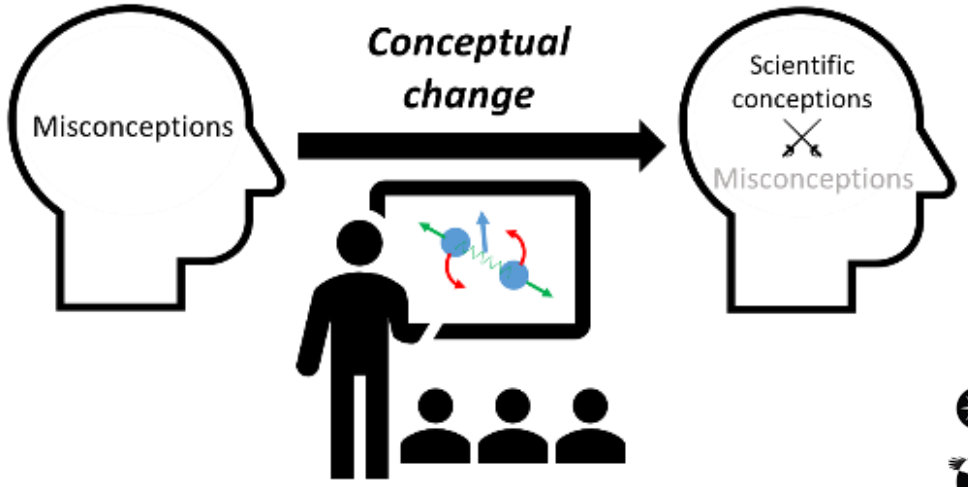
The battle between misconceptions and scientific conceptions

Using Conceptual Change in the university classroom to improve the teaching of counterintuitive concepts in science

Vincent Natalis, Ph.D.

Post-doc fellow at UQÀM



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What is conceptual change trying to solve?

1. Why do students make conceptual mistakes?
2. Why are misconceptions (alternative conceptions) persistent ?
3. Why do students always go back to their initial conceptions?

How this presentation is structured

Key *concepts* in conceptual change

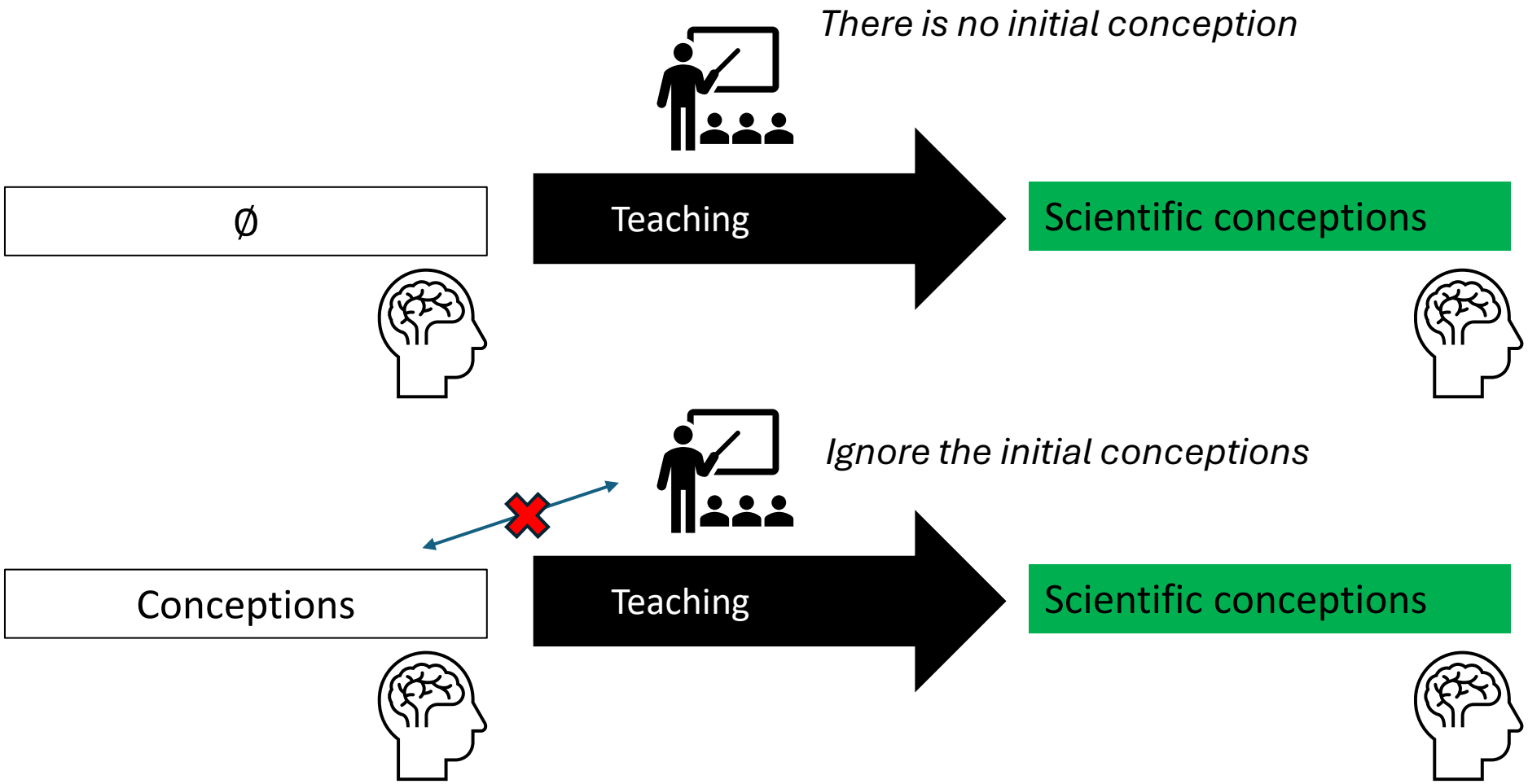
Key *models* in conceptual change

Resources

Two examples from my research

Key *concepts* in conceptual change

Transmissive teaching



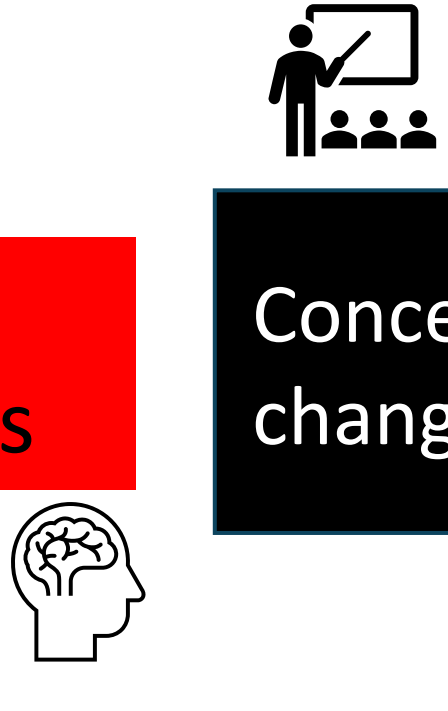
Bélanger & Richard (2024)

Conceptual change: alternative conceptions

A set of hypothetical knowledge or procedures

Alternative conceptions

Which does not correspond to the scientifically accepted conception ("misconception, preconception")



Scientific conceptions

Conceptual change: alternative conceptions

Alternative conceptions

- "The **most important single factor influencing learning** is what the learner already knows. Ascertain this and teach him accordingly" - Ausubel
- Foundation for future knowledge
- **Need to take them into account when teaching**

Ausubel (1968)

Conceptual change: alternative conceptions

Examples in bonding

A broken bond releases energy

The atoms of polyatomic ions are bound together by ionic bonds

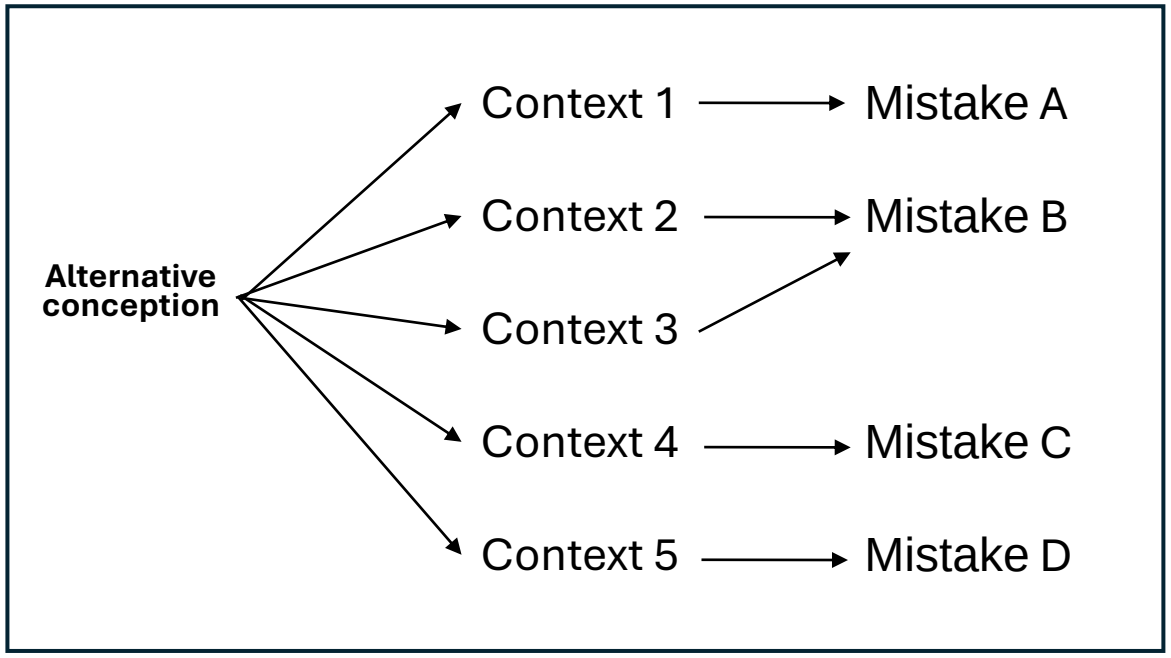
A molecule is polar because it has a polarized bond

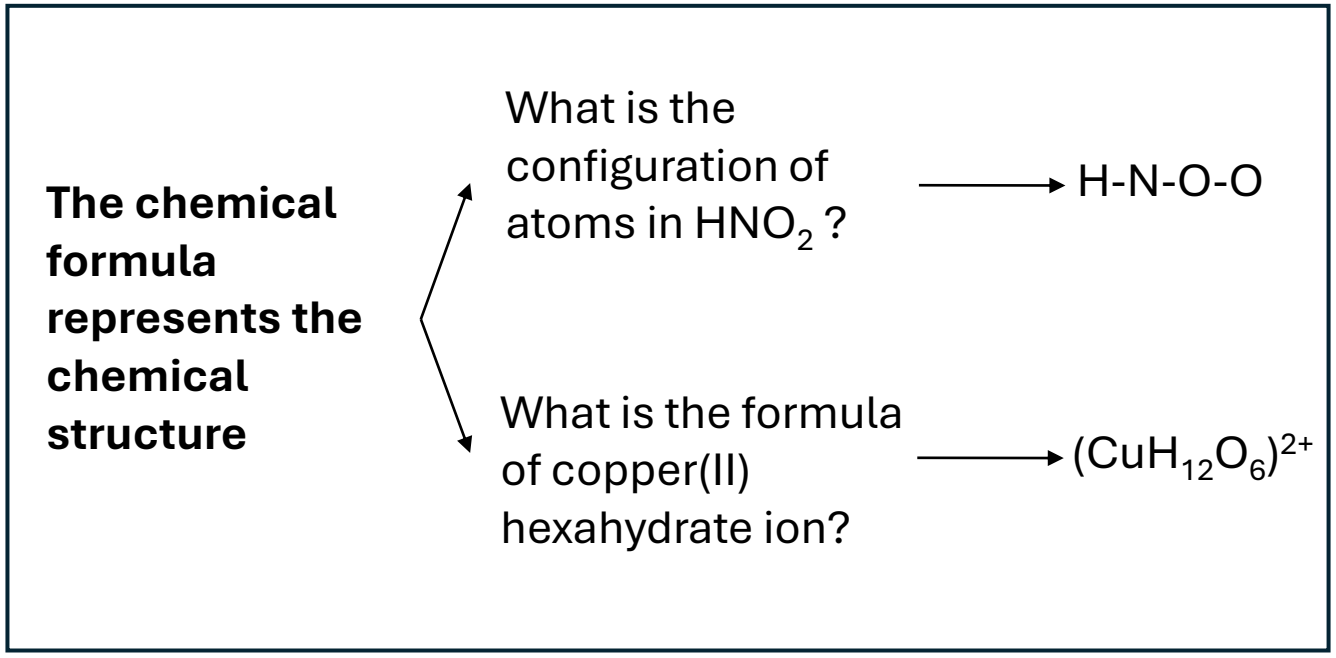
An ionic bond can only take place between two ions (and no more)

Potvin, Malenfant-Robichaud et al. (2020)

Conceptual change: mistakes >< conceptions

Dependence on context! Need for replication and multiple studies/scenarios





A selection of alternative conceptions

Adapted from Potvin, Malenfant-Robichaud et al. (2020)

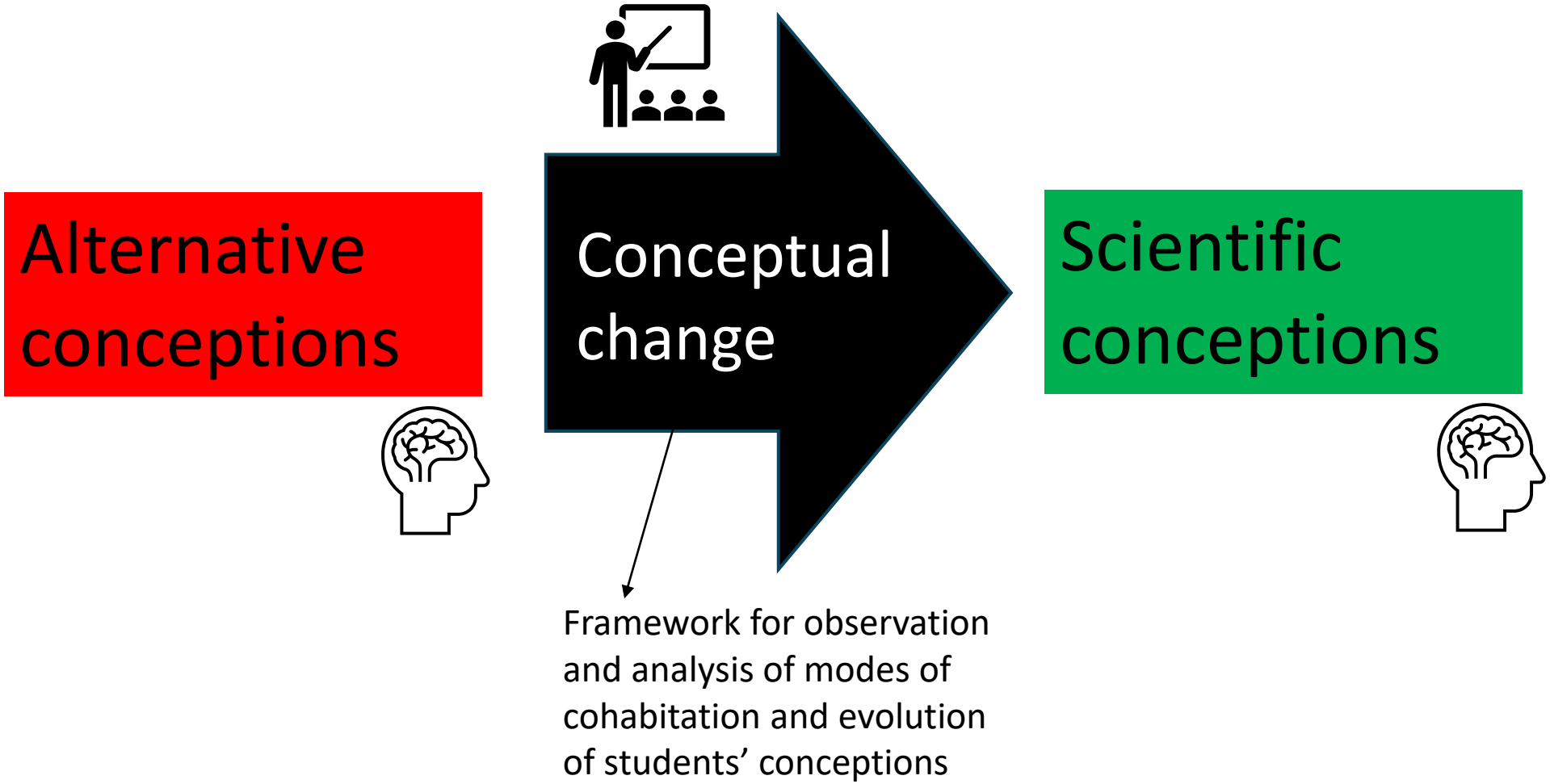
Physical chemistry	The boiling temperature of a substance is always the same (pressure) Only hot objects have thermal energy The entropy of a system must always increase Evaporation only takes place at boiling temperature Temperature varies during phase change Temperature and heat are the same thing Heating an exothermic reaction does not increase its speed At equilibrium, the concentrations of the reactants are always equal to those of the products Gas bubbles in a boiling liquid are composed of air Solids are heavier than liquids Solutes melt when they dissolve A solid must be rigid	**Structure and formula**	The chemical formula represents the chemical structure Ionic compounds form molecules Atoms have the same physical properties as the substance they form (e.g. colour) A pure substance is an element The more protons an element has, the larger its volume The mole is a unit of mass Neutrons neutralize protons The stoichiometric coefficients and subscripts in chemical formulae have the same function All molecules comply with the octet rule A full byte is always more stable The chemical symbol corresponds to the first letter of the element There is no space (vacuum) between the particles
Bonding	A broken bond releases energy There are two types of bonding: covalent and ionic The atoms of polyatomic ions are bound together by ionic bonds Metal bonding is a type of covalent bond A molecule is polar because it has a polarized bond An ionic bond can only take place between two ions (and no more)	**Acids and bases**	The strength of an acid depends on its number of Hs Neutralization means that the products of the reaction are neutral The more concentrated an acid is, the stronger it is
		Substance -related	Diamonds cannot burn Rust causes mass loss All radioactive elements are dangerous Smoke is immaterial

Key *concepts* in conceptual change

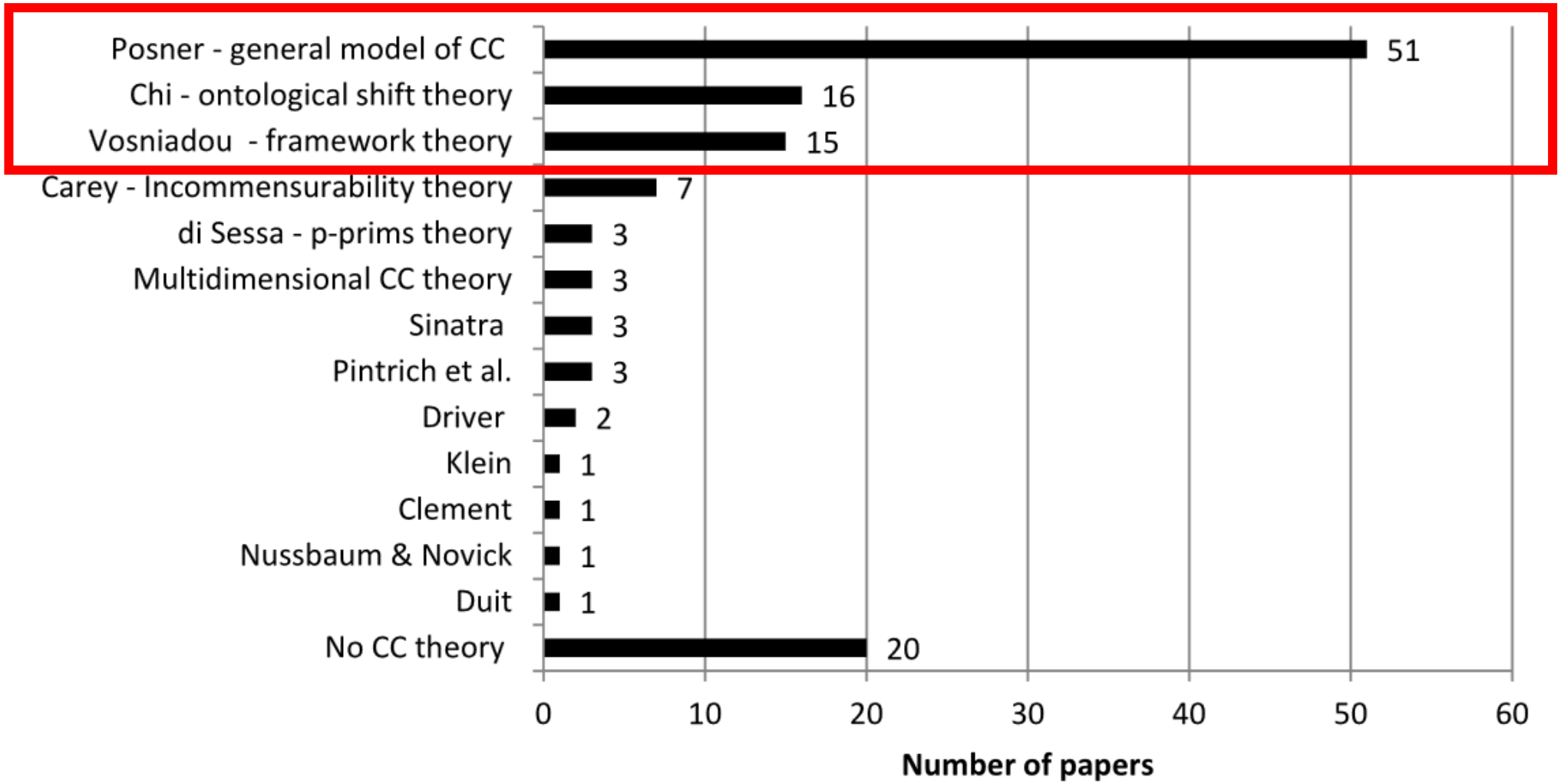
Key *concepts* in conceptual change

Key *models* in conceptual change

Conceptual change: models

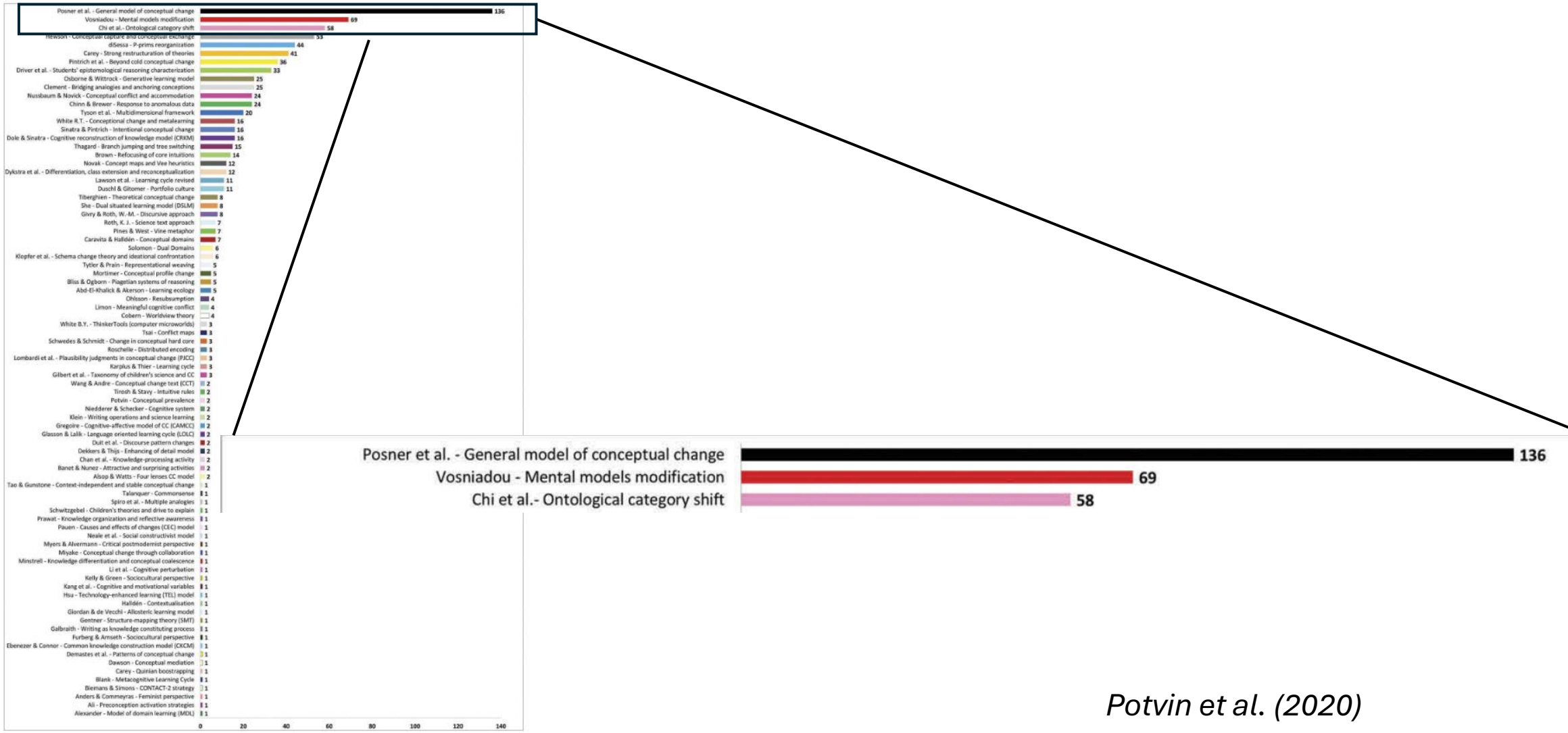


Conceptual change: huge diversity of models



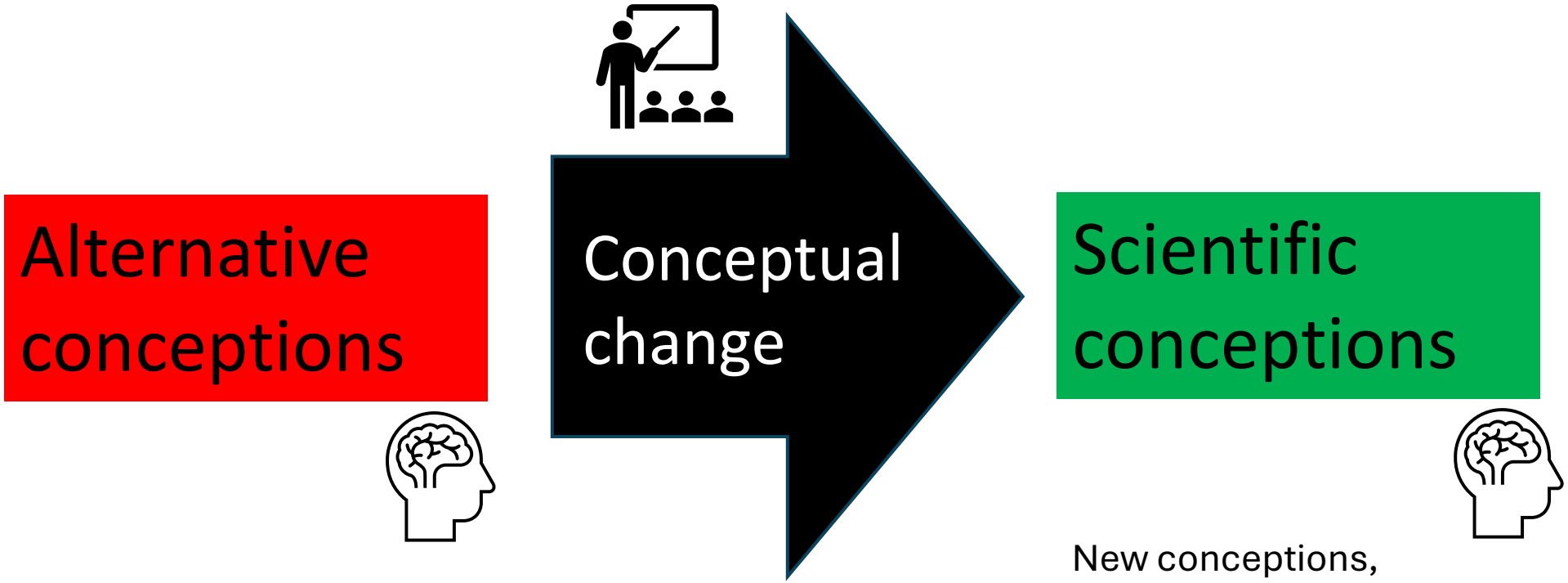
Aleknavičiūtė et al. (2020)

Conceptual change: huge diversity of models



Potvin et al. (2020)

Conceptual change: Posner's model



Posner et al. (1982)

Conceptual change: Vosniadou's model

Alternative conceptions

Distinction between Preconceptions and Synthetic conceptions
= preconceptions + teaching

Structured framework

Conceptual change

Enrichment
Revision

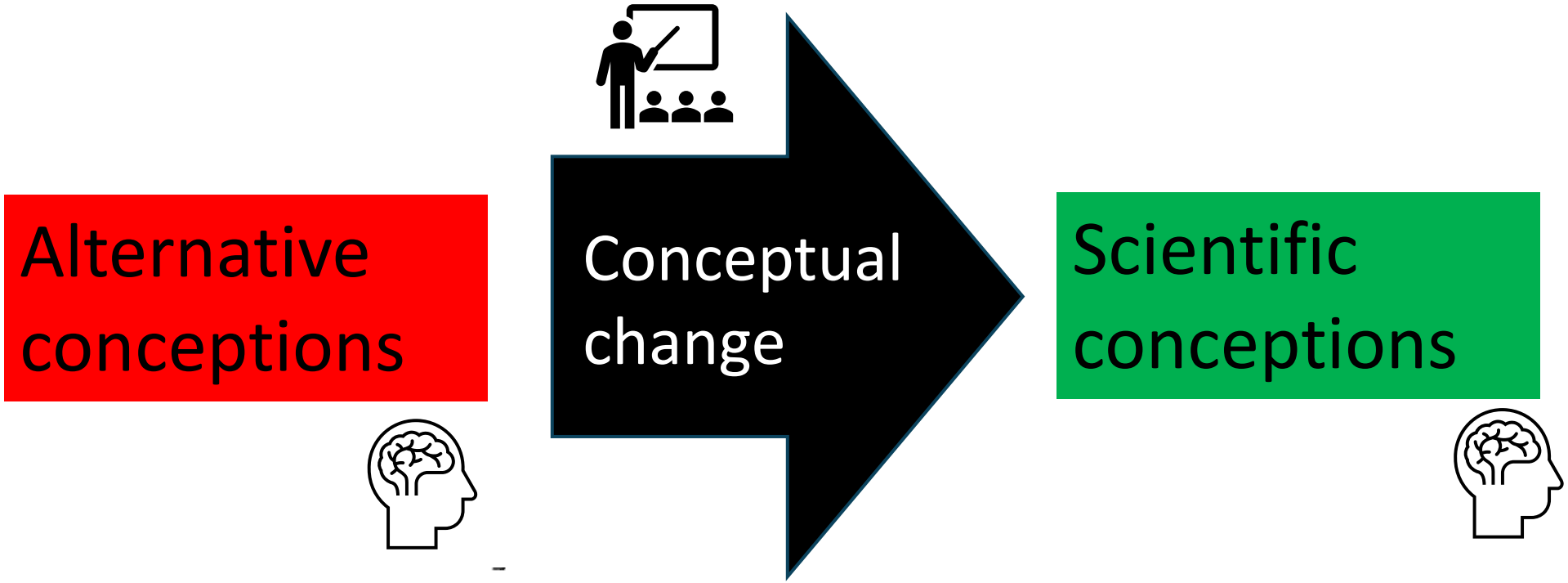
Slow and gradual process

Scientific conceptions

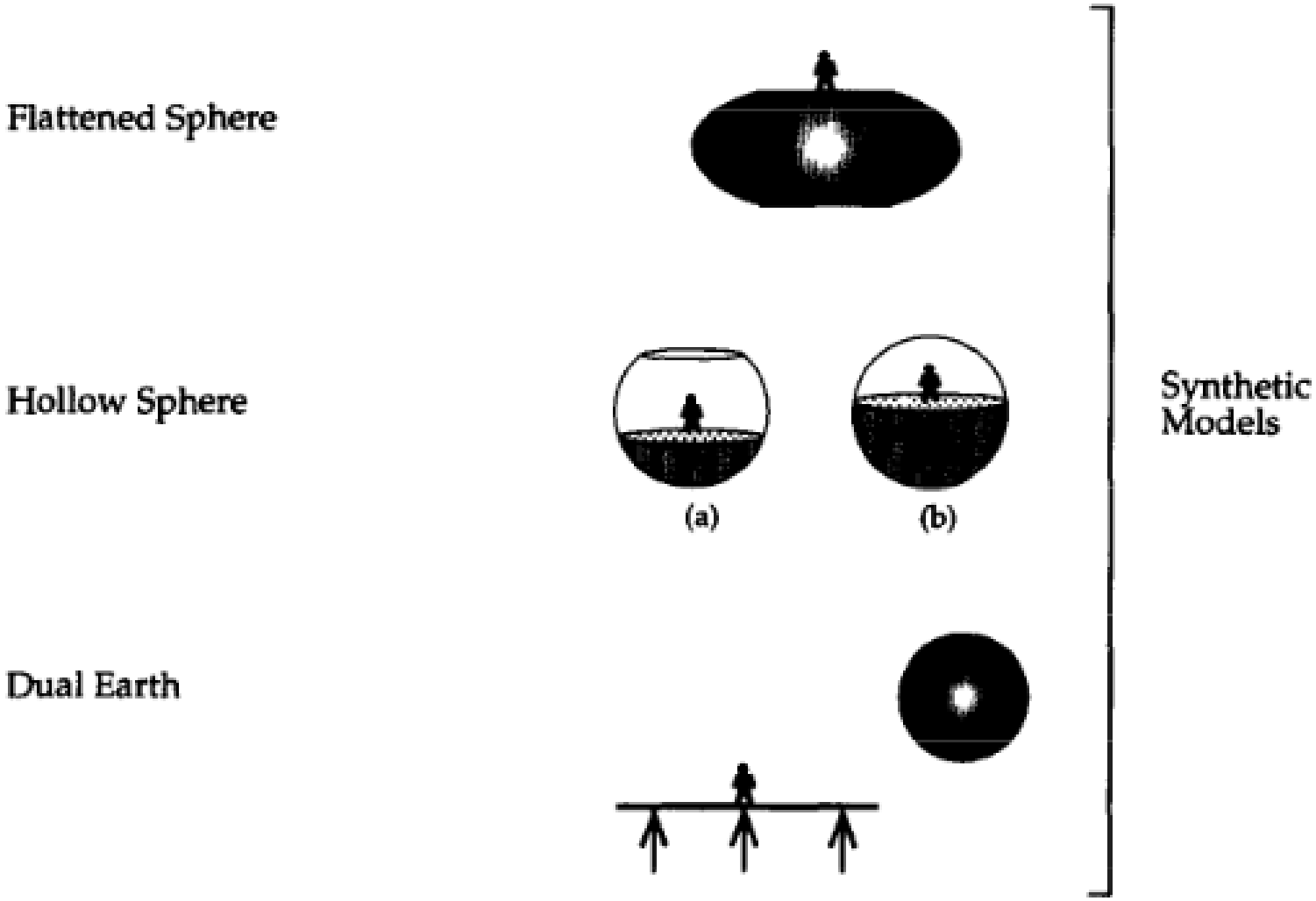
New synthetic conceptions

Vosniadou (1994)

Conceptual change: Vosniadou's model



Conceptual change: Vosniadou's model



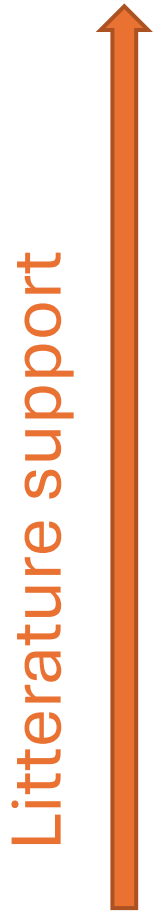
Comparison

Litterature support

1	**Posner**	CC = (1) Dissatisfaction with alternative conceptions and new conceptions, (2) plausible, (3) intelligible, (4) fruitful
2	**Vosniadou**	CC = gradual modification of mental models by enrichment (adding new information) or revision (changing the connections of the mental model)

Potvin et al. (2020)

From conceptual change to modern theories



1	**Posner**
2	**Vosniadou**

Neuroscience results from the 2010's

Conceptual prevalence

Potvin et al. (2020)

Neuroscience studies: inhibition

Task

1. Give the criteria to describe "a living being"
2. Give examples of "living beings“

“Experts” participants

Task	20 elderly people with Alzheimer's	24 elderly people **without** Alzheimer's
1	They mention "moving" more as a criterion for a living being (incorrect)	Mention more "feeding, breathing" as criteria for a living being (correct)
2	More often give animals as examples of living things	Give as many animals as plants as examples of living things
	N.B. identical age, identical performance in intellectual tasks	

Conclusion: participants have poorer expertise when their inhibition decreases

Zaitchik & Solomon (2008)

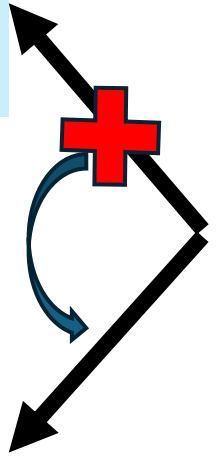
Neuroscience studies: system 3

1

Heuristic system

« automatic » and intuitive thinking

Fast but makes mistakes



3

Inhibition system

Interrupts system 1 to activate system 2,

« referee » function

Algorithmic system

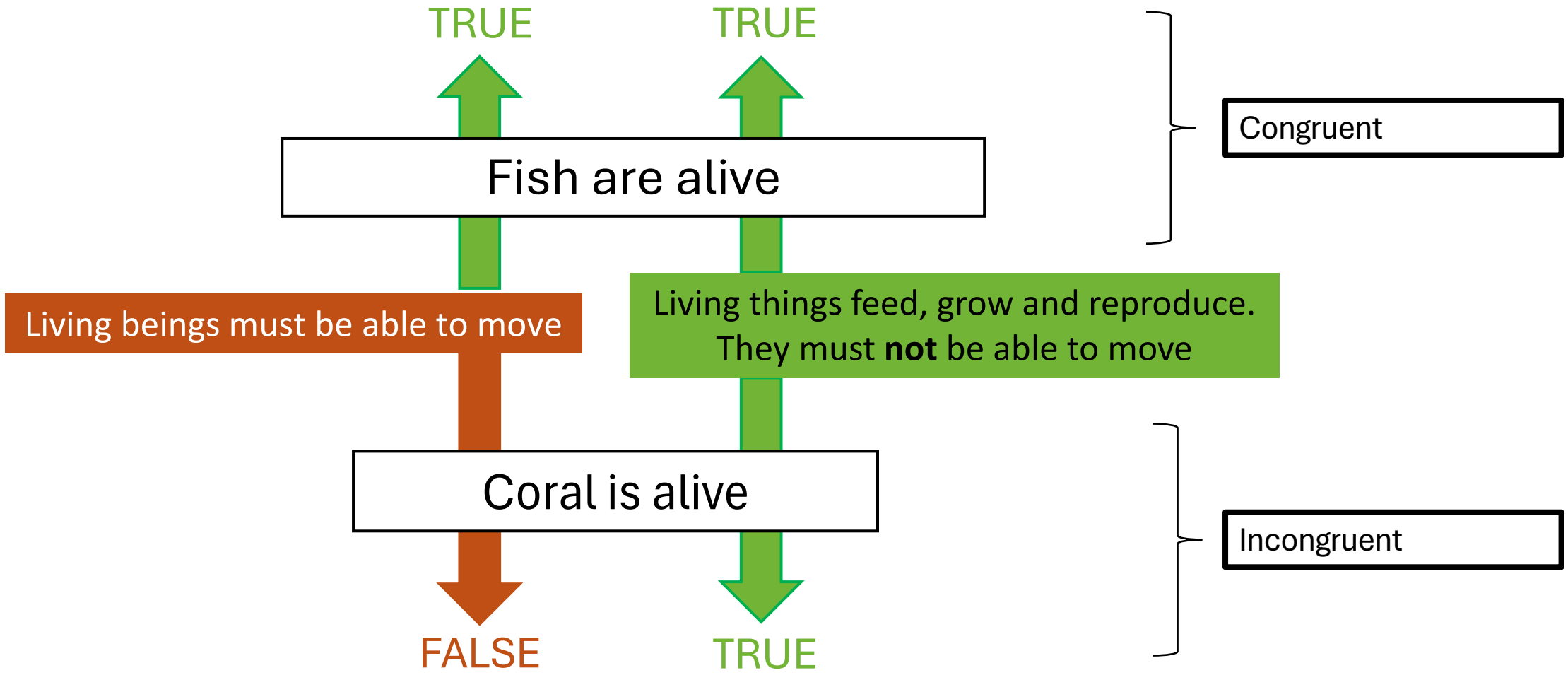
« logic-mathematical », reflexive thinking

Slow but accurate

2

Adapted from Houdé (2000)

Neuroscience studies: (in)congruent tasks



Shtulman & Valcarcel (2012)

Neuroscience studies: coexistence

Concept	Alternative conception	Scientific conception	Phrase
La vie	V	V	Fish are alive
	F	F	Stones are alive
	V	F	The sun is alive
	F	V	Coral is alive

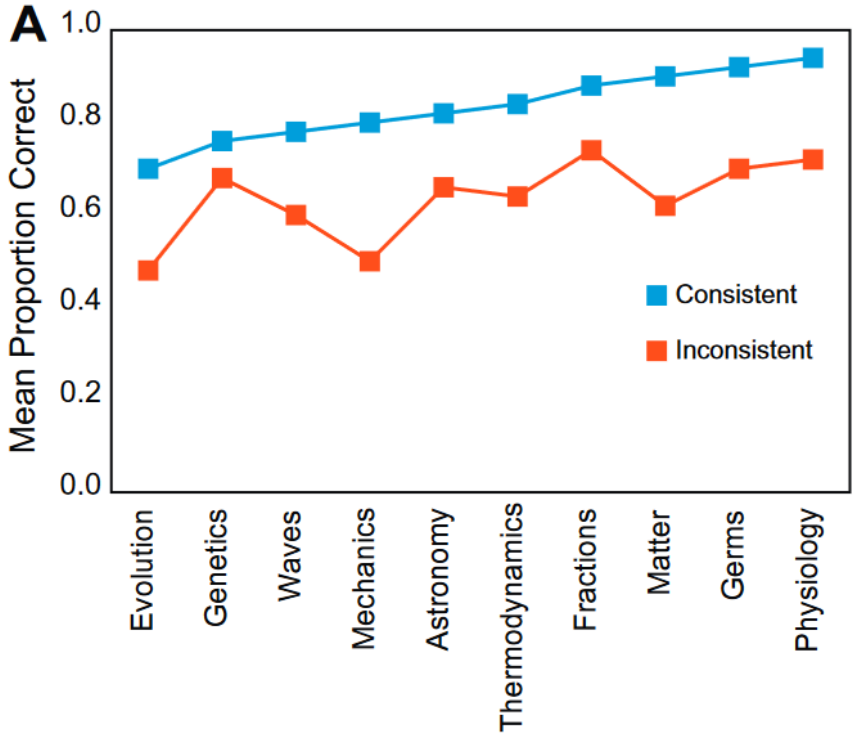
Congruent

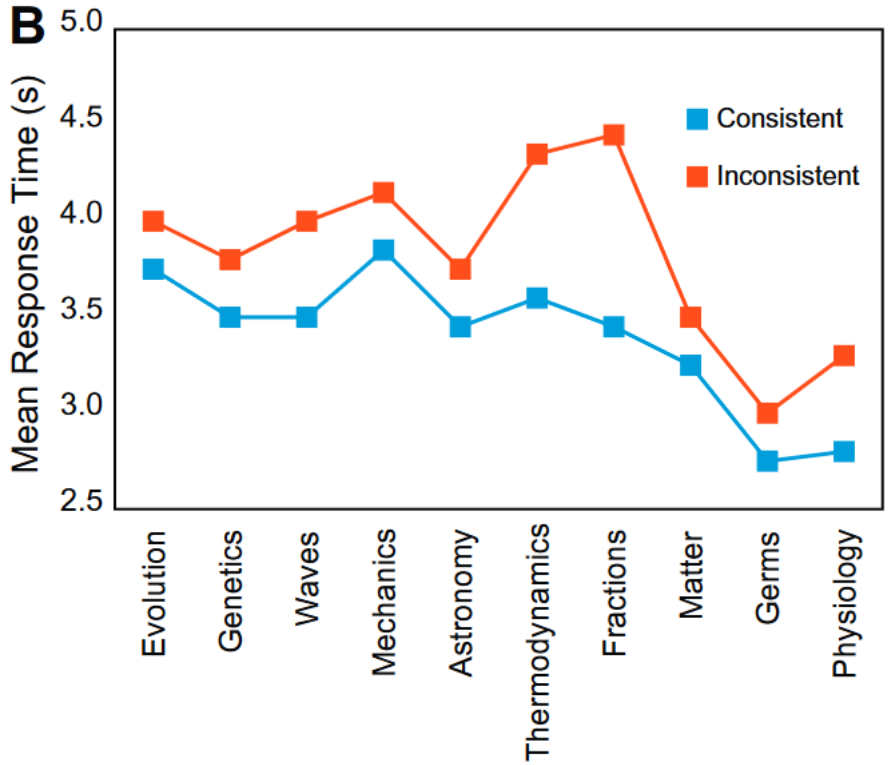
Incongruent

Neuroscience studies: coexistence

Subjects: 150 first-year university "experts" students

Tasks: 200 T/F sentences in 10 domains





Congruent accuracy > Incongruent accuracy

Congruent response time < incongruent response time

+ results with « experts » experts

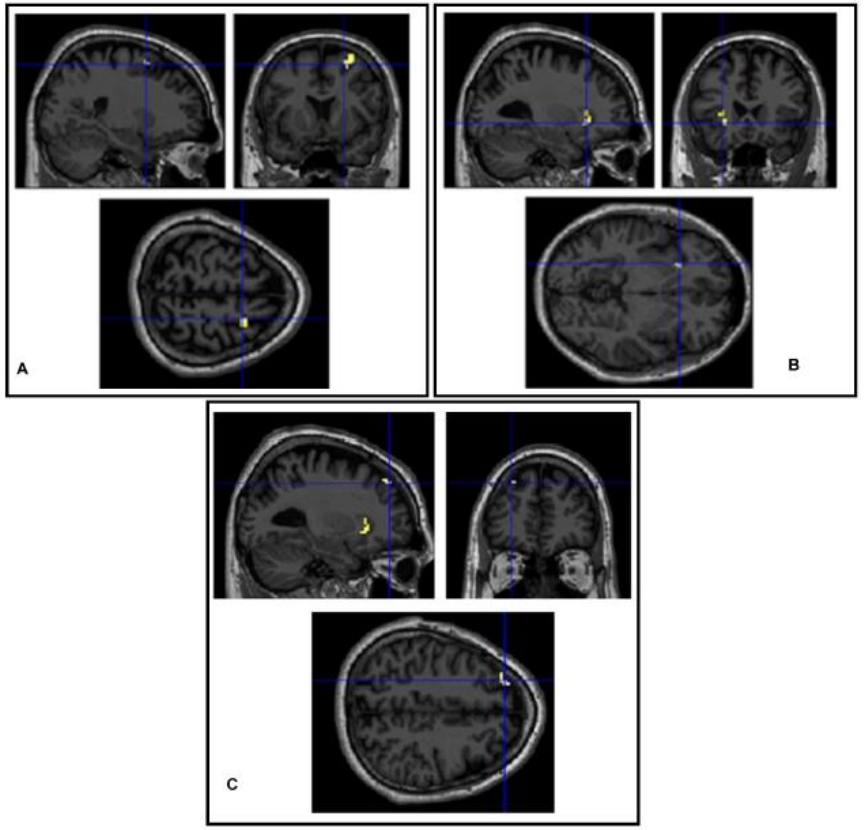
Neuroscience studies: coexistence

17 experts chemistry professors in "high school" or university (min. 5 years experience)

Items from a collection in the literature (see table)

Congruent accuracy > incongruent accuracy
Congruent RT < incongruent RT

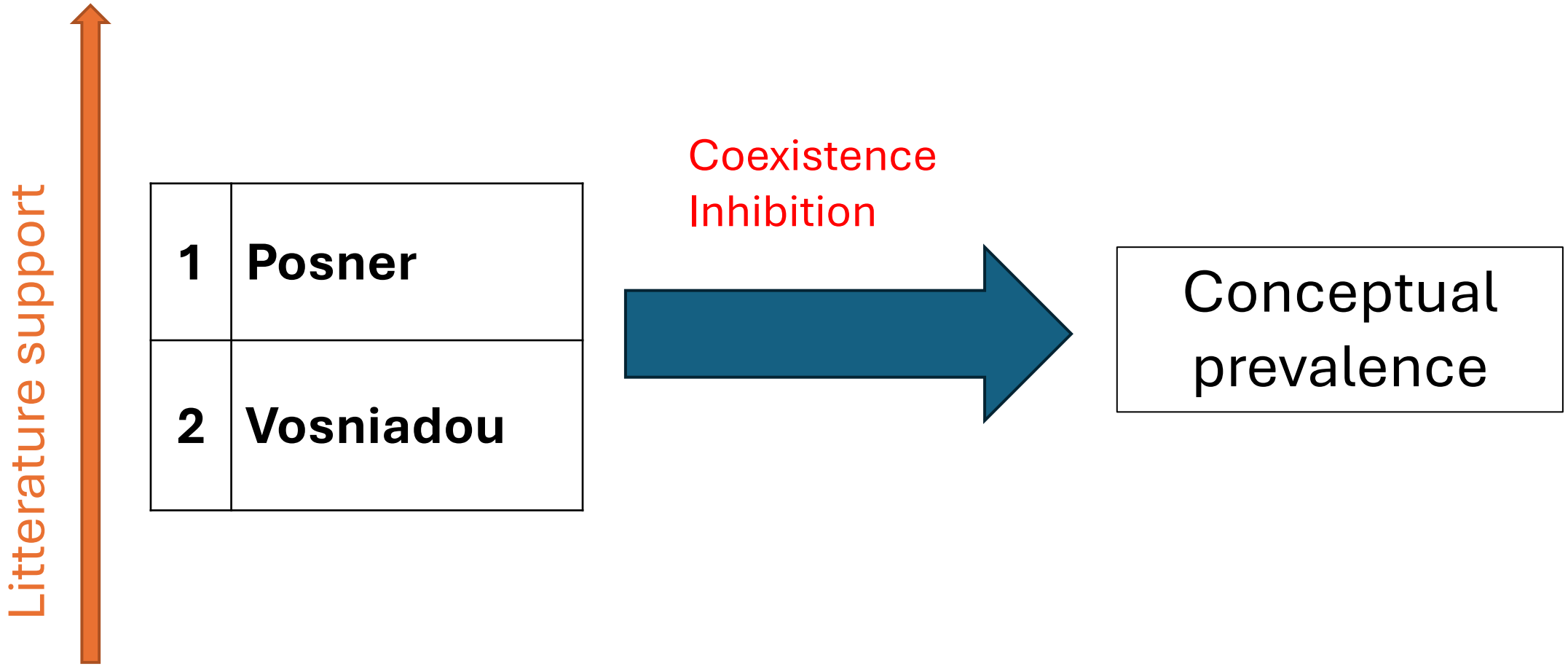
+ Activation of brain areas of inhibition



ctivation (sagittal, coronal and axial) of the pre-SMA **(A)**, the left VLPFC-Anterior insula **(B)**, and the left DLPFC **(C)** (incongruent > congru
corrected; minimum 8 voxels; random effects analysis).

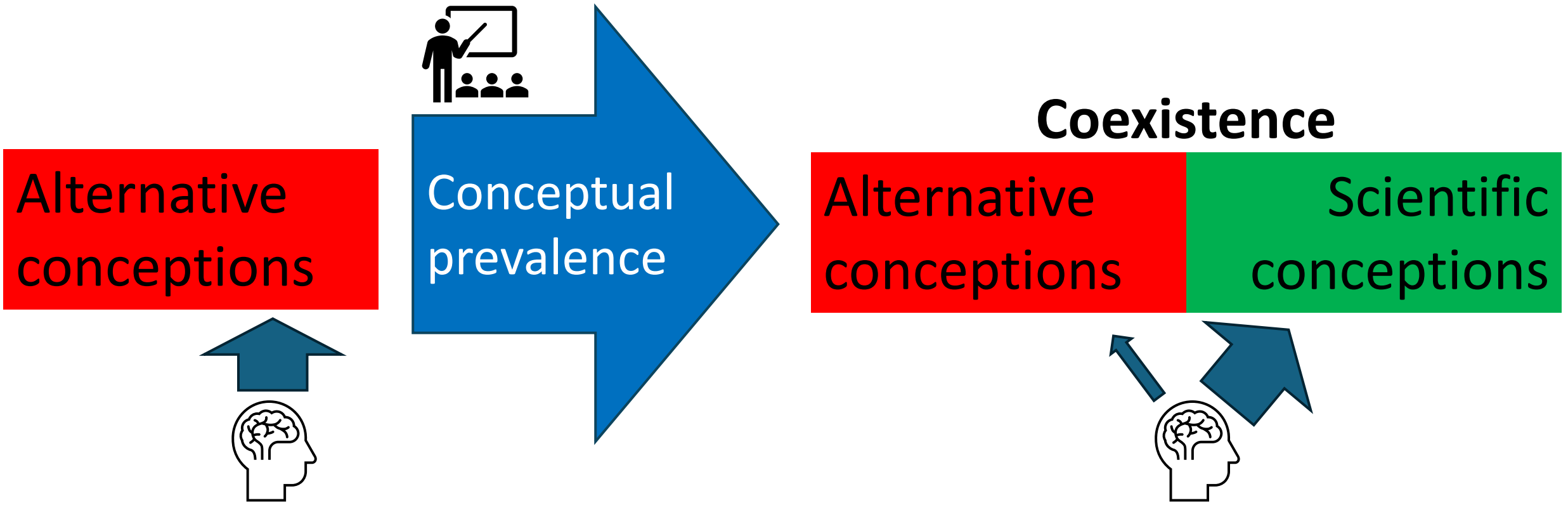
Potvin et al. (2020-

From conceptual change to modern theories



Potvin et al. (2020)

Modern theories: conceptual prevalence



Potvin et al. (2015)
Potvin et al. (2017)

Key *concepts* in conceptual change

Key *models* in conceptual change

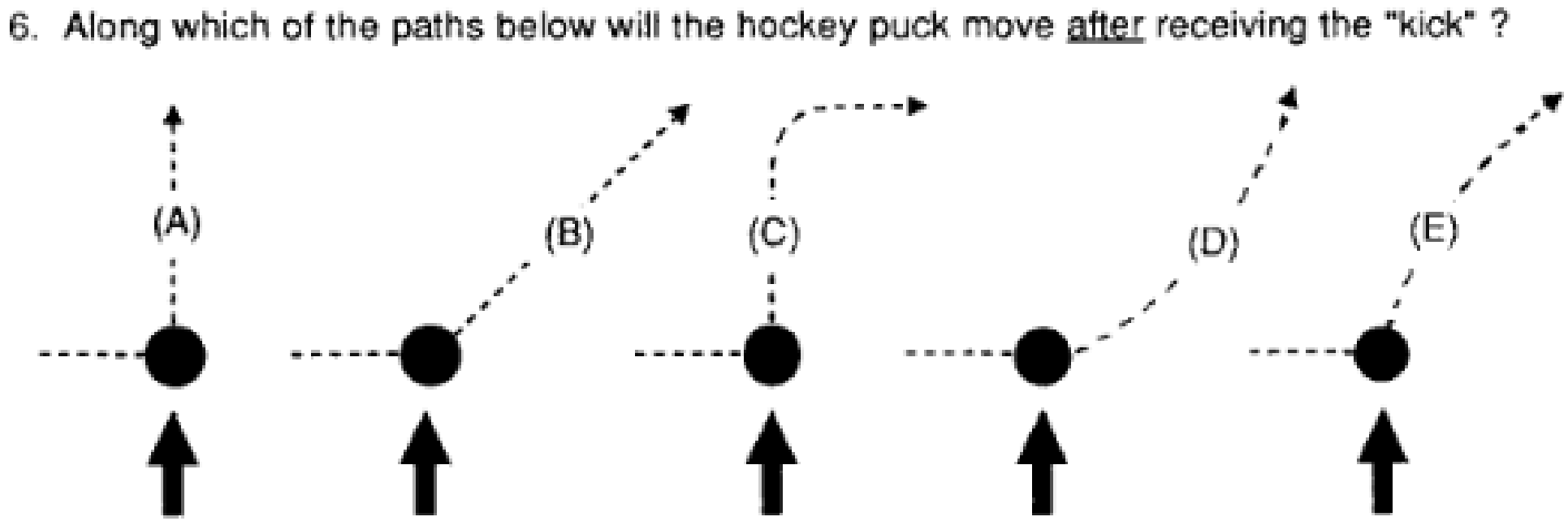
Key *concepts* in conceptual change

Key *models* in conceptual change

Resources

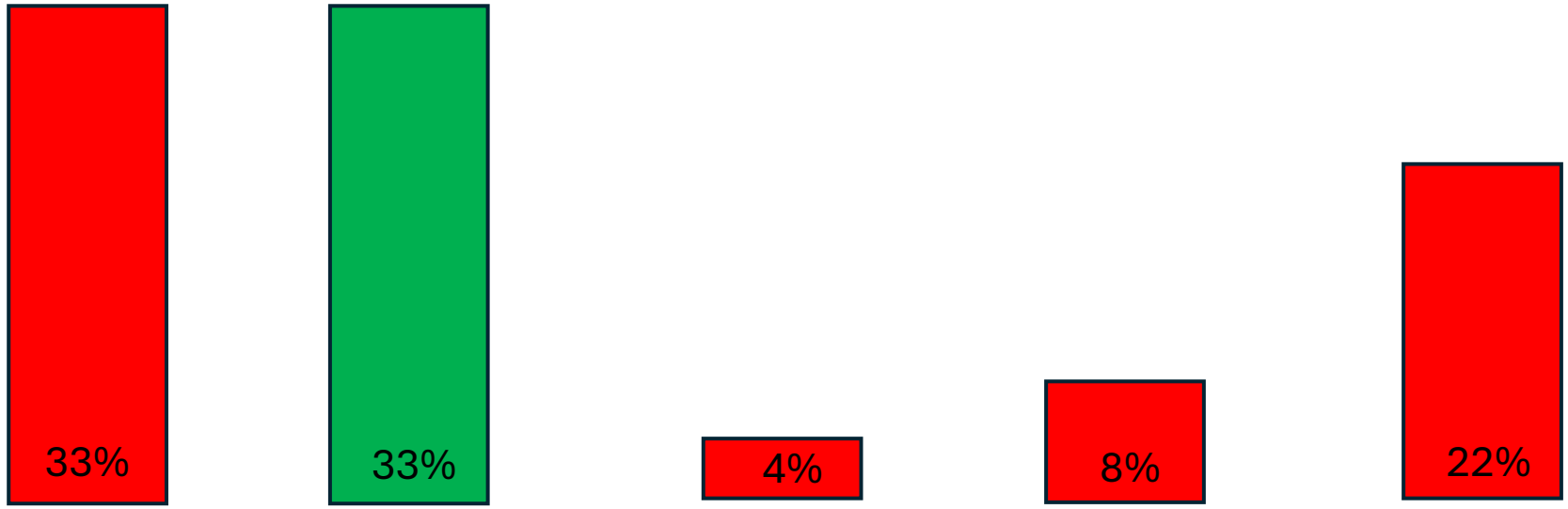
Suggestion 1: getting to know alternative conceptions

e.g. Force Concept Inventory

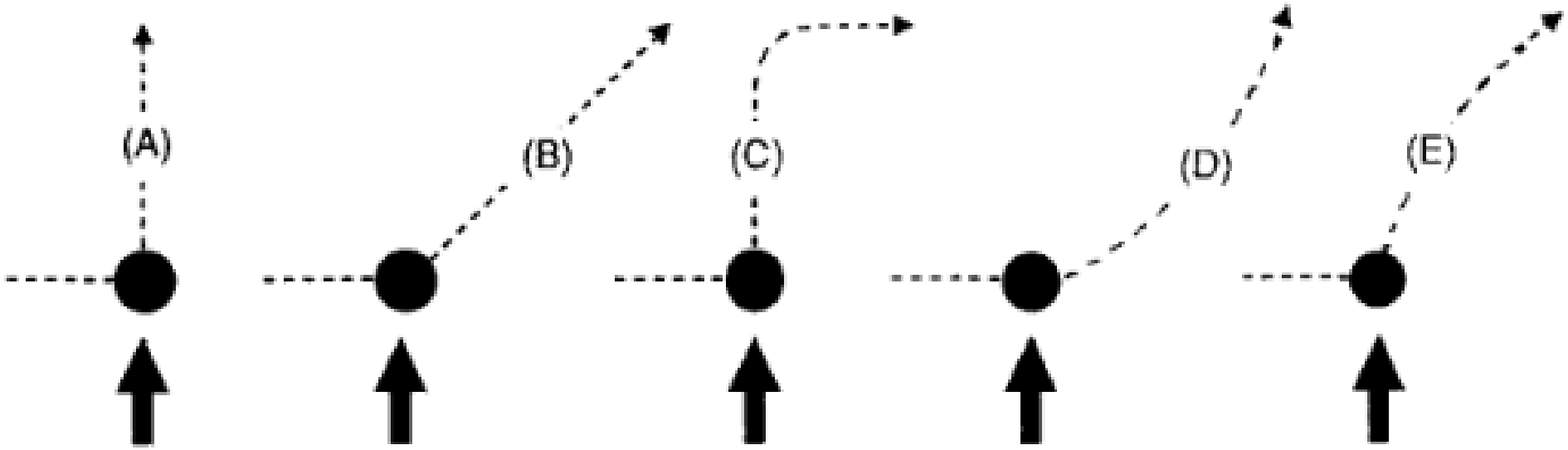


Hestenes et al. (1992)

N = 612 students from Arizona high school



6. Along which of the paths below will the hockey puck move after receiving the "kick" ?



Suggestion 1: getting to know alternative conceptions

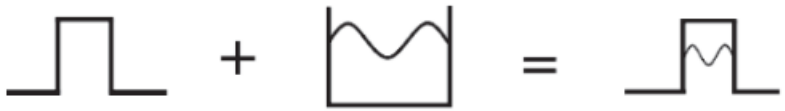
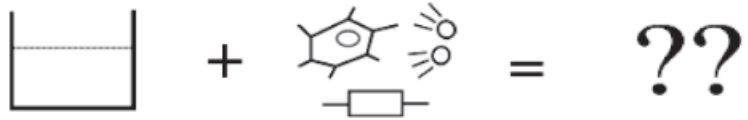
- *Force Concept Inventory*

➔Other concept inventories : https://www.physport.org/assessments/

➔ Other ideas for alternative conceptions: https://assess.bscs.org/science/topics

(security warning?)

➔ JCED, PRPE, ERIC, Scholar : “misconception”, “alternative conception”, “misunderstanding”

Synthetic model	Visual representation and quote
1 the potential well is a physical well (L1)	 *'The edges are the sides of the well?'(S12)*
2 a mix-up with classical waves (C1)	 *'The particle moves like a wave …' (S12)*
3 a mix-up of well and barrier (C2)	 *'Because it keeps moving back and forward [points to the barrier] …' (S13)*
4 a mix-up with energy level (C3/P1)	 *The electron is moving and gets a higher energy, because the second part of the sine is higher than the first.' (S11)*
5 a mix-up with other classical concepts (C4)	 *'This way the concept "resistance" can be clarified.' (S12)* *"… waves with a smaller wavelength are further from the cell wall' (S37)*
6 the use of inappropriate atomic models (E1)	 *'The nodes and antinodes show the shape of the shell in which the particle is located' (S59)*
7 deterministic reasoning in terms of movement (E2)	 *'The particle doesn't go over the barrier, but through it.' (S10)*
8 classical reasoning in terms of energy (E3)	 *'… the particle needs to have more energy to get across.' (S5)*

Krijtenburg-Lewerissa et al. (2020)

Suggestion 2: trigger inhibition

2. Assume a beaker of pure water has been boiling for 30 minutes. What is in the bubbles in the boiling water?

		Pre	Post
(a)	Air.	47	32
(b)	Oxygen gas and hydrogen gas.	399	360
(c)	Oxygen.	101	93
(d)*	Water vapor.	368	435
(e)	Heat.	12	4

Mulfold & Robinson (2002)

Suggestion 2: trigger inhibition

Standard

Select the correct option below

Assume a beaker of pure water has been boiling for 30 minutes. What is in the bubbles in the boiling water?

a. Air
b. Oxygen gas and hydrogen gas
c. Oxygen
d. Water vapor
e. Heat

Talanquer (2017)

Suggestion 2: trigger inhibition

Paired

Select the correct option below

Assume a beaker of pure water has been boiling for 30 minutes. What is in the bubbles in the boiling water?

a. Air
b. Oxygen gas and hydrogen gas
c. Oxygen
d. Water vapor
e. Heat

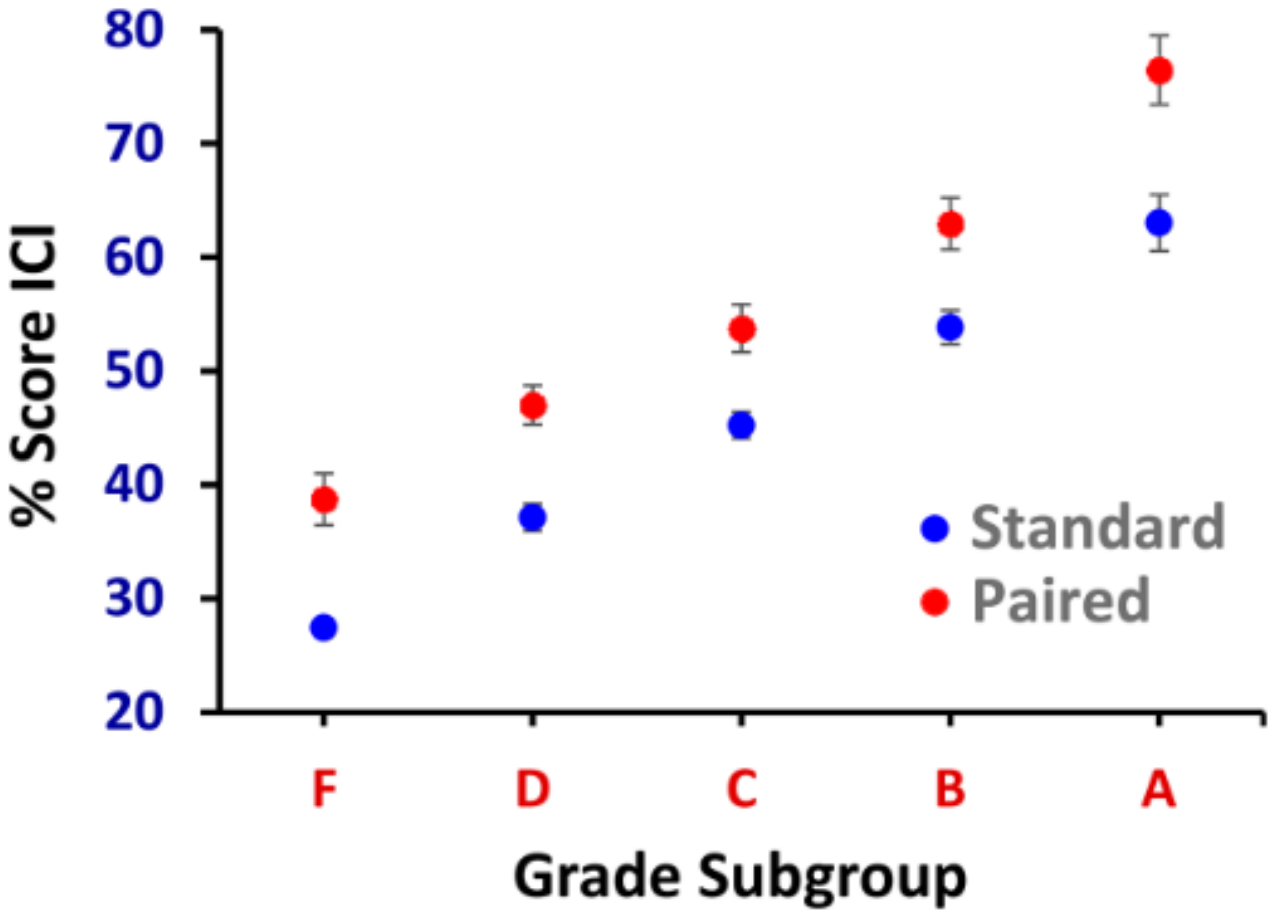
Select the option below that you think is most commonly chosen by students who get this question wrong because they do not carefully reflect on what the question is asking or are misguided by their intuition.

Assume a beaker of pure water has been boiling for 30 minutes. What is in the bubbles in the boiling water?

a. Air
b. Oxygen gas and hydrogen gas
c. Oxygen
d. Water vapor
e. Heat

Suggestion 2: trigger inhibition

N (standard) = 1076
N (paired) = 397



Suggestion 3: apply prevalence principles

1. **Making the correct design available**
   (Timing matters)

   ✓Make the correct conception available first

   ✓Make way for didactics and pedagogy

   ✓Note: resistance if feeling of attack

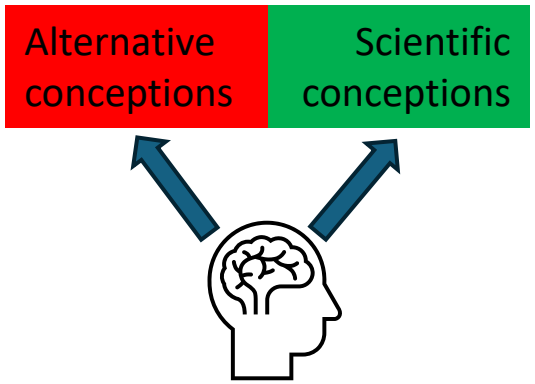
Alternative conceptions

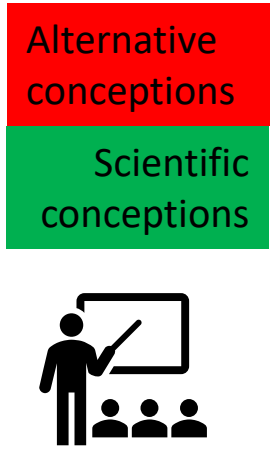
Scientific conceptions

Suggestion 3: apply prevalence principles

2. Debate, discuss alternative conceptions

- ✓ (preamble:) get to know alternative conceptions
- ✓ Presenting them in conflict with the correct conception
- ✓ Remove label, let students decide

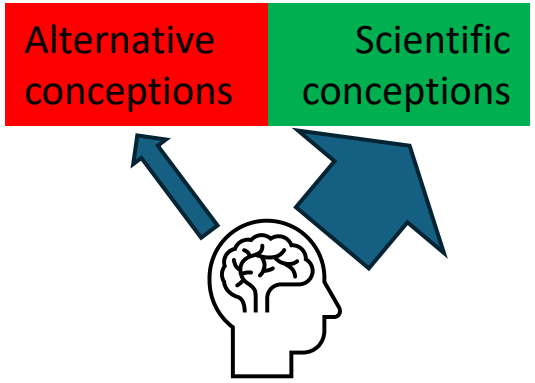




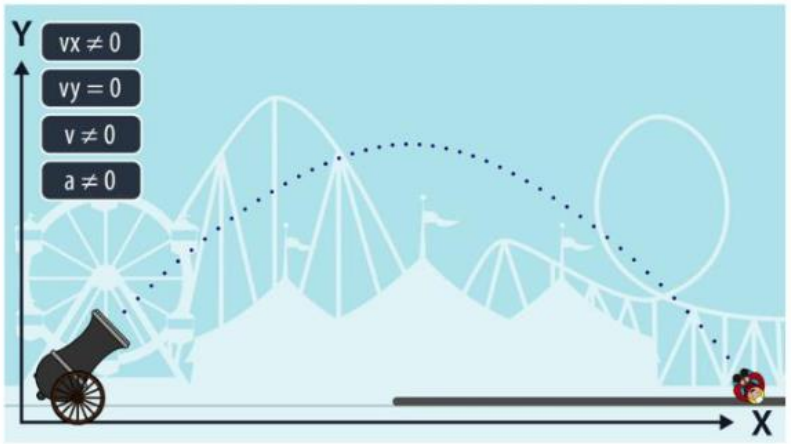
Suggestion 3: apply prevalence principles

3. Train inhibition

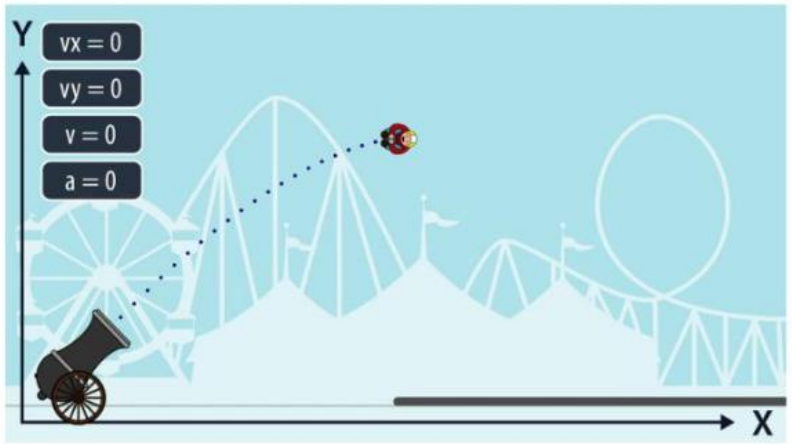
- ✓Drill
- ✓Fight ephemeral learning
- ✓Use explicit teaching, examples and counter-examples inspired by alternative conceptions ("pitfalls")



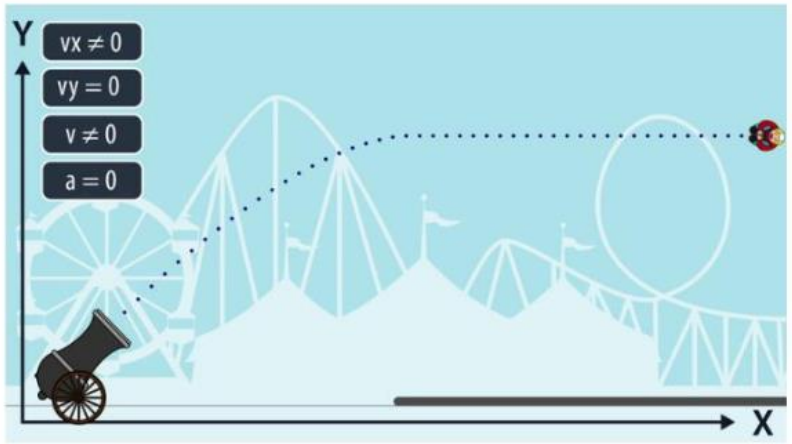
Suggestion 4: use simulations



(a)



(b)



(c)

(d)

Marique (2024)

How this presentation is structured

Key *concepts* in conceptual change

Key *models* in conceptual change

Resources

How this presentation is structured

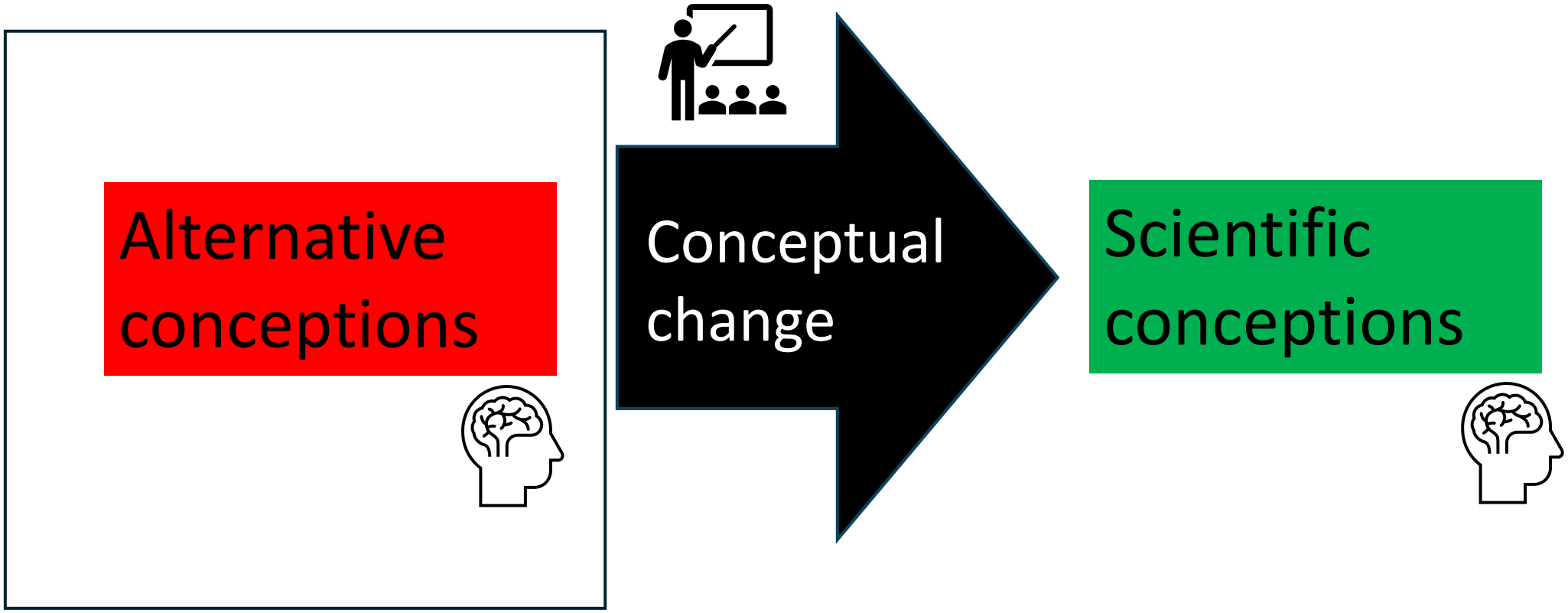
Key *concepts* in conceptual change

Key *models* in conceptual change

Resources

Two examples from my research

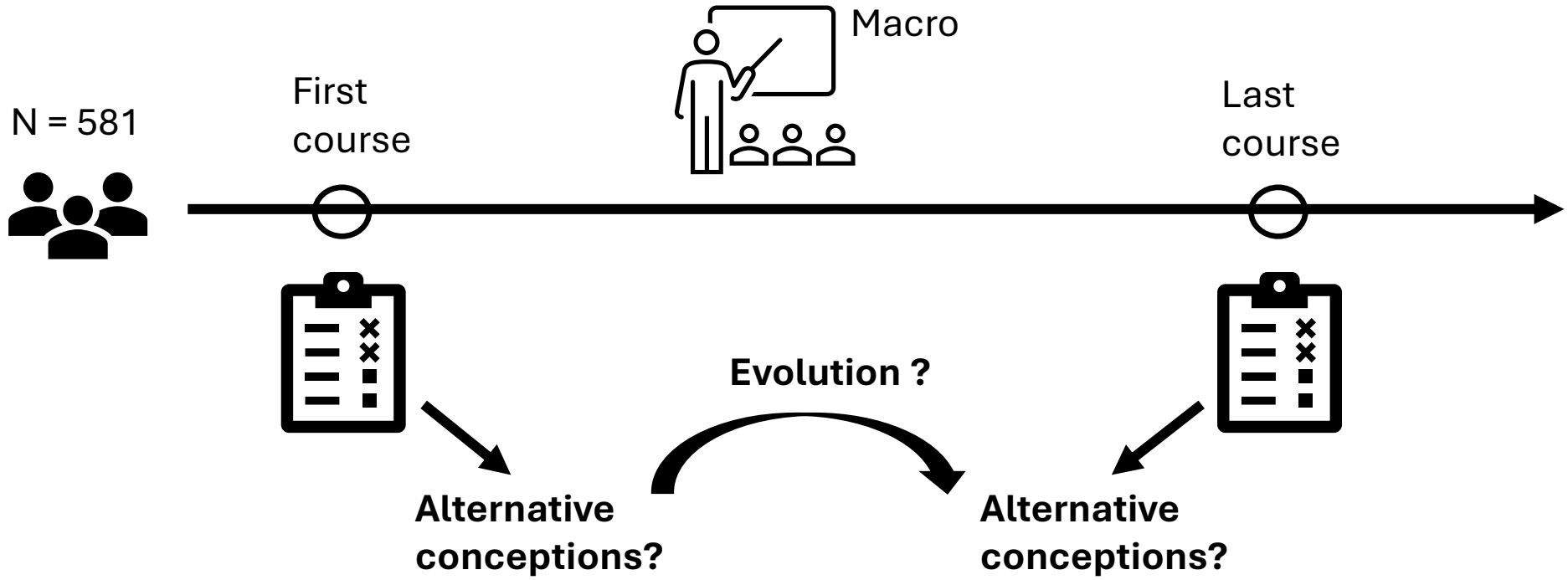
Examples from research 1: alternative conceptions



What are these for entropy and the second law of thermodynamics?

Examples from research 1: alternative conceptions

- Method

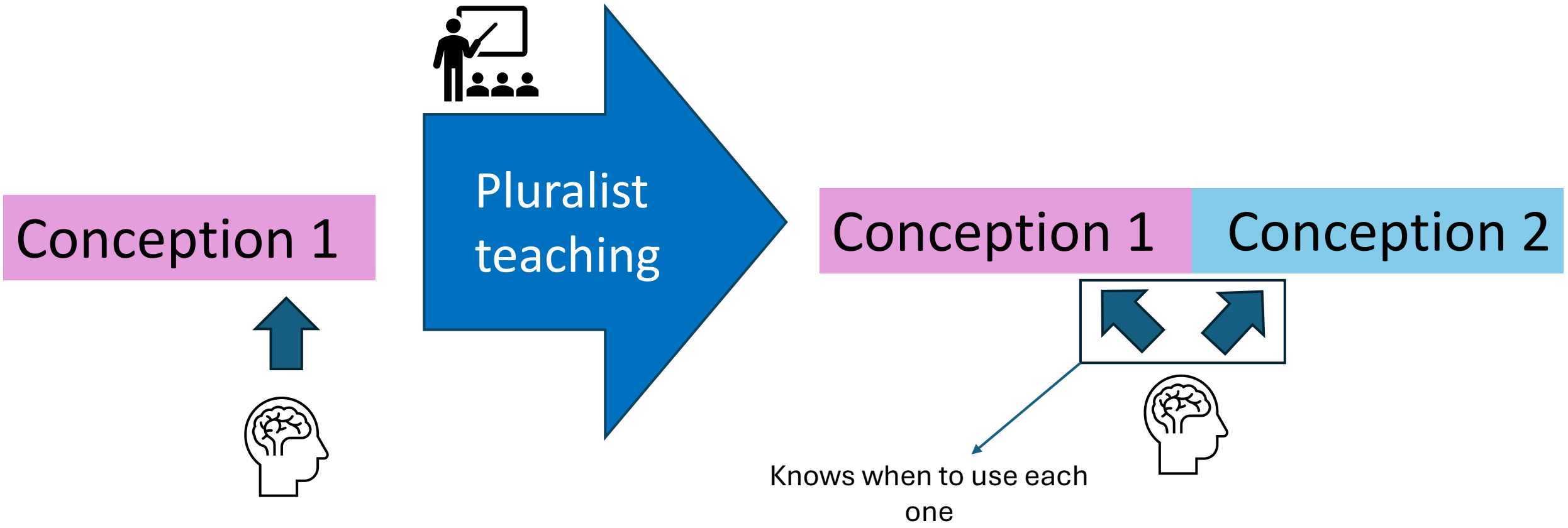


+ Interviews

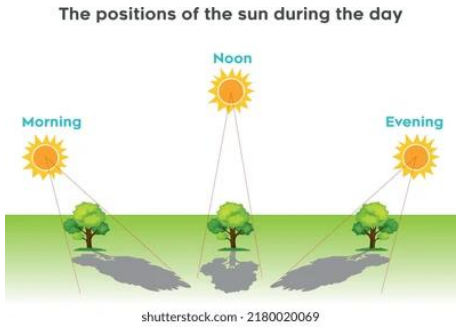
Examples from research 1: alternative conceptions

Name of the AC	Statement of the AC
Stability	Molecules that are chemically more stable have a lower entropy
Ordering	Fusion requires an energy input to disorganize solid molecules into a disordered liquid, and crystallization requires an energy input to organize liquid molecules into an ordered solid
Freedom	Entropy increases with the freedom of movement of particles
Mixing	Entropy increases when two substances are mixed up
Collisions	If molecules have a higher chance of colliding, the entropy of the system is higher
Isolated	Entropy does not change in an isolated system

Examples from research 2: pluralism

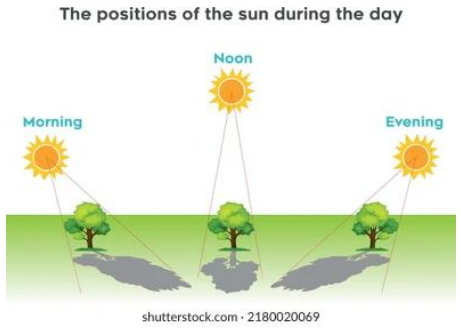


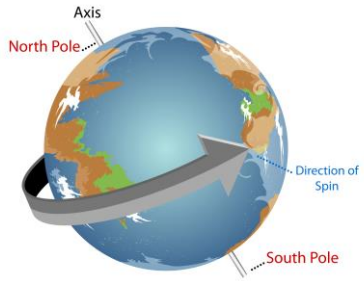
Examples from research 2: pluralism



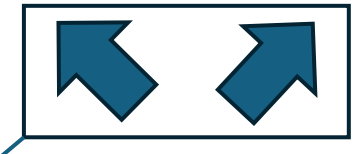
Conception 1

Pluralist teaching



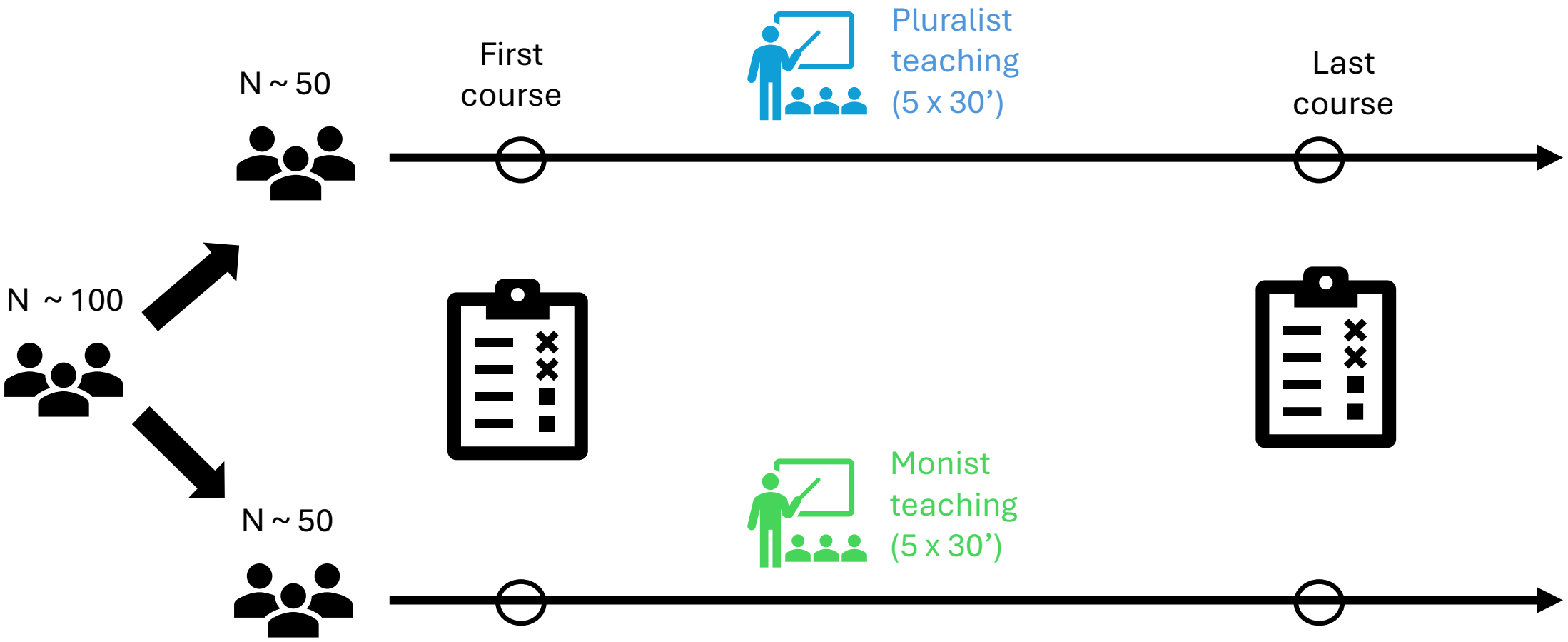


Conception 1 Conception 2



Knows when to use each one

Examples from research 2: pluralism



Examples from research 2: pluralism

Compares

Talks about the other conception

Aim : help students manage conceptions

Affirms

Does not talk about the other conception

Aim : help students understand the desired conception

Practical summary

- Students hold (many) alternative conceptions
- They change gradually following cognitive conflict
- They should be taken into account when teaching
- They coexist (forever) with scientific conceptions
- They must be inhibited

- In your practice, you can
  - Get to know alternative conceptions
  - Trigger inhibition
  - Apply the 3 steps of conceptual prevalence

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The battle between misconceptions and scientific conceptions

Using Conceptual Change in the university classroom to improve the teaching of counterintuitive concepts in science

Contact:
vincent.natalis@uliege.be

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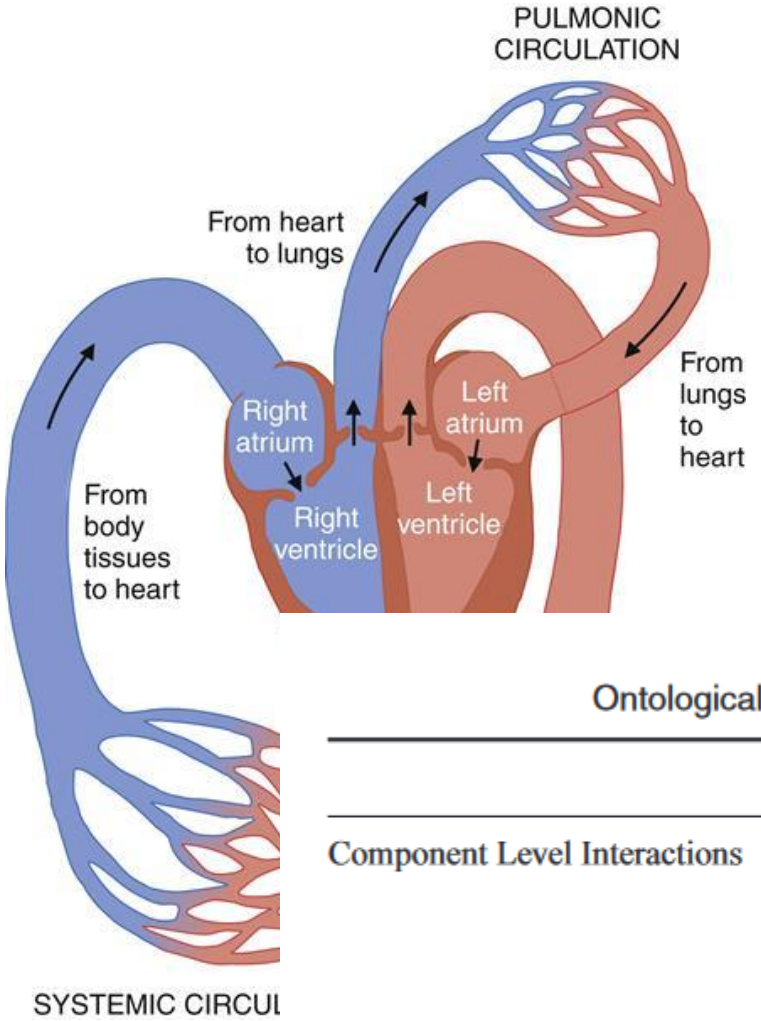
Conceptual change: Chi's model



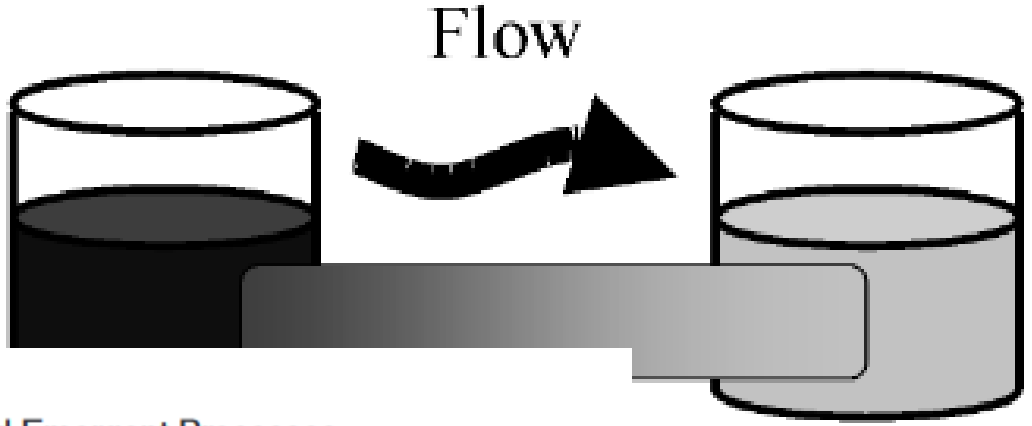


TABLE 1
Ontological Attributes of Direct and Emergent Processes

	Direct Processes	*Emergent Processes*
Component Level Interactions	1. Distinct	Uniform
	2. Constrained	Unconstrained (random)
	3. Sequential	Simultaneous
	4. Dependent	Independent
	5. Terminating	Continuous