Student Ideas Regarding Entropy

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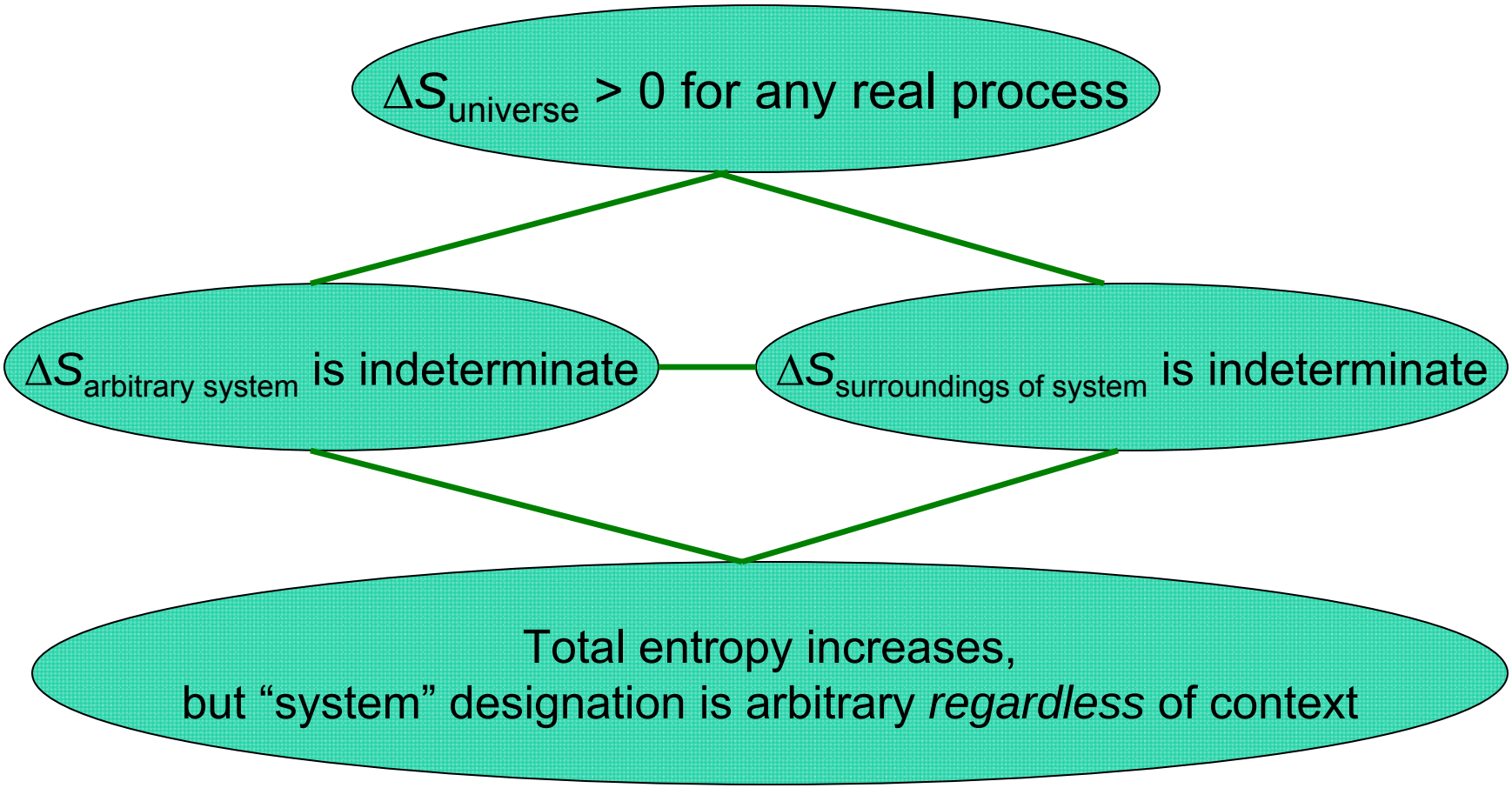
Student Ideas Regarding Entropy

- Students' thinking regarding entropy and the second law of thermodynamics was probed in an introductory calculus-based physics course.

- A variety of diagnostic questions were administered before and after instruction over a period of two years. Here we highlight responses to two separate sets of questions, one set in a "general context" and the other in a "concrete context."

Entropy-Increase Target Concepts



General-Context Question

[Introductory-Course Version]

For each of the following questions consider a system undergoing a naturally occurring ("spontaneous") process. The system can exchange energy with its surroundings.

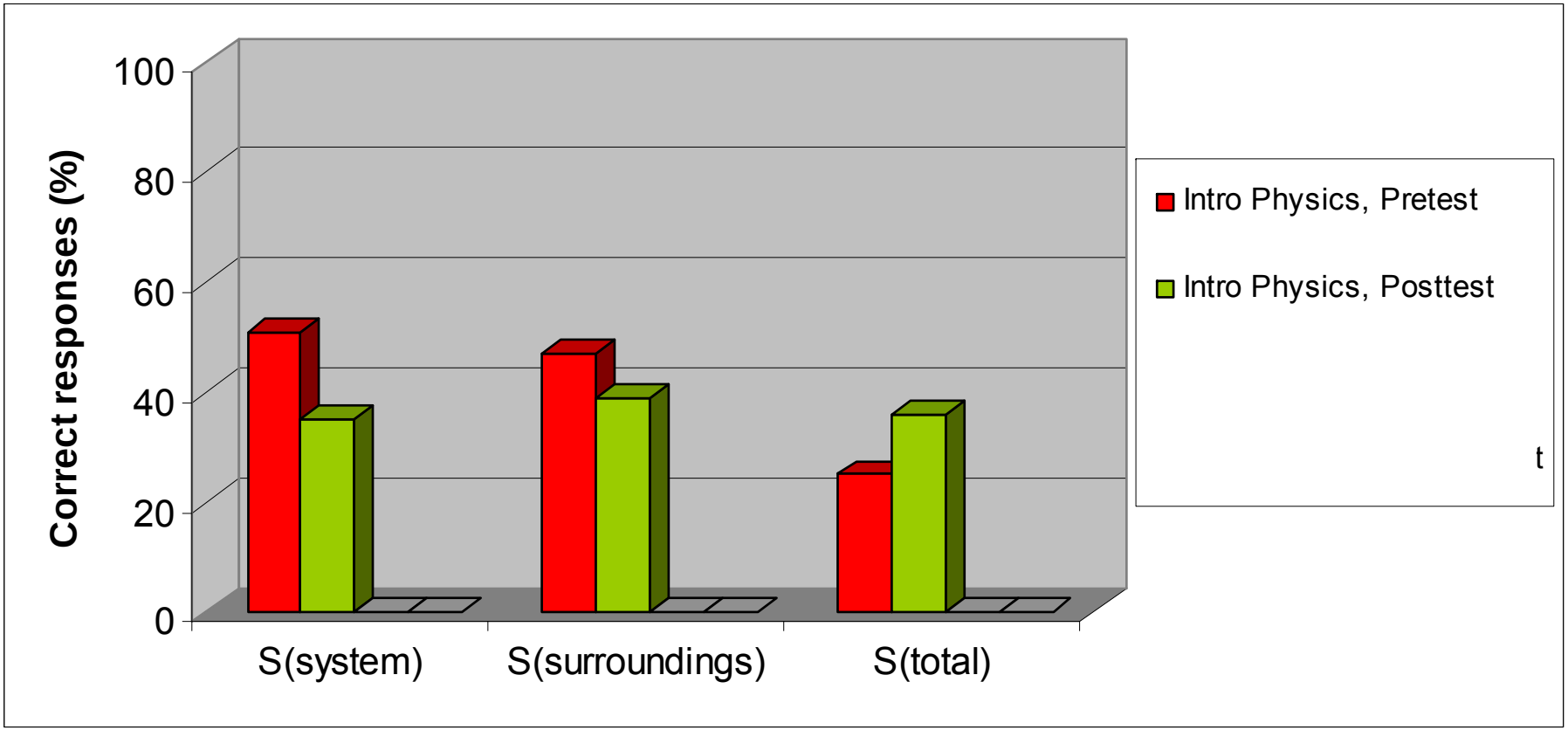
A. During this process, does the entropy of the **system** [S_{system}] *increase*, *decrease*, or *remain the same*, or is this *not determinable* with the given information? ***Explain your answer.***

B. During this process, does the entropy of the **surroundings** [$S_{surroundings}$] *increase*, *decrease*, or *remain the same*, or is this *not determinable* with the given information? ***Explain your answer.***

C. During this process, does the entropy of the system *plus* the entropy of the surroundings [$S_{system} + S_{surroundings}$] *increase*, *decrease*, or *remain the same*, or is this *not determinable* with the given information? ***Explain your answer.***

Responses to General-Context Questions

before … and *after* instruction…



Little change on post-test

Introductory Physics Students' Thinking on Spontaneous Processes

- Tendency to assume that "system entropy" must *always* increase

- Slow to accept the idea that entropy of system plus surroundings ***increases***

  - *Most students give incorrect answers to all three questions*

"Concrete-Context" Question

An object is placed in a thermally insulated room that contains air. The object and the air in the room are initially at different temperatures. The object and the air in the room are allowed to exchange energy with each other, but the air in the room does not exchange energy with the rest of the world or with the insulating walls.

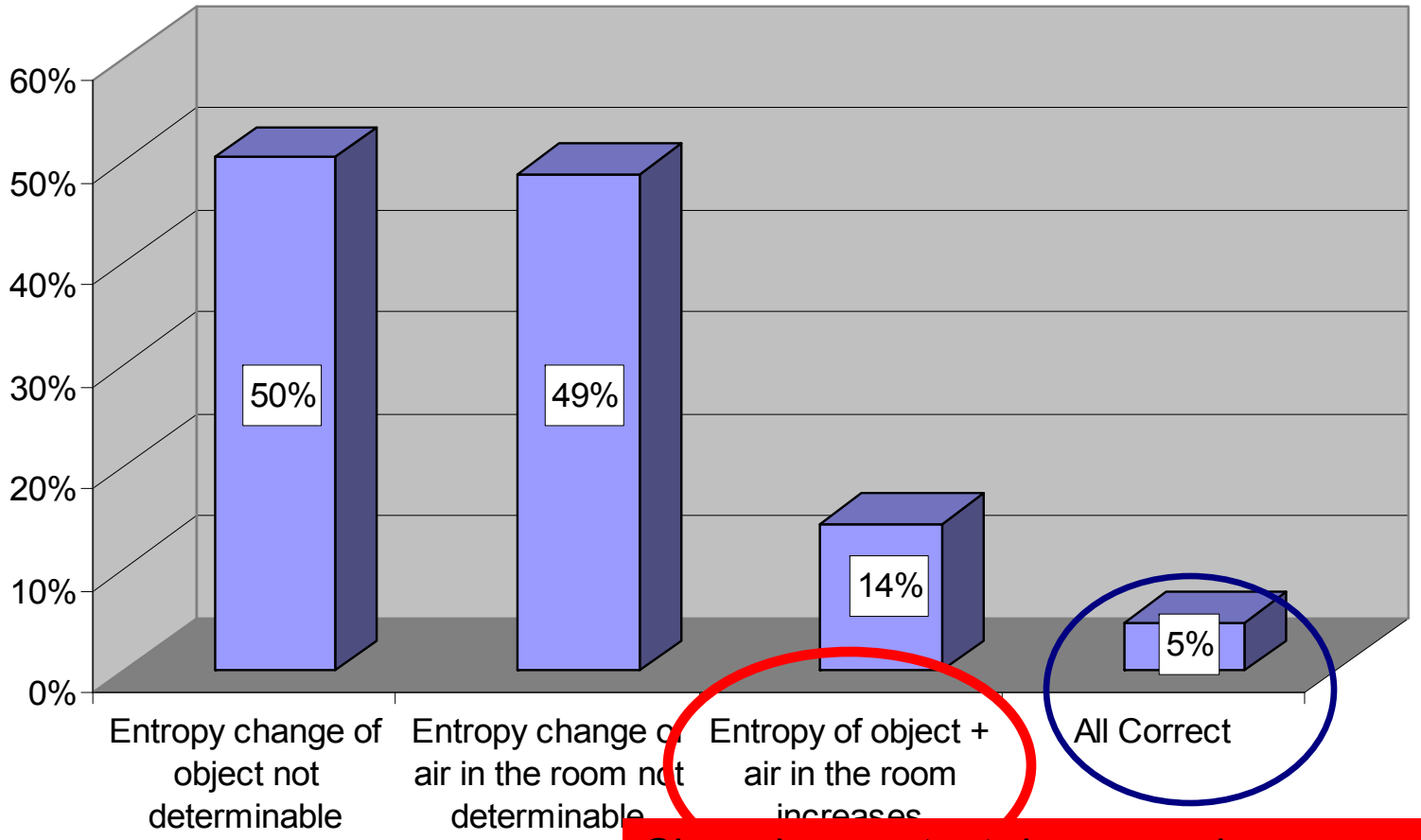
A. During this process, does the entropy of the **object** [S_{object}] *increase*, *decrease*, *remain the same*, or is this *not determinable* with the given information? ***Explain your answer.***

B. During this process, does the entropy of the **air in the room** [S_{air}] *increase*, *decrease*, *remain the same*, or is this *not determinable* with the given information? ***Explain your answer.***

C. During this process, does the entropy of the object *plus* the entropy of the air in the room [$S_{object} + S_{air}$] *increase*, *decrease*, *remain the same*, or is this *not determinable* with the given information? ***Explain your answer.***

Responses to Concrete-Context Questions

Correct Responses *(N = 609)*



Changing context does *not* change results

“Total entropy” responses

- Nearly two-thirds of all students responded that the “total entropy” (“system plus surroundings” or “object plus air”) remains the same.
- We can further categorize these responses according to the ways in which the other two parts were answered
- 90% of these responses fall into one of two specific conservation arguments:

Conservation Arguments

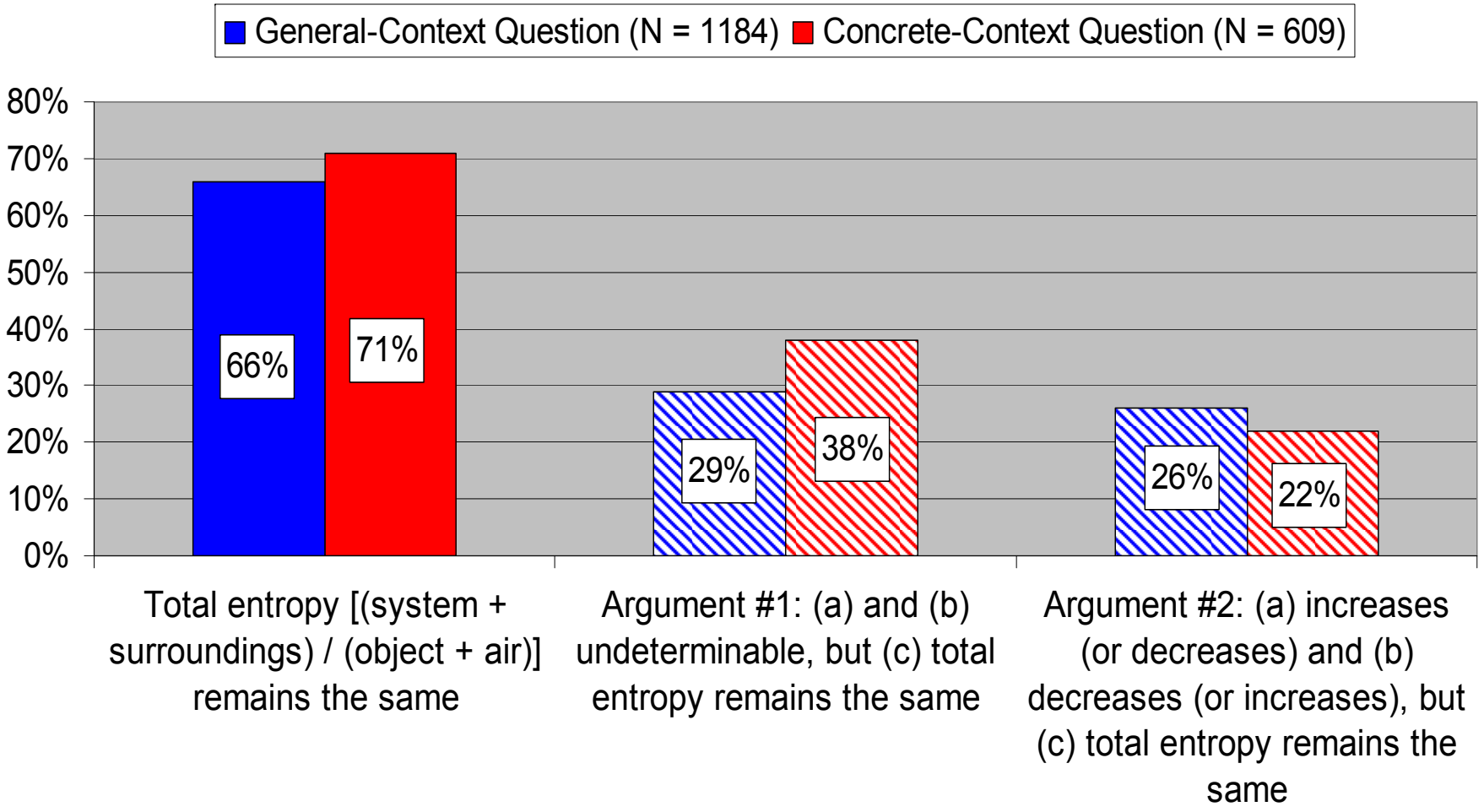
Conservation Argument #1

ΔS_{System} not determinable,
$\Delta S_{Surroundings}$ not determinable, and
$S_{System} + S_{Surroundings}$ stays the same

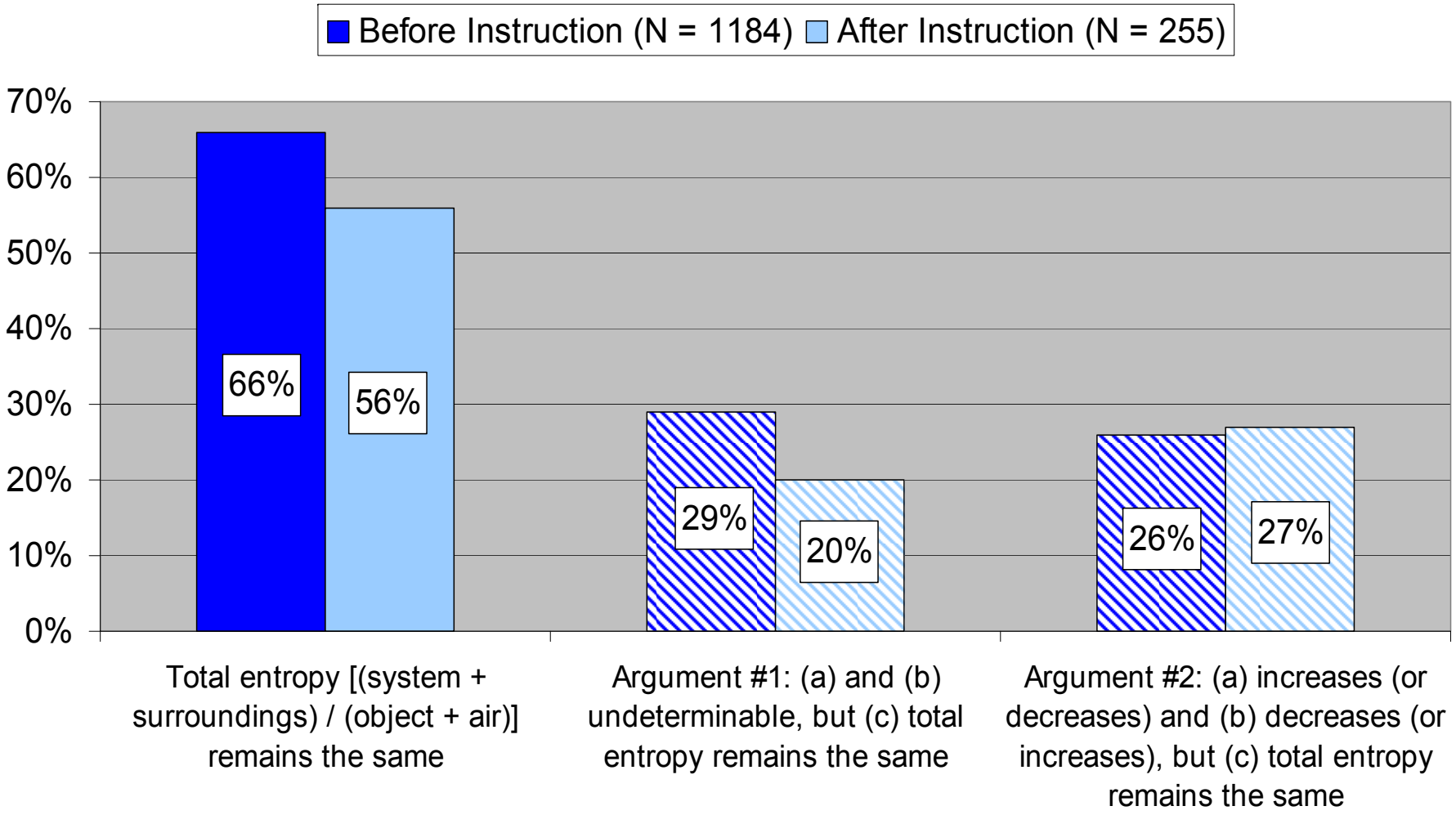
Conservation Argument #2

S_{System} increases [*decreases*],
$S_{Surroundings}$ decreases [*increases*], and
$S_{System} + S_{Surroundings}$ stays the same

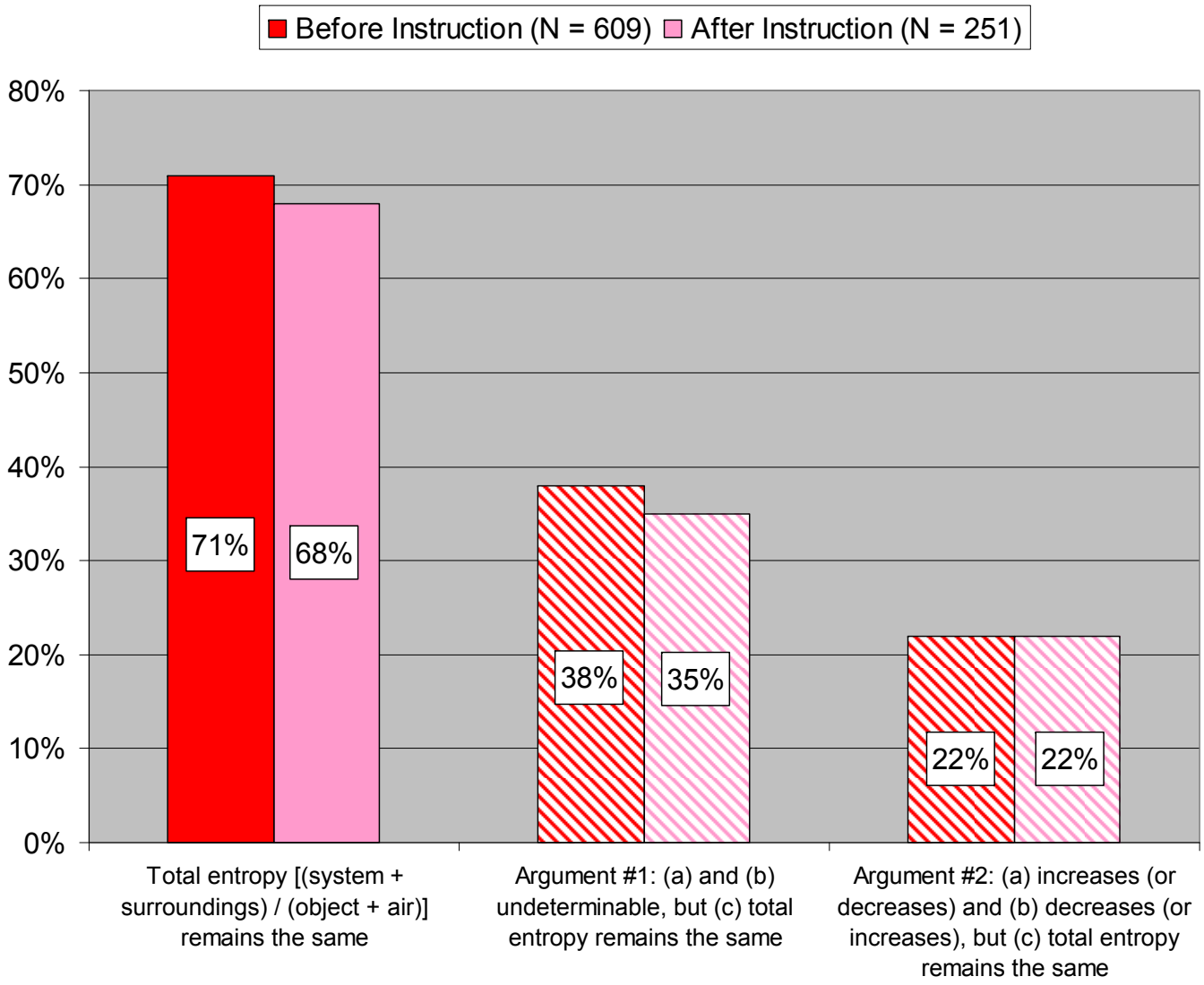
Pre-Instruction Responses Consistent with Entropy "Conservation"



General-Context Question Pre-Instruction vs. Post-Instruction



Concrete-Context Question, Pre-Instruction vs. Post-Instruction



Findings from Entropy Questions

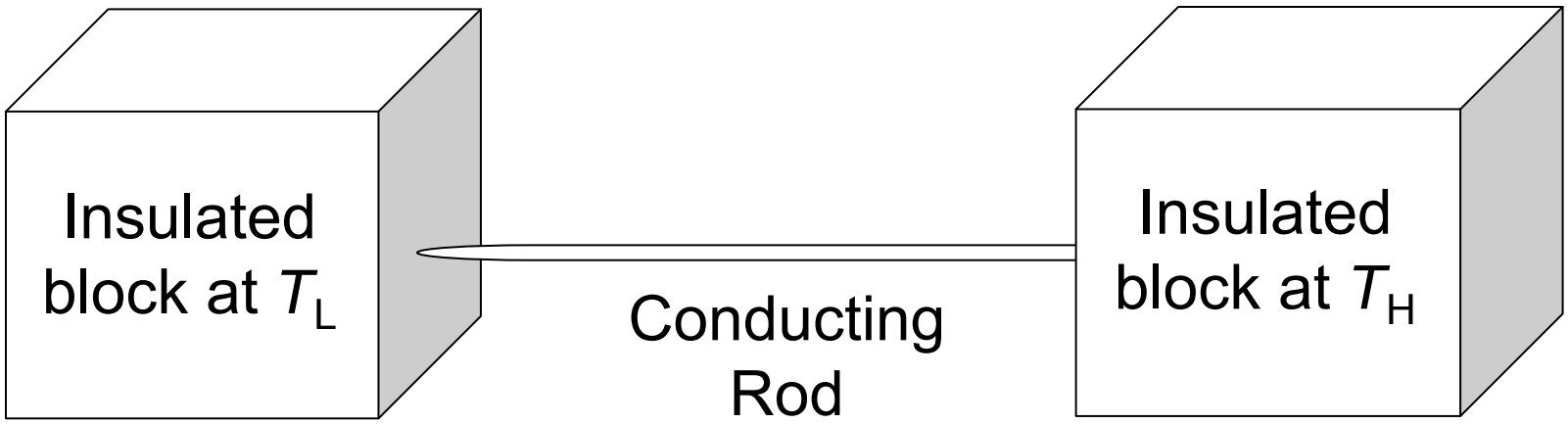
Both before and after instruction…

In both a general and a concrete context:

- Introductory students have significant difficulty applying fundamental concepts of entropy
- More than half of all students utilized inappropriate conservation arguments in the context of entropy

“Two-Blocks” Entropy Tutorial

(draft by W. Christensen and DEM, undergoing class testing)



- Consider slow heat transfer process between two thermal reservoirs (insulated metal block connected by thin metal pipe)
  - ➢Does total energy change during process? *[No]*
  - ➢Does total entropy change during process? *[Yes]*

Entropy Tutorial

(draft by W. Christensen and DEM, undergoing class testing)

- Guide students to find that:

  Entropy gain of low-temperature block is *larger* than entropy loss of high-temperature block, so *total entropy increases*

  and that definitions of “system” and “surroundings” are arbitrary

  Preliminary results are promising…

Responses to General-Context Question
Introductory Students