Chapter 2:

Basic Concepts in Learning Sciences
What did you learn?

• To solve equations
• To compute a standard deviation
• To play soccer
• To appreciate Giacometti
• To ride a bike
• To wake up early
• To accept that people have different opinions
• To be happy despite problems
• .....

2
Informal learning is learning that occurs in daily life, in the family, in the workplace, in communities and through interests and activities of individuals.

Non-formal learning is learning that has been acquired in addition or alternatively to formal learning. In some cases, it is also structured according to educational and training arrangements, but more flexible. It usually takes place in community-based settings, the workplace and through the activities of civil society organisations.

Formal learning takes place in education and training institutions, is recognised by relevant national authorities and leads to diplomas and qualifications. Formal learning is structured according to educational arrangements such as curricula, qualifications and teaching learning requirements.
Digital technologies blur the lines between formal and informal education.
Examples of exam questions

① In the following learning environment, would the learner rather encounter problems due to cognitive load or to metacognition?

② What should you change in this learning environment to engage the learner into inductive reasoning?
What is the capital of Greenland? 

NUUK
The capital of Greenland is Nuuk
The capital of Greenland is Nuuk
As you can guess, the Danish name of this city is Godthåb
What is the capital of Greenland?
The Lecture Model

**Information**

- Perception
  - Sensory Memory: ¼ second

- Processing
  - Working Memory: The capital of Greenland is Nuuk
    - 20-30 seconds

**Knowledge**
My phone number is 079 474 48 99

*Remember it and call me after the video (1 min)*

*Don’t write it !!!*
My phone number is xxx xxx xx xx

Call me now
The Lecture Model

**Information**

- Perception
- Sensory Memory
  - ¼ second
- Working Memory
  - 20-30 seconds
- Articulatory Loop

**Knowledge**

The phone number is ....
My phone number is 078 676 48 55

Remember it and call me after the next activity
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.
My phone number is xxx xxx xx xx

Call me now
The Lecture Model

Information

Perception

Processing

Storage

Knowledge

Sensory Memory

Working Memory

The phone number is ...

¼ second

Articulatory Suppression

« Dual Task »

20-30 seconds
My password is  32 45 80

*Remember it and call after reading this text 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.
What is my password?
Information

Perception

Processing

Storage

Knowledge

Sensory Memory

Working Memory

- Verbal / Phonological Loop
- Visual-Spatial Sketchpad
What is the capital of Greenland?
The capital of Greenland is Nuuk
Information
Perception
Processing
Storage
Knowledge

Long Term Memory
Nuuk is to Copenhagen,

what

Saint-Denis is to ...... ?
Nuuk is to Copenhagen
What Saint-Denis is to ...... ?
Experience

UNLIMITED, MULTIMODAL

Working Memory

Long Term Memory

EXTREMELY LARGE, SEMANTIC

MOSTLY VERBAL
LIMITED in SIZE (7 ± 2)
LIMITED In Time (20-30 s)

Storage

Knowledge

Processing

Perception

Information
Working Memory

Genealogy Game

Manuel is the son of Liam
Liam is the father of Elenna
Liam is the brother of Walter
Who is the uncle of Elenna?

[Interactive genealogy game interface with options to select Liam, Walter, Manuel, or 'I don't know!']
Cognitive overload

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

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

Sophie est la sœur de Serge
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

7 ± 2
Michel is the father of Martine
Martine is the sister of Serge
Serge is the father of Tristan
Luc is the brother of Tristan
Lucie is the mother of Serge
Nadine is the daughter of Tristan

➔ Who is the ant of Luc?
Who will win the next race?
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

\[
\sum_{n=0}^{N-1} a_n e^{-2\pi i nk/N} = \sum_{n=0}^{N/2-1} a_{2n} e^{-2\pi i (2n)k/N} + \sum_{n=0}^{N/2-1} a_{2n+1} e^{-2\pi i (2n+1)k/N}
\]

\[
= \sum_{n=0}^{N/2-1} a_{\text{even}} e^{-2\pi i nk/(N/2)} + e^{-2\pi i k/N} \sum_{n=0}^{N/2-1} a_{\text{odd}} e^{-2\pi i nk/(N/2)}.
\]
Extrinsic Cognitive Load

Example demonstrating split attention

Integrated example

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 angles are equal)

= 80°
Cognitive load

Which statements are correct?

① Cognitive load prevents learning

② There is no learning without cognitive load

③ Cognitive over-load prevents learning

④ There is no learning without over-load
Working Memory
Reducing cognitive load: Compilation

<table>
<thead>
<tr>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check the barreer</td>
</tr>
<tr>
<td>Tune radio</td>
</tr>
<tr>
<td>Speak</td>
</tr>
<tr>
<td>Listen</td>
</tr>
<tr>
<td>Get your badge</td>
</tr>
<tr>
<td>Slow down</td>
</tr>
<tr>
<td>Turn</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Action</th>
</tr>
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<tbody>
<tr>
<td>Freiner</td>
</tr>
<tr>
<td>Embrayer</td>
</tr>
<tr>
<td>Changer</td>
</tr>
<tr>
<td>Débrayer</td>
</tr>
<tr>
<td>Freiner</td>
</tr>
</tbody>
</table>
Is knowledge a simple recording of information?
Is knowledge a copy of information?

Information

Perception

Processing

Storage

Knowledge

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

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

Processing

Knowledge

2.2 Queries and Transformations on Sets

In this part, we are interested in functions used to make requests on elements of a set. The first function is the following algorithm:

```
def search(S: Set, x: Int -> Boolean): Boolean
```

Note that there is no direct way to find which elements are in a set. `contains` only allows to know whether we have to iterate over all integers, testing each time whether it is included in the set, and if we do, to check whether the search is successful.

1. Implement `search` using linear recursion. For this, use a helper function `is搜索(k: Int, i: Int) -> Boolean`; `maximum = 0`

```java
    def isSearch(k: Int, i: Int): Boolean = |
        if (k > i) |
            return true |
    else: |
        return isSearch(k, i + 1)
```

Expected number of iteration = [ ]

Generic attack

\[ H: M \rightarrow \{0,1\}^n \]

1. Choose 2 random elements in \( M \) \( m_1, m_2 \)
2. For \( i = 1, \ldots, 2^m \) compute \( t = H(m_i) \in \{0,1\}^n \)
3. Look for a collision \( t_1 = t_2 \). If not found, go back to step 2.
Where is there more knowledge?

① Encyclopaedia Britannica

② Wikipedia

③ British Library (112,505,998)

④ The brain of a 4 years old child

http://blog.trustpilot.com/trusting-information-digital/
Information
Perception
Processing
Storage
Knowledge

CS-411 Designing rich Learning Activities
There are different types of knowledge

The capital of Greenland is Nuuk
If you add some butter when boiling the water, the pasta do not glue to each other.

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

<table>
<thead>
<tr>
<th>Category</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facts</td>
<td>Brussels is the capital of Belgium</td>
</tr>
<tr>
<td>Classes, concepts</td>
<td>A square is a quadrilateral shape with 4 right angle and 4 isometric sides</td>
</tr>
<tr>
<td>Rules, principles, algorithms</td>
<td>If you add some butter when boiling the water, the pasta do not glue to each other</td>
</tr>
<tr>
<td>Theories, systems</td>
<td>Restricted relativity</td>
</tr>
</tbody>
</table>
Knowledge Taxonomy

- **Facts**
- **Classes, concepts**
- **Procedures**
- **Laws**
- **Theories, systems**
Procédural versus Declarative Knowledge
How to be a good manager?

- Declarative Knowledge
- Procedural Knowledge

- Elicitation
- Reflection
- Self-explanation
How to be a good manager?

Declarative Knowledge

Procedural Knowledge

Top things to make a good manager

Acknowledge your staff:

When a member of staff does a job well, make sure you notice it, and acknowledge her or him for it. Don't let the opportunity to praise a piece of good work go by.
« Si la vitesse de la lumière est incompressible, c'est le temps qui est élastique. »

- Perception
- Processing
- Storage
- Knowledge

Information

Sensory Memory

Working Memory

Long Term Memory

Ability to do something

Compute
Repeat
Repair
Predict
Bloom’s Taxonomy

- **Remembering**: Can the student recall or remember the information?
  - Define, Duplicate, List, Memorize, recall, Repeat, Reproduce, State

- **Understanding**: Can the student explain ideas or concepts?
  - Classify, Describe, Discuss, Explain, Identify, Locate, Recognize, Report, Select, Translate,

- **Applying**: Can the student use the information in a new way?
  - Choose, Demonstrate, Dramatize, Employ, Illustrate, Interpret, Operate, Schedule, Sketch, Solve, Use, Write

- **Analyzing**: Can the student distinguish between the different parts?
  - Appraise, Compare, Contrast, Criticize, Differentiate, Discern, Distinction, Examine, Experiment, Question, Test

- **Evaluating**: Can the student justify a stand or decision?
  - Appraise, Argue, Defend, Judge, Select, Support, Value, Evaluate

- **Creating**: Can the student create a new product or point of view?
  - Assemble, Construct, Create, Design, Develop, Formulate, Write

*Over-represented in exams*

West Greene Elementary 2011
Cognitive Task

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

Taxonomy:
Bloom
D’Hainaut

Content
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
Application
Exploration
Mobilisation
Problem solving

Does an object belong to a class?

SPUCs
What kind of clouds are shown here?

- Nimbostratus
- Noir clouds
- Stratocumulus
- Shelf clouds

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

Reproduction
Conceptualisation
Application
Exploration
Mobilisation
Problem solving

Apply an algorithm to the object produces the product

?
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
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
Heuristic knowledge
(Problem solving strategies)

• To solve a complex problem, decompose it into small simple problems
• Before to write the code, first thing about the data structure
• Orienteering: To reach the corner, select a drift-proof azimuth
• ...
Reproduction

Conceptualisation
- Describe the learning processes triggered by a technology-based activity

Application
- Explain how a technology feature influences learning processes

Exploration
- Elaborate a study that measures the learning effects of a digital environment

Mobilisation
- Select appropriately a learning technology given the target audience and the expected learning outcomes

Problem solving
- Apply machine learning methods to educational traces
  - Design a learning environment based on orchestration graphs
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

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”)
Transversal Skills

• Collaboration Skills
• Information appraisal skills
• Critical thinking skills
• Computational thinking skills
• Learning to learn
• Creativity
• Rigor
• …
• Resilience
• …
• …
How to solve problems?

George Polya

1. Understand the problem
2. Make a plan
3. Carry out the plan
4. Look back
(defun m-length (list)
  (if (null list)
      0
      (+ 1 (m-length (cdr list))))
)

(defun print-list (list)
  (if (not (null list))
      (progn
        (princ (car list))
        (print-list (cdr list)))
      ())))

((1 5 x) o l) a) 7 2 3)

(defun sum-numbers (list)
  (if
Transversal Skills

Are they domain-independent? Mostly, NOT

Can they be taught? Mostly, NOT

How can they be learned? Transversally
Transversal skills must be acquired **transversally**

- Collaboration Skills
- Information appraisal
- Critical thinking skills
- Computational thinking
- Learning to learn
- Creativity
- Rigor

<table>
<thead>
<tr>
<th>Course 1</th>
<th>Course 2</th>
<th>Course 3</th>
<th>Course 4</th>
<th>Course 5</th>
<th>Course 6</th>
<th>Course 7</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="Course 1" /></td>
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<td><img src="image6.png" alt="Course 6" /></td>
<td><img src="image7.png" alt="Course 7" /></td>
</tr>
</tbody>
</table>
Instructional design starts with:

What should learners *know* at the end? (which they did not know at the beginning)

What should learners *be able to do* at the end? (which they could not do at the beginning)

How will I know they are able to do it?

What would be the exam questions or tasks?
What should learners be able to do at the end?

Pedagogical Objectives

Learning Goals

Learning Outcomes
Instructional design works backwards:

What are they able to do at the beginning?

What should learners be able to do at the end?

(which they could not do at the beginning)

Pre-Requisites

Objectives
Prior Knowledge can be wrong

2 ice cubes at midnight, $t = 20\,^\circ C$

Which ice cube will melt faster?
Instructional design works backwards:

What are they able to do at the beginning?

What should learners **be able to do** at the end?

(which they could not do at the beginning)

- **Pre-Requisites**
- **Pre-Representations**
- **Objectives**