Student Thinking Regarding Entropy and the Second Law of Thermodynamics *

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*Supported in part by NSF grants #DUE-9981140 and #PHY-0406724.

Context of Investigation

- Part of a broad study of student understanding of thermodynamics in a second semester calculus-based physics course at Iowa State University
- In collaboration with John Thompson at the University of Maine and David Meltzer at the University of Washington in upper-level thermal physics courses

Pre-instruction Testing

- Initial testing took place before all instruction on entropy and the second law of thermodynamics

Spontaneous Process Question

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.***

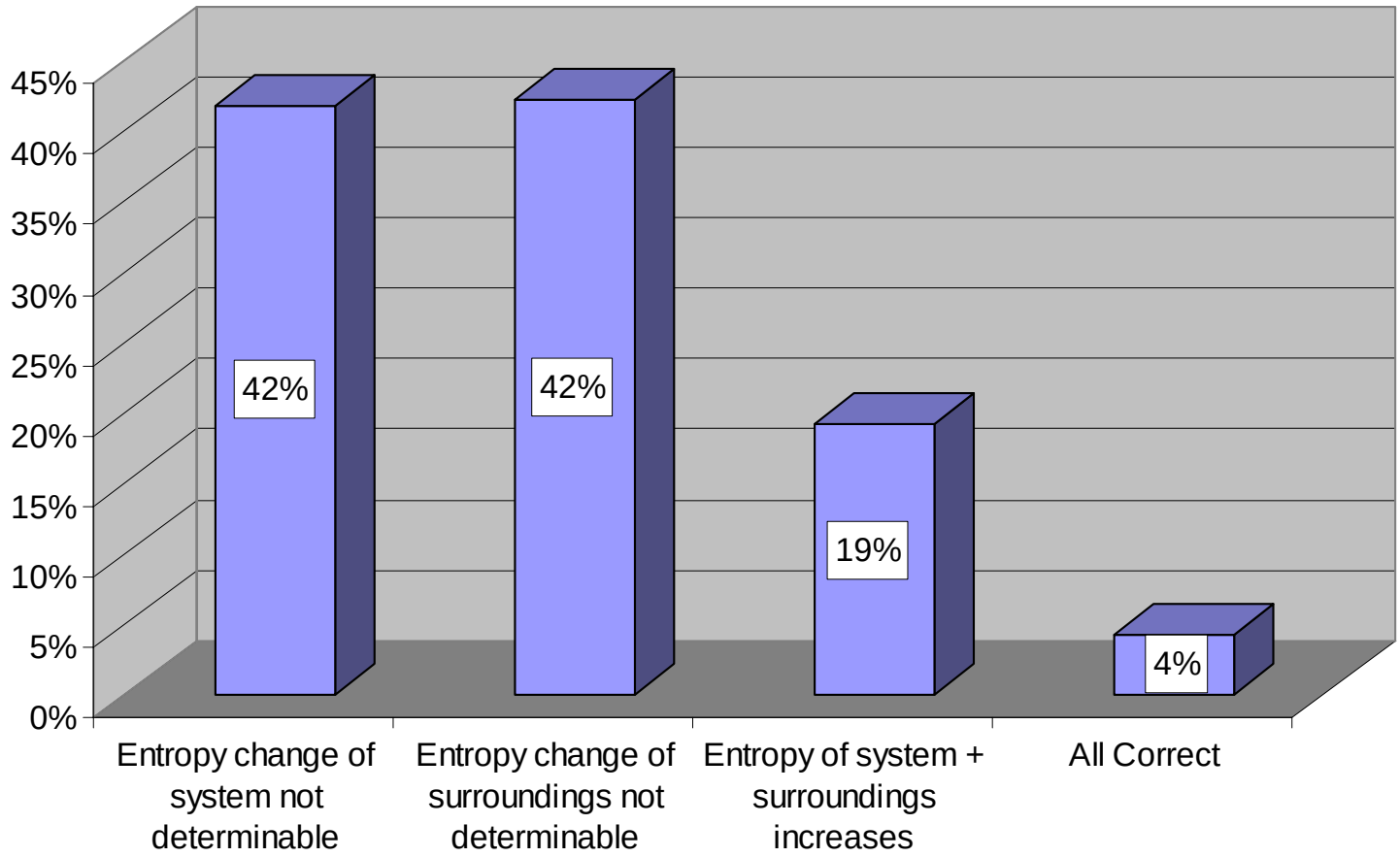
B. During this process, does the entropy of the **surroundings** [$S_{surroundings}$] *increase*, *decrease*, or *remain the same*, or is this *not determinable* with the given information? ***Explain your answer.***

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.***

Pre-instruction Data

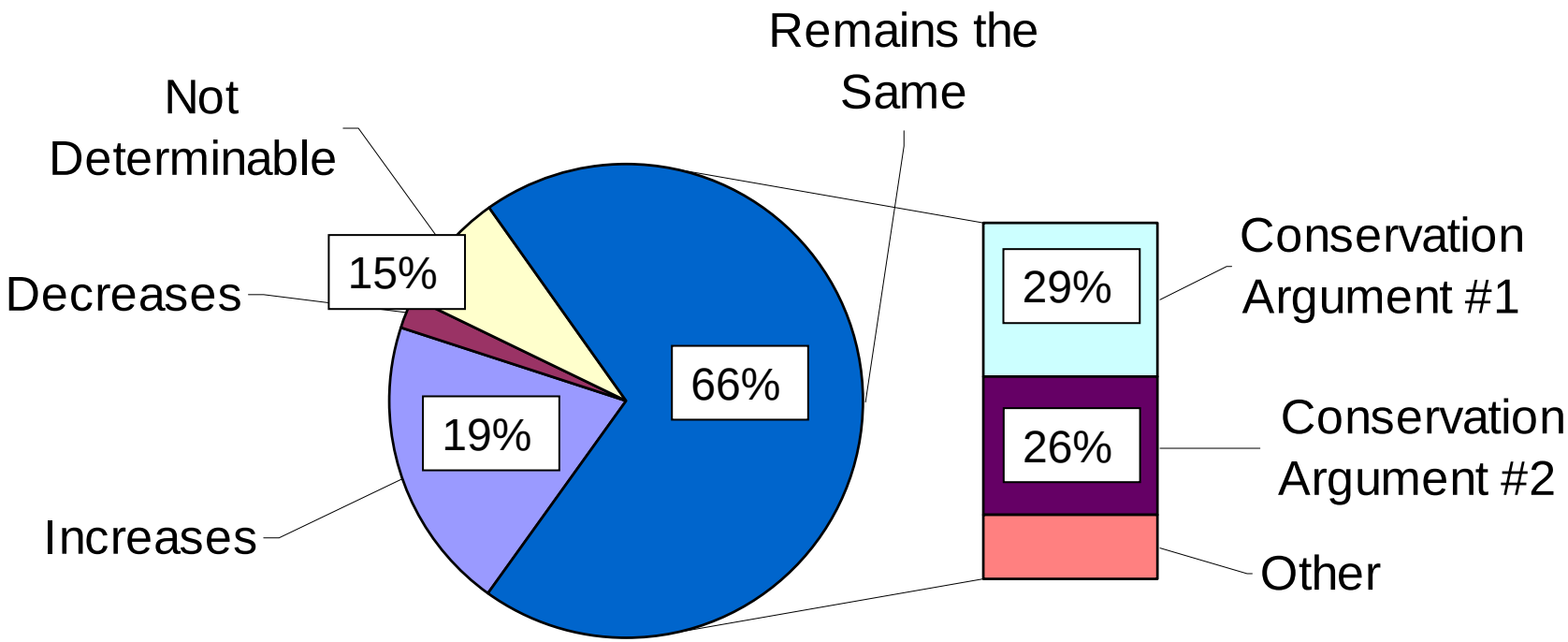
Correct Responses

Fall 2004, Spring 2005, Fall 2005, Spring 2006 (*N* = 1184)



Entropy of system + surroundings…

Fall 2004, Spring 2005, Fall 2005, Spring 2006 (*N* = 1184)



Conservation Arguments

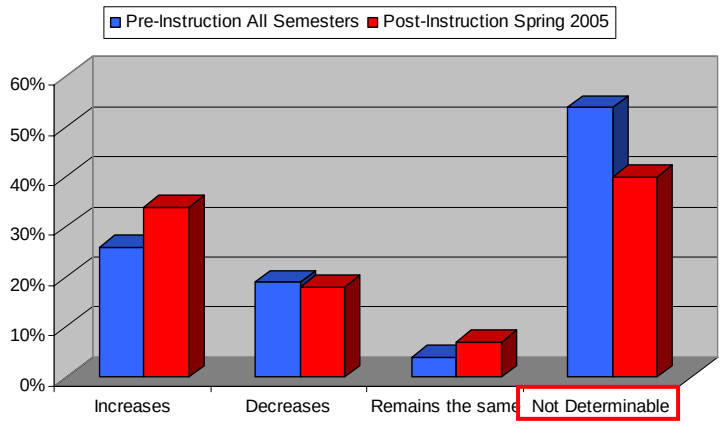
- **Conservation Argument #1 (29%)**

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

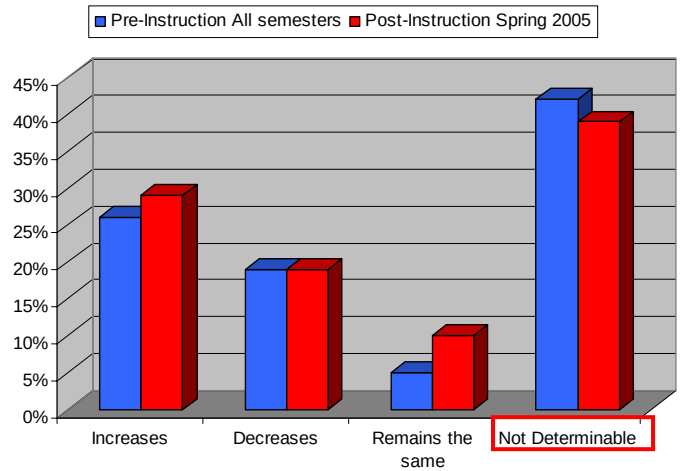
- **Conservation Argument #2 (26%)**

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

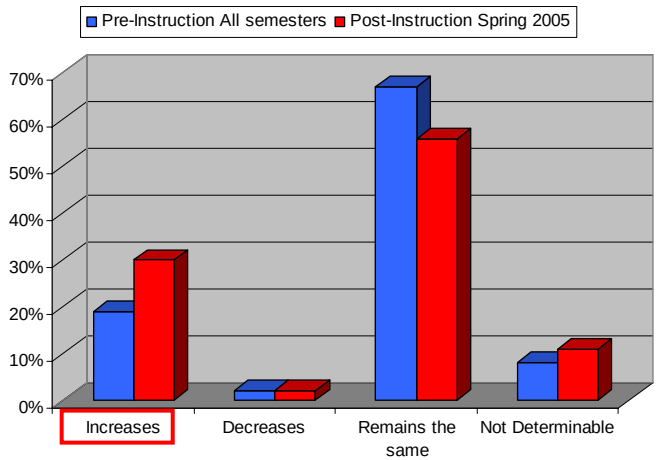
Pre- v. Post-Instruction Data



Entropy of the system...



Entropy of the surroundings...



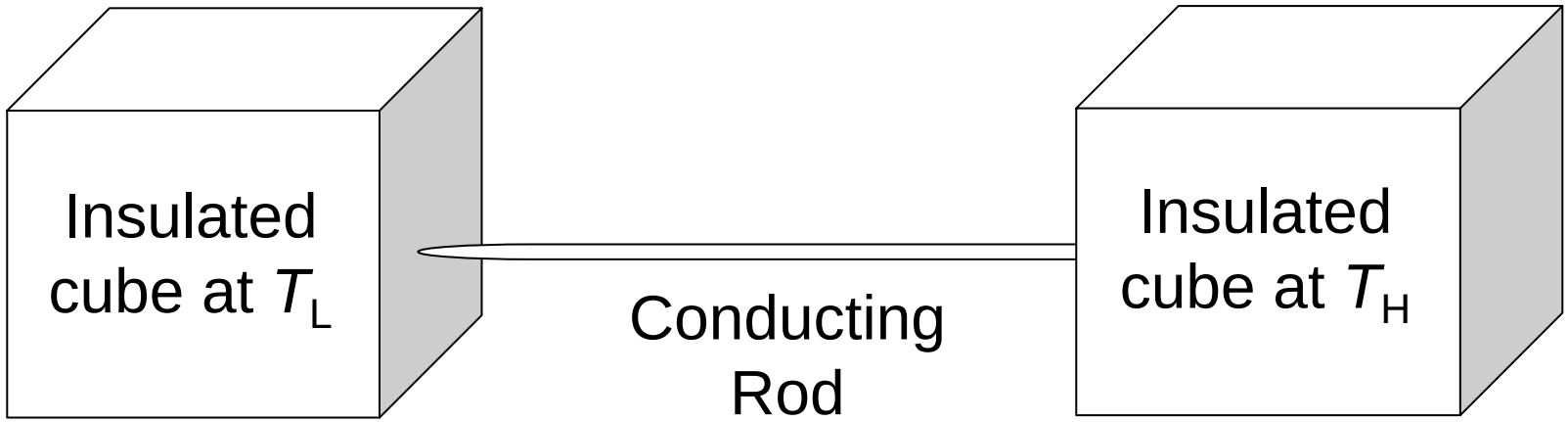
Entropy of the system + surroundings..

Post-instruction testing showed small or negative gains

A Research-based Tutorial

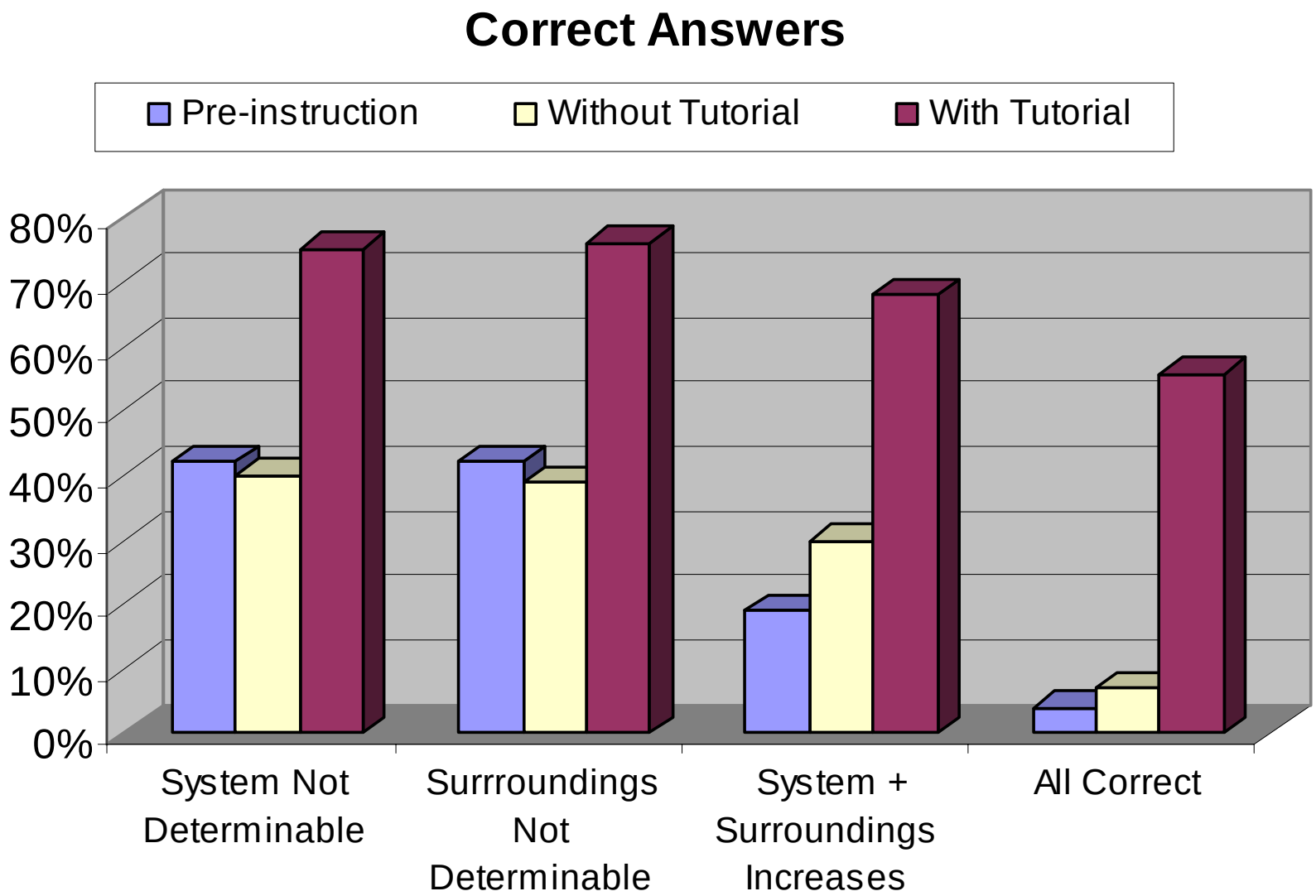
- We created a worksheet to address these ideas for use in the Spring 2006 course.

Tutorial Design



- Identify Q_H, Q_L, and discuss energy conservation
- Calculate ΔS_H, ΔS_L, compare the magnitudes, and deduce entropy non-conservation

Pre/Post-instruction comparison



Conclusions

- Before instruction students often apply ideas about energy conservation to entropy
- Instruction with tutorials showed improved responses from students for some questions
- This instruction is still in the early stages of testing and many questions are yet to be answered