Teaching entropy at bachelor level in a conceptual change perspective

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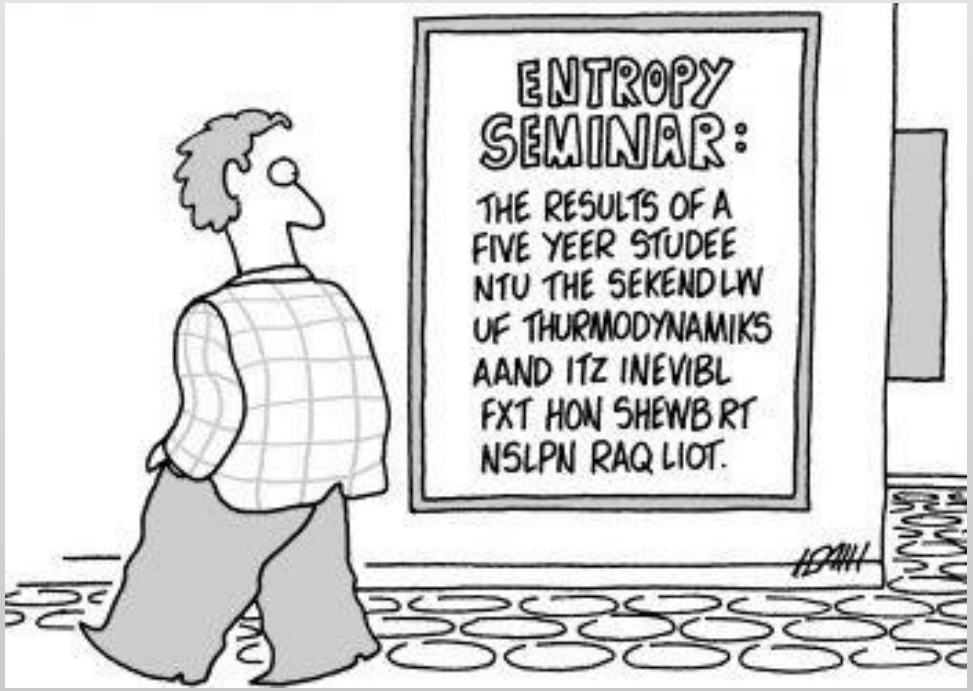

New Perspectives in Science Education Conference 2021

What is entropy ?

Fundamental concept in thermodynamics, the study of heat, temperature, and work.

Disorder
Chaos

S

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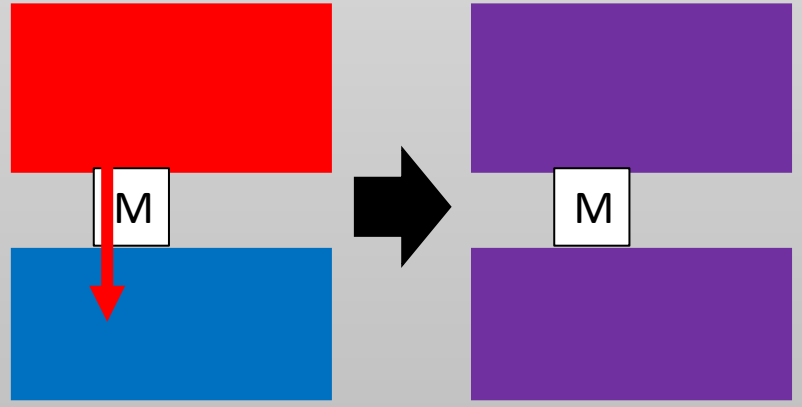
Energy spread, dispersal
Energy quality



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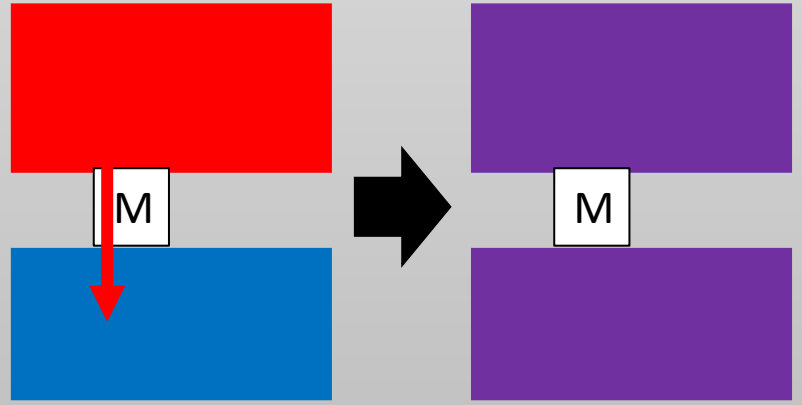

Important features

- Entropy is a property of a system
- The entropy of the universe only ever increases
- Entropy is linked to the arrow of time

Entropy is a key notion that highlights the obstacles to teaching chemistry at bachelor level

- Macroscopic properties emergence from microscopic models
- Conflicts and conciliations between two historical models

Emergence is not always intuitive !

Entropy is Disorder

Disorder in gas > Disorder in liquid > Disorder in solid

$S_{gaz} > S_{liquid} > S_{solid}$

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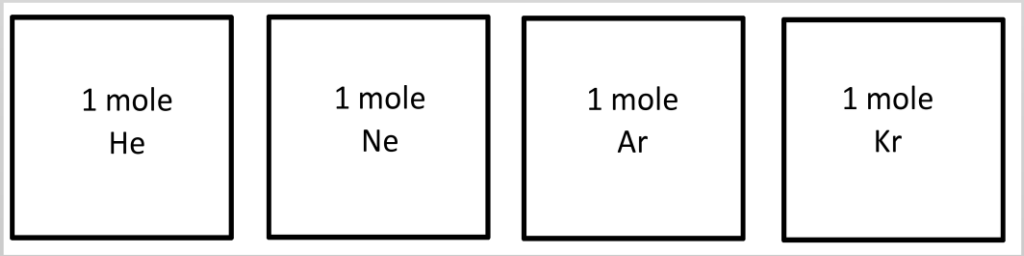
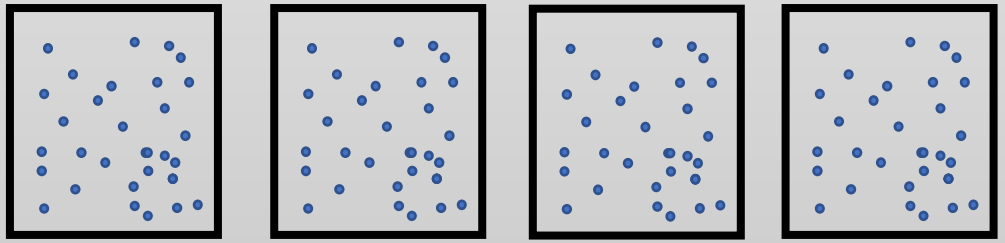
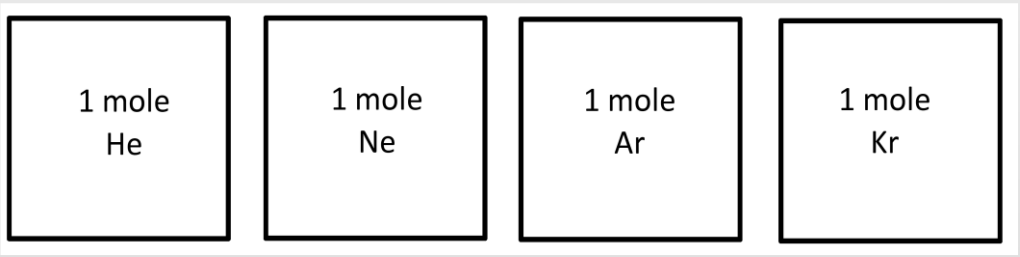


Entropy is Disorder

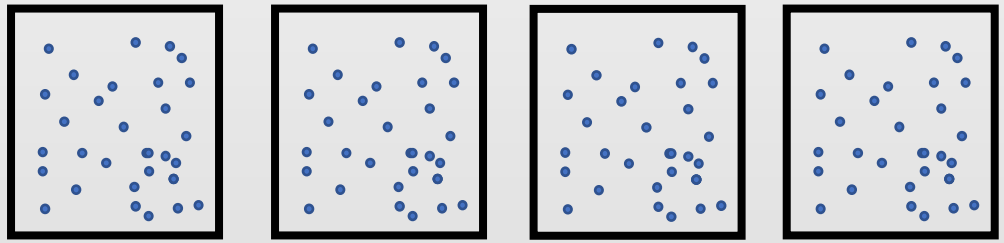


$S_{He} = S_{Ne} = S_{Ar} = S_{Kr}$

Emergence is not always intuitive !



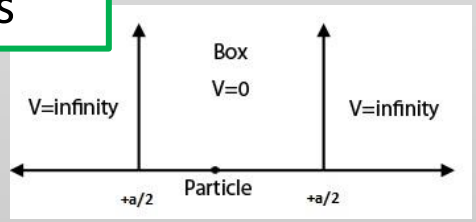
Entropy
is
Disorder



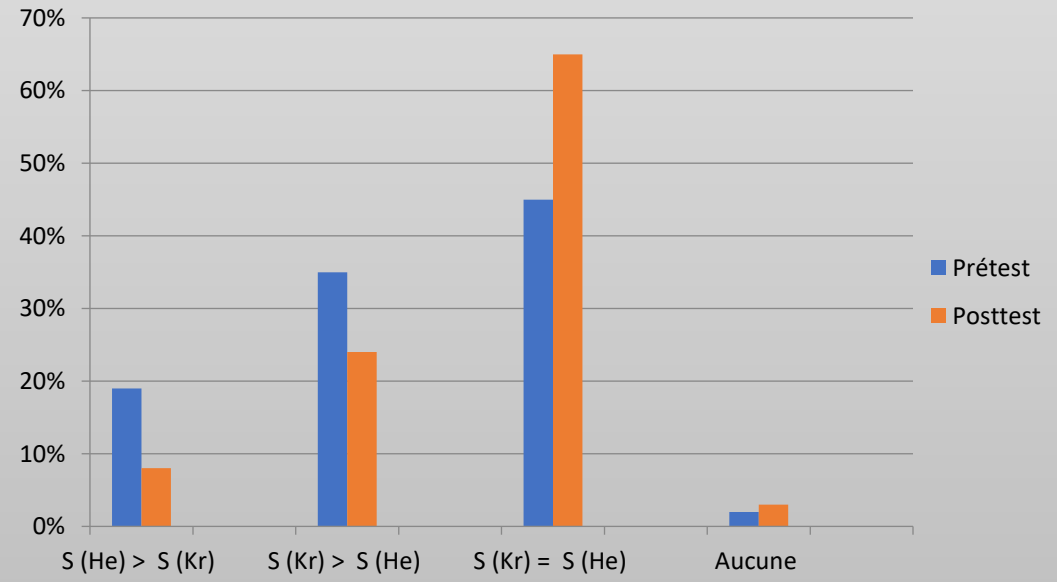
$S_{He} = S_{Ne} = S_{Ar} = S_{Kr}$

✓

Entropie
∝ atomic
masses



$S_{He} < S_{Ne} < S_{Ar} < S_{Kr}$



Carnot (1823)

Clausius (1865)

Clausius (1876)

Boltzmann (1877)

Defines a statistical origin to entropy

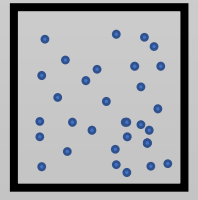
Creation of the « disorder » metaphor

Macroscopic model

Does not need atoms !

?

Disorder
Chaos



Microscopic model

Particles statistics

Pedagogical framework : conceptual change

Misconception

“Any reasoning mobilized by the student which is not in accordance with the scientifically accepted concept”

Naïve, incomplete, ou plane false

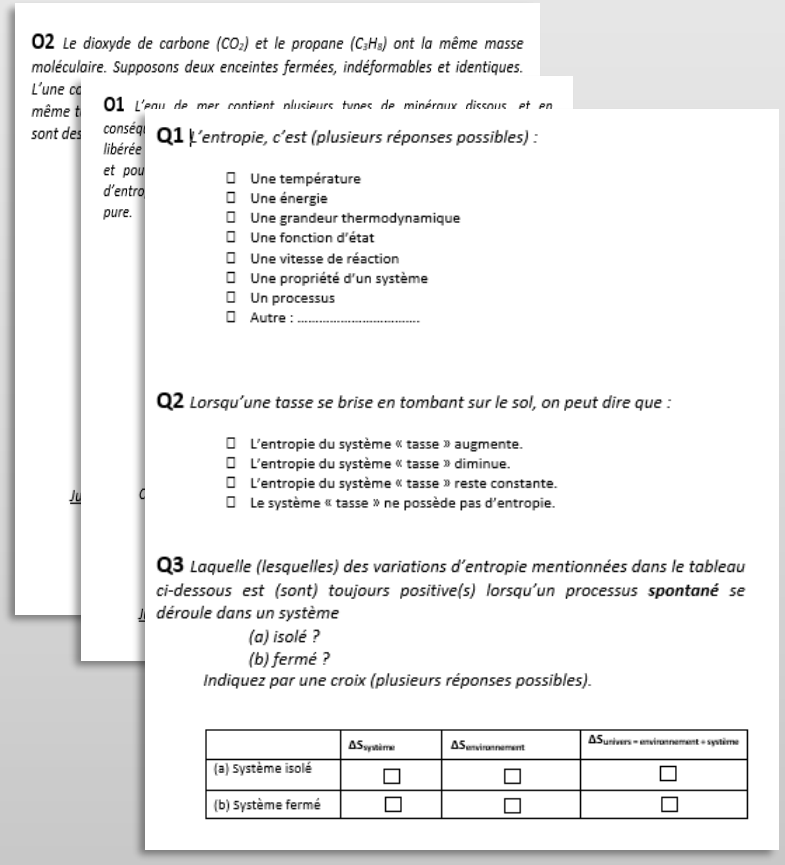
Conceptual change theory

A framework for observing and analyzing the ways in which students’ conceptions coexist and evolve

Research questions

- By which answers and erroneous justifications do the misconceptions of undergraduate students in higher education about entropy and the second law of thermodynamics manifest themselves in multiple choice tests ?
- How are these misconceptions influenced by a general thermodynamics course based on the macroscopic model ?

Method



Q2 *Le dioxyde de carbone (CO_2) et le propane (C_3H_8) ont la même masse moléculaire. Supposons deux enceintes fermées, indéformables et identiques.*

Q1 *L'entropie, c'est (plusieurs réponses possibles) :*

- ☐ Une température
- ☐ Une énergie
- ☐ Une grandeur thermodynamique
- ☐ Une fonction d'état
- ☐ Une vitesse de réaction
- ☐ Une propriété d'un système
- ☐ Un processus
- ☐ Autre : .....

Q2 *Lorsqu'une tasse se brise en tombant sur le sol, on peut dire que :*

- ☐ L'entropie du système « tasse » augmente.
- ☐ L'entropie du système « tasse » diminue.
- ☐ L'entropie du système « tasse » reste constante.
- ☐ Le système « tasse » ne possède pas d'entropie.

Q3 *Laquelle (lesquelles) des variations d'entropie mentionnées dans le tableau ci-dessous est (sont) toujours positive(s) lorsqu'un processus **spontané** se déroule dans un système*

(a) isolé ?
(b) fermé ?

Indiquez par une croix (plusieurs réponses possibles).

	$\Delta S_{système}$	$\Delta S_{environnement}$	$\Delta S_{univers = environnement + système}$
(a) Système isolé	☐	☐	☐
(b) Système fermé	☐	☐	☐

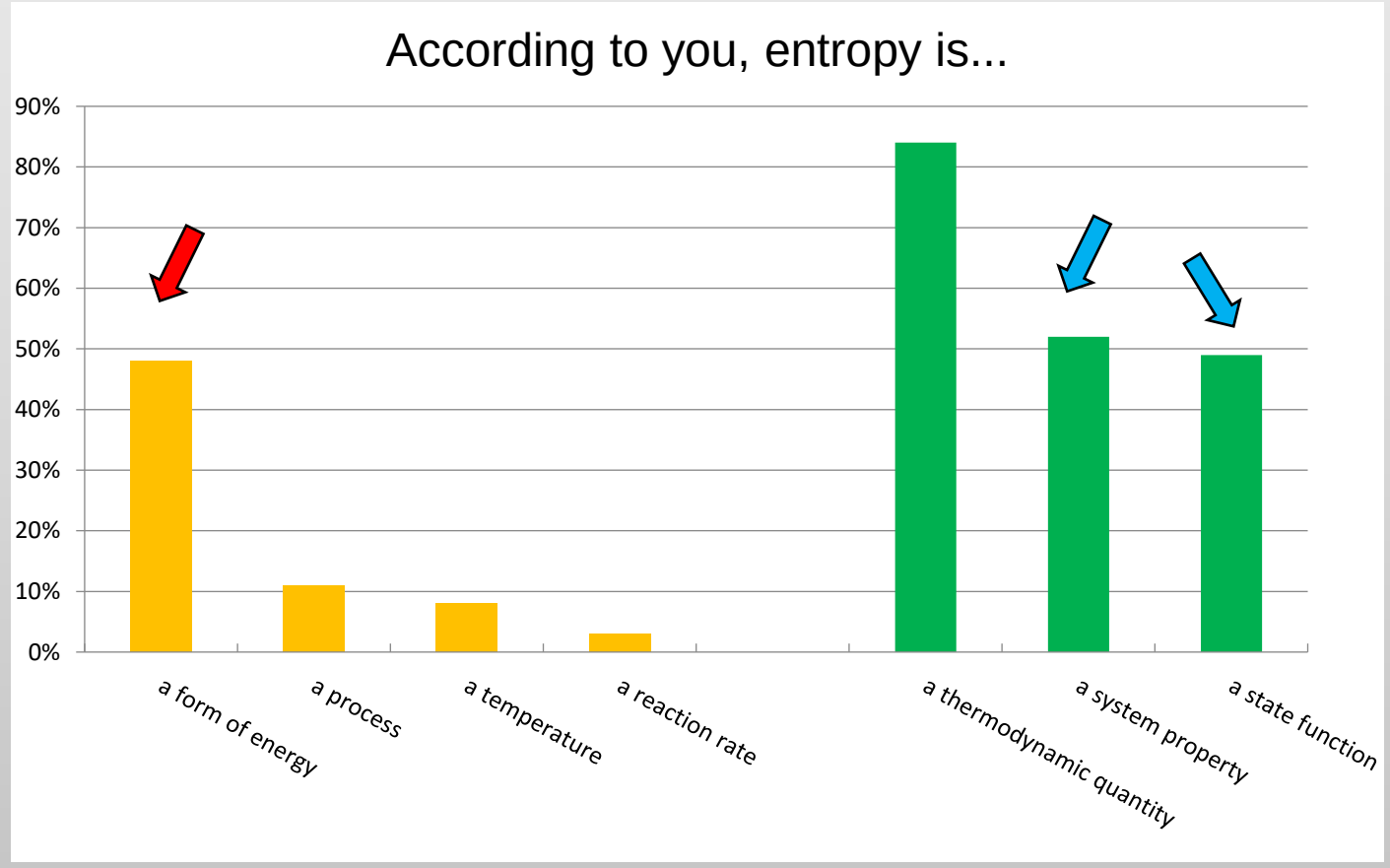
Test (and online test)

- Groups :
  - First-year undergraduates : pharmacists, chemists, geologists
  - Second-year undergraduates : chemical engineers
  - Experts
- 11 questions, 6 of them open to justification
- Questions have been designed to make misconceptions arise
- One test before, one test after the entropy lesson

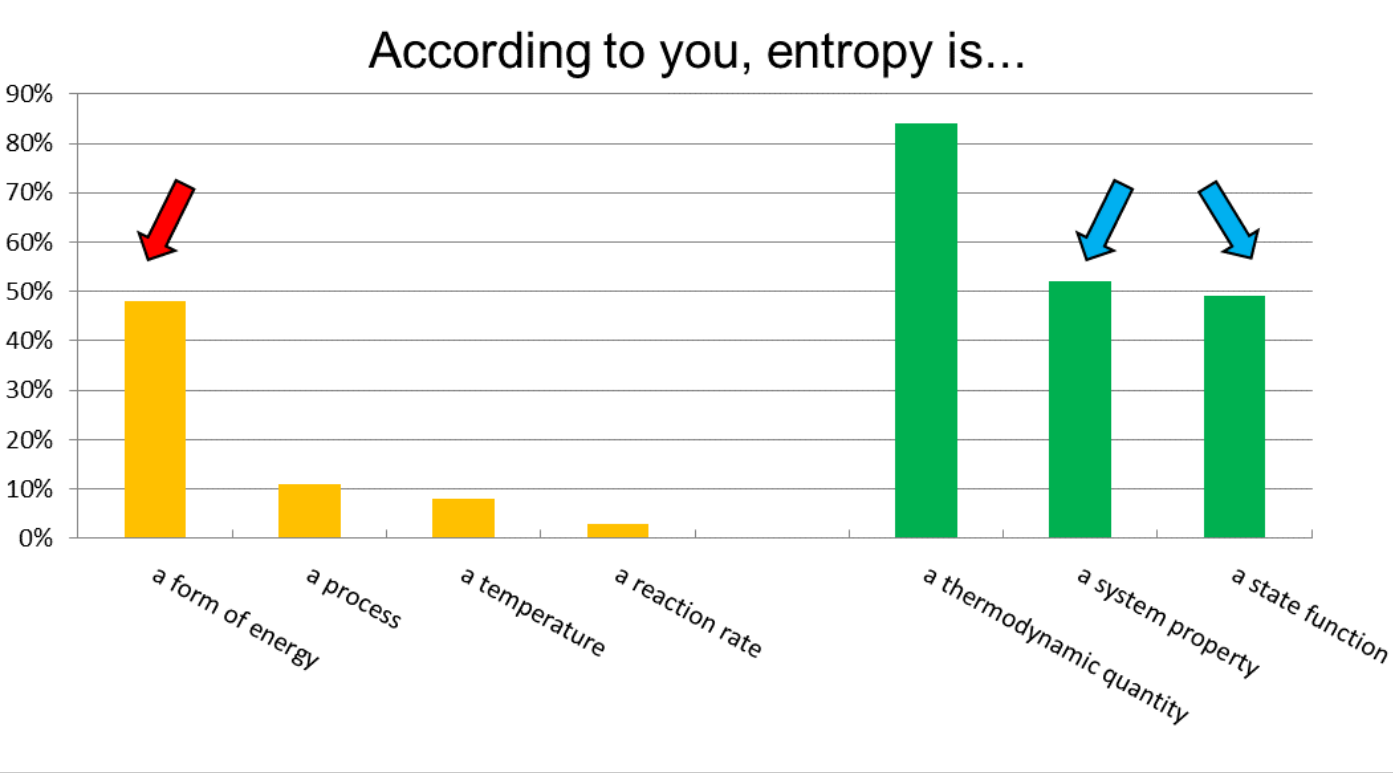
Results from the definition question

According to you, entropy is (multiples answers possible) :

- A temperature
- A form of energy
- A thermodynamic quantity
- A state function
- A reaction rate
- A system property
- A process
- Other : ……



Results from the definition question



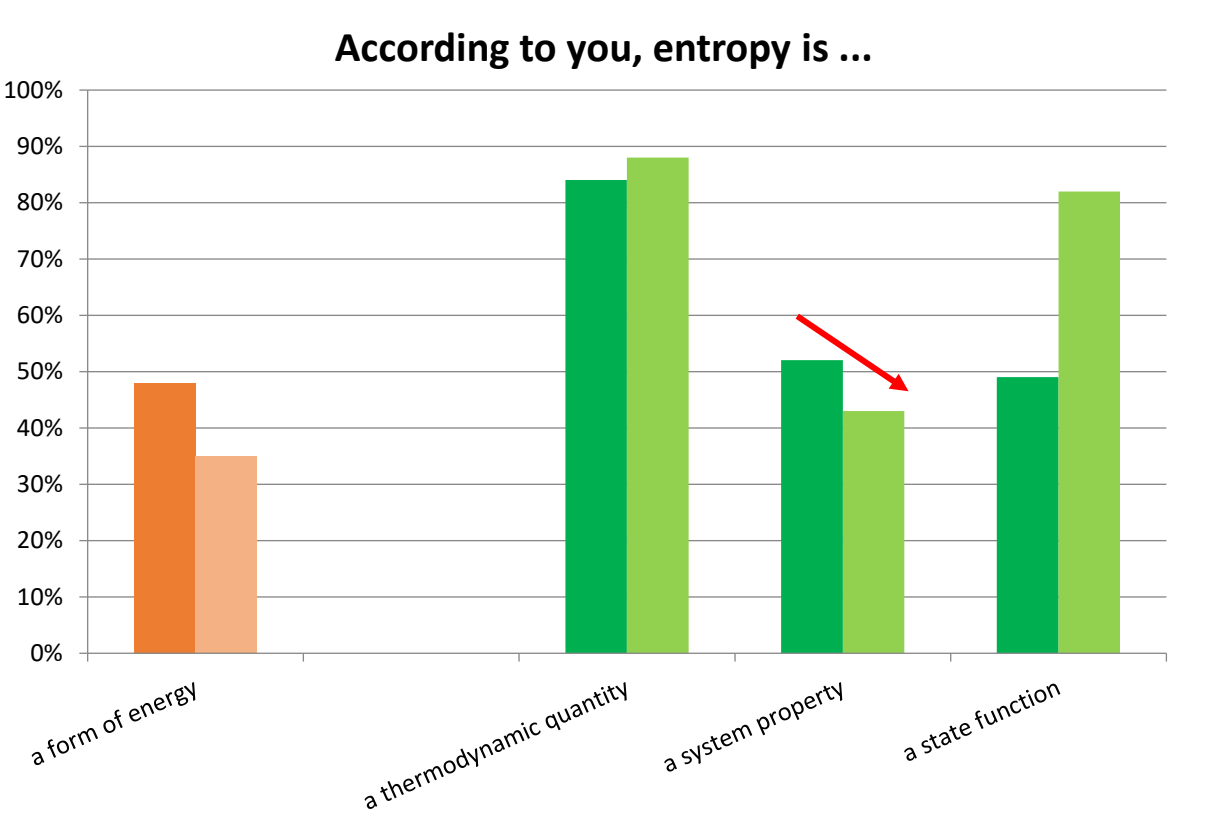
- Major energy-entropy confusion (48%)

- Major ignorance of properties of entropy
  - Property of a system
  - State function

=> The macroscopic approach insists on *process*, not *properties*

(ΔS, not S)

Results from the definition question



- Improvements
  - Energy item
    - ➢ $dS = \delta Q_{reversible} / T$?
    - ➢ SD interviews
  - Thermodynamic quantity
  - State function
    - ➢ Key feature in the macro model

- Worsening

system property

- ➢ ΔS, not S

Conclusion

- Macroscopic model >< microscopic model
- A macroscopic model-based course doesn’t necessarily improve misconceptions

➔ Create a new joint explanation of the disorder metaphor from the two methods

➔ Use this new explanation in a novel educationnal environnement (lab, simulation)

Thanks !