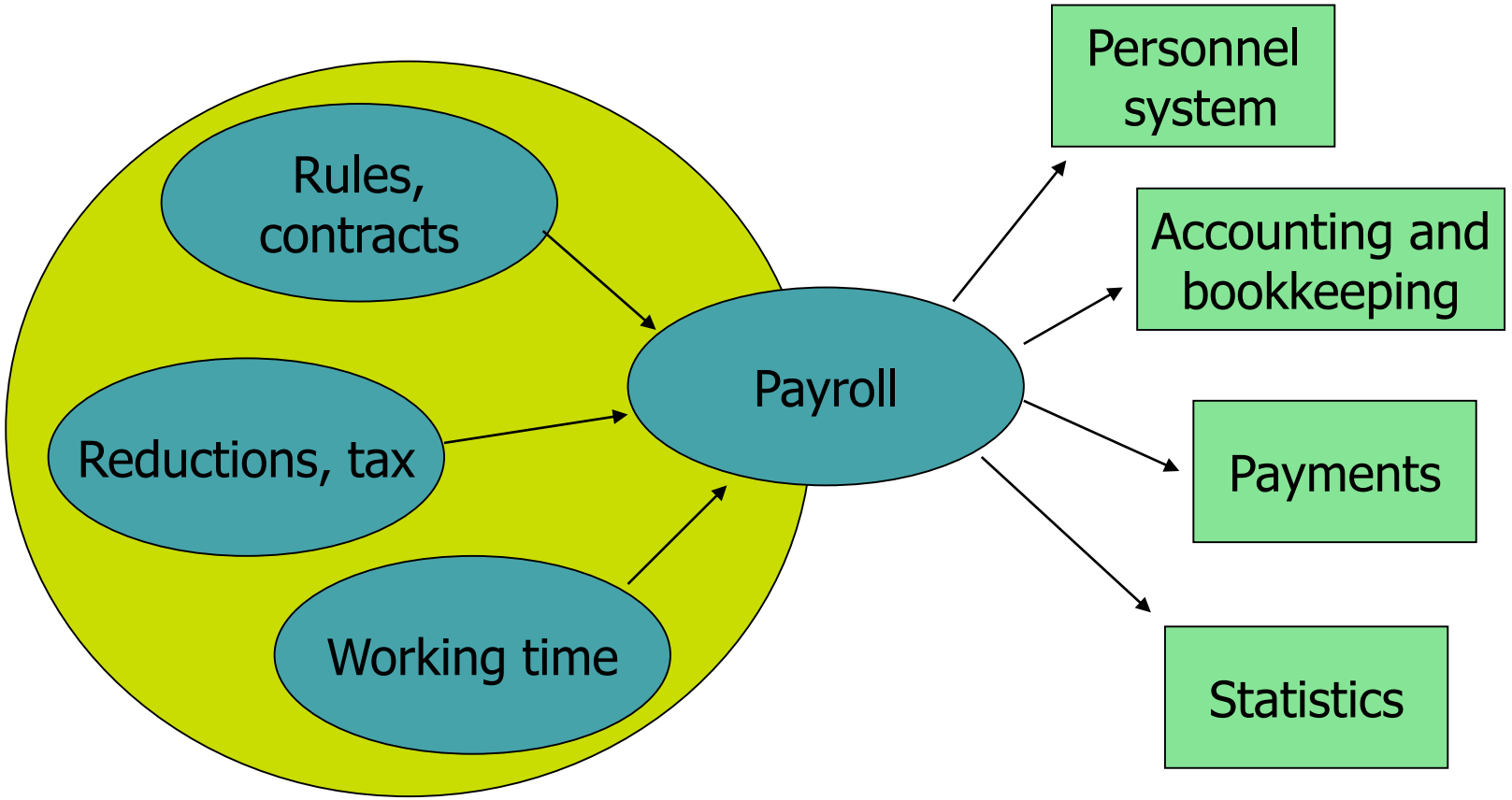
Problem-solving

Requires

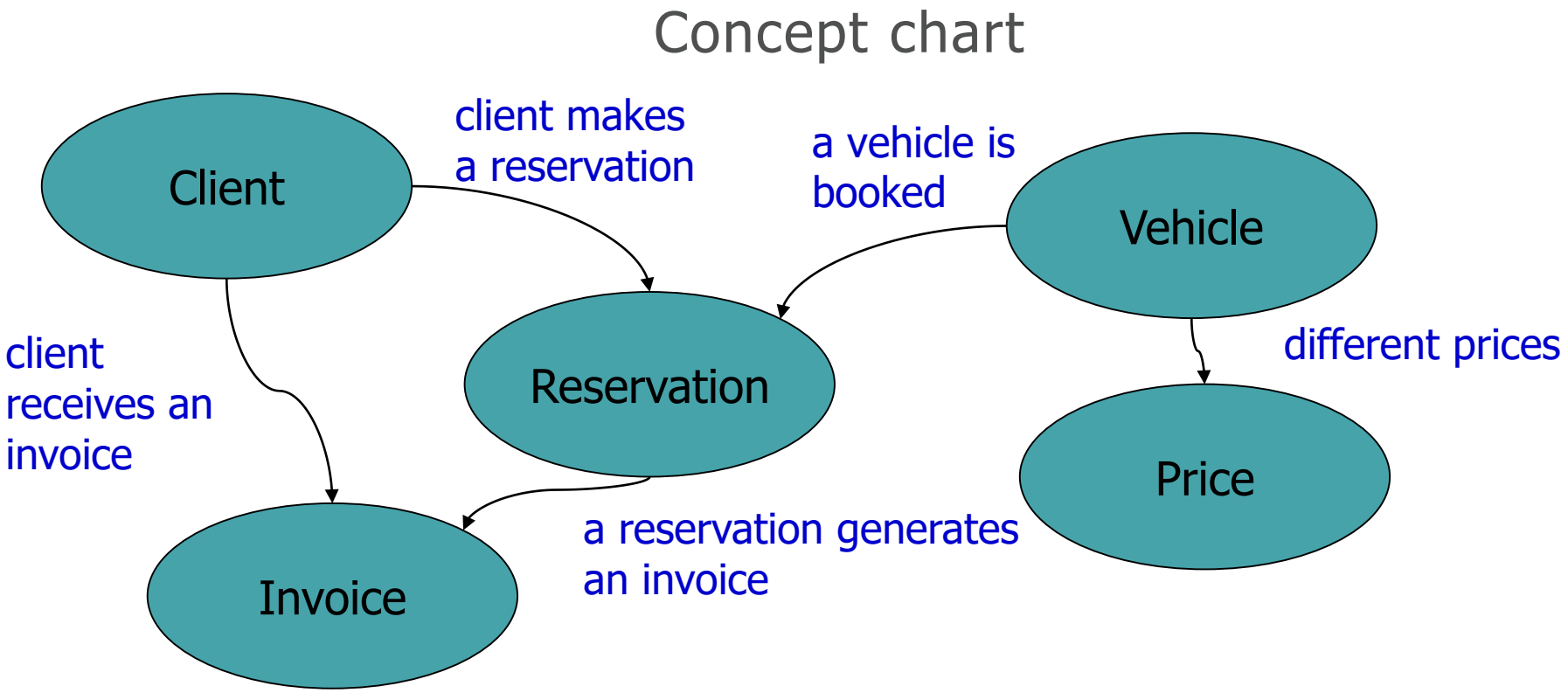
- divergent thinking
- openness to ideas
- tolerance of ambiguity
- intrinsic motivation
- attention to all aspects and details

Systems approach: definition and boundaries

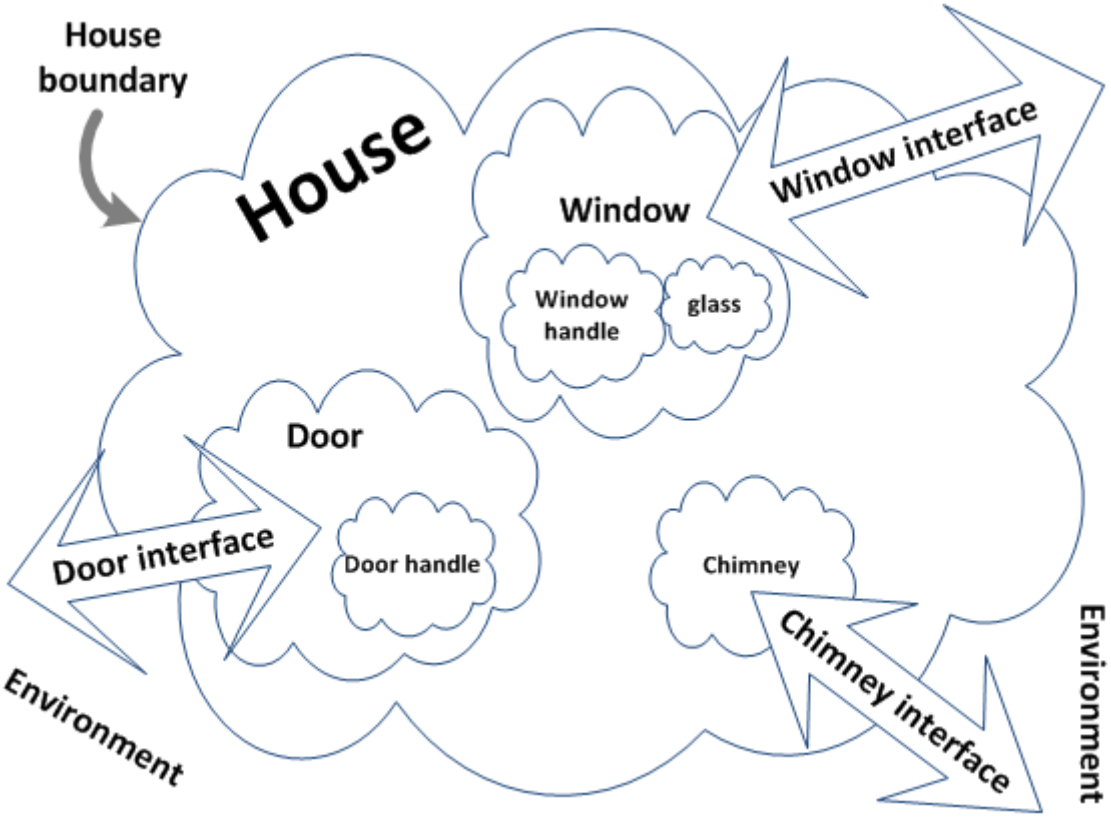
Subsystems, environment, connections, dependencies



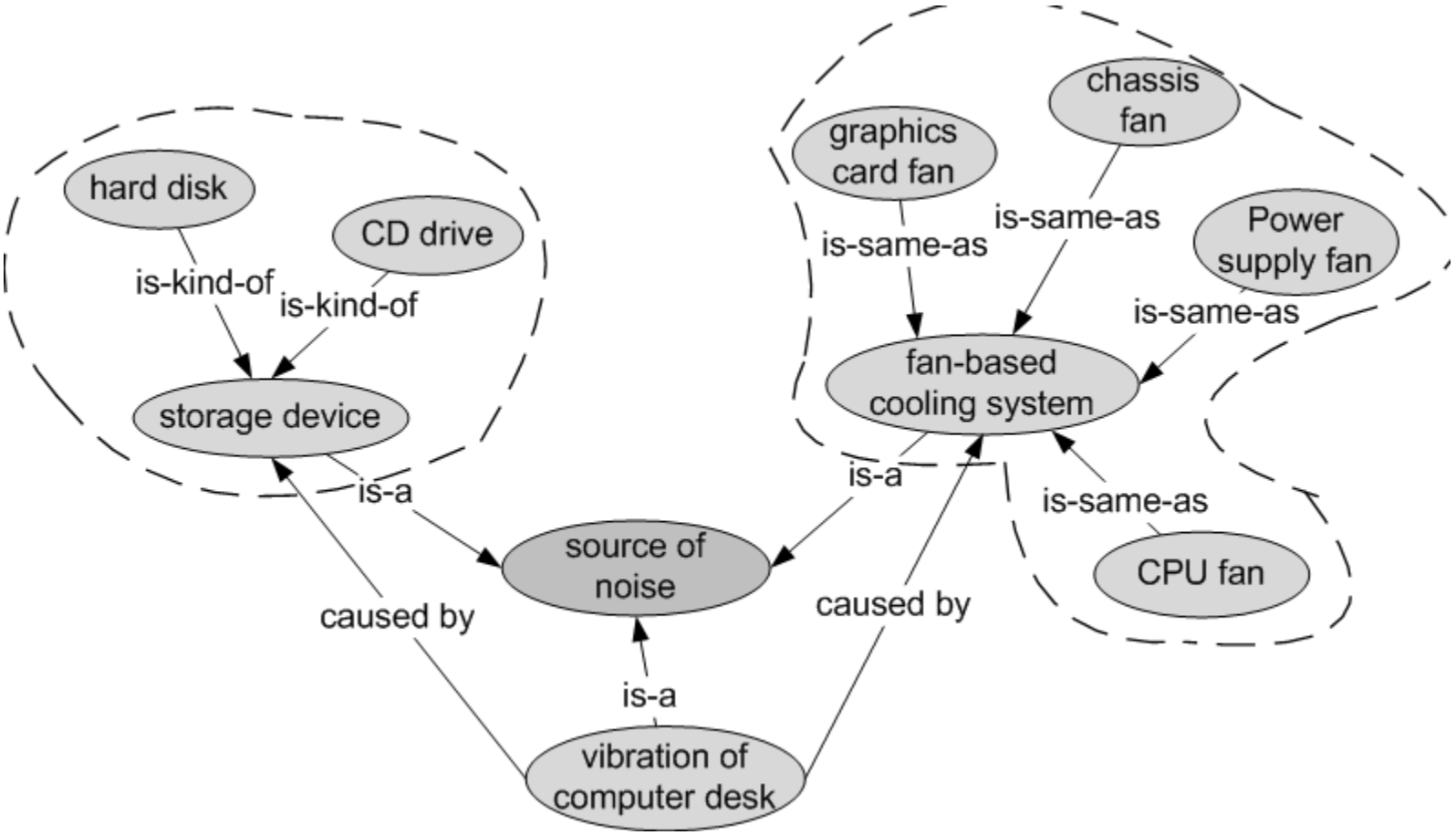
Rental car agency



Parts of a house:
a functional perspective



Computer noise problem



Warm-up analysis

- Why won't my car start?
- Write a set of rules or a decision tree to describe the fault-finding process
- http://www.mindtools.com/dectree.html

Passwords & pin codes & user ids

- What are the current problems/ difficulties?
- Consider also Tube2 single-sign-on pros and cons
- How many solutions can you come up with? Why have they not been implemented?
- Analyze the situation and propose a workable solution.
- Discuss again considerations from the producer/ service provider perspective and the consumer/ user perspective.

The mess with electronic gadgets and wires

- 20 years ago people had very few electronic devices at home: a CD player/ radio, a tv with a VCR, a walkman and possibly a PC
- Now you have to update your mobile phone, laptop, MP3 player, digital camera, etc. Every two or three years and new gagdets flood market
- You also have tens of batteries, chargers, cables, wires, etc.
- Is this feasible? Globally or individually?
- Outline a strategy to cope with electronics.

Cleaning robots

- Robots are widely used in manufacturing, space exploration, warfare, etc.
- Explore possible solutions for cleaning robots (i.e. in schools and school cafeterias)
- What are limitations and what might be feasible in near future?

Producer perspective

Consumer perspective

purpose

has purpose

Engineering environment

produced by

artifact

Used in

Operating environment

has form

form

Can a design of this form be produced at acceptable cost that serves the intended purpose with resources available in this environment?

Does a design of this form have acceptable performance when serving its intended purpose in this environment?

Second day

Stereotypes of international engineers working in cross-cultural teams

	Y				N
are fast decision-makers					
are easy to communicate with					
are reliable co-workers					
are aggressive communicatiors					
are stubborn					
are flexible communicators					
are very able to apply professional knowledge					
communicate professional matters effectively					
tend to work as individuals					
are effective group members					

Finns	Y				N
are fast decision-makers					
are easy to communicate with		x			
are reliable co-workers					
are aggressive communicatiors					
are stubborn		x			
are flexible communicators					
are very able to apply professional knowledge	x				
communicate professional matters effectively				x	
tend to work as individuals	x				
are effective group members					

Americans	Y				N
are fast decision-makers					
are easy to communicate with		x			
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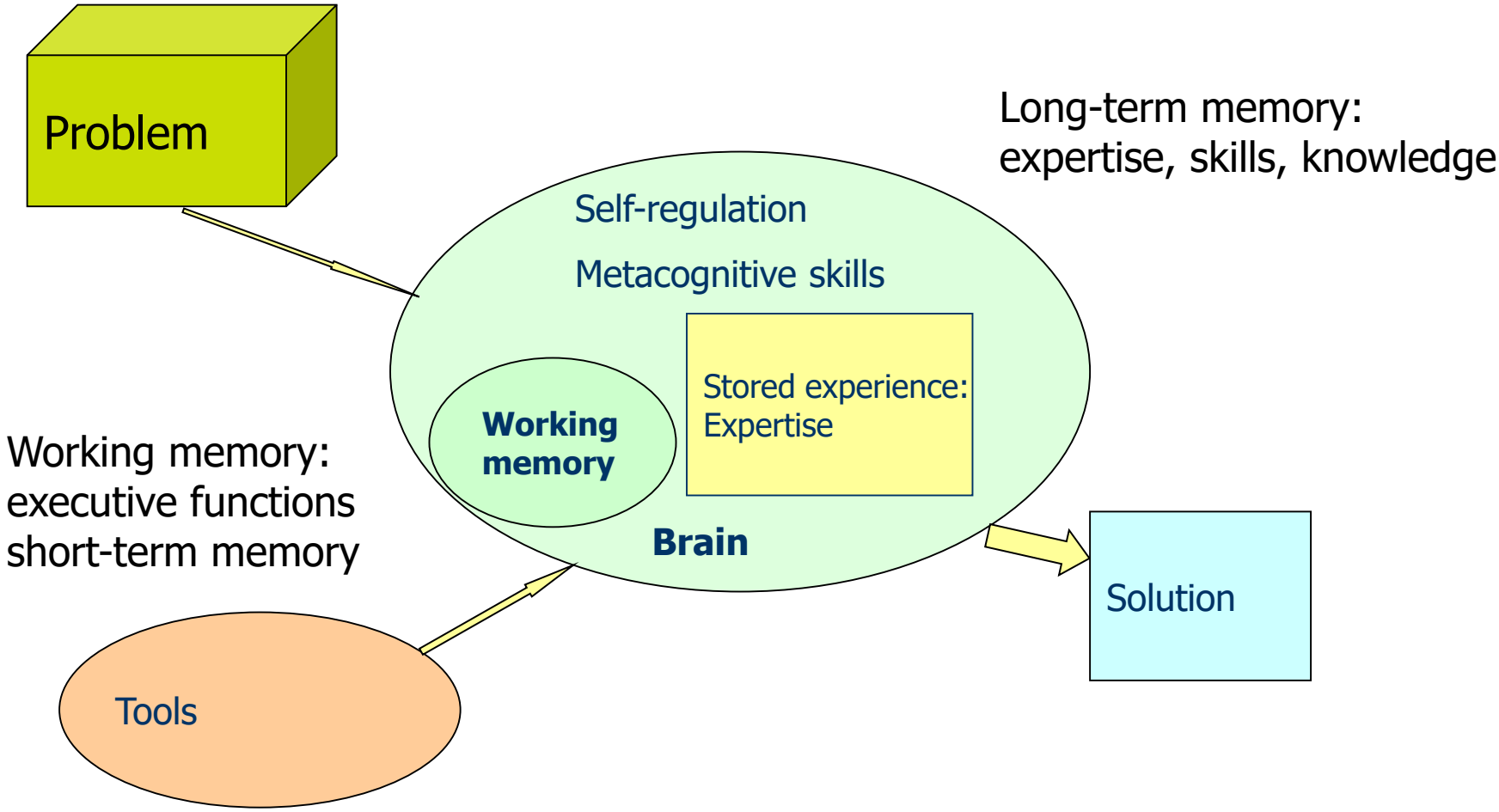
are stubborn		x			
are flexible communicators				x	
are very able to apply professional knowledge					
communicate professional matters effectively		x			
tend to work as individuals					
are effective group members					

Source: Benna Research 2010

What does the brain do in problem-solving?



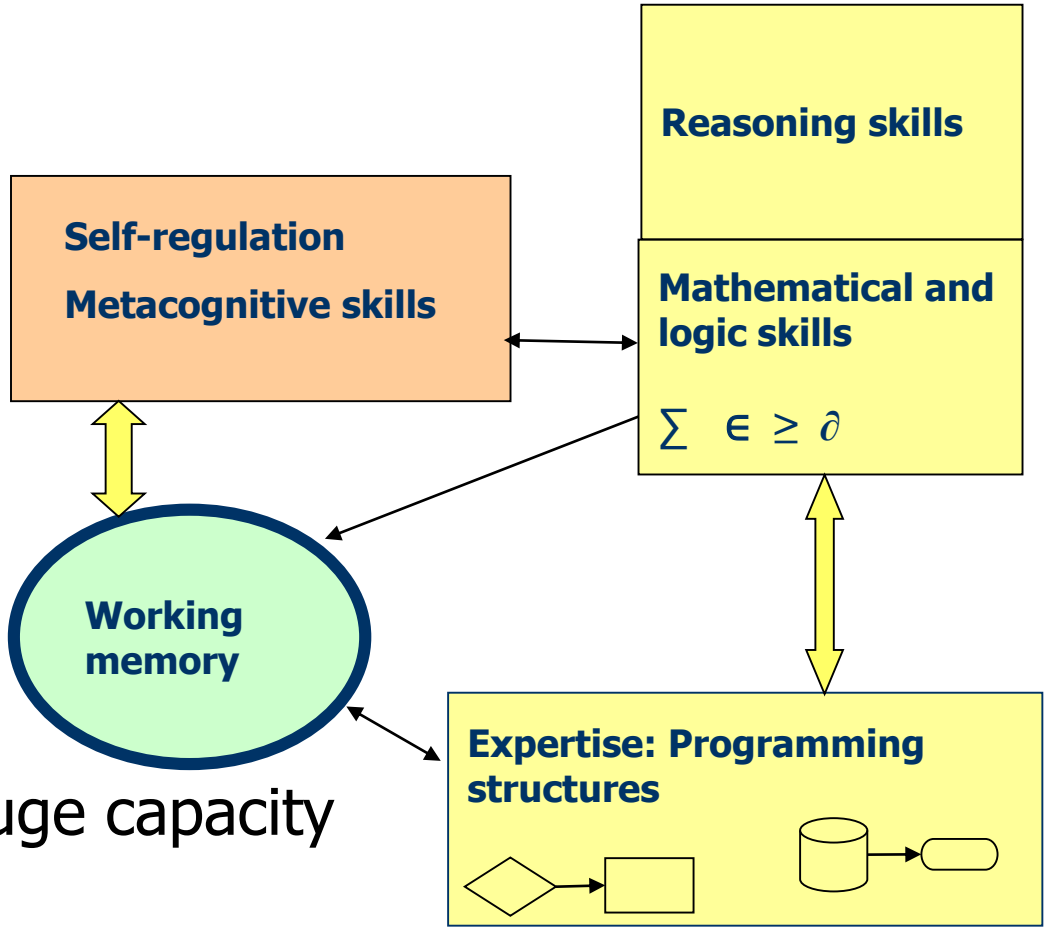
How do you solve these problems?

- 2 x 7 =
- 49 x 2 =
- Can you explain?

- 5427 x 57 =

Intelligence and expert performance

Background skills



The brain has a huge capacity

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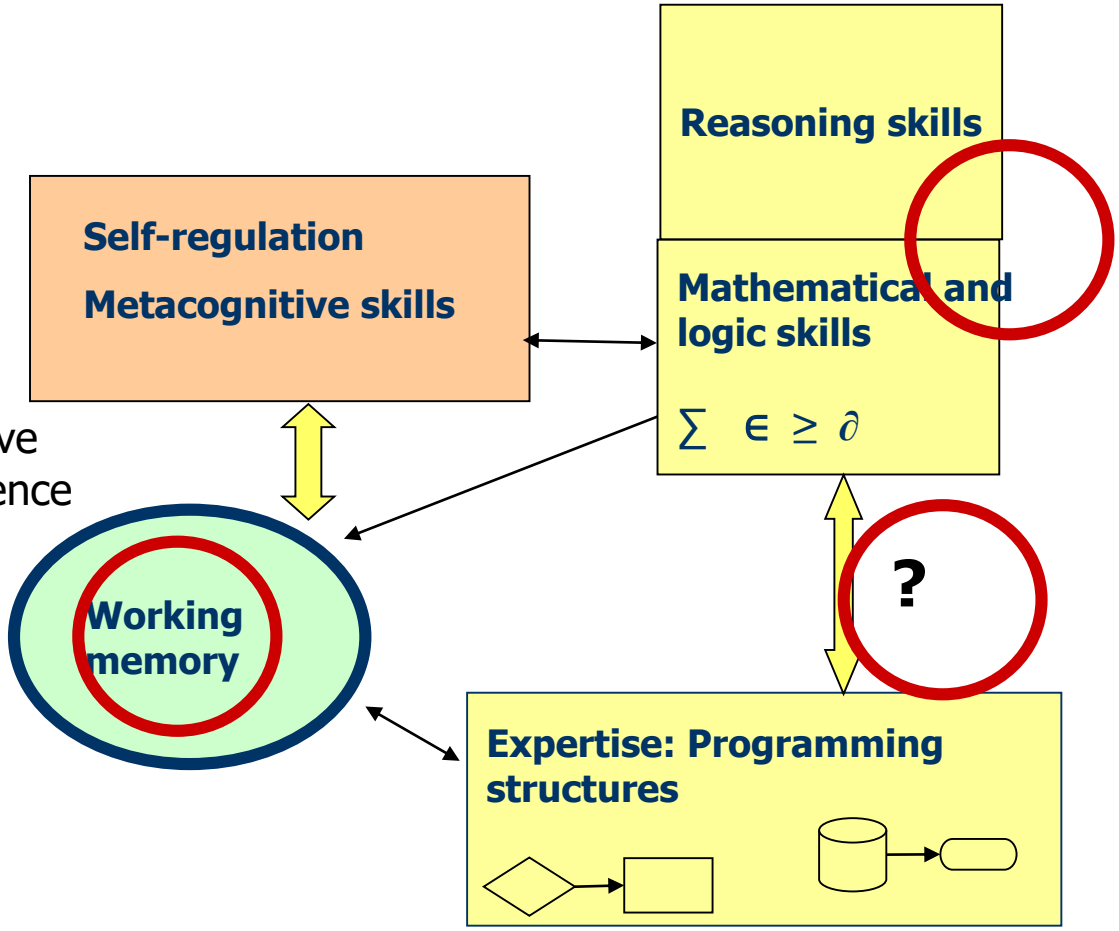
the working memory has a tiny capacity

Background skills

Self-regulation and metacognitive skills have been shown to influence Problem-solving ability and learning



Unconscious processes
Awareness

IQ, general intelligence

- Linguistic competence
- Reasoning
- Spatial ability
- Analytic and number skills
- General knowledge
- Visual & auditory processing
- Long-term storage and retrieval
- Working memory and processing speed

Views of intelligence

- Academic success requires analytical intelligence, GI
- Modern society versus instinctive behavior
  - evolution prepared us for natural surroundings,
  - schooling prepares us for information society
- IQ does not seem to predict expertise nor does it predict the acquisition of complex problem-solving competence

Successful intelligence (Sternberg)

- analytical intelligence,
- practical intelligence
- creative intelligence
- executive processes to plan and control activity are instrumental for successful performance.

Other views on intelligence

- Intelligent action
  - as deciding what to do next;
  - if the environment is well-designed and well-known to the person, intelligent action is greatly facilitated.
  - people are not particularly good at tasks that require abstract reasoning or intensive recall but they excel at using resources in a systematic but creative fashion to work their way to solutions.

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.

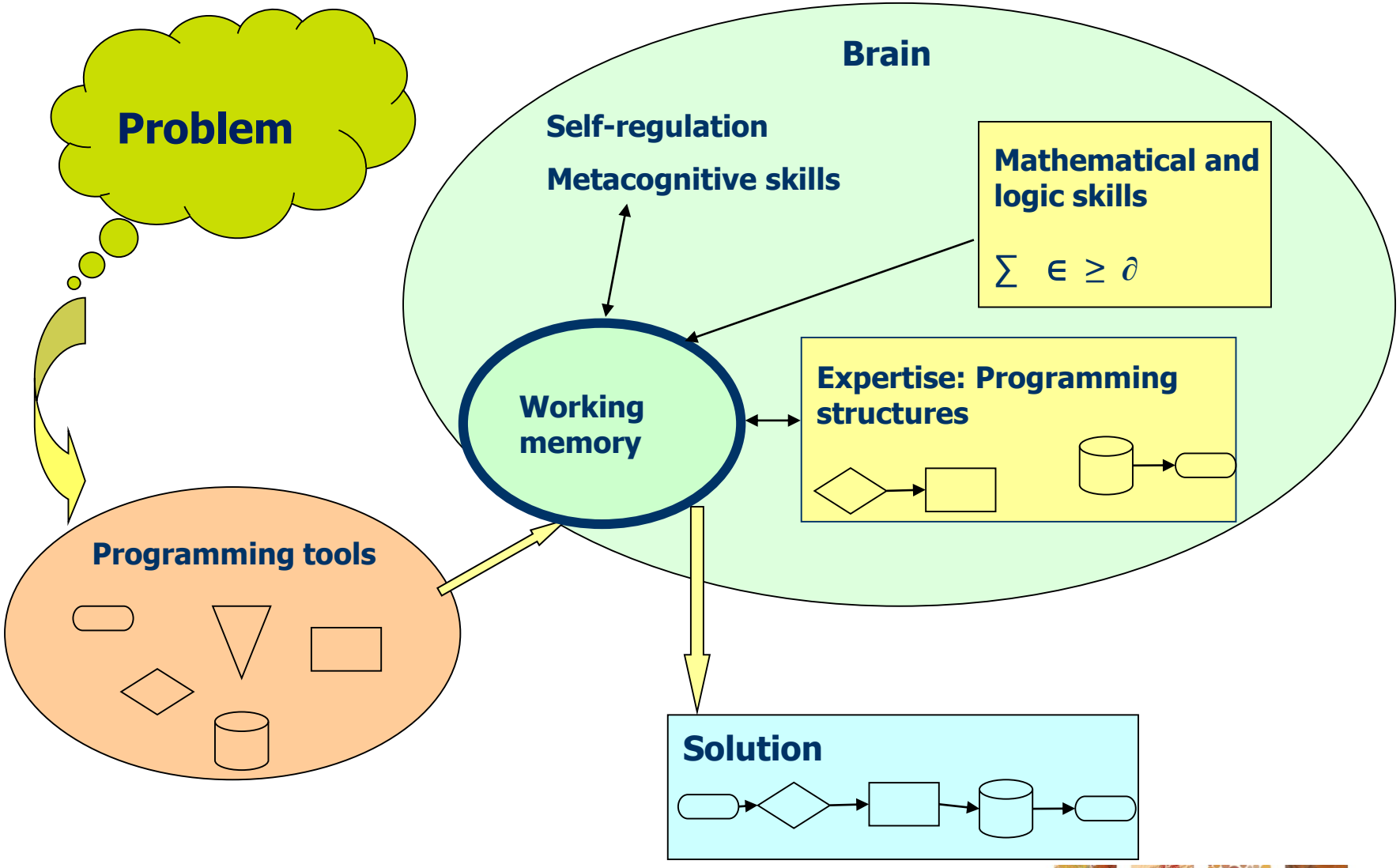
The acquisition of expert performance

- 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



Intuitive and formal reasoning systems

- deductive reasoning
- categorization
- analogical reasoning
- decision-making
- belief formation
- social cognition
- Western:
  analytical mode of thought dominant (?)
- East Asian:
  holistic mode of thought (?)

Contextualization in reasoning

- Environment of evolutionary adaptedness (EEA) favored the tendency to contextualize a problem with as much prior knowledge as is easily accessible
- the tendency to socialize problems. To see deliberate design and pattern in situations that lack intentional design. (superstition)
- Seeing intentional design in random events.
  - Financial analysts tend to concoct elaborate explanations for every little fluctuation in stock market prices even though the fluctuations are mainly random.
- The intentional interpreter in our brains does not automatically decouple itself from problems when it is not needed.
- The narrative mode of thought.

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

Music in brain

- Brain imaging studies: when people listen to music, the neural activation proceeds from the auditory system to regions related to planning, expectation and language as well as arousal, pleasure, mood and rhythmic movement.
- Music engages nearly every area of the brain.
- Music promotes cognitive development.
- Music reaches deep into the brain's most primitive structures, including the "reptilian brain" tied to motivation, reward and emotion.
- Music elevates dopamine levels.

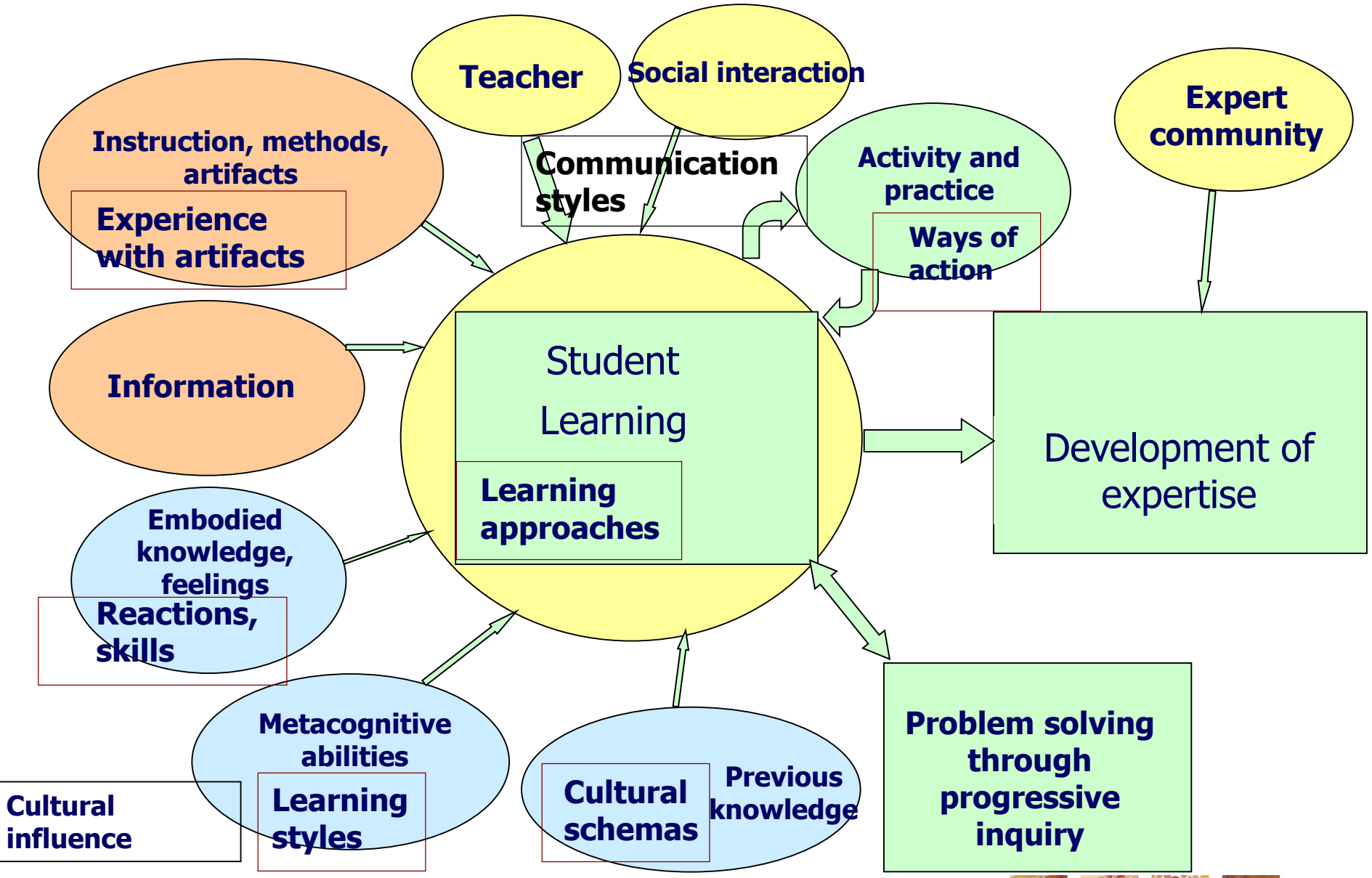
The growth mind-set

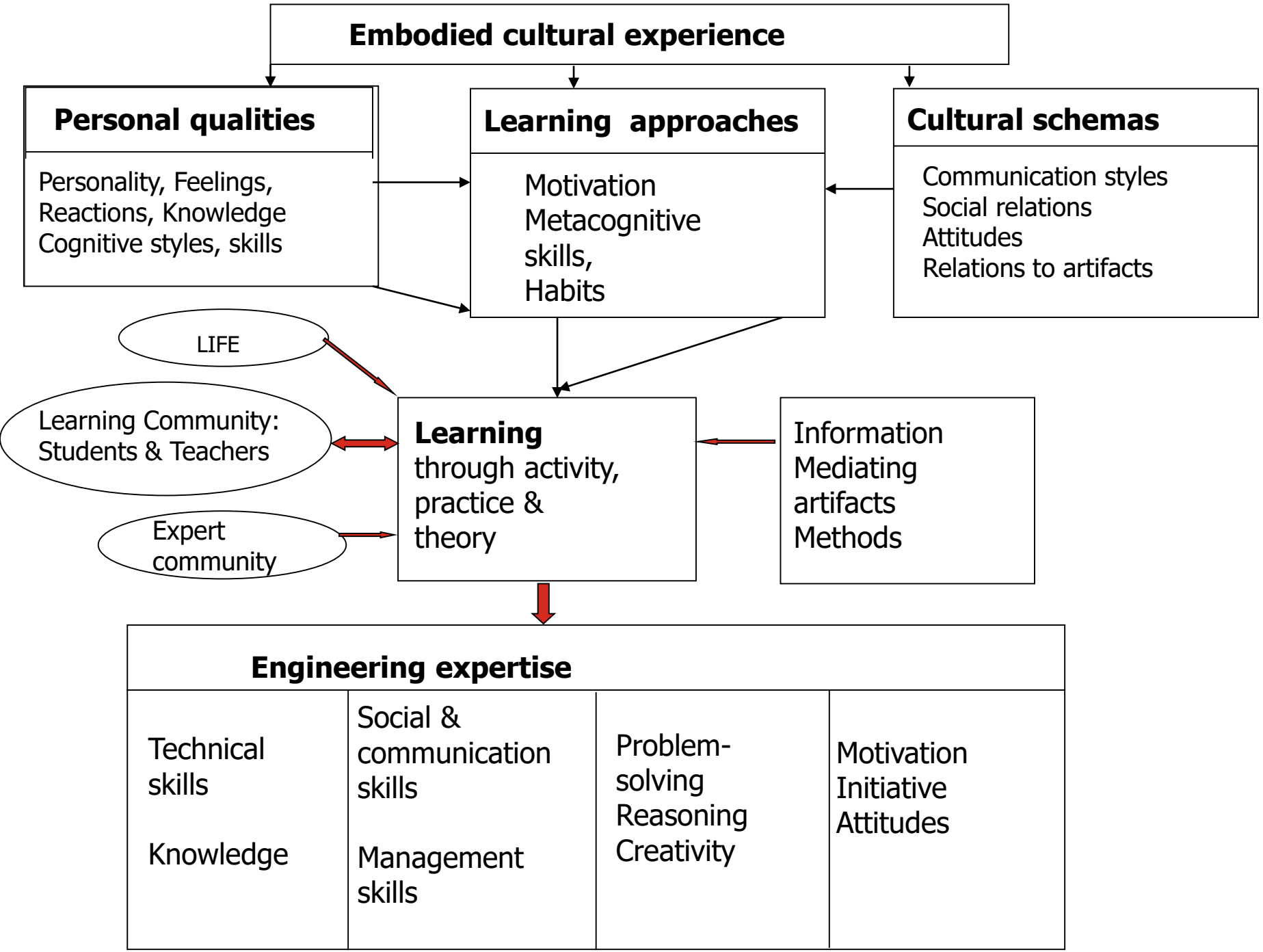
- Focus on effort rather than on talent produces high achievers in school life.
- Attributing poor performance to a lack of ability depresses motivation and leads to a helpless attitude.
- Mistakes are problems to be solved!
- Motivation: those who place high premium on learning rather than on getting good grades, earned the best grades

—

Napoleon Bonaparte quotes

- I have never found the limit of my capacity for work.
- If you want a thing done well, do it yourself.
- Different subjects and different affairs are arranged in my head as in a cupboard. When I wish to interrupt one train of thought, I shut that drawer and open another. Do I wish to sleep, I simply close all the drawers and then I am - asleep.
- The word 'impossible' is not in my dictionary.


Teacher
Social interaction
Expert community
Instruction, methods, artifacts
Experience with artifacts
Communication styles
Activity and practice
Ways of action
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


Embodied cultural experience
Personal qualities
Personality, Feelings,
Reactions, Knowledge
Cognitive styles, skills
Learning approaches
Motivation
Metacognitive
skills,
Habits
Cultural schemas
Communication styles
Social relations
Attitudes
Relations to artifacts
LIFE
Learning Community:
Students & Teachers
Expert
community
Learning
through activity,
practice &
theory
Information
Mediating
artifacts
Methods
Engineering expertise
Technical
skills
Knowledge
Social &
communication
skills
Management
skills
Problem-
solving
Reasoning
Creativity
Motivation
Initiative
Attitudes