Testing the microscopic teaching of entropy to undergraduates to promote conceptual change

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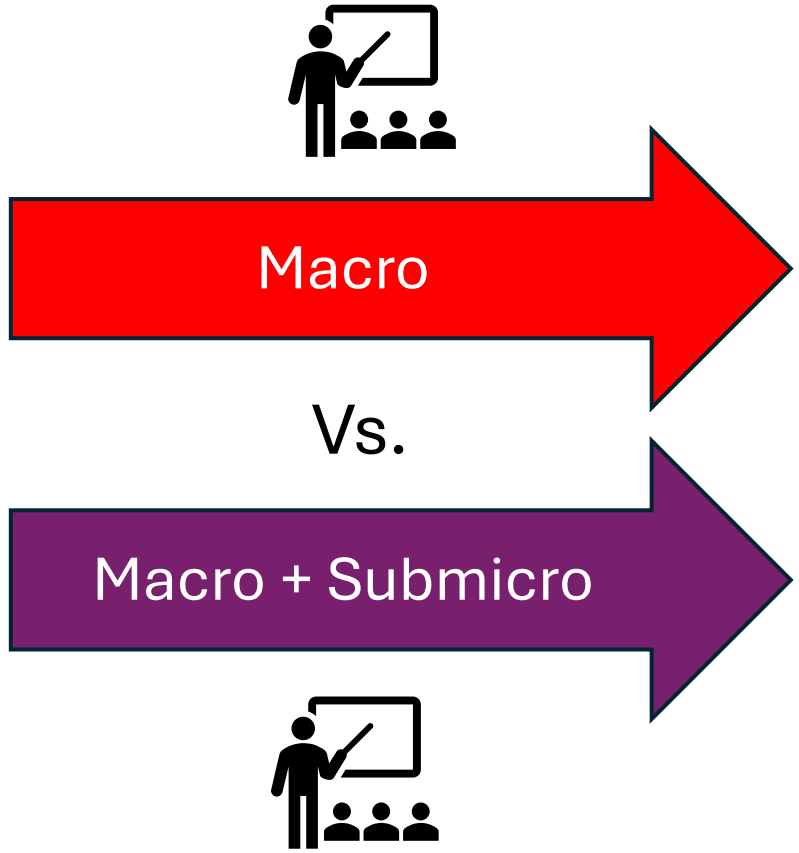


What's the context?

- Thesis work: improve the teaching of thermodynamics for undergraduates
  - Identification of alternative conceptions (AC) (previous Sig 03 meeting)
  - Try to curb them (this presentation)

- Mix of chemistry education and conceptual change

Why is this research important?

- Entropy is challenging to teach for many reasons
  - Asbtraction
  - Emergence
  - Disorder metaphor
  - …
- Review shows that **<10%** of articles test their teaching method in chemistry/physics education
- Important conceptual « leap » of emergence

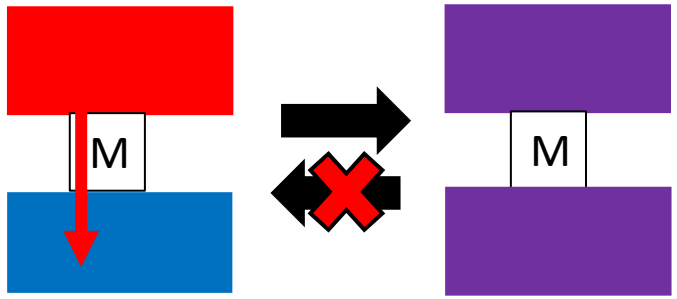
Natalis & Leyh (n.d.)

What is entropy?

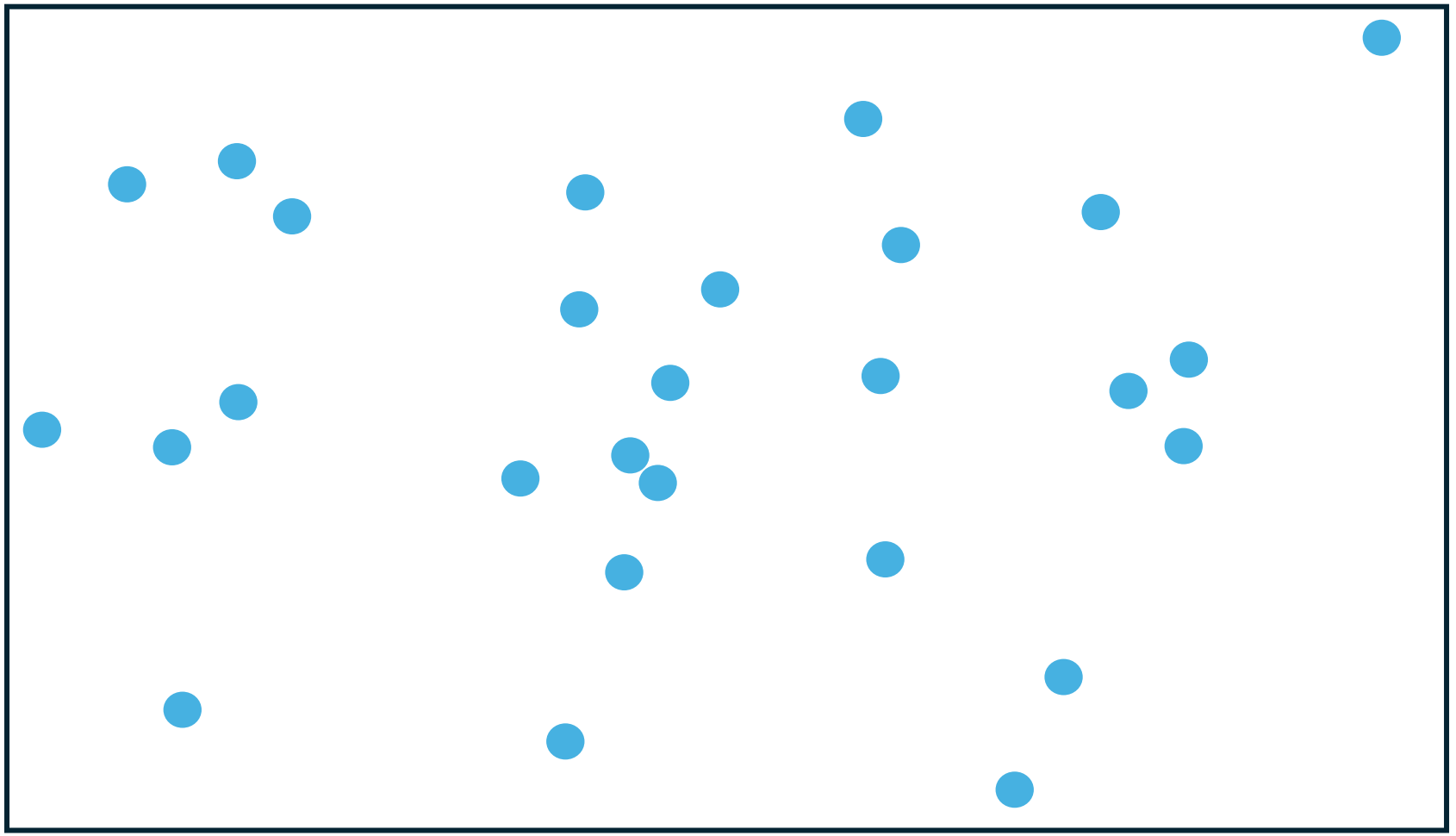
Fundamental concept in thermodynamics = the study of energy transfers

Disorder
Chaos

Energy spread, dispersal
Energy quality

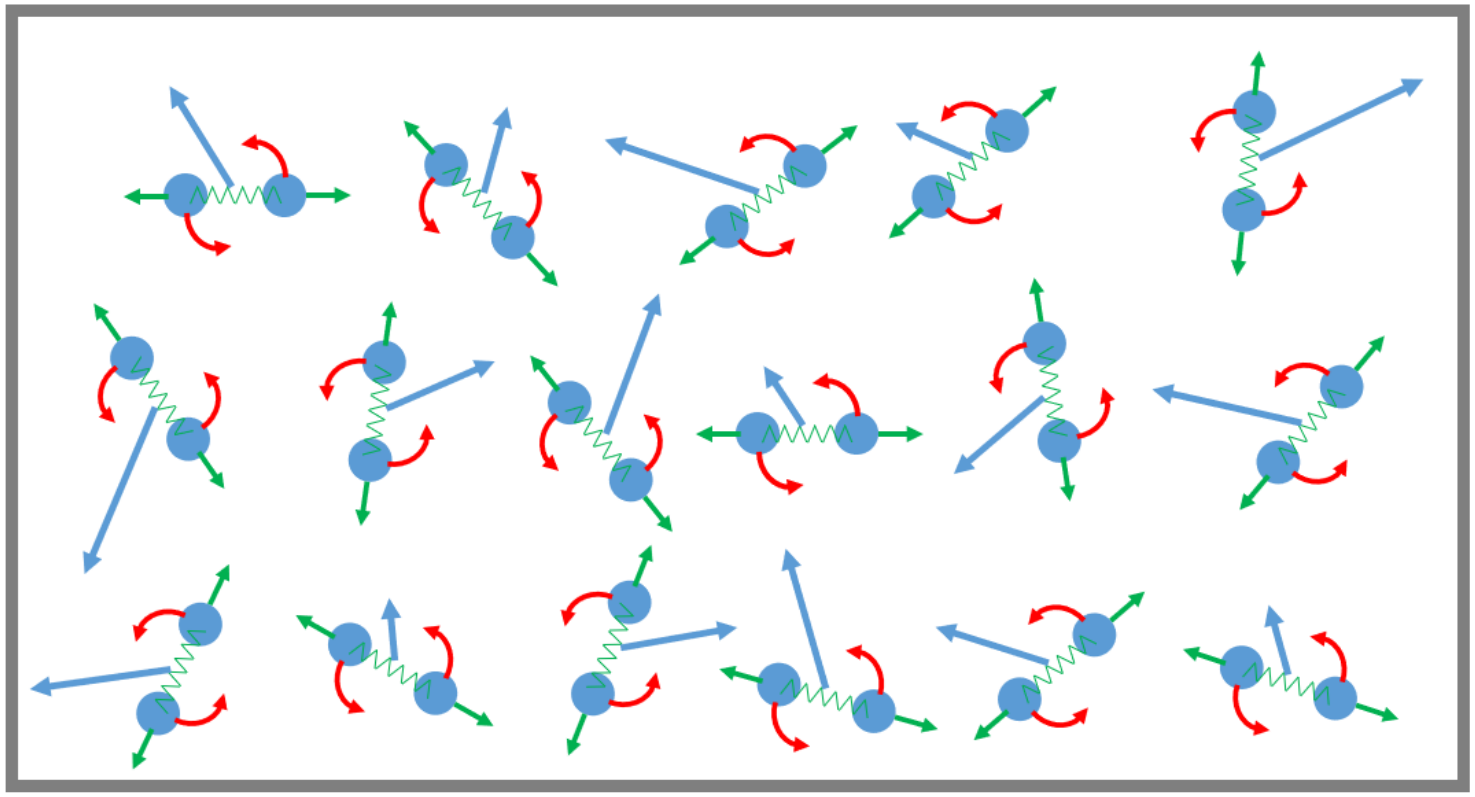


What is entropy?



$O_{2\,(g)}$

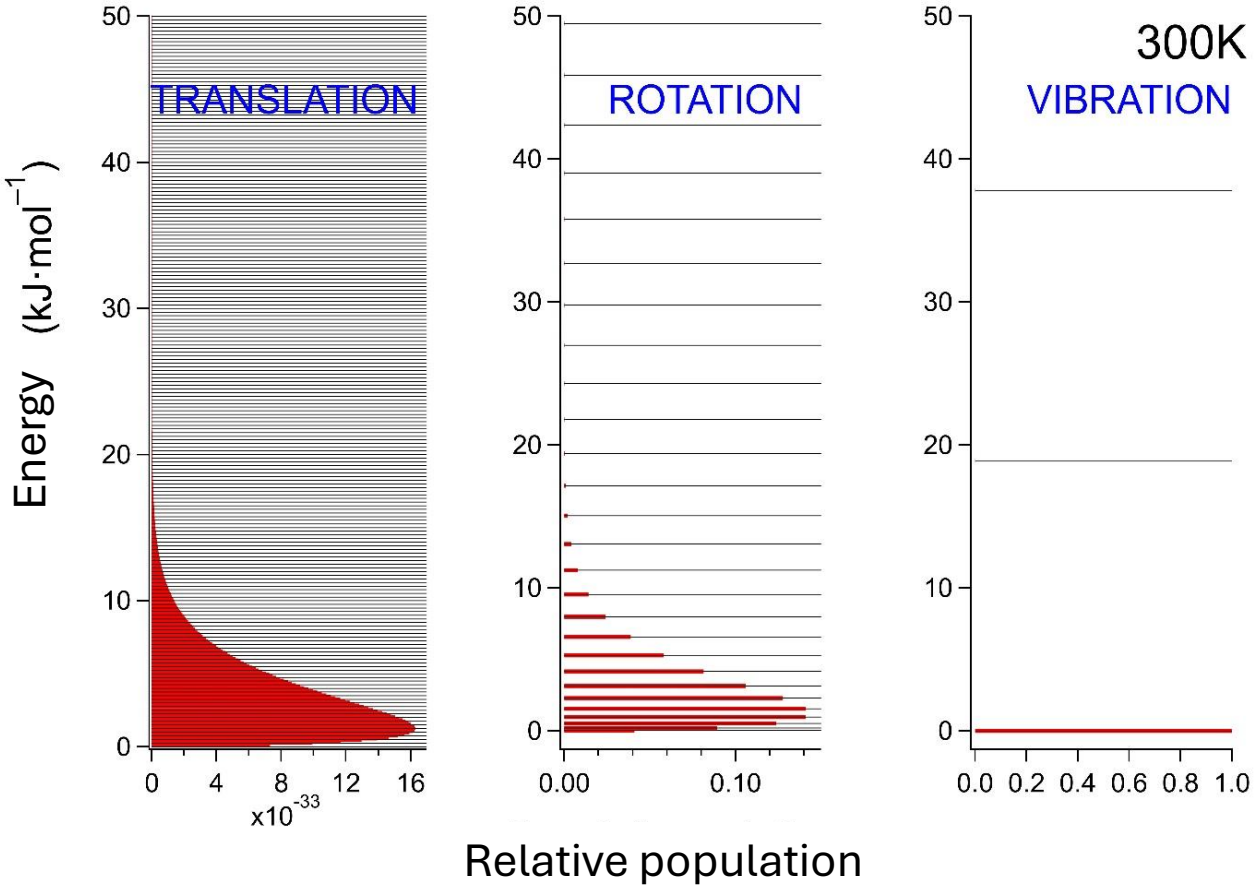
What is entropy?



$$S_{total} = S_{translation} + S_{rotation} + S_{vibration}$$

$O_{2\,(g)}$

What is entropy?



$O_{2\,(g)}$

Our version of conceptual change

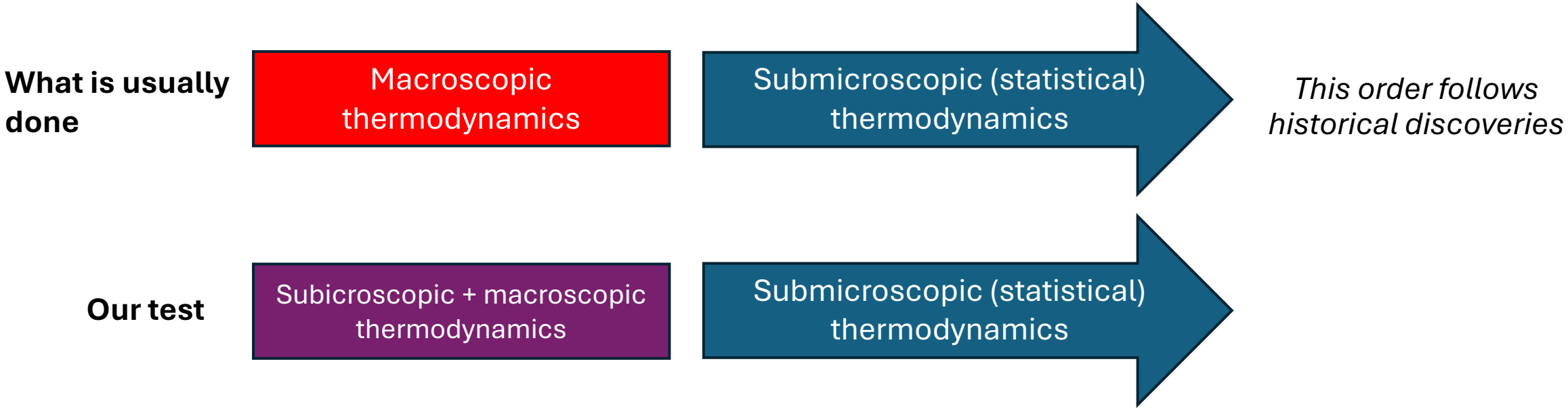
- Most influential: Vosniadou's framework theory & Potvin's conceptual prevalence

- ACs are underlying, robust rationales of students

  >< *most use of ACs in chemistry education research*

- Two competing, valid representations (submicro and macro) that
  - Have the same range of validity
  - But different practical utility

What we tested: introduce micro first



What is the impact on entropy AC of an early nearly mathematics-free introduction of submicroscopic concepts?

Research method

- Conceptual questionnaire: 2 MCQ + 5 MCQ with justification to identify AC
- Macroscopic first-year course for pharmacists, geologists, chemists
- Pre-post design, control-intervention design with baseline verification
- Complementary teaching (~~replacement~~)
- Participants: $N_{test} = 98$, $N_{control} = 87$

The difference between test and control

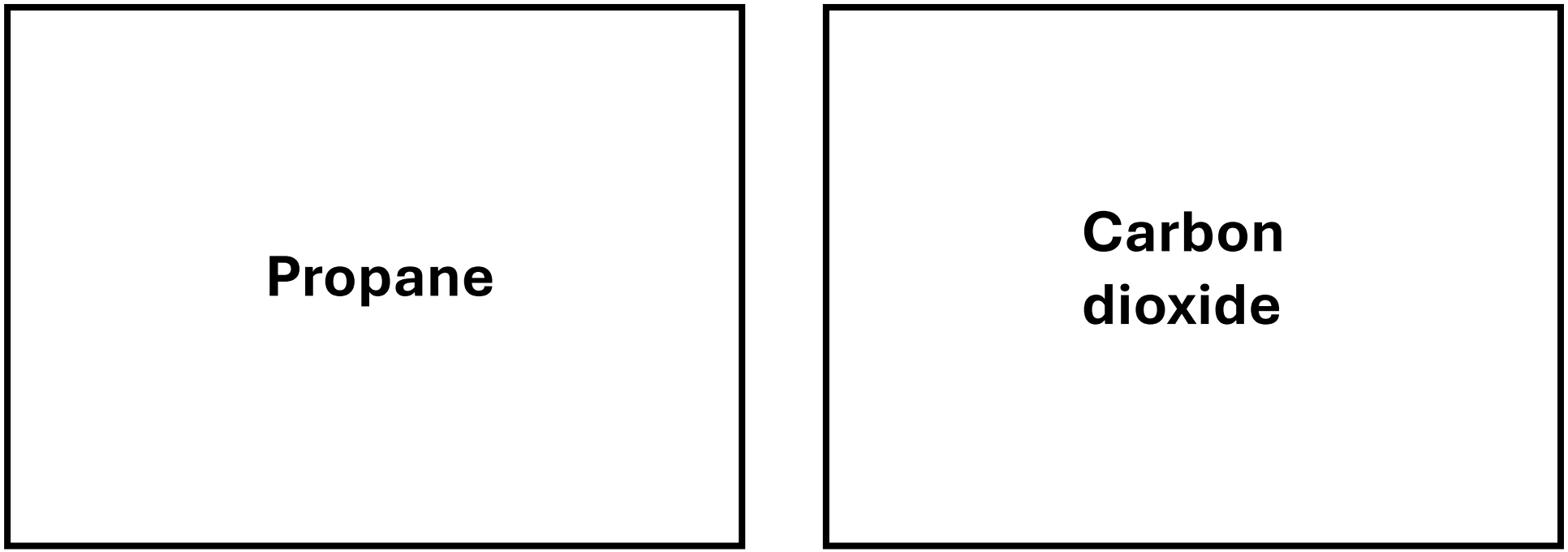
	Control	Test
Lectures	30 hours	30 hours + 2 hours on entropy
Exercises tutorials	18-24 hours	18-24 hours with one modified session (2 hours)
Laboratories	36 hours	36 hours + one homework

What are the alternative conceptions of entropy?

	MCQ with no justification		*MCQ with justification*				
			Gases questions			Phase change questions	
	Definitions	**Isolated Closed**	**CO_2 vs propane**	**Noble gases**	**Mixing gases**	**Seawater**	**Supercooled liquid**
AC-disorder	X		X	X	X	X	X
AC-spatial			X	X	X	X	X
AC-universe1		X					
AC-increase1		X					X
AC-increase2		X					
AC-isolated		X					
AC-pure					X	X	
AC-energy	X		X	X	X	X	X
AC-speed						X	
AC-mixing					X		
AC-substance			X	X			
AC-levels			X	X			
AC-collisions			X		X		
AC-freedom			X	X	X		
AC-stability			X	X			
AC-ordering						X	

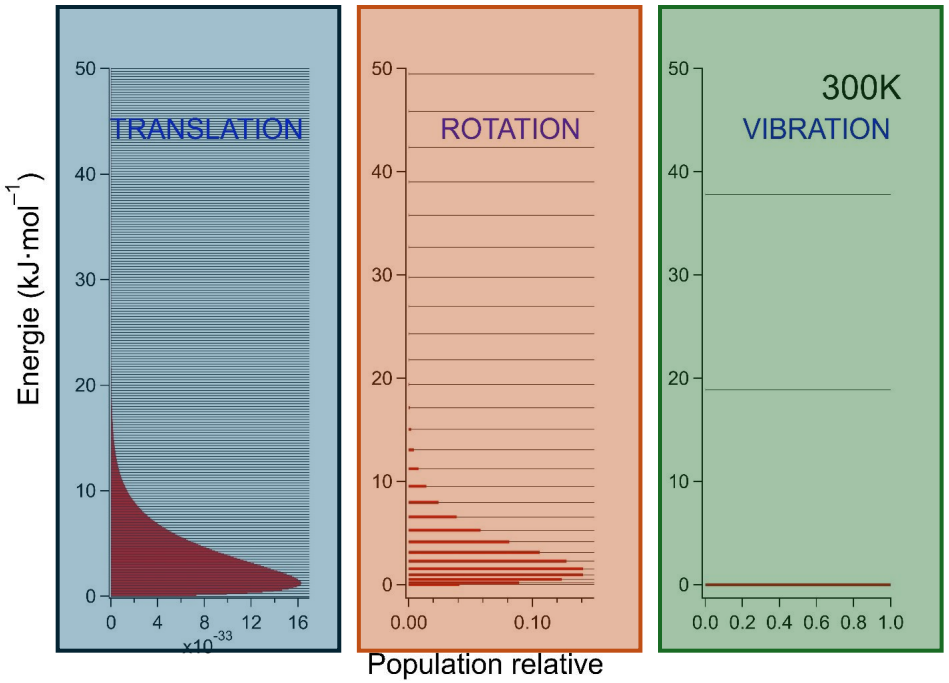
Entropy is independent of the internal structure of the pure substance contained in a system

One example question

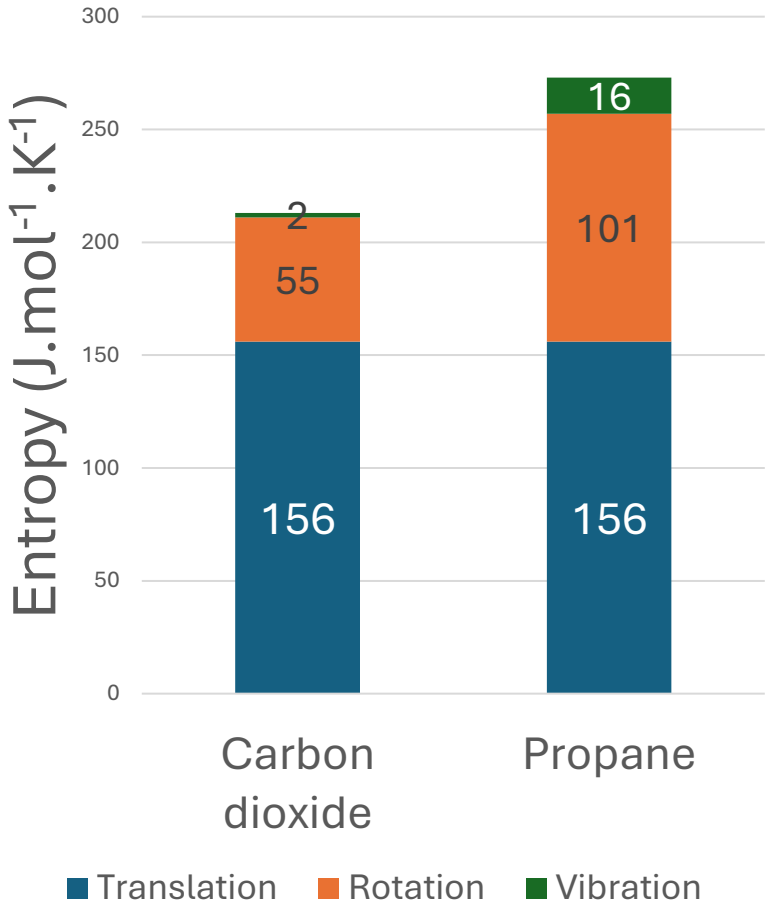


Carbon dioxide (CO_2) and propane (C_3H_8) have the same molecular weight. Assume two closed, non-deformable and identical chambers. One contains 1 mole of CO_2 and the other 1 mole of C_3H_8. The two gases are at the same temperature. How do the entropies of the two gases compare? Assume the gases are ideal. Adapted from (Sözbilir & Bennett, 2007)

One example question



Correct answer



Results: baseline equivalence

Conceptual questionnaire score
General chemistry, part 1
Socio-economic index
Weekly science hours in secondary school
Weekly latin hours in secondary school

Indicators all non statistically different

Weekly math hours in secondary school

→ Slighlty statistically different
M_C = 5.3 hours/week
M_T = 5.9 hours/week

Results: overview

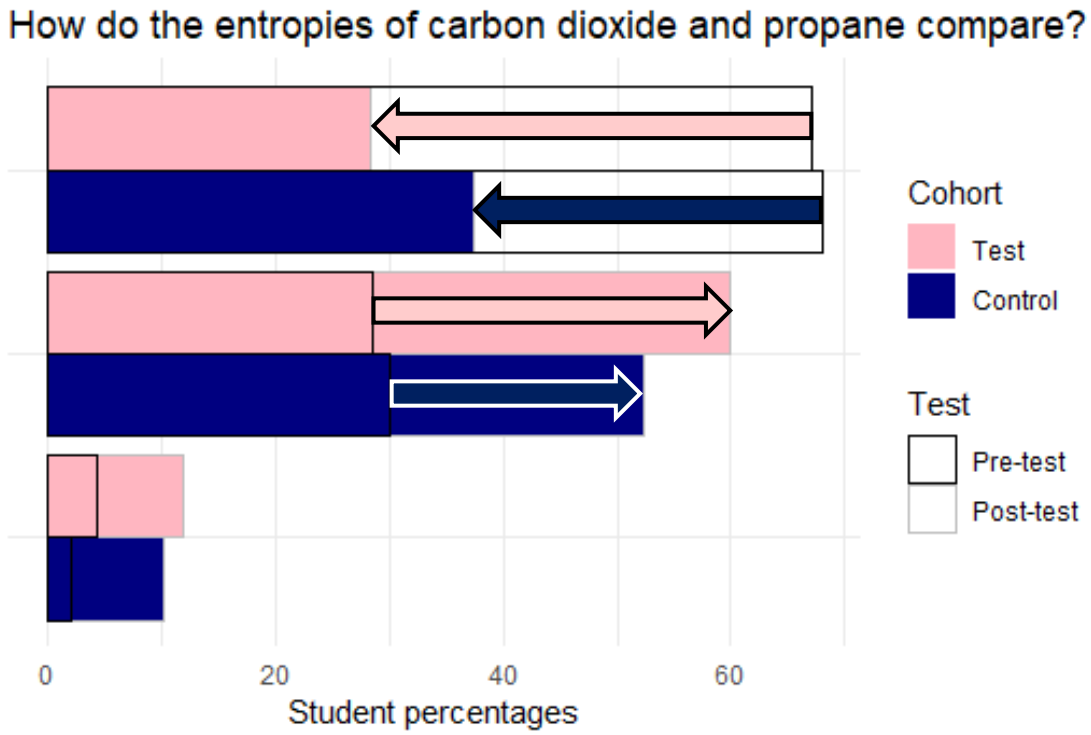
- Quantitative: d_{ppc2} = **0.2**, small *(indicative, unvalidated questionnaire)*

- Qualitative: improvement of AC-substance without worsening other AC

Results: AC-substance

Incorrect answer
(= AC-substance?)

Correct answer
(= correct conception?)



Φ = -0.38

Φ = -0.29

Φ = 0.30

Φ = 0.21

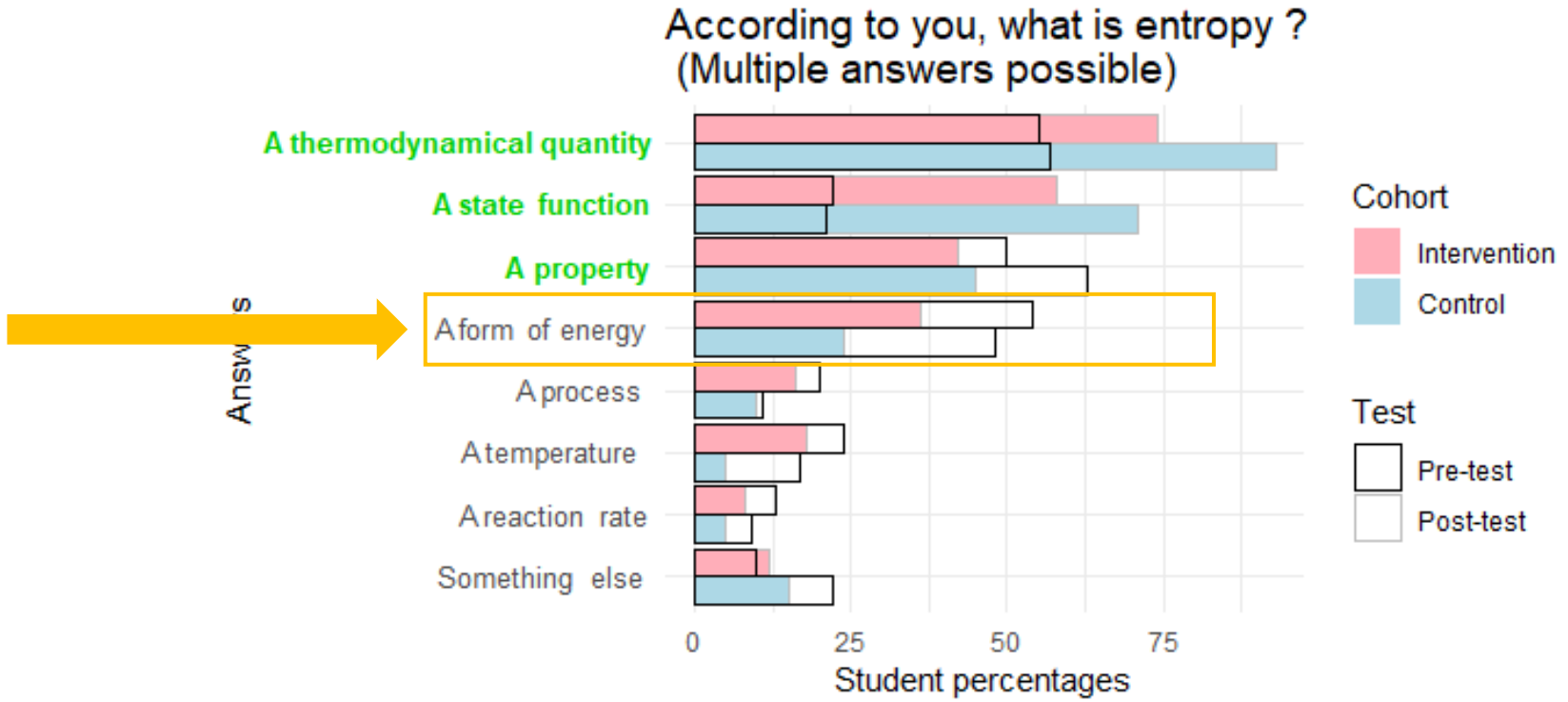
Discussion: impact on other ACs

	MCQ with no justification		*MCQ with justification*				
			Gases questions			Phase change questions	
	Definitions	**Isolated Closed**	**CO_2 vs propane**	**Noble gases**	**Mixing gases**	**Seawater**	**Supercooled liquid**
AC-disorder	X		X	X	X	X	X
AC-spatial			X	X	X	X	X
AC-universe1		X					
AC-increase1		X					X
AC-increase2		X					
AC-isolated		X					
AC-pure					X	X	
AC-energy	X		X	X	X	X	X
AC-speed						X	
AC-mixing					X		
AC-substance			X	X			
AC-levels			X	X			
AC-collisions			X		X		
AC-freedom			X	X	X		
AC-stability			X	X			
AC-ordering						X	

Entropy is a form of energy

Discussion: impact on other ACs

Example: is AC-energy be impacted by microscopic teaching ?



Limitations

- Addition and not replacement ➔ needs further testing
- Convenience randomization (family names)
- Undesired transmission between control and test

Perspectives and conclusion

- **Main result**: use of micro elements in a macro course shows improvement on one micro AC and no worsening of other AC
- **Next step**: improve a full thermodynamics course using alternative conceptions knowledge (1st law + 2nd law)
- **About the method**: improve diversity of method, and try a control-intervention design with replacement
- **About tertiary education CC research**: complexity of high-level concepts & loads of teacher/course constraints

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