Teaching entropy at undergraduate level in the framework of conceptual change

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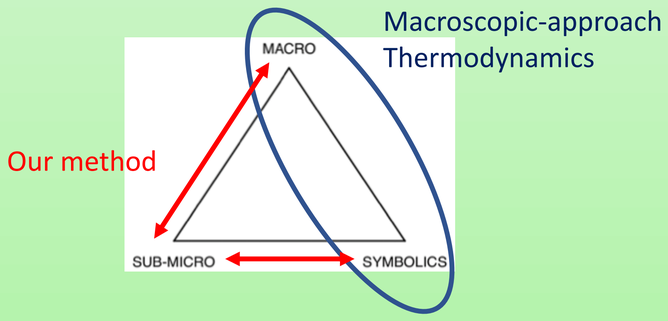
INTRODUCTION

- **Identification of misconceptions** and their replacement by scientifically validated conceptions is a central aspect of any teaching in the framework of conceptual change theories
- Recent neuroscientific explorations show the importance of inhibitory processes for validated conception development
- Physical chemistry at the undergraduate level is known for being a difficult topic:
  - ❑ Abstract character
  - ❑ Requires physical insight and mathematical toolkit
- **Entropy and the second law of thermodynamics** are central concepts in the physical chemistry curriculum, upon which most STEM students step during their 1st and 2nd year at university.
- Specific difficulties associated with these concepts include the existence of two possible approaches, rarely connected at a basic level :
  - ❑ Macroscopic : introducing state functions along the first and second laws
  - ❑ Molecular/statistical : degrees of freedom, micro- and macrostates, MB statistics,, partition functions, and links with equilibrium state functions



RESEARCH QUESTIONS

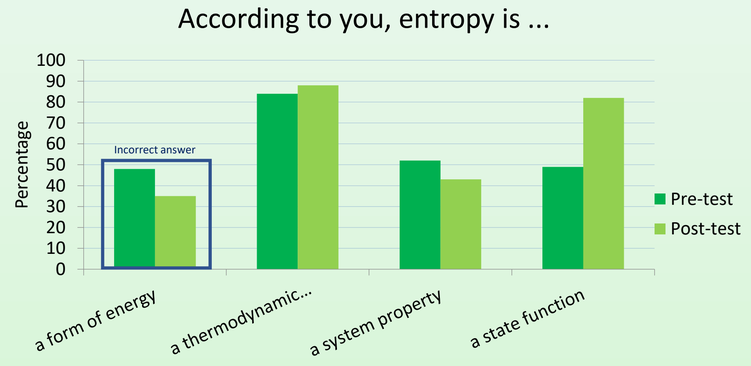
- What are the alternative conceptions (AC) of university 1st-year bachelor students concerning entropy and the 2nd law and how does a macroscopic approach-based lecture influence these preconceptions ?
- How does an innovative statistical thermodynamics-based approach change student conceptions and understanding?

METHODS

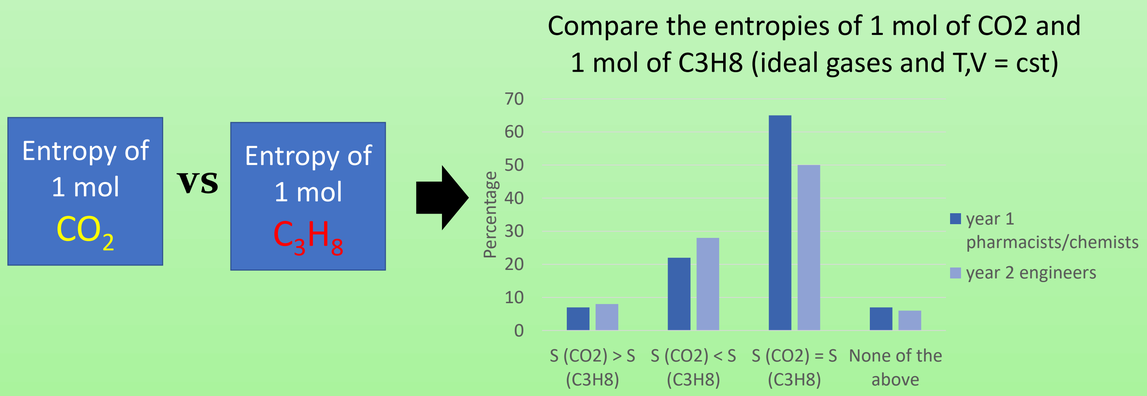
- AC identification for 1st-year bachelor students in chemistry, pharmacy and geology and 2nd-year engineers at ULiège by using a questionnaire (multiple choice + open-ended questions) before and after a one-semester course (pre-test, post-test).
- Test of an innovative method to teach entropy by implementing statistical thermodynamics elements into a 1st year general chemistry thermodynamics course.

RESULTS

- Some of the identified preconceptions are comparable to those published in the literature, and new ones are detected. Some misconceptions are rather of ontological nature whereas other ones result from inappropriate interpretation of analogies.
- As far as 1st-year bachelor students are concerned, the results indicate that most erroneous conceptions remained after the one-semester course and that some were even aggravated.



- Entropy is quasi-always used as synonym for position disorder, students forgetting about momentum dispersion.
- Open-ended questions show a great diversity of misconceptions, some known, and some new.
  - ❑ e.g. stability and reactivity, order and number of bonds, collisions and size of particles, ideal gas law, …
  - ❑ Multiple causes : reference books, counter-intuition, limitation of formulas and/or models, …



- Interviews revealed more nuanced AC, and helped identify new ones.
- Preliminary results of the innovative method of teaching implemented in 2023 show that answers to the pre-test questionnaire are stable and comparable to previous 2019 and 2020 results and student feedback was positive.

PERSPECTIVES

- Further research is needed to connect the microscopic view of entropy with other thermodynamic variables and chemical equilibrium.

KEY TAKEAWAYS

1. Entropy is difficult to teach because of multiple factors, including lack of connection to microscopic POV.
2. Questionnaires targeting entropy comprehension in undergraduates show multiple alternative conceptions.
3. An innovative microscopic-approach teaching unit was developed and tested on undergrads, showing promise.

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