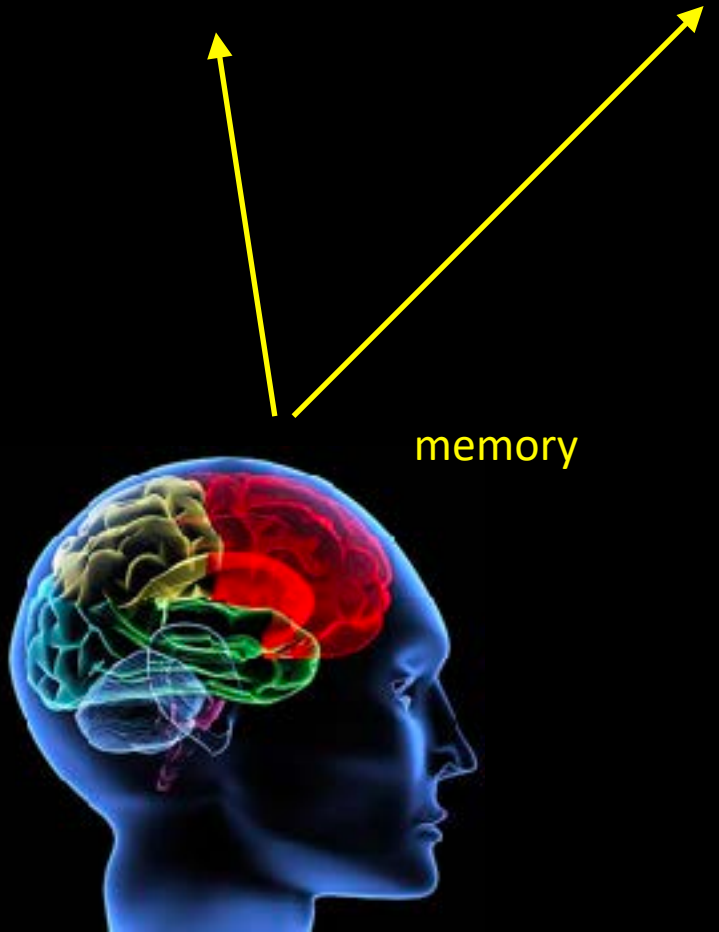
Chapter 2:
Learning & Memory

To understand how people learn, we need to 'understand' the constraints of our memory system.

To understand how people learn, we need to ‘understand’ the contraints of our memory system.

Learning is about producing knowledge and skills that is stored to be used later on for performing tasks.



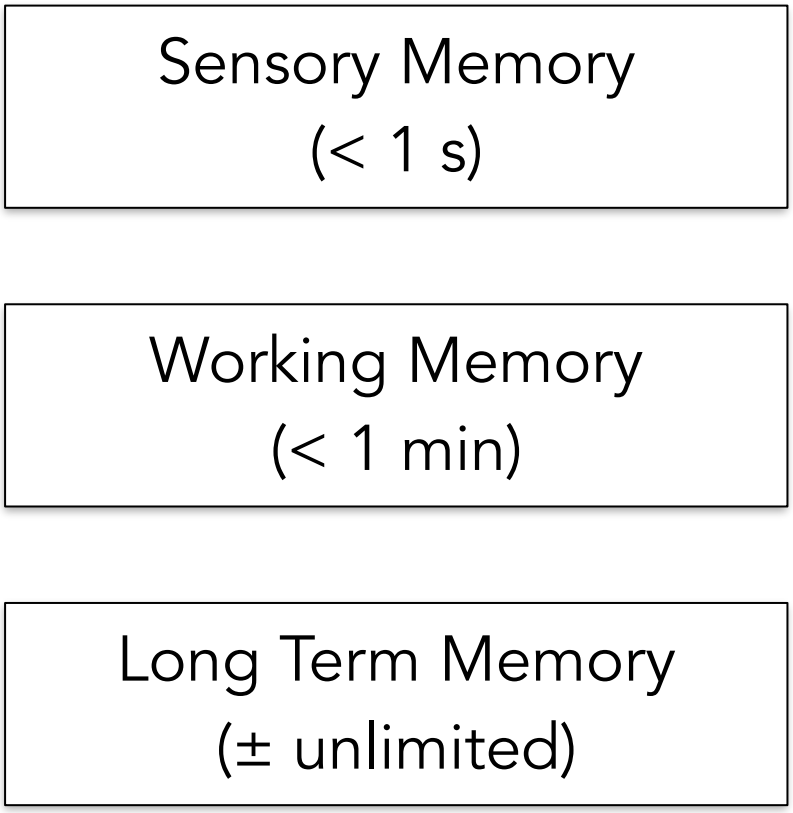
Test 1

Please cite as many cities as possible in 30 seconds

Test 2

Please memorize the following cities list during 1 minute

1. Manchester
2. Brussels
3. Lille
4. Athens
5. Lisbon
6. Amsterdam
7. Lisbon
8. Washington
9. Camberra
10. Tunis
11. Montreal
12. Tokyo
13. Oslo
14. Berlin
15. Bratislava
16. Tashkent
17. Bejing
18. Calcutta
19. Marseille
20. Luzern



The list is see / hear /…

The list I memorized

All the cities I know

Cognitive Psychology

To understand how people learn, we need to ‘understand’ the contraints of our memory system.

But learning is much more than memorizing

A lesson

NUUK

What is the capital of Greenland?

The Lecture Model

Information

Perception

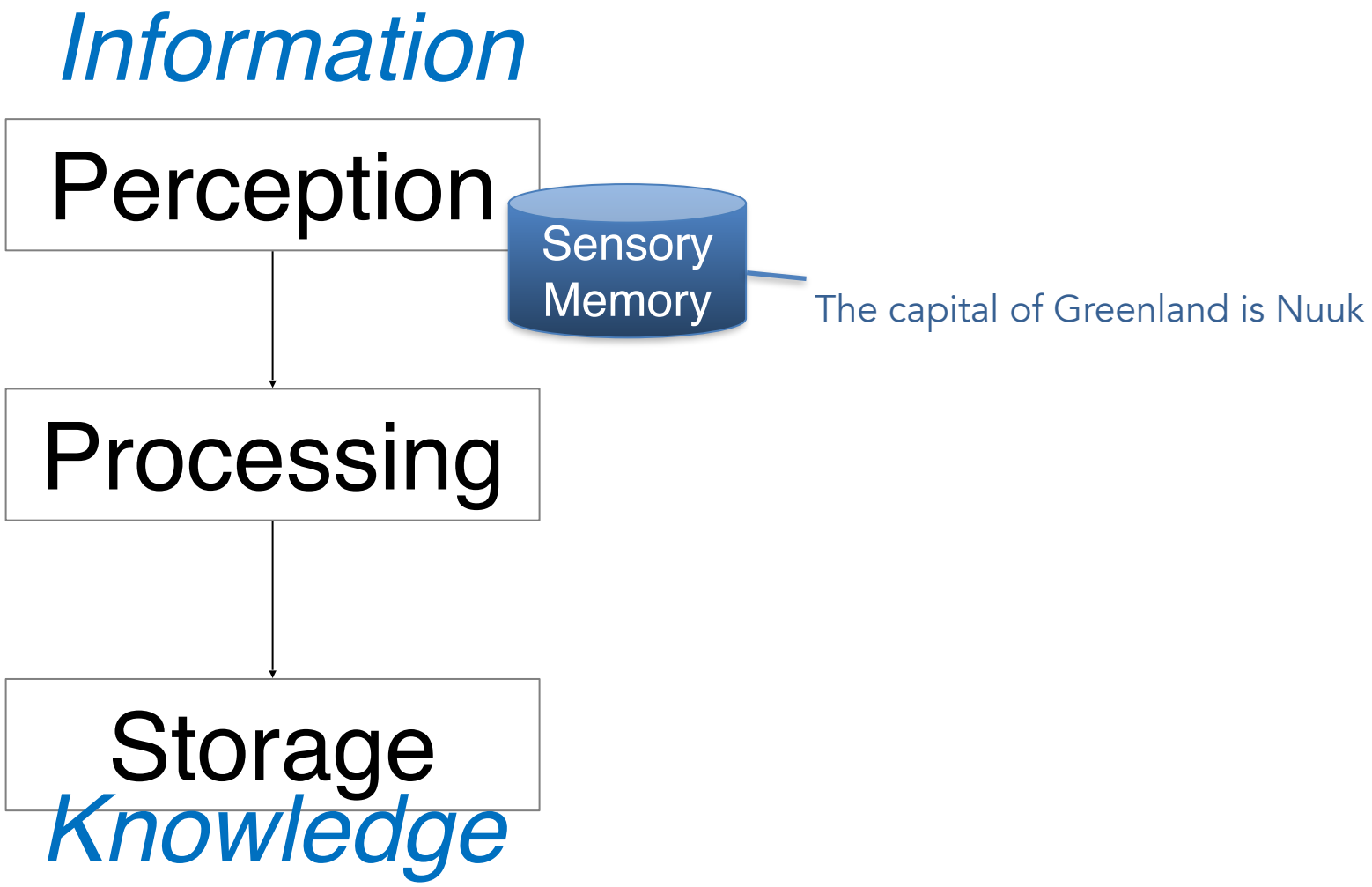
Processing

Storage

Knowledge

The capital of Greenland is Nuuk

The Lecture Model

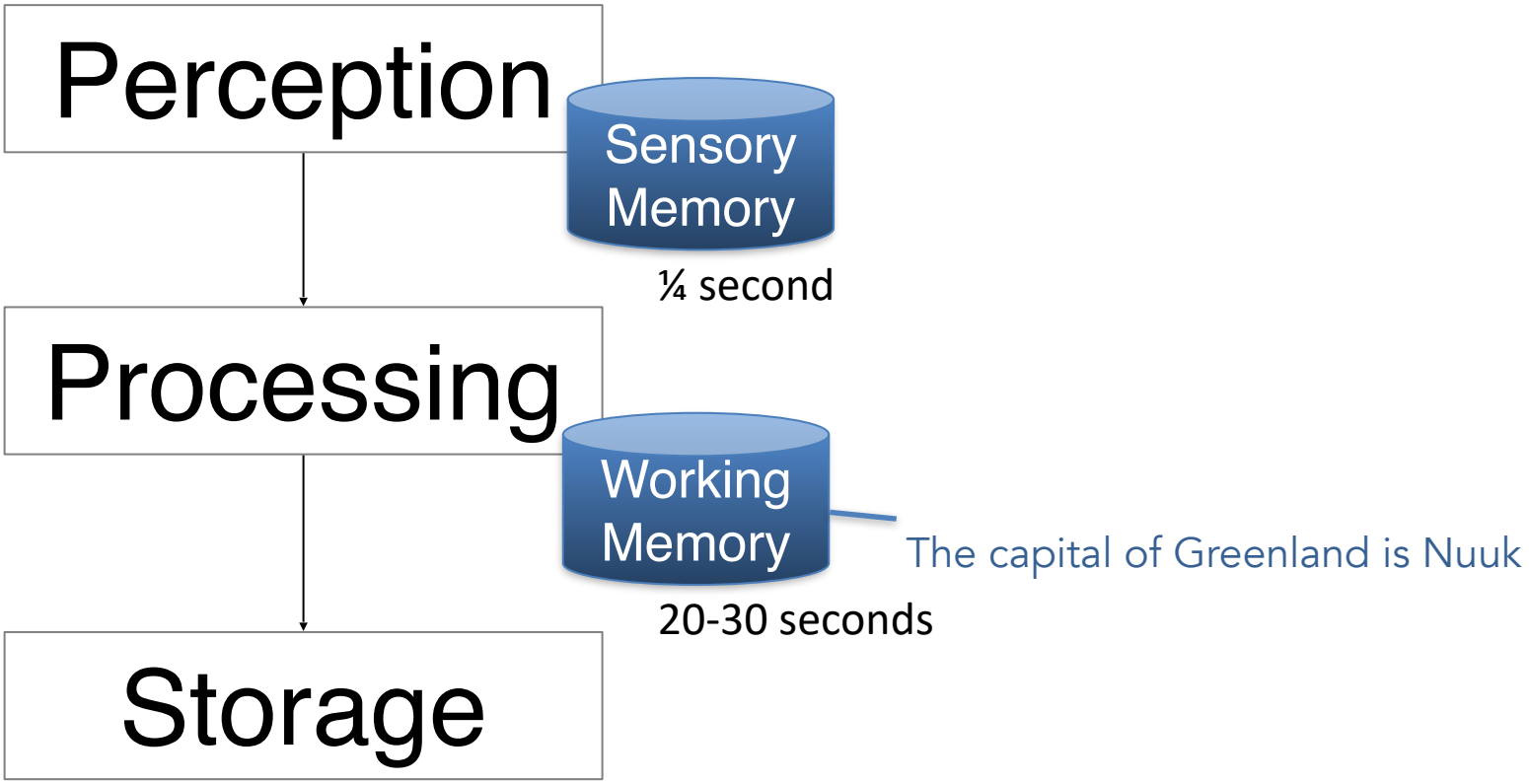


As you can guess, the Danish name of this city is Godthåb

What is the capital of Greenland ?

The Lecture Model

Information

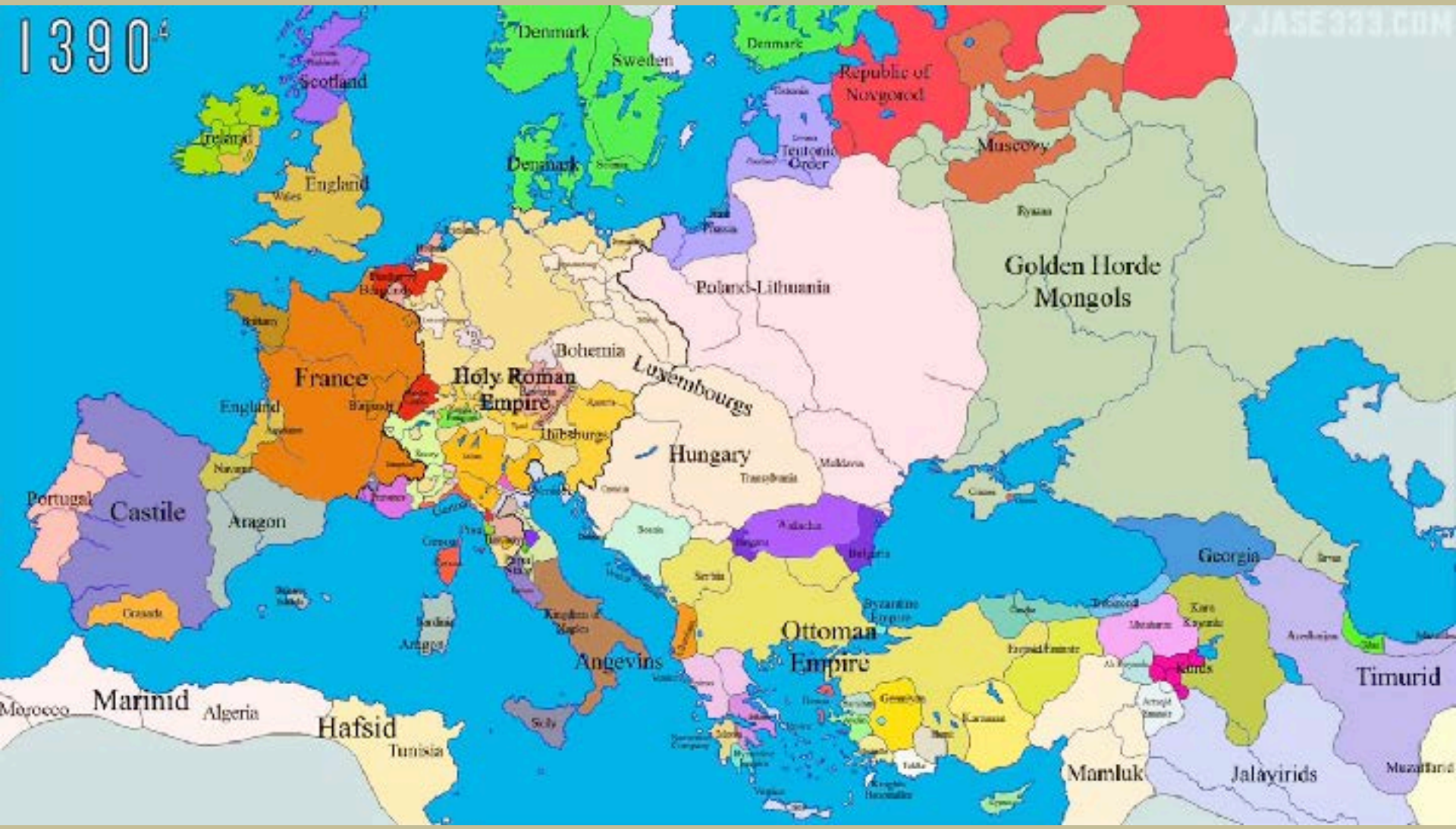


Knowledge

My phone number is 076 825 34 57

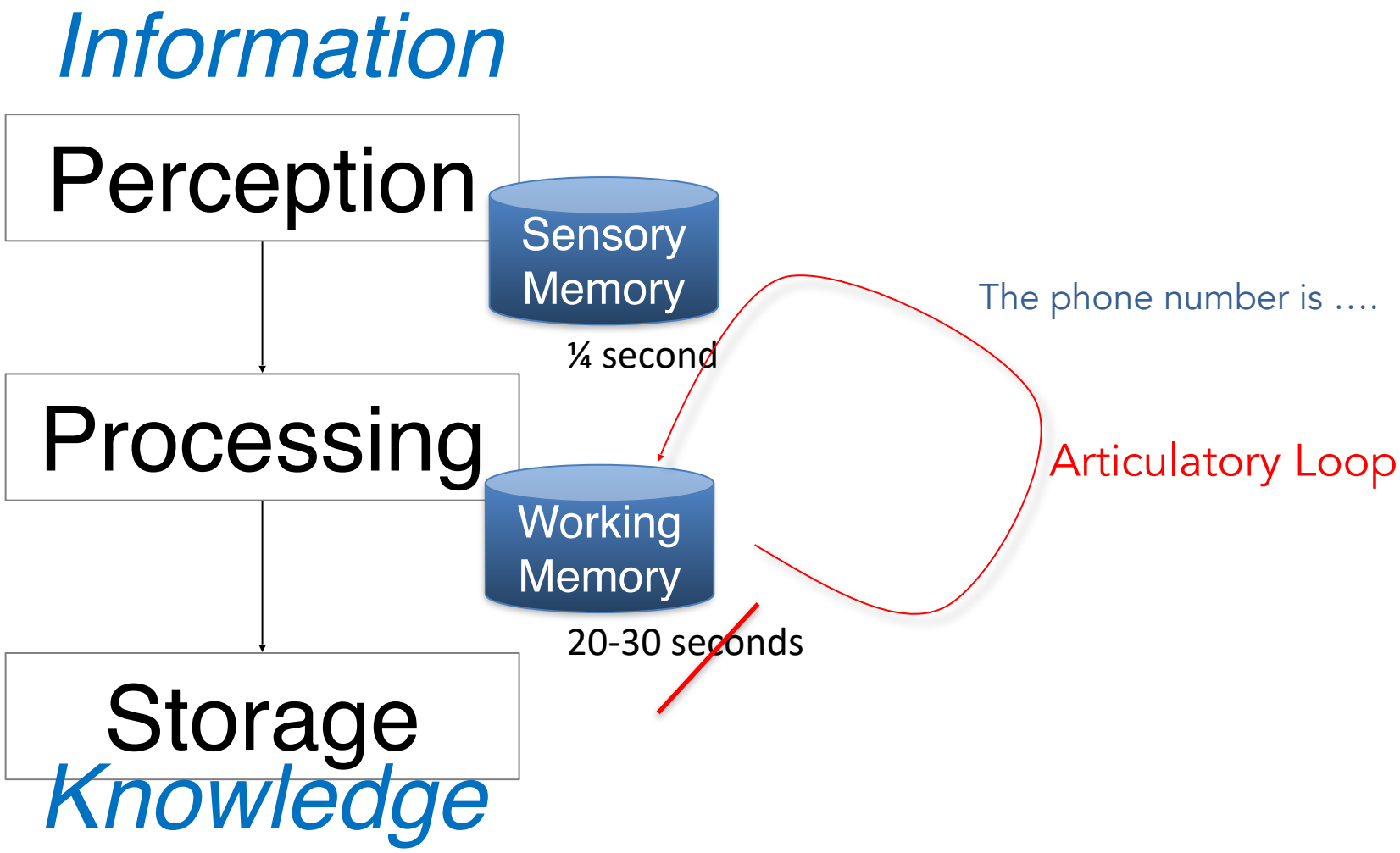
My phone number is 076 825 34 57

My phone number is 079 353 11 64


1390
Denmark
Sweden
Scotland
Ireland
England
Denmark
Republic of Novgorod
Teutonic Order
Muscovy
Golden Horde Mongols
Poland-Lithuania
Bohemia
Luxembourgs
France
Holy Roman Empire
Habsburgs
Hungary
Portugal
Castile
Aragon
Georgia
Ottoman Empire
Angevins
Timurid
Marinid
Morocco
Algeria
Hafsid
Tunisia
Mamluk
Jalayirids

My phone number is 079 353 11 64

The Lecture Model



My car plates are VD 657 31 07

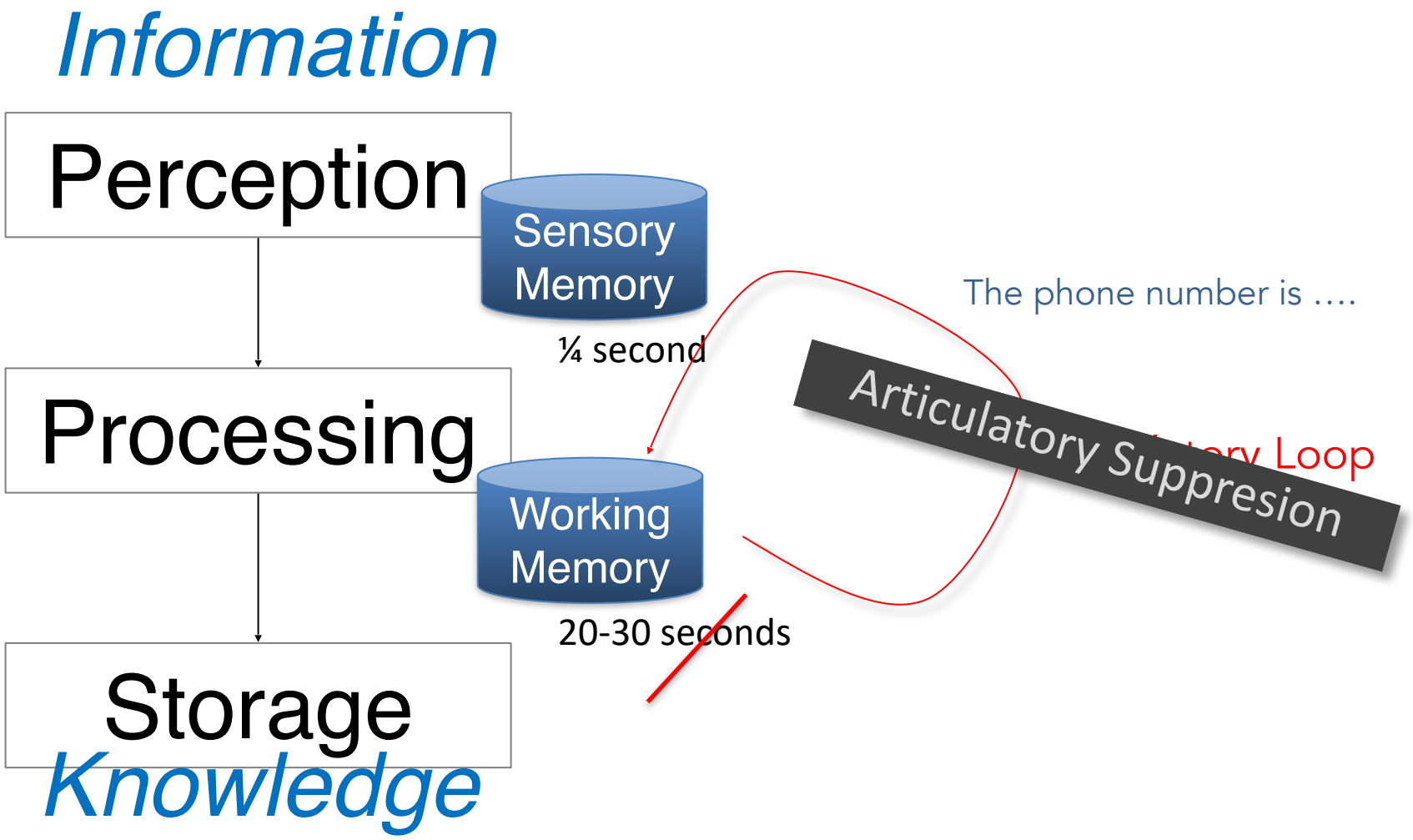
READ ALOUD

Nuuk has a long history of habitation. The area around Nuuk was first occupied by the ancient pre-Inuit, Paleo-Eskimo people of the Saqqaq culture as far back as 2200 BC when they lived in the area around the now abandoned settlement of Qoornoq.

https://en.wikipedia.org/wiki/Nuuk

My car plates are VD 657 31 07

The Lecture Model



My password is 123680

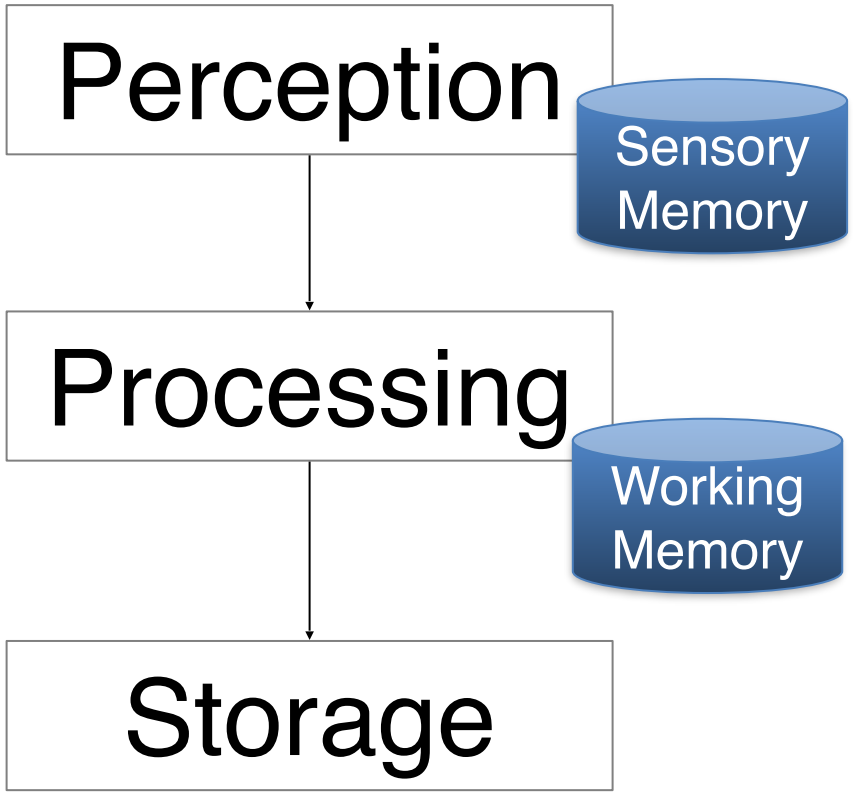
READ ALOUD

For a long time, Nuuk was occupied by the Dorset culture around the former settlement of Kangeq but they disappeared from the Nuuk district before AD 1000. The Nuuk area was later inhabited by Viking explorers in the 10th century (Western Settlement), and shortly thereafter by Inuit peoples.

https://en.wikipedia.org/wiki/Nuuk

What is my password ?

Information

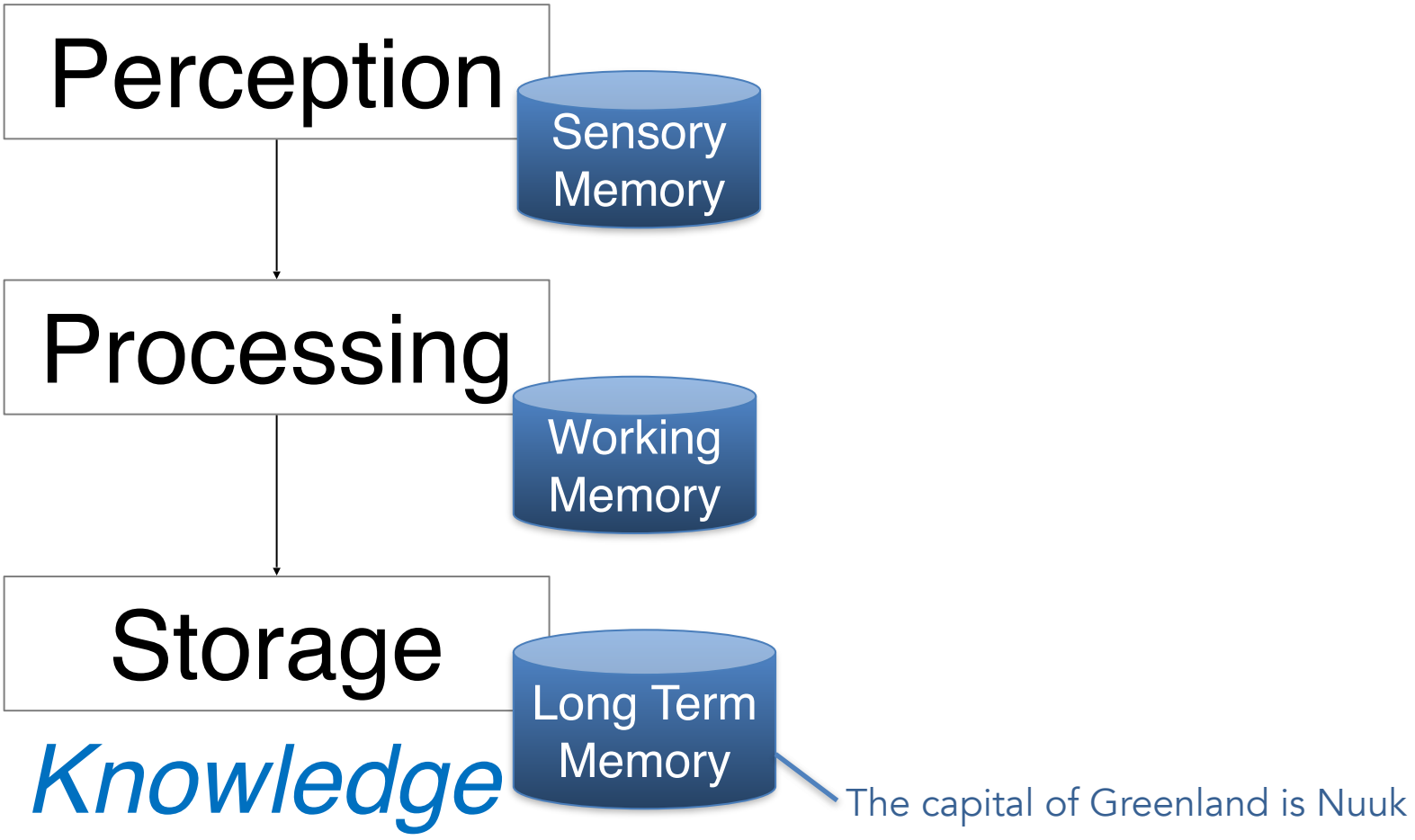


- Verbal / Phonological Loop
- Visual-Spatial Sketchpad

Knowledge

What is the capital of Greenland ?

Information



Knowledge

Information

Perception

Processing

Working Memory

Storage

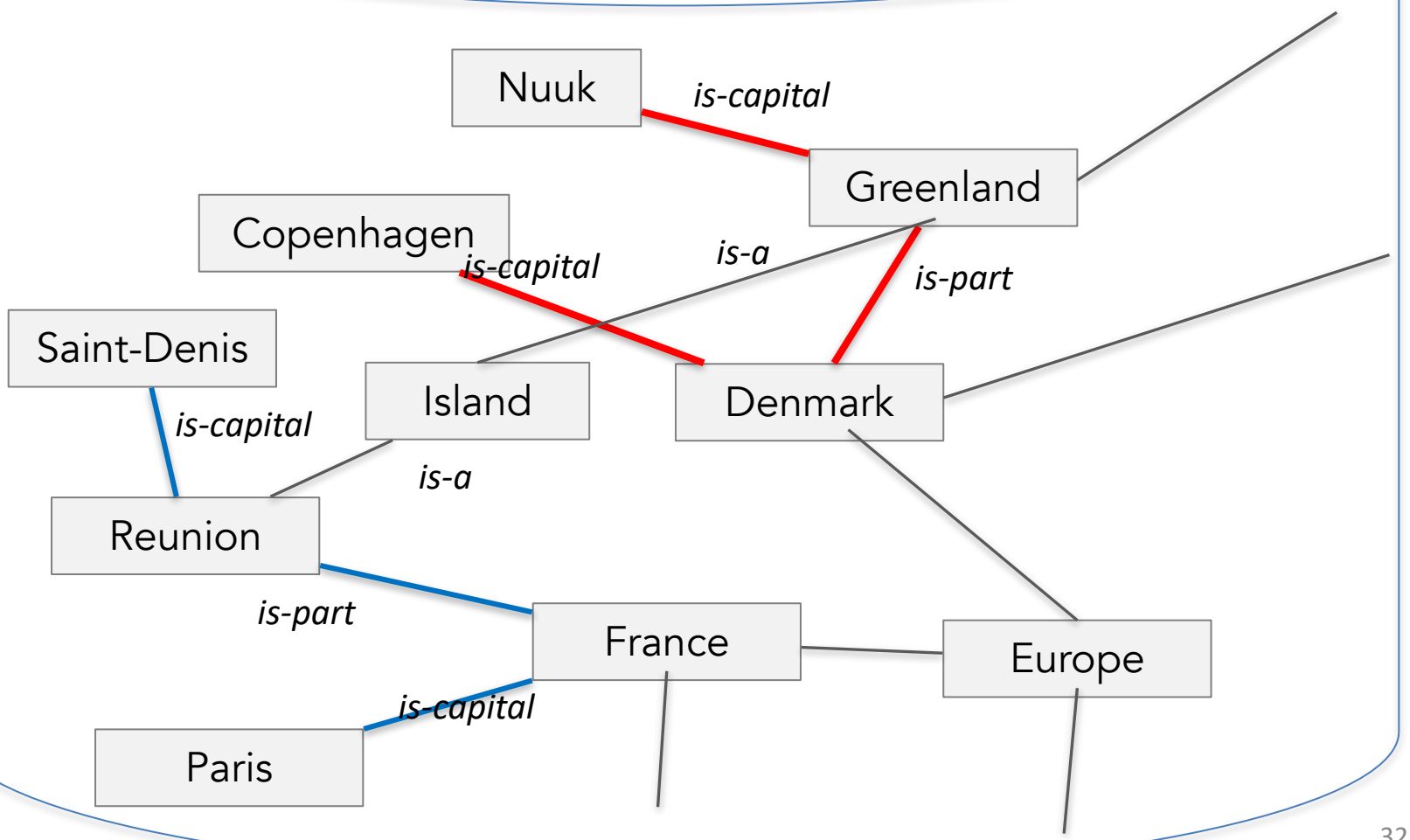
Knowledge

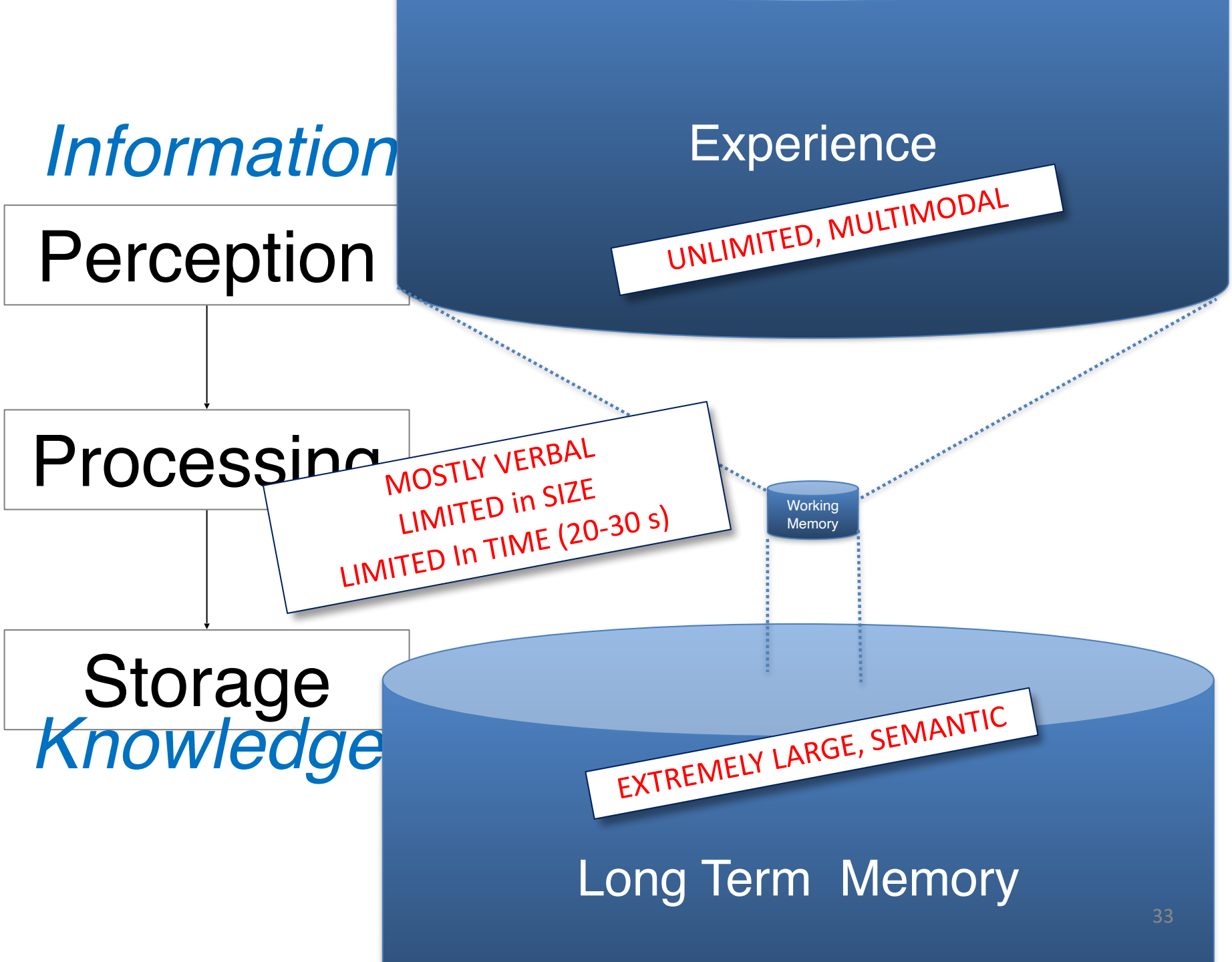
Nuuk is to Copenhagen,

what

Saint-Denis is to …… ?

Nuuk is to Copenhagen
What Saint-Denis is to …… ?



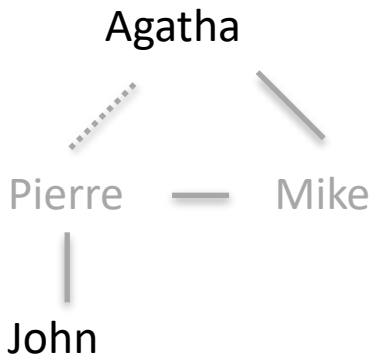

Information
Perception
Processing
Storage
Knowledge
Experience
UNLIMITED, MULTIMODAL
MOSTLY VERBAL
LIMITED in SIZE
LIMITED In TIME (20-30 s)
Working Memory
EXTREMELY LARGE, SEMANTIC
Long Term Memory


« I learned »
Long Term Memory

1. John is the son of Pierre
2. Pierre is the brother of Mike
3. Mike is the son of Agatha

Who is the grand-son of Agatha ?

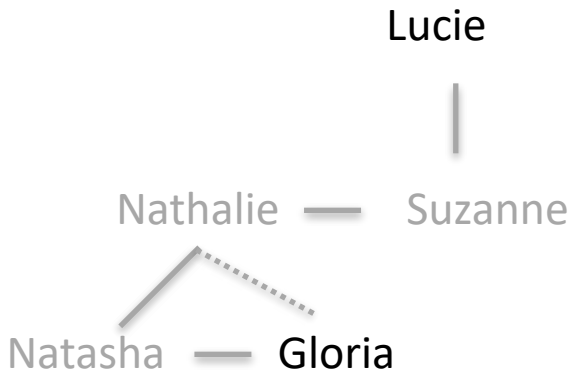
- John
- Pierre
- Mike



1. Nathalie is the sister of Suzanne
2. Suzanne is the daughter of Lucie
3. Natasha is the daughter of Nathalie
4. Gloria is the sister of Natasha

Who is the grand-mother of Gloria?

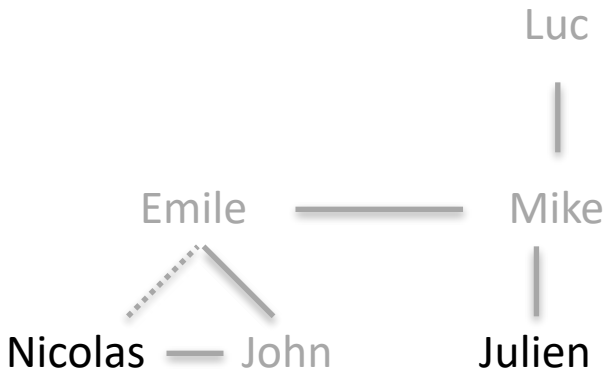
- Nathalie
- Suzanne
- Natasha
- Lucie



1. Luc is the father of Mike
2. Mike is brother of Emile
3. John is the son of Emile
4. Nicolas is the brother of John
5. Julien is the son of Mike

Who is the cousin of Nicolas?

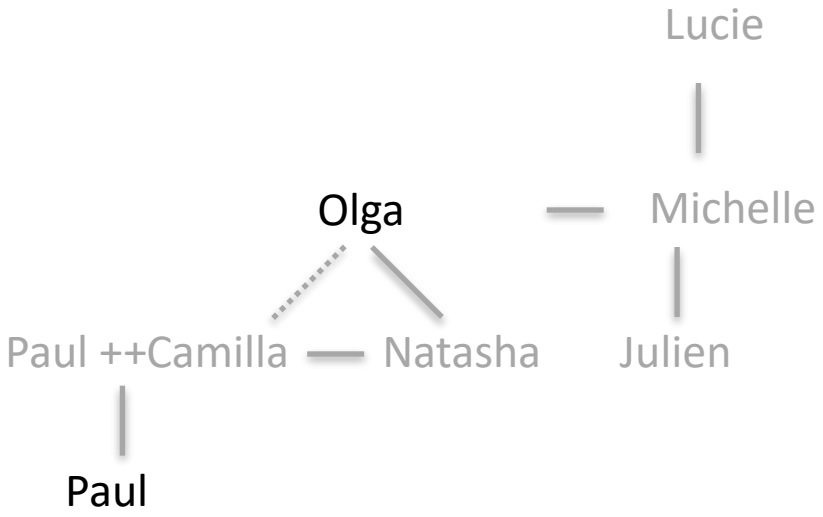
- Luc
- Mike
- John
- Luc
- Nicolas



1. Olga is the sister of Michelle
2. Michelle is the daughter of Lucie
3. Natasha is the daughter of Olga
4. Camilla is the sister of Natasha
5. Paul is the husband of Camilla
6. Donald is the son of Paul

Who is the grand-mother of Donald ?

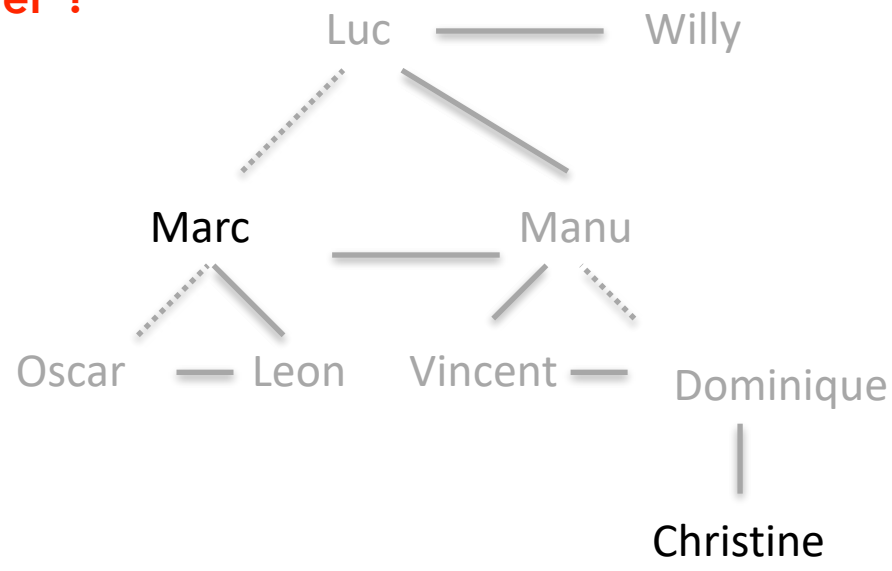
- Michelle
- Olga
- Natasha
- Camilla
- Lucie



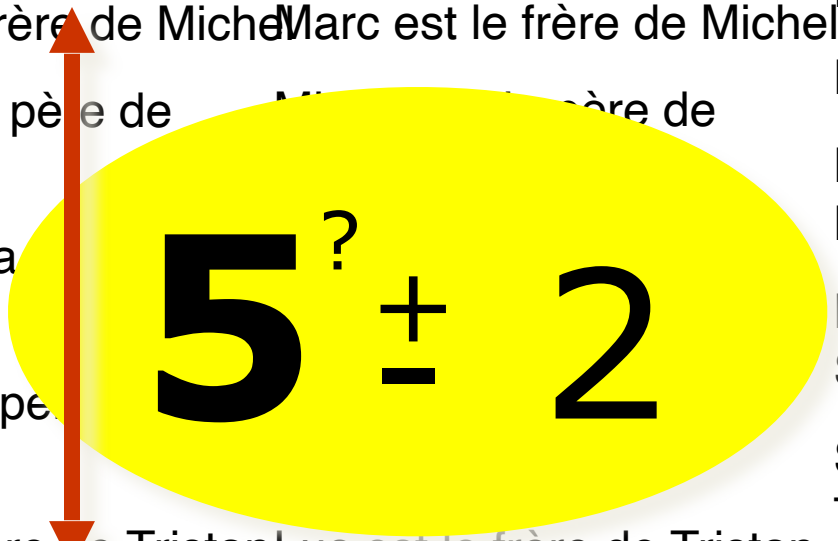
1. Marc and Manu are brothers
2. Leon and Oscar are brothers
3. Leon is the son of Marc
4. Vincent is the son of Manu
5. Willy is the uncle of Marc
6. Dominique is the brother of Vincent
7. Christine is the daughter of Dominique

Who is the brother of Christine's grand-father ?

- Willy
- Dominique
- Marc
- Manu
- Leon
- Oscar
- Vincent



Cognitive overload



Lena est la sœur de Lucie

Marc est le frère de Michel

Michel est le père de Martine

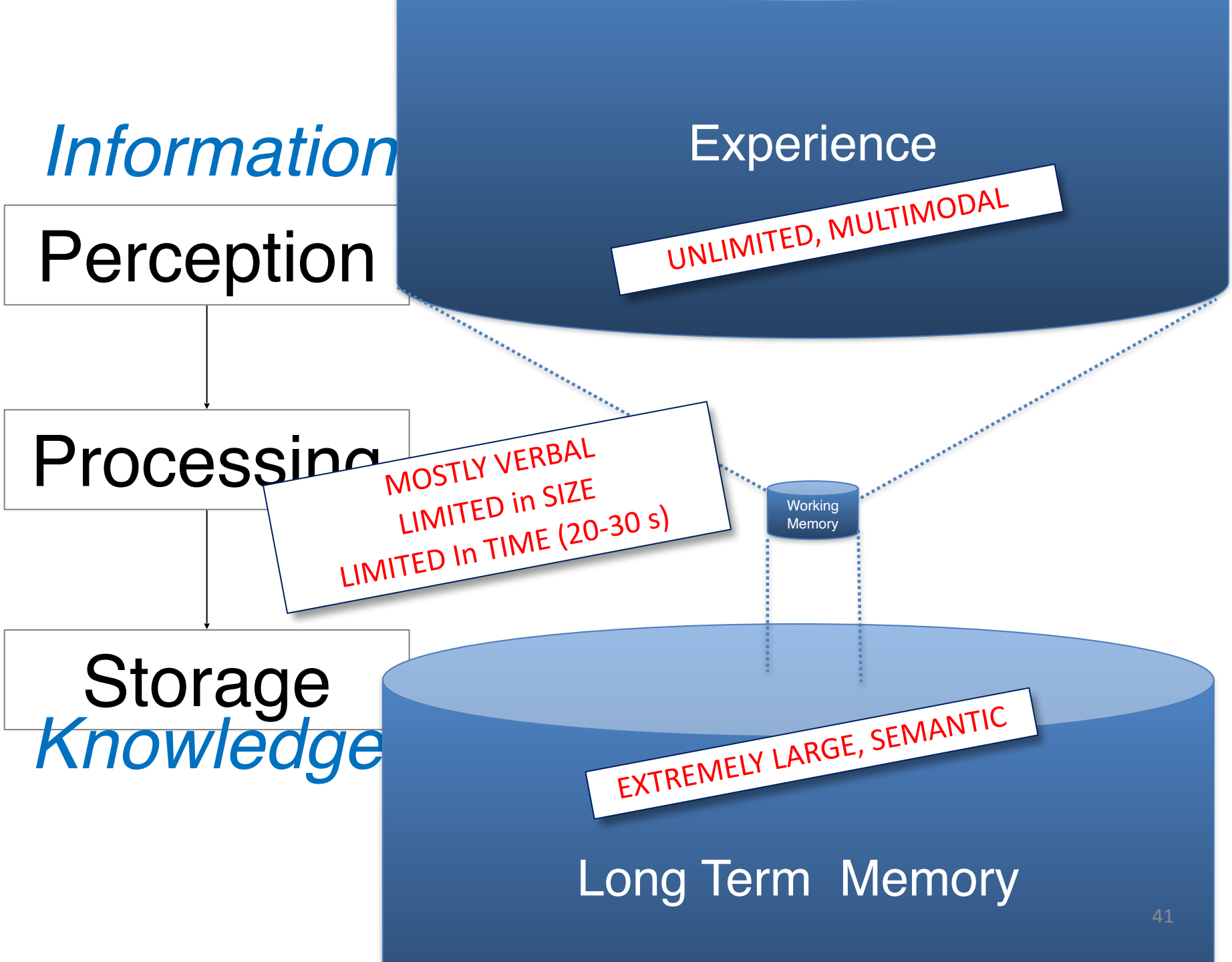
Martine est la sœur de Serge

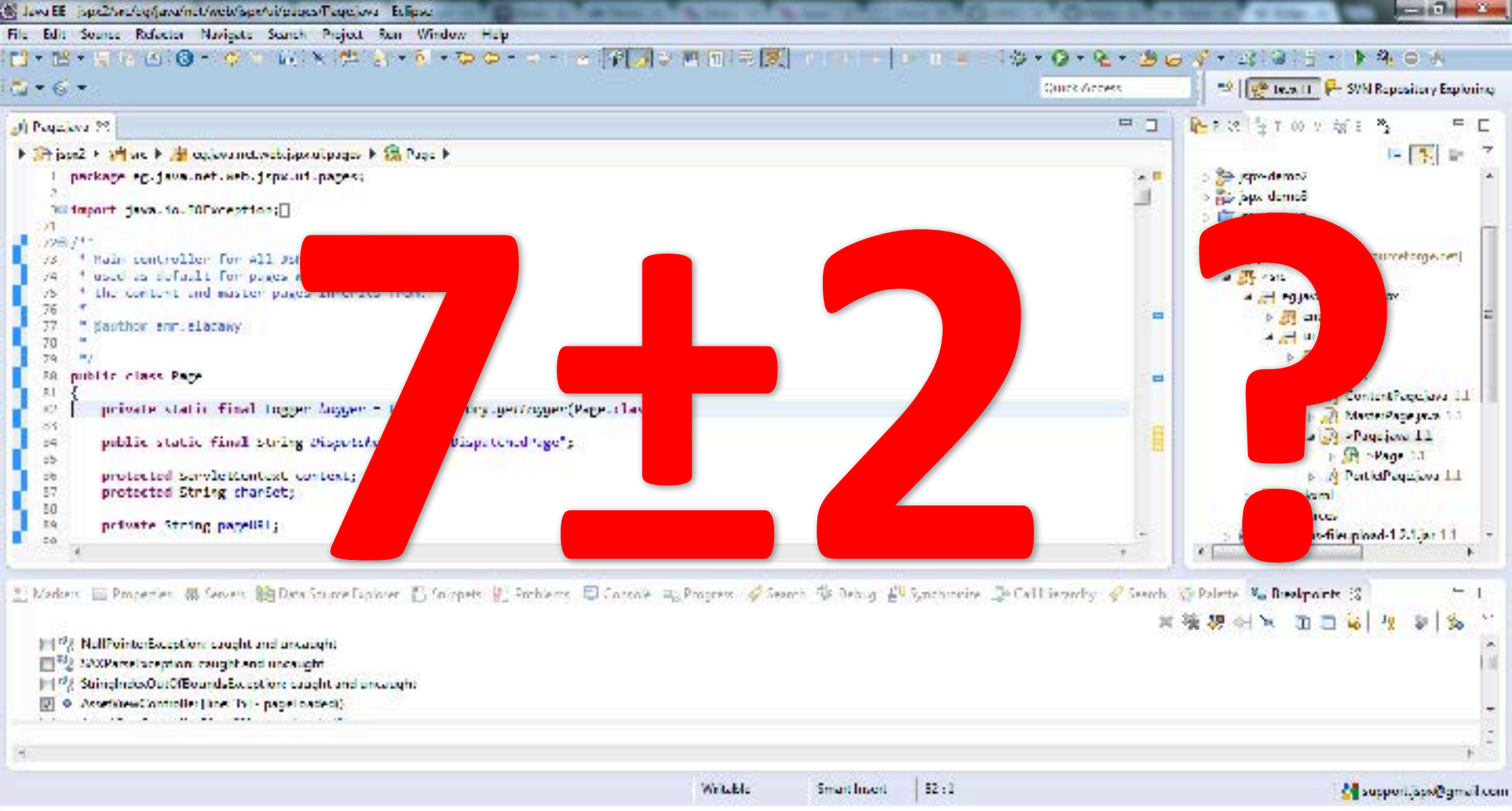
Serge est le père de Tristan

Luc est le frère de Tristan

Lucie est la mère de Serge

Nadine est la fille de Tristand


Information
Perception
Processing
Storage
Knowledge
Experience
UNLIMITED, MULTIMODAL
MOSTLY VERBAL
LIMITED in SIZE
LIMITED In TIME (20-30 s)
Working Memory
EXTREMELY LARGE, SEMANTIC
Long Term Memory



Working Memory

Reducing cognitive load:
Compilation

- Check the barreer
- Tune radio
- Speak
- Listen
- Get your badge
- Slow down
- Turn

- Freiner
- Embrayer
- Changer
- Débrayer
- Freiner

Who did what?

Dave wrote a play

Jean made a discovery

Lara ate an apple

Rebecca pressed the light switch

John set for sail

Carol made a movie

Emmanuel sang a song

Timothy played football

Zoe performed a dance

Recall

Who wrote a play?

Who made a discovery?

Who ate an apple?

Who pressed the light switch?

Who set for sail?

Who made a movie?

Who sang a song?

Who played football?

Who performed a dance?

Who did what?

Shakespeare wrote a play

Einstein made a discovery

Adam ate an apple

Edison pressed the light switch

Columbus set for sail

Jackie Chan made a movie

Elton John sang a song

Ronaldo played football

Michael Jackson performed a dance

Recall

Who wrote a play?

Who made a discovery?

Who ate an apple?

Who pressed the light switch?

Who set for sail?

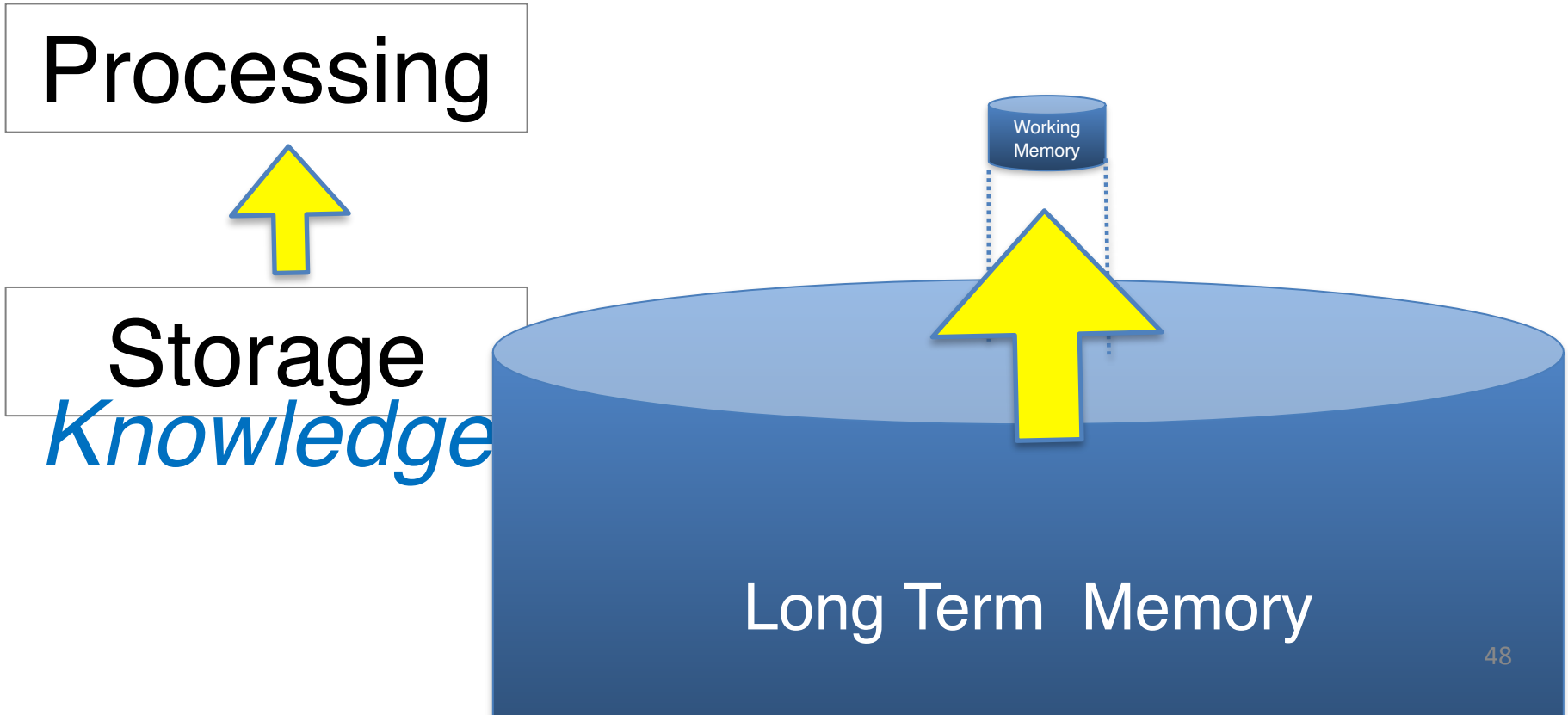
Who made a movie?

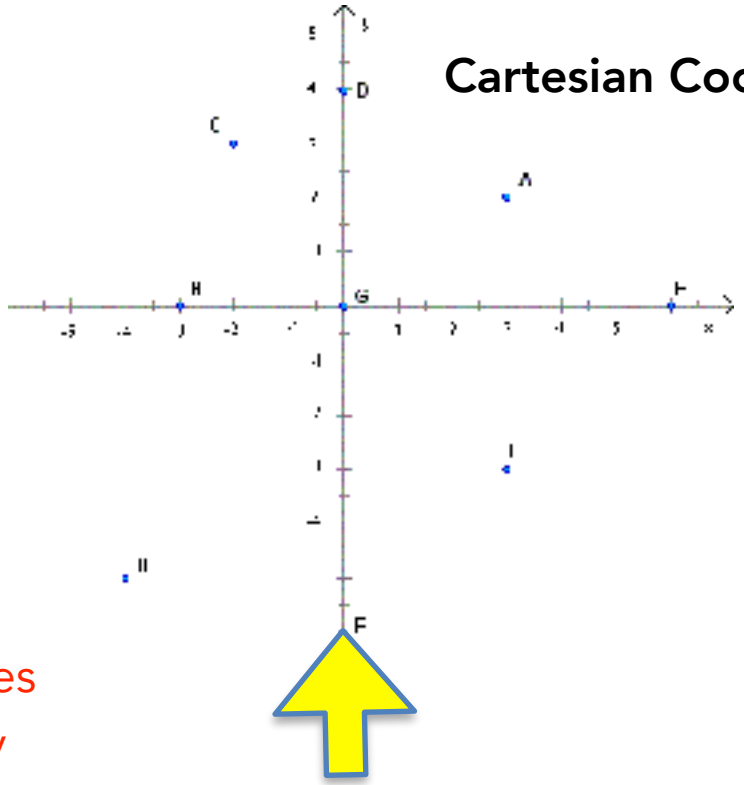
Who sang a song?

Who played football?

Who performed a dance?

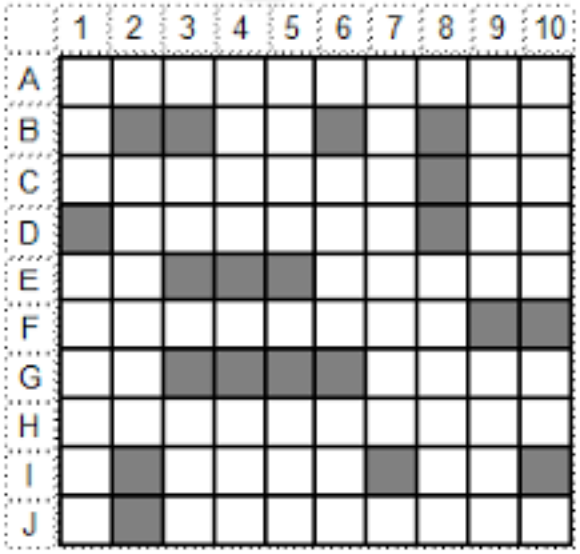
Working memory taps into long-term memory





Cartesian Coordinates System

An ‘advance organizer’ pre-activates elements of the long term memory that we’ll need to be used in the working memory



Battleship

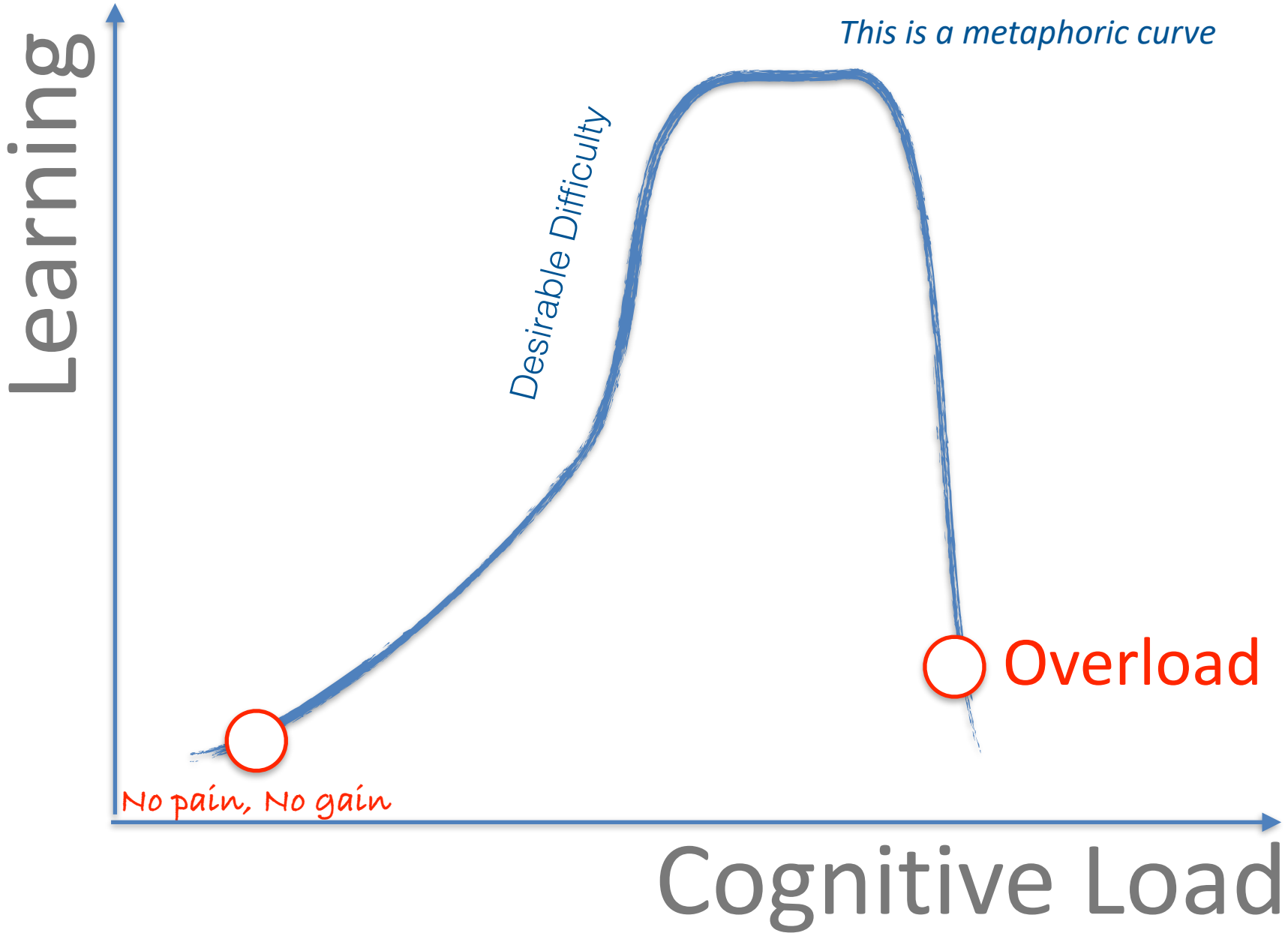
Learning comes from processing information

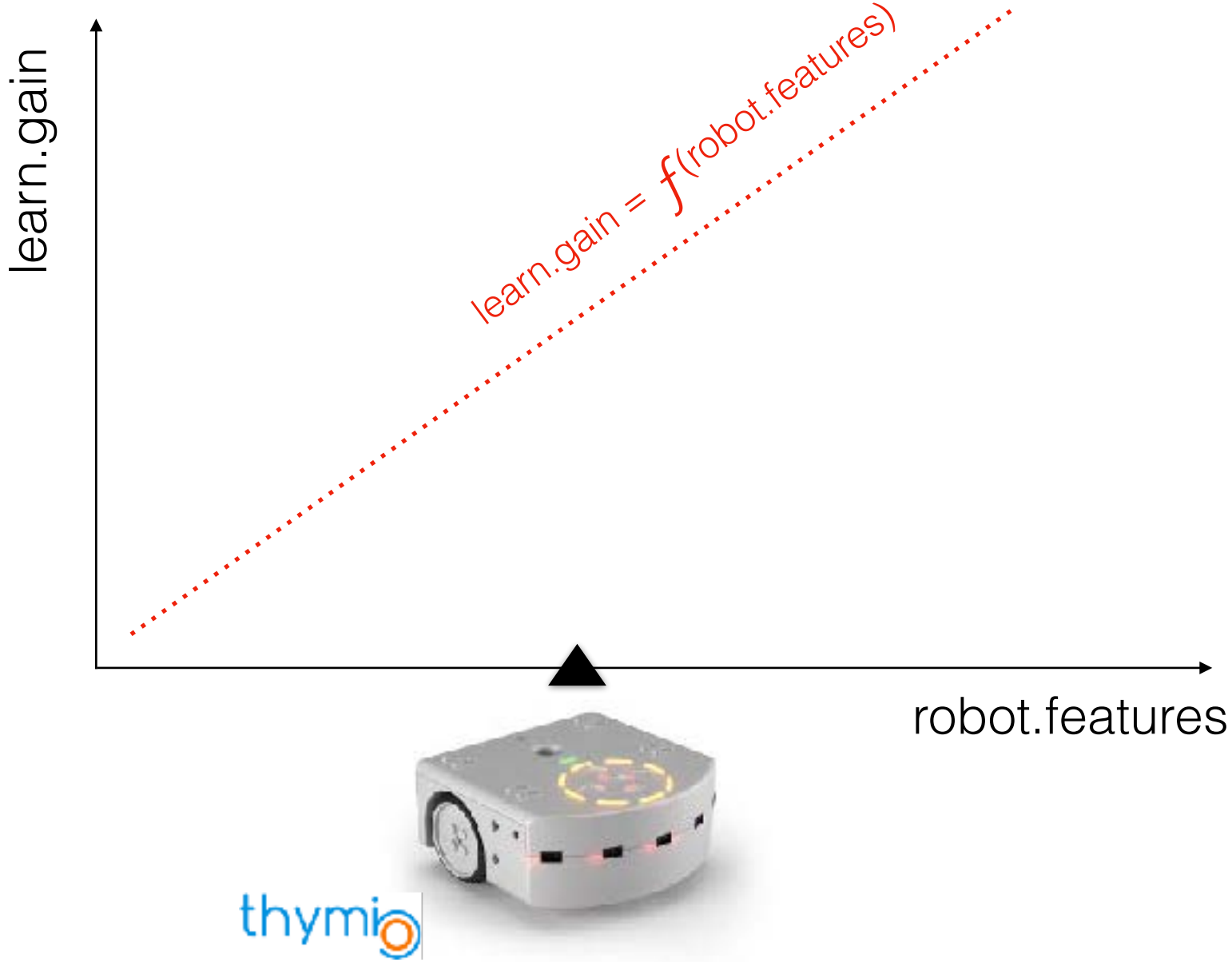
perceived or stored in long-term memory

Processing information is managed by the working memory

If cognitive overload, processing will fail, hence no learning

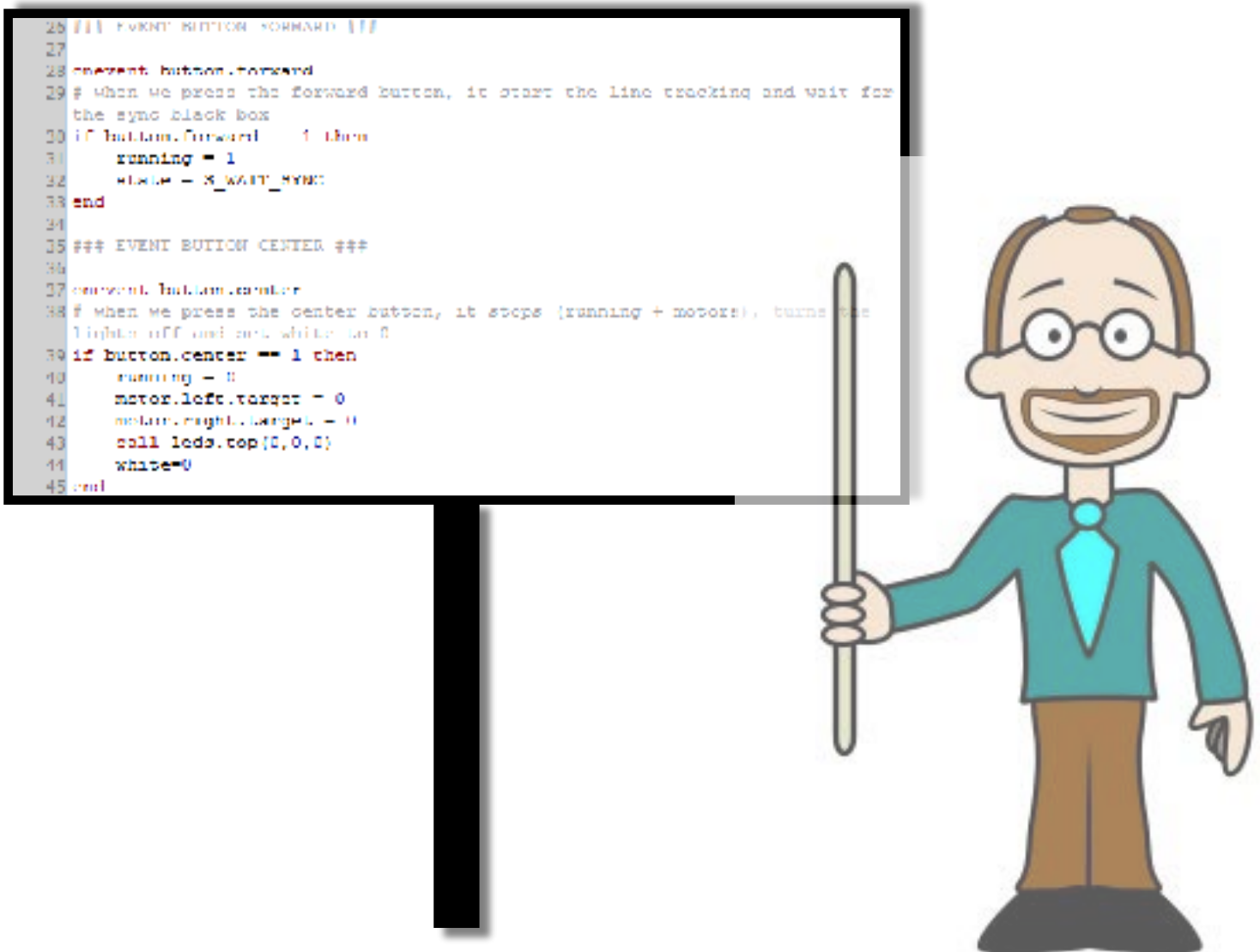
If no processing, no cognitive load but no learning


Learning
This is a metaphoric curve
Desirable Difficulty
Overload
No pain, No gain
Cognitive Load

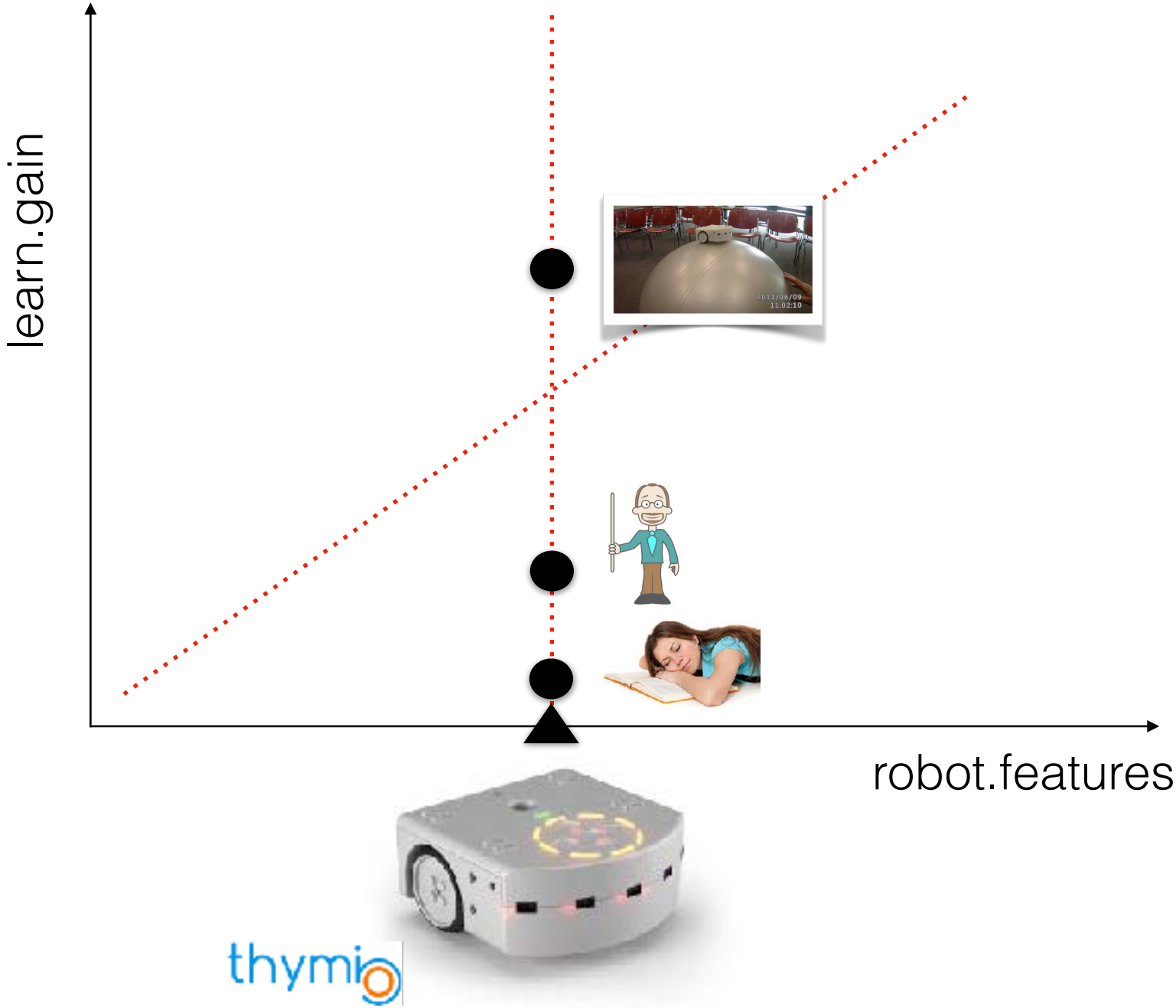

learn.gain
learn.gain = f(robot.features)
robot.features
thymio

Experience 1

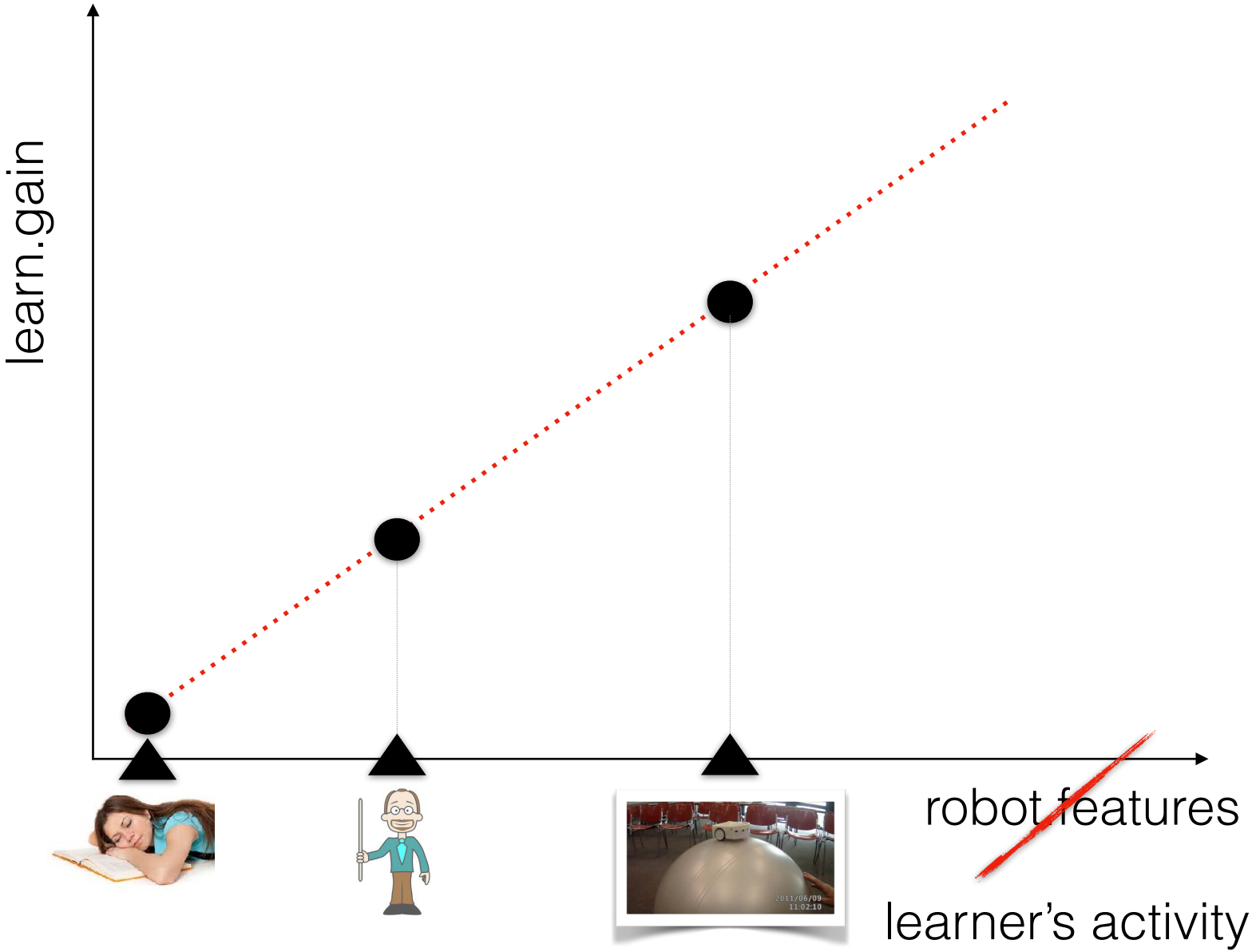
Experience 2



https://fr.dreamstime.com/photo-stock-le-bel-%C3%A9tudiant-dort-sur-le-livre-image19226880


learn.gain
robot.features
thymio

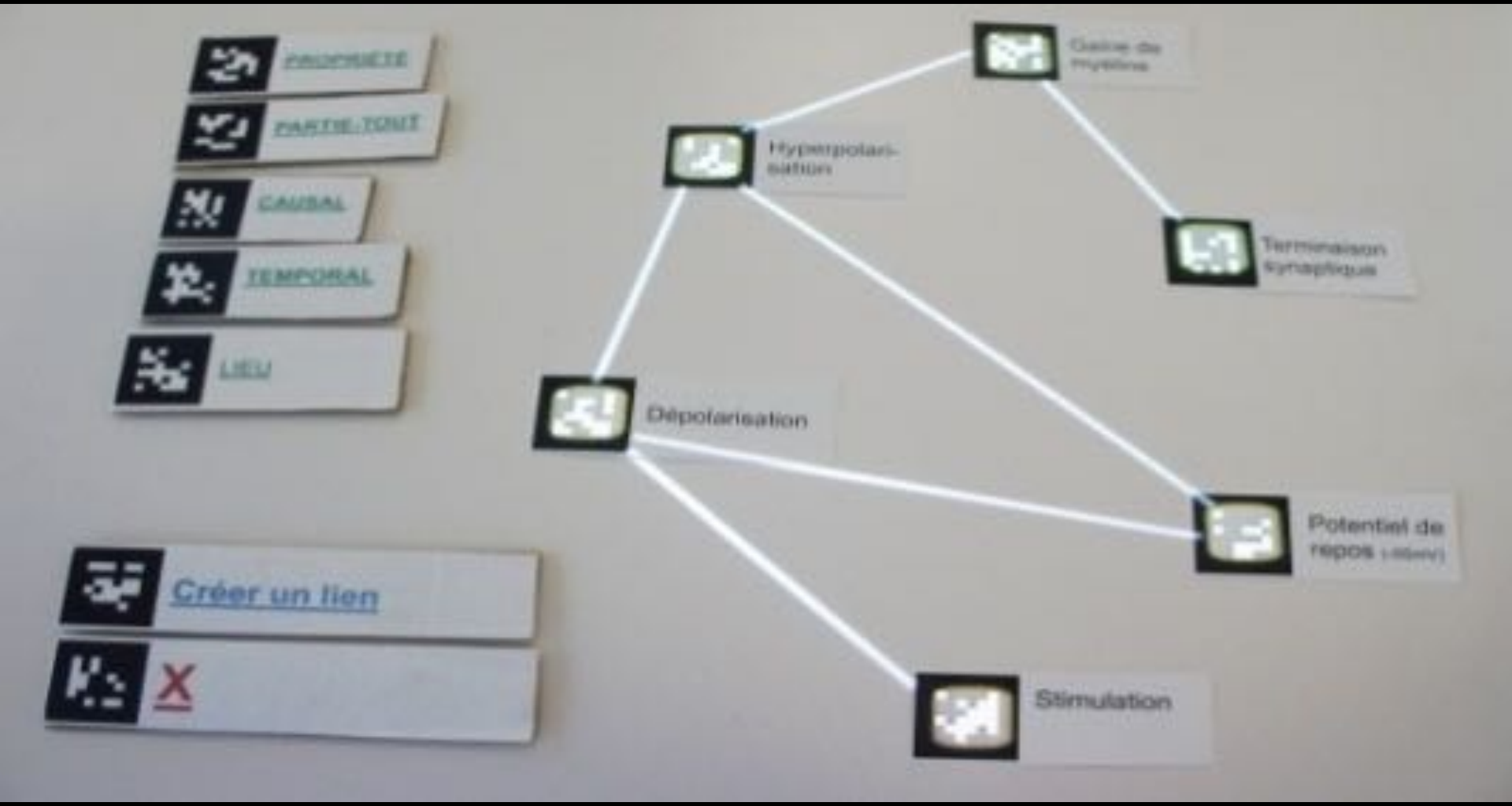
learn.gains = f(learn.activity)



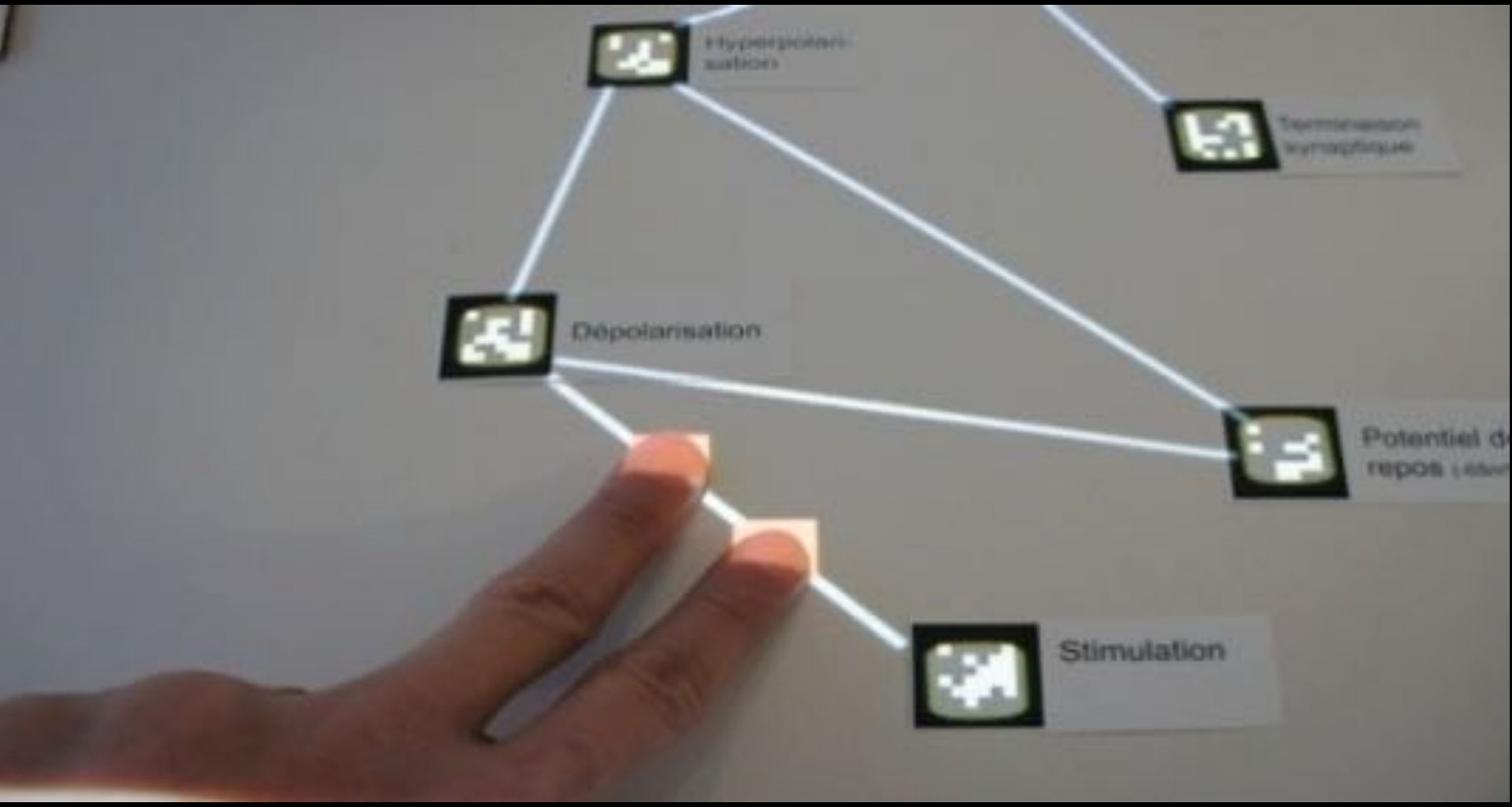
http://www.morahanvisuals.com/tag/running/

Who will win the next race ?

Desirable Difficulty



Concept Map: paper concepts, augmented links

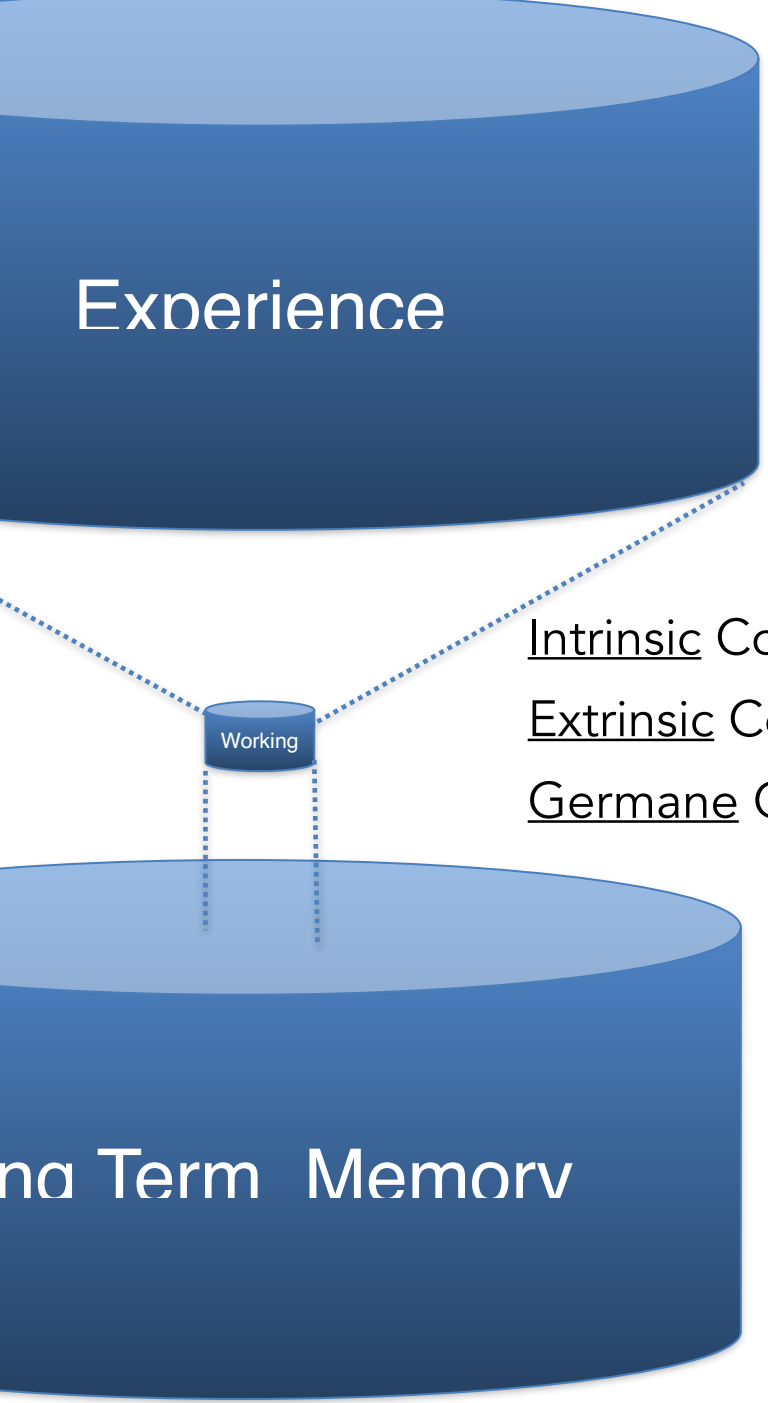


Concept Map: gestures (e.g. cut)

8 teams in the experimental condition

8 teams in the control condition

<



Intrinsic Cognitive Load: some things are harder to learn

Extrinsic Cognitive Load: due to bad design

Germane Cognitive Load : the effort to create schemas

Intrinsic Cognitive Load

3 Modular forms

Let $\mathbb{H}$ be the upper half-plane $\{z \in \mathbb{C} \mid \mathrm{Im}(z) > 0\}$. The modular group $\Gamma(1) := \mathrm{PSL}_2(\mathbb{Z})$ acts on $\mathbb{H}$ by linear fractional transformations

$$\left(\begin{smallmatrix} a & b \\ c & d \end{smallmatrix}\right) z := \frac{az+b}{cz+d}.$$

Let N be a positive integer. The *level N principal congruence subgroup* of $\Gamma(1)$ is

$$\Gamma(N) := \left\{ \left(\begin{smallmatrix} a & b \\ c & d \end{smallmatrix}\right) \in \Gamma(1) \,\middle|\, \left(\begin{smallmatrix} a & b \\ c & d \end{smallmatrix}\right) \equiv \left(\begin{smallmatrix} 1 & 0 \\ 0 & 1 \end{smallmatrix}\right) \bmod N \right\}.$$

A subgroup $\Gamma \subset \Gamma(1)$ is called a *congruence subgroup* if $\Gamma(N) \subset \Gamma$ for some $N \in \mathbb{N}$. An important example of a congruence subgroup is

$$\Gamma_0(N) := \left\{ \left(\begin{smallmatrix} a & b \\ c & d \end{smallmatrix}\right) \in \Gamma(1) \,\middle|\, c \equiv 0 \bmod N \right\}.$$

Let $z \in \mathbb{H}$, $k \in \mathbb{Z}$, and $\left(\begin{smallmatrix} a & b \\ c & d \end{smallmatrix}\right) \in \mathrm{SL}_2(\mathbb{Z})$. The *automorphy factor* of weight k is defined as

$$j_k\left(z, \left(\begin{smallmatrix} a & b \\ c & d \end{smallmatrix}\right)\right) := (cz+d)^{-k}.$$

The automorphy factor satisfies the *chain rule*

$$j_k(z, \gamma_1\gamma_2) = j_k(z, \gamma_2)\, j_k(\gamma_2 z, \gamma_1).$$

Let F be a function on $\mathbb{H}$ and $\gamma \in \mathrm{PSL}_2(\mathbb{Z})$. Then the *slash operator* acts on F by

$$(F|_k\gamma)(z) := j_k(z, \gamma)\, F(\gamma z).$$

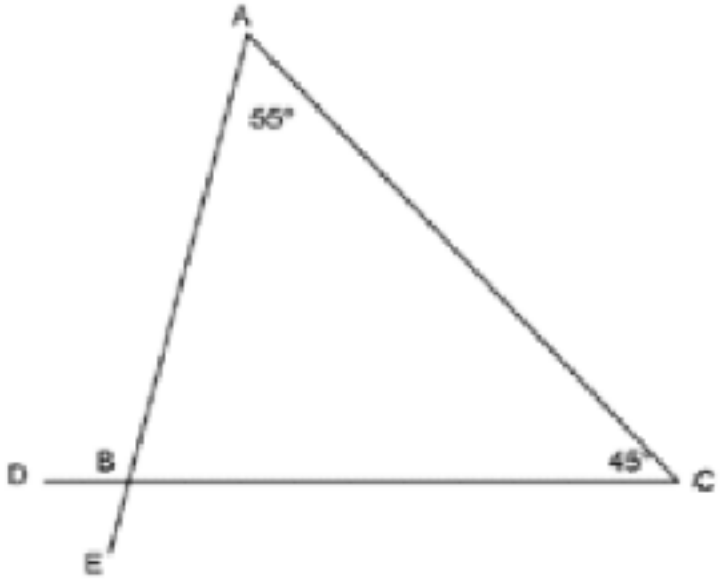
The chain rule implies

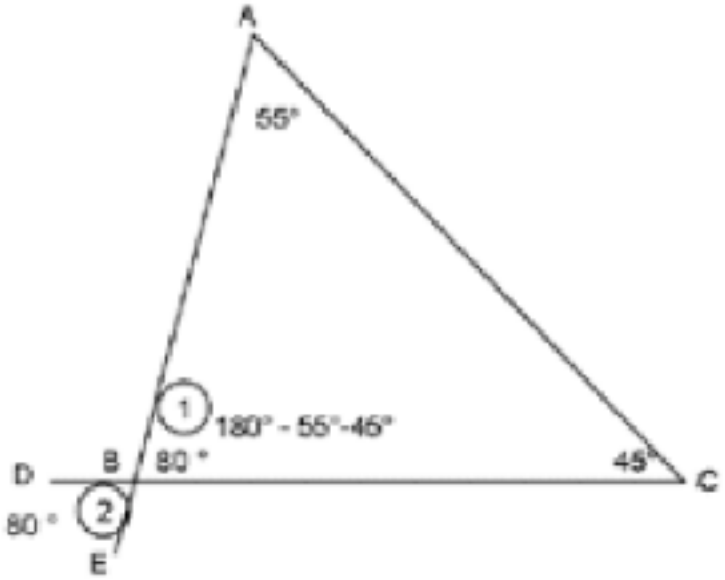
$$F|_k\gamma_1\gamma_2 = (F|_k\gamma_1)|_k\gamma_2.$$

A *(holomorphic) modular form* of integer weight k and congruence subgroup Γ is a holomorphic function $f : \mathbb{H} \to \mathbb{C}$ such that:

Maryna Viazovska

Extrinsic Cognitive Load





In the above figure, find a value for Angle DBE

Solution:
Angle ABC =180° - Angle BAC-Angle BCA (internal angles of a triangle sum to 180°)

= 180° - 55°-45°

= 80 °

Angle DBE = Angle ABC (vertically opposite angels are equal)
= 80 °

Split Attention Effect

http://en.wikipedia.org/wiki/Split_attention_effect

Cognitive load

Which statements are correct?

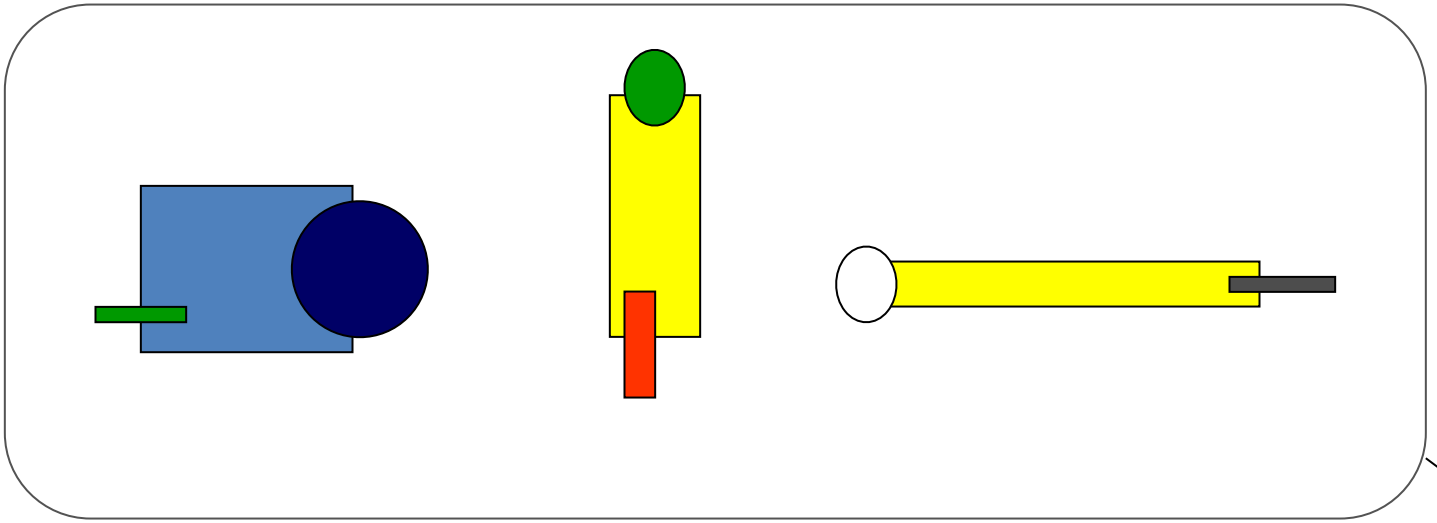
①Cognitive load prevents learning

②There is no learning without cognitive load

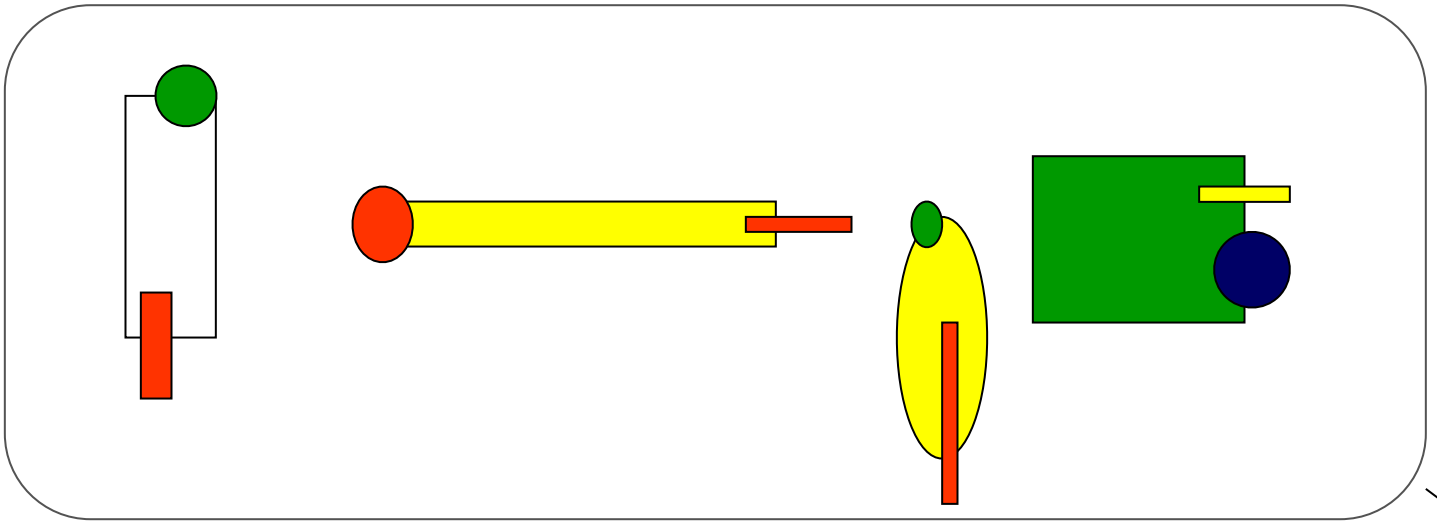
③Cognitive over-load prevents learning

④There is no learning without over-load

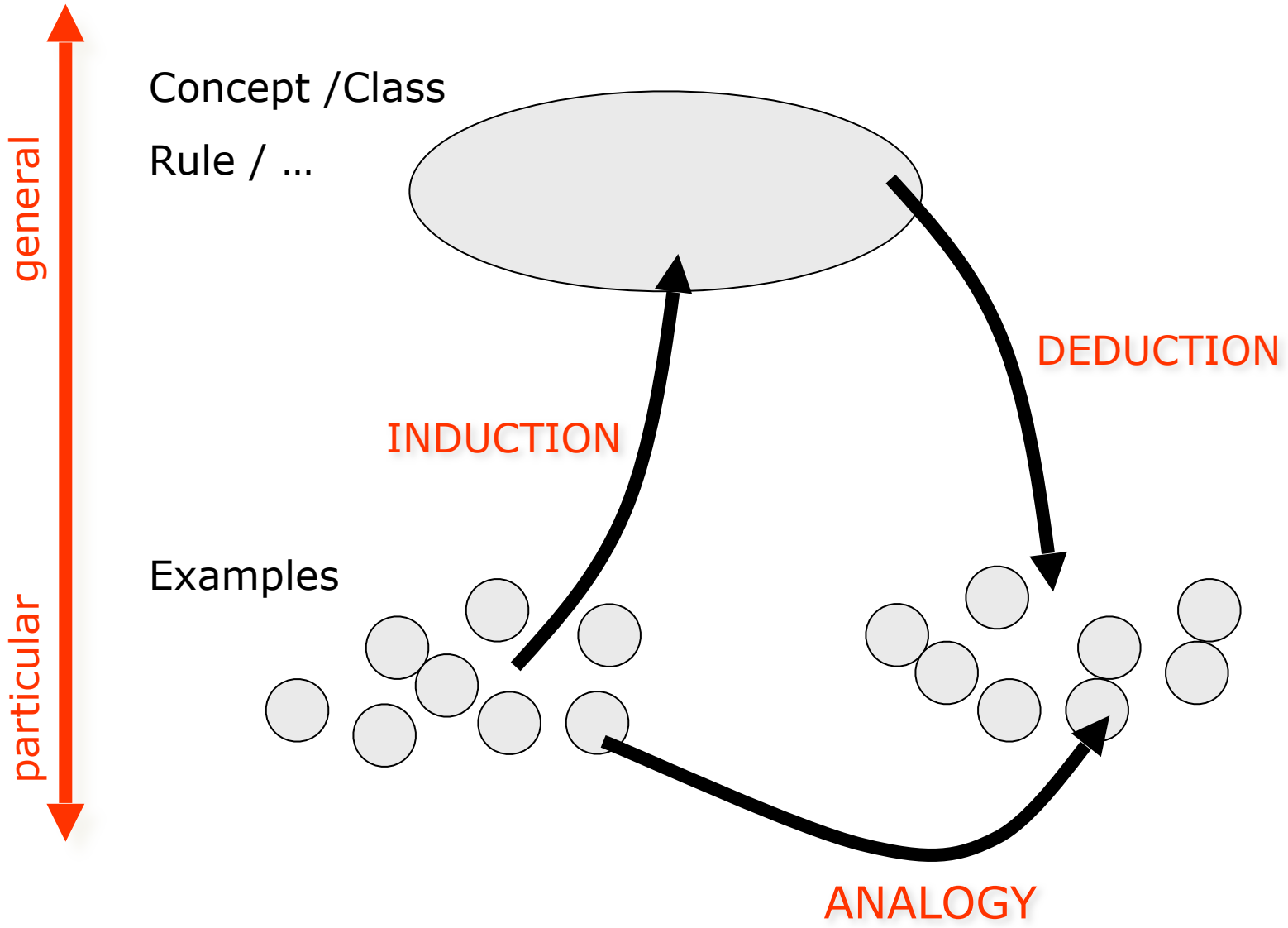
Germane Cognitive Load



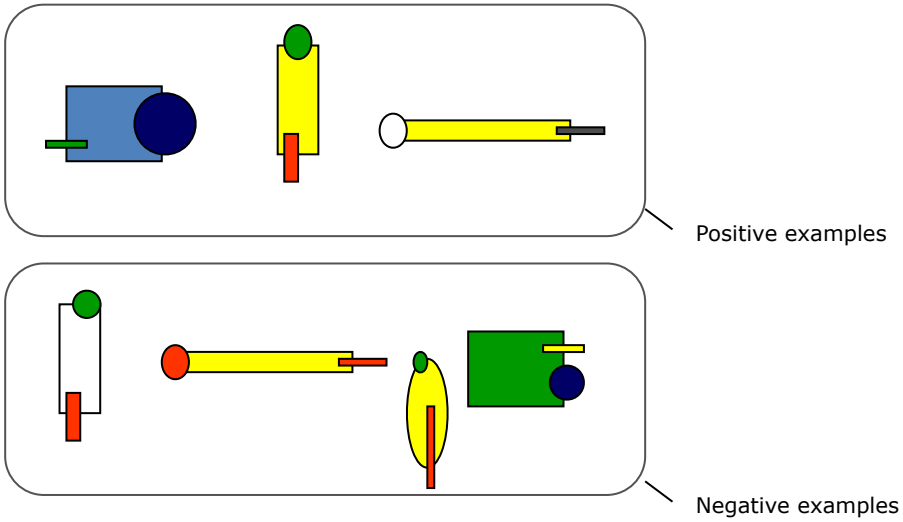
Positive examples



Negative examples


general
particular
Concept /Class
Rule / …
Examples
INDUCTION
DEDUCTION
ANALOGY

Germane Cognitive Load



I-PS

1. A SPUC is… !
2. Is this a SPUC ?

PS-I

« Contrasted cases »

1. What is a SPUC (induction/discrimination)
2. A SPUC is… !
3. Is this a SPUC ?

Intrinsèque

CHARGE COGNITIVE

Extrinsèque

Germane

« If the speed of light is incompressible
then time is elastic »

Long-term memory is not a ‘storage’ place like a book shelve

Knowledge elements are accessible via connections to other elements

Connections are constructed by **meaning making**

Is knowledge a copy of information ?

Information

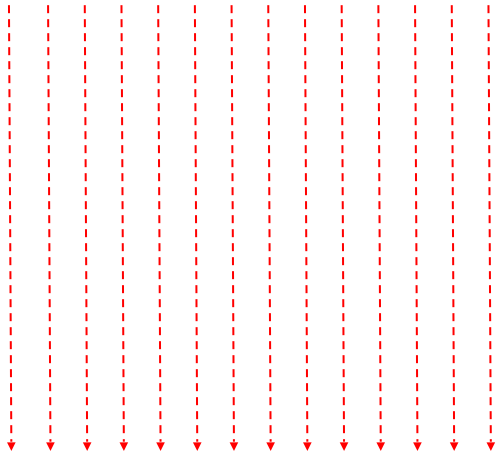
Perception

Processing

Storage

Knowledge

« If the speed of light is incompressible then time is elastic »



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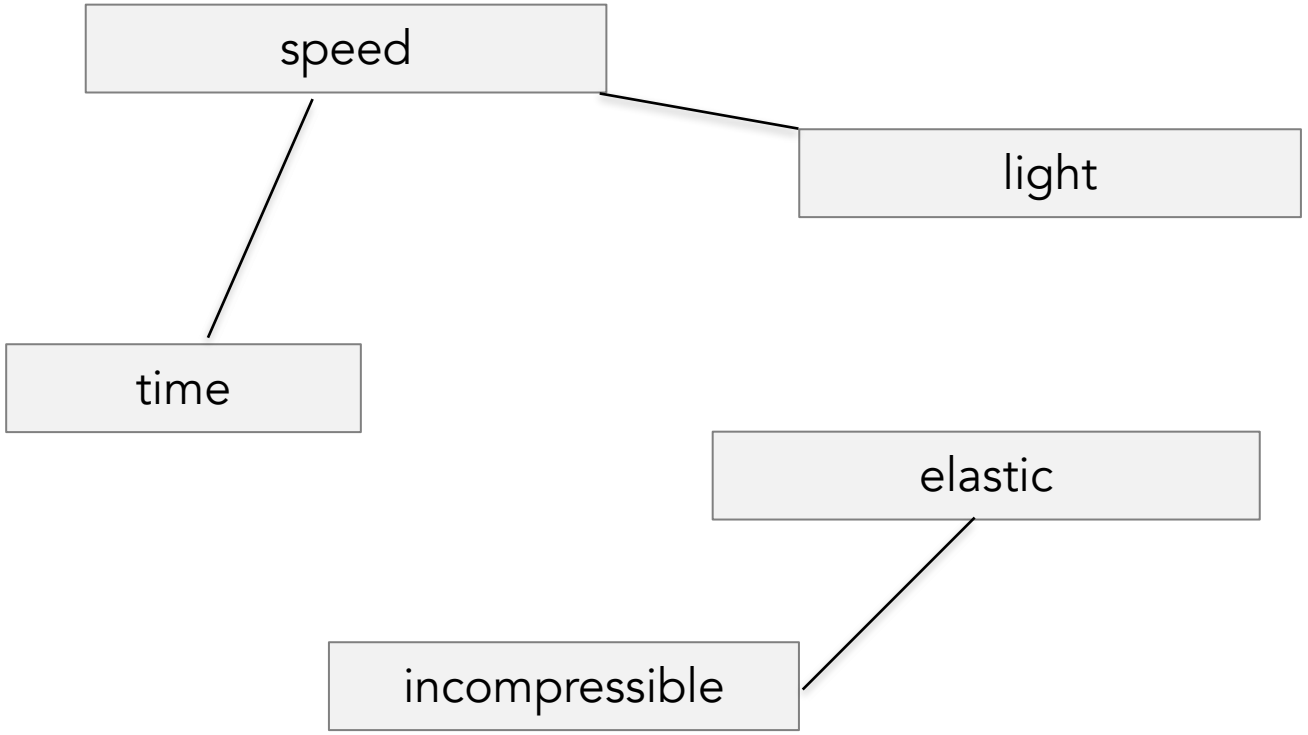

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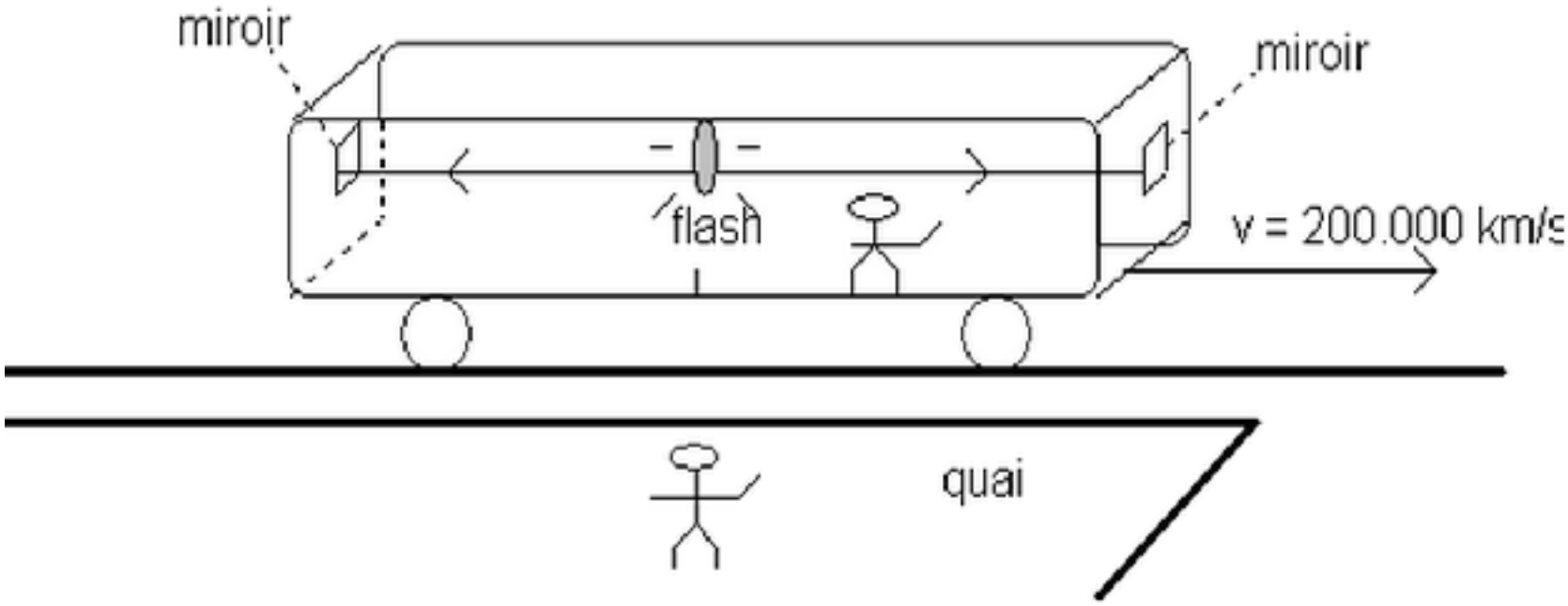
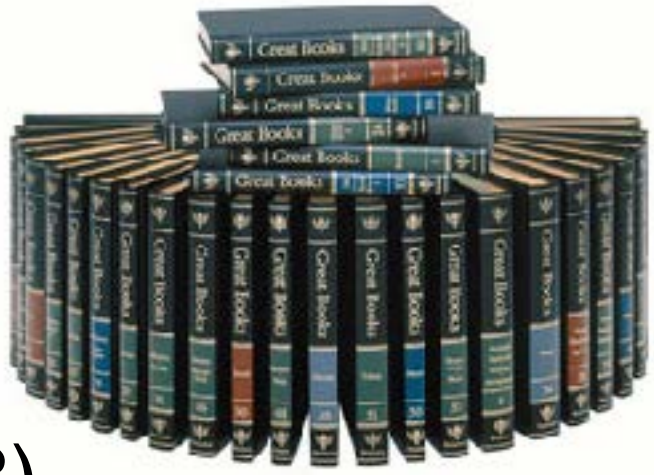


Where is there more knowledge ?

① Encyclopaedia Britannica

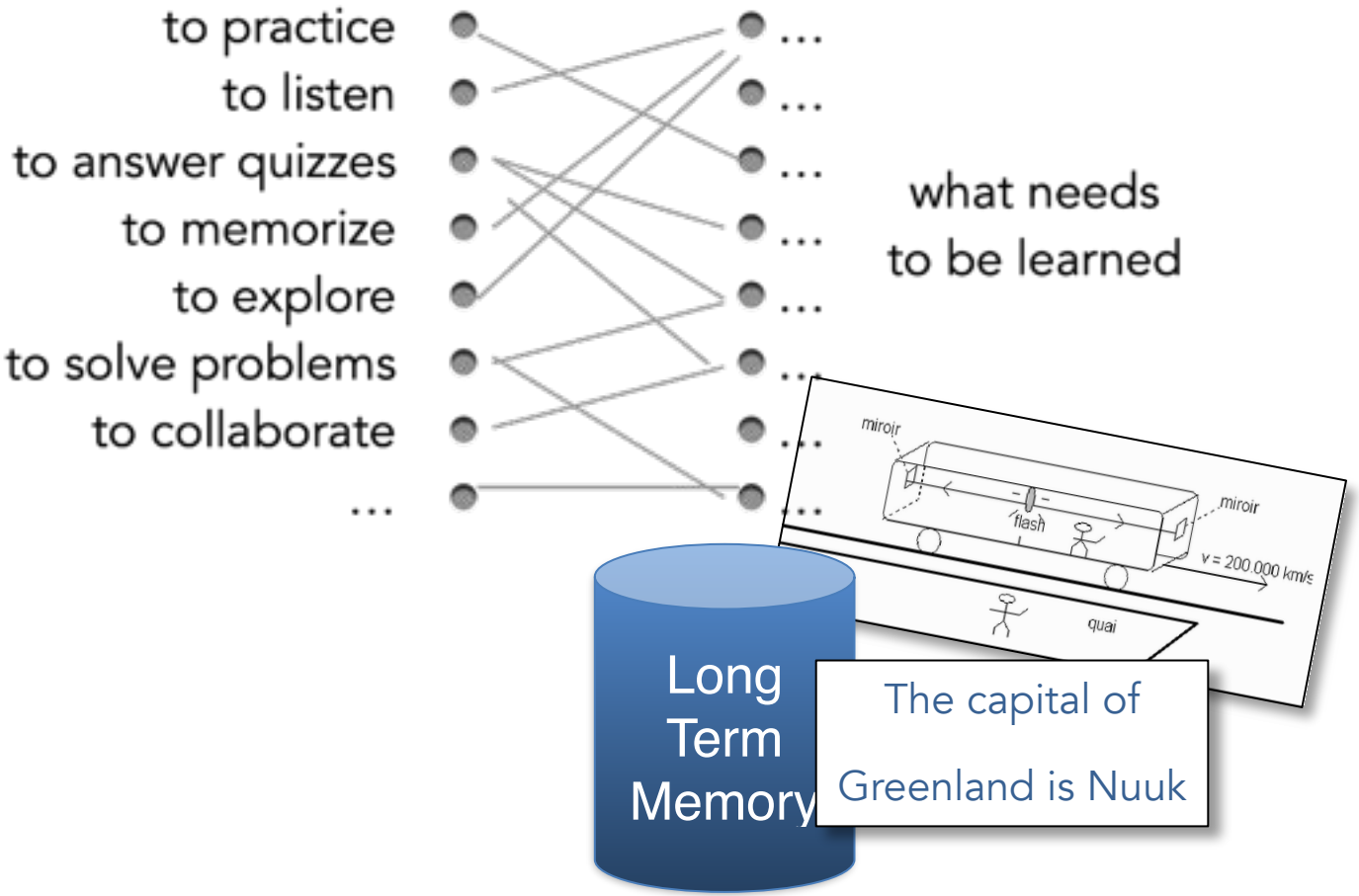
② Wikipedia

③ British Library (112,505,998)



http://blog.trustpilot.com/trusting-information-digital/

④ The brain of a 4 years old child



There are different types of knowledge

Knowledge Taxonomy

If you add some butter when boiling the water, the pasta do not glue to each other

Restricted relativity

The symbol for hydrogen is H

A square is a quadrilateral shape with 4 right angle and 4 isometric sides

The split attention effect refers to the increase of cognitive load due to the distance between a legend and the symbols used in the legend

Evolution (also known as biological, genetic or organic evolution) is the change in the inherited traits of a population of organisms through successive generations.[1] This change results from interactions between processes which introduce variation into a population, and other processes which remove it. As a

Brussels is the capital of Japan

The length of the hypotenuse is the square root of the sum of the squares of each other side of the triangle.

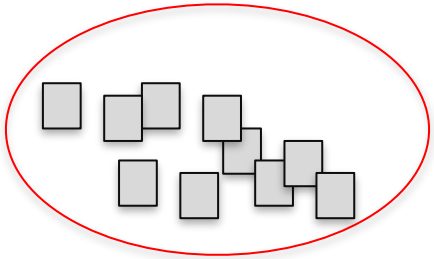
Knowledge Taxonomy

Facts	Brussels is the capital of Belgium
Classes, concepts	A square is a quadrilateral shape with 4 right angle and 4 isometric sides
Rules, principles, algorithms	If you add some butter when boiling the water, the pasta do not glue to each other
Theories, systems	Restricted relativity

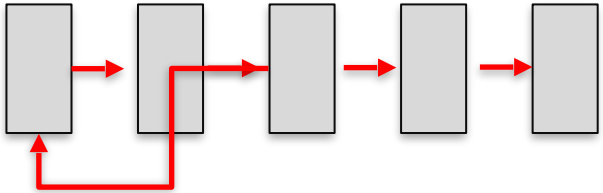
Knowledge Taxonomy

Facts

Classes, concepts

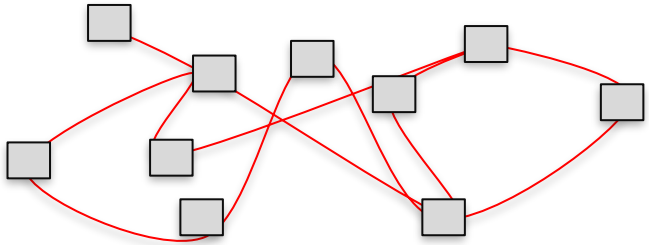


Procedures

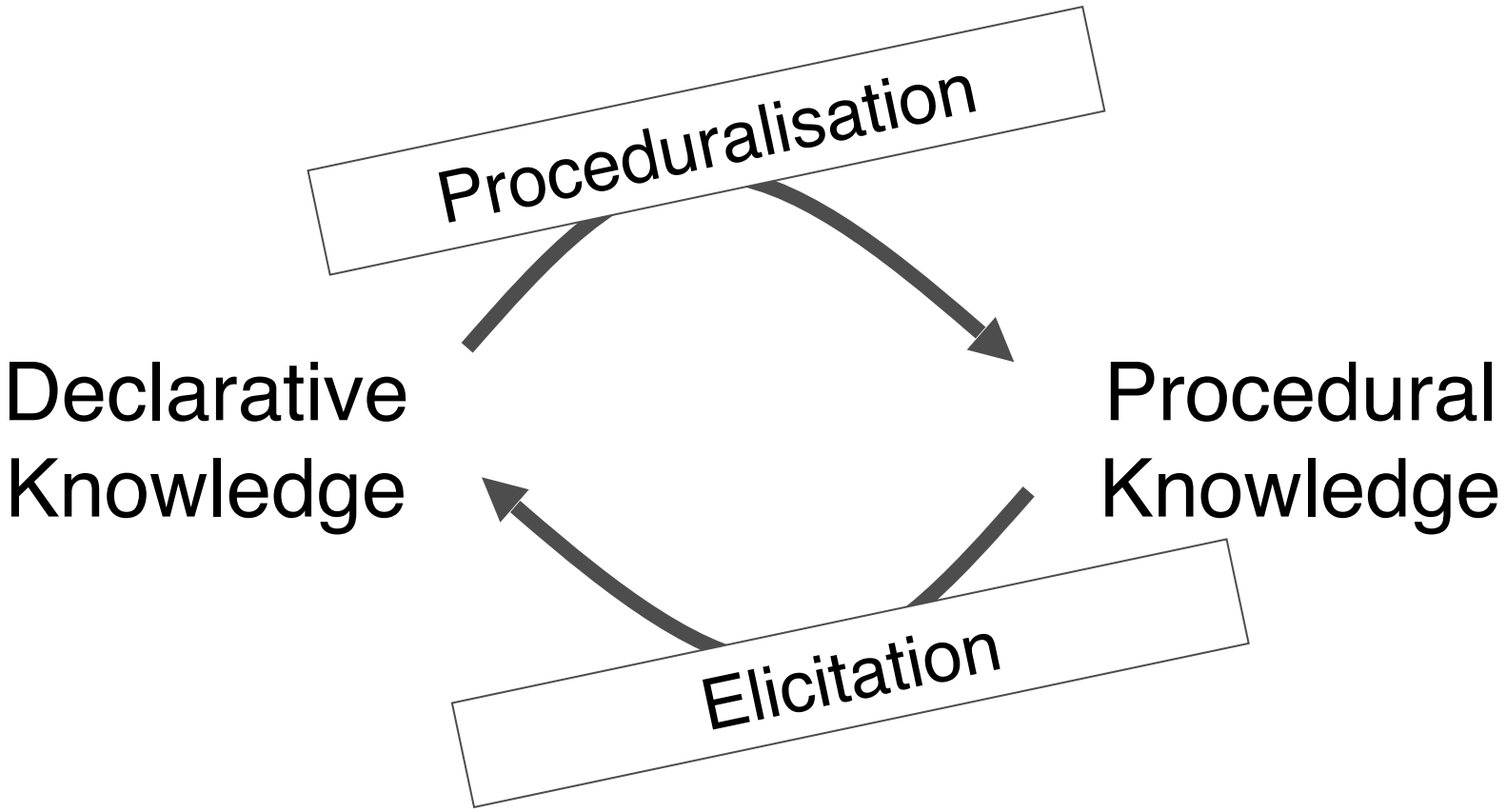


Laws

Theories, systems



Procédural versus Declarative Knowledge


Proceduralisation
Declarative Knowledge
Procedural Knowledge
Elicitation

Heuristic knowledge
(Problem solving strategies)

- To solve a complex problem, decompose it into small simple problems
- Before to write the code of a function, first thing about the data structure
- ...

Metacognition

An army bus holds 36 soldiers. If 1128 soldiers are being bused to their training site, how many buses are needed?

29% 31 remainder 12
18% 31
23% 32
30% did not do the computation correctly

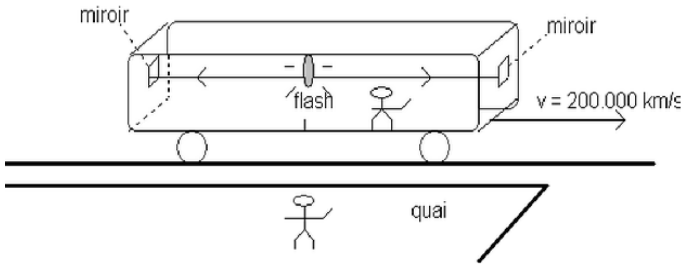
USA National Assessment of Education Progress secondary mathematics exam, 45,000 students nationwide

Schoenfeld, A. H. (1987). What's all the fuss about metacognition? In A. H. Schoenfeld (Ed.), *Cognitive science and mathematics education* (pp. 189-215). Hillsdale, NJ: Lawrence Erlbaum Associates.

Metacognition

- Knowledge about one's own knowledge (e.g. "I am not good with numbers", "I don't understand")
- Regulation of problem-solving: monitoring one's own plan application (e.g. "If the equation becomes too long, it is not good")

« Si la vitesse de la lumière est incompressible, c'est le temps qui est élastique »

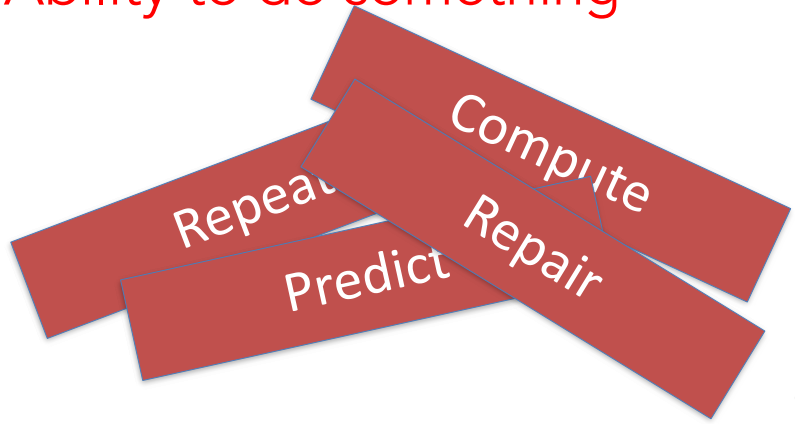


Knowledge

- fact, concept, rule, theory, …
- declarative, procedural, heuristic
- meta-cognition

Cognitive Activity

Ability to do something



Knowledge

- fact, concept, rule, theory, …
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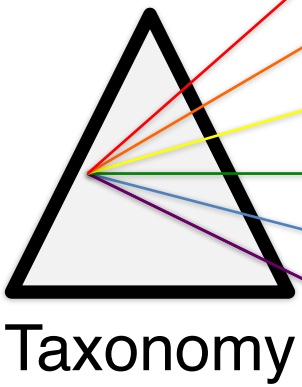


Cognitive Activity

- Reproduction
- Conceptualisation
- Application
- Exploration
- Mobilisation
- Problem solving

Cognitive Task

Reproduction

Conceptualisation

Application

Exploration

Mobilisation

Problem solving

The object and the product of the task have been associated before

Types of reproduction tasks

Free recall:

What is the capital of Greenland ?

……

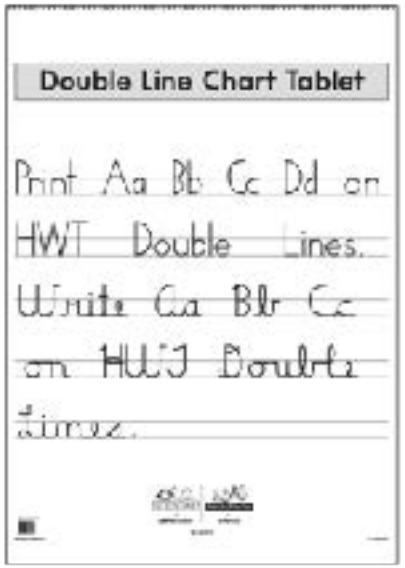
Recognition:

Which is the capital of Greenland ?

- *Tokyo*
- *Lausanne*
- *Nuuk*

Imitation:

Copy « lines »



Cognitive Task

Reproduction

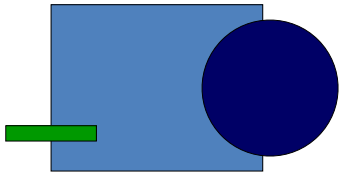
Conceptualisation → Does an object belong to a class ?

Application

Exploration

Mobilisation

Problem solving



SPUCs

Conceptualisation

https://www.mnn.com/earth-matters/climate-weather/quiz/can-you-name-these-clouds

QUESTION 4 OF 15 SCORE: 0

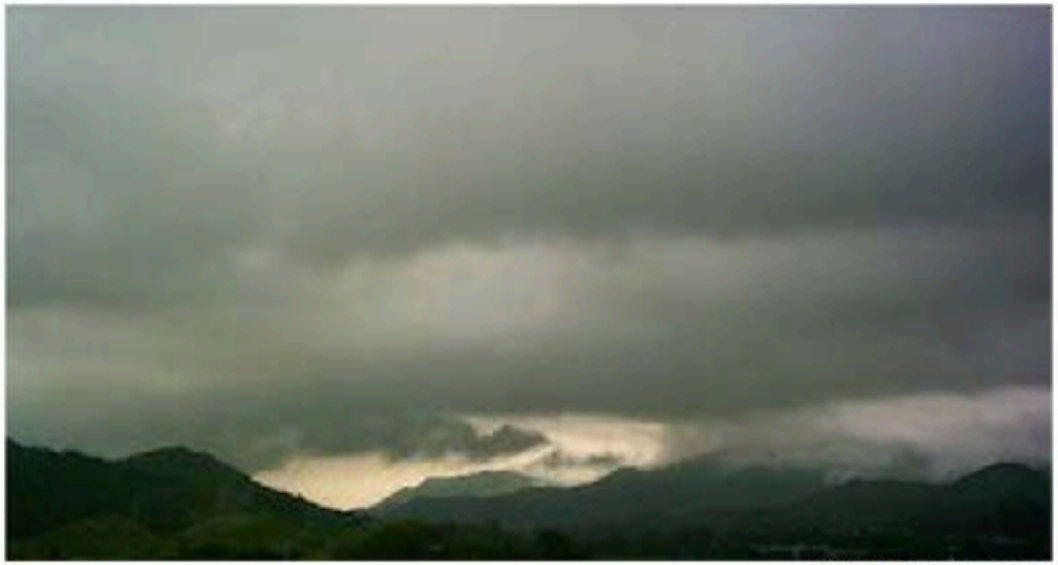


Photo: Wikimedia Commons

What kind of clouds are shown here?

- Nimbostratus
- Noir clouds
- Stratocumulus
- Shelf clouds

Cognitive Task

Reproduction

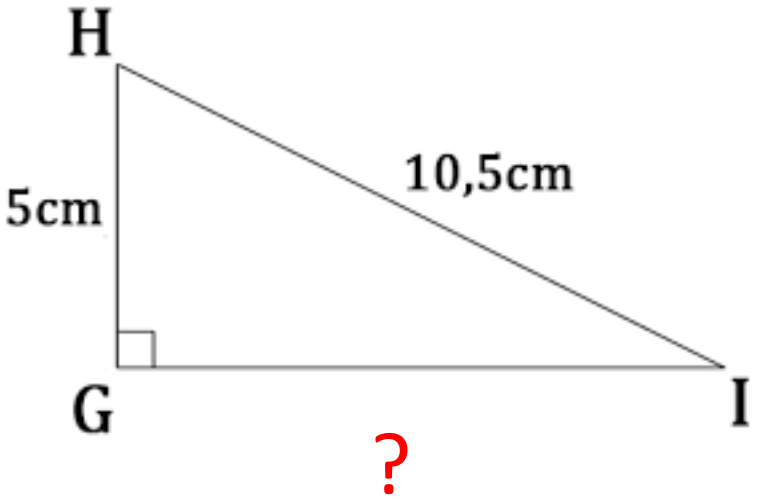
Conceptualisation

Application → Apply an algorithm to the object produces the product

Exploration

Mobilisation

Problem solving



Cognitive Task

Reproduction

Conceptualisation

Application

Exploration

Mobilisation

Problem solving

Identify a product in some material that matches criteria (object)

- *Find 2 metaphors in this text*
- *Find 2 prime number above 19*
- *Find a tumor on this image*

Cognitive Task

Reproduction

Conceptualisation

Application

Exploration

Mobilisation

Problem solving

Invent a product that matches criteria (object)

- *Find 2 metaphors*
- *Find 3 different ways to solve this exercise*

Cognitive Task

Reproduction

Conceptualisation

Application

Exploration

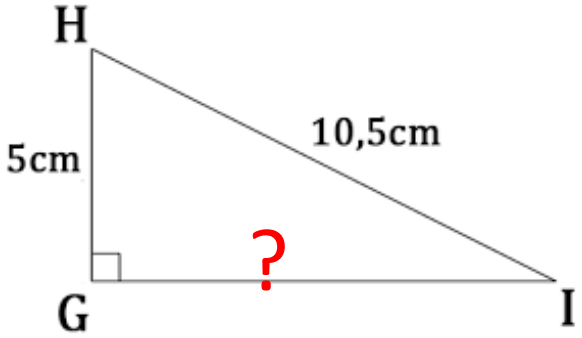
Mobilisation

Problem solving

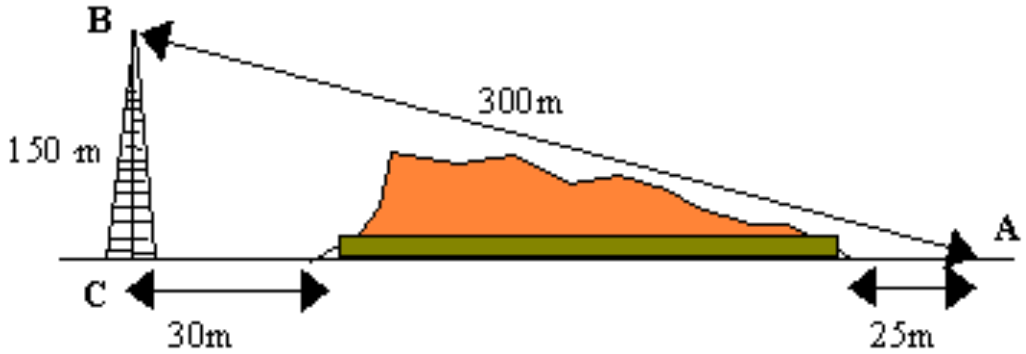
The learner has not the algorithm to compute the solution; this is a novel situation

The learner may combine segments of algorithm in a novel way

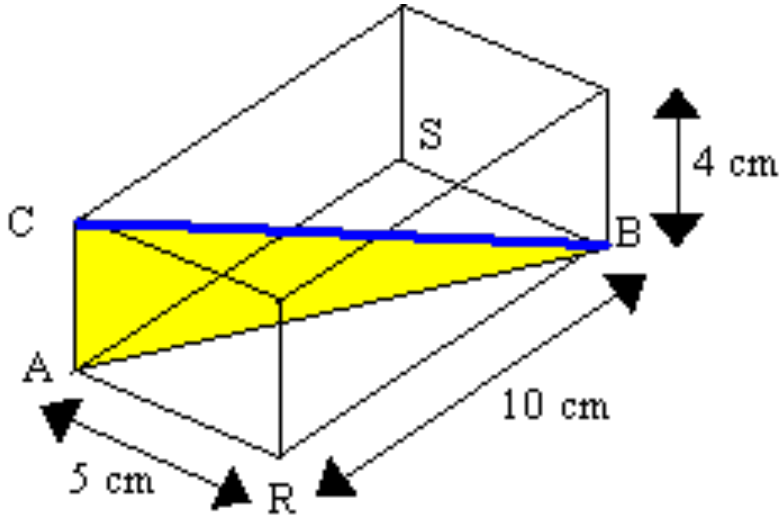
Application



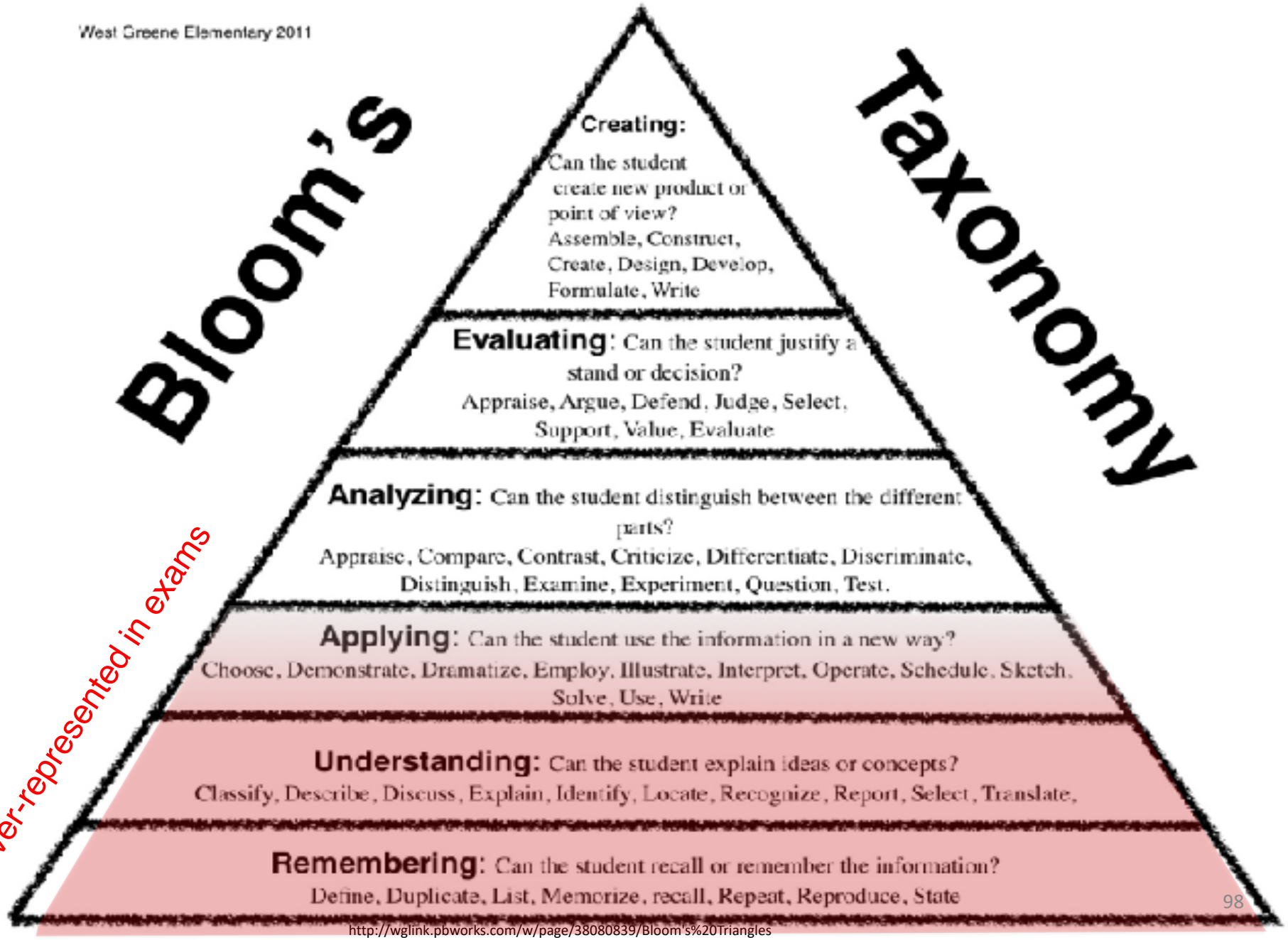
Extrapolation



Problem



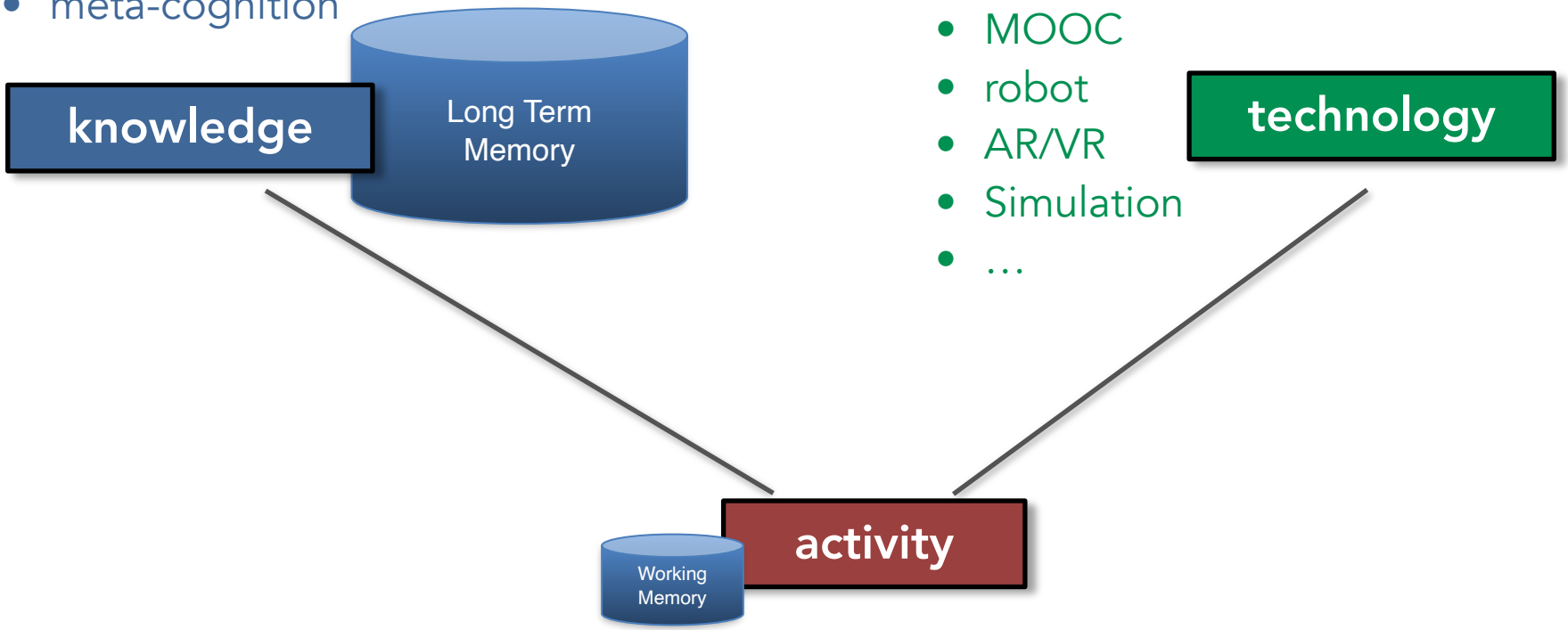
Bloom's Taxonomy



http://wglink.pbworks.com/w/page/38080839/Bloom's%20Triangles

Summary

- fact, concept, rule, theory, …
- declarative, procedural, heuristic
- meta-cognition



- drill
- MOOC
- robot
- AR/VR
- Simulation
- …

- reproduce
- classify
- compute
- find errors
- …

For your project

- Minimize extrinsic cognitive load
- Problem solving triggers germane cognitive load
- Problem solving should avoid overload

- Set goals in the upper part of Bloom's taxonomy

Figure 1 **Common ways of overwhelming and supporting intrinsic and extraneous load**

Type of Cognitive Load	Ways Load Can Be Overwhelmed
Intrinsic Load	• Presenting concepts that are too complex (i.e., concepts that are outside students' instructional level) • Using technical and other unknown language • Presenting too many concepts at once • Presenting interesting but unessential information • Assuming students have memorized formulas, facts, or other needed background knowledge needed to complete a novel task
Extraneous Load	• Presenting a large amount of text on a screen while providing oral instruction (e.g., splitting attention between two competing sources of input) • Presenting large amounts of information in one burst • Presenting abstract information without illustrative images • Presenting processes and strategies without demonstrations • Stimuli from the environment (e.g., noise from other groups or classrooms, uncomfortable temperature, activity outside windows, etc.)

Type of Cognitive Load	Ways Germane Load Resources Can Be Conserved
Intrinsic Load	• Repeat key information • Use rich images to illustrate content • Chunk information into meaningful segments • Provide worked examples • Filter out interesting but unnecessary details • Make connections between content and real-world scenarios • Monitor oral instruction for jargon or other potentially unknown words
Extraneous Load	• Use slides or other instruction with clear images and limited text • Limit distractions not related to lesson • Break instruction into chunks of content and amount of time • Provide frequent breaks and comprehension checks • Use principles of explicit instruction to design and deliver instruction (Archer & Hughes, 2011).

Kirchner

Example of 2023 exam question

c. Cognitive overload

A student has learned to compute correlations on numerical data and (s)he has also learned to convert data (e.g., changing miles into kilometers or changing Euros into dollars), but…*(complete the sentence…)*

Why is this cognitive overload?