Investigations of Student Understanding of Heat and Temperature

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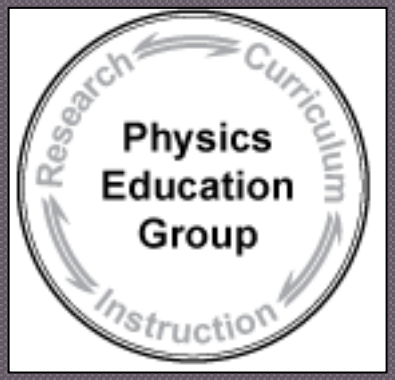
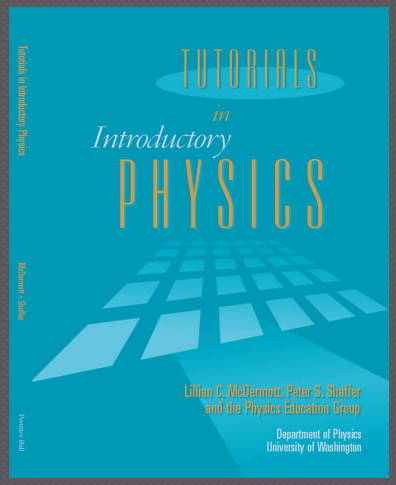


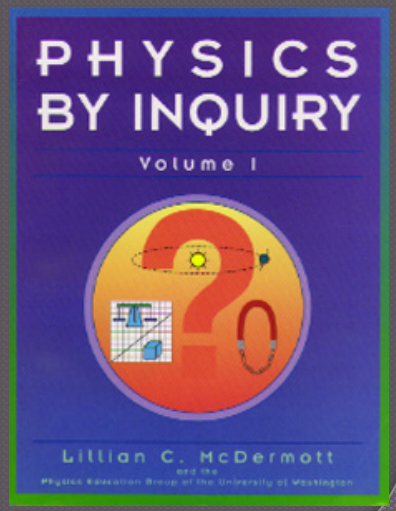
Investigations of Student Understanding of Heat and Temperature

- PEG- An Introduction to the Physics Education Group
- Student Understanding of Thermal Equilibrium
- Suggestions for Future Research

Introduction to PEG

- "Teaching by telling" is an ineffective approach to physics instruction
  - Many students lack a coherent conceptual understanding
  - Many incorrect understandings persist
  - Students may not gain reasoning ability
- Research, Curriculum Development, Instruction
- Two Curricula-
  - Tutorials in Introductory Physics
  - Physics by Inquiry





The NSF Summer Institute

- Structure
  - 32 pre-service and in-service K-12 teachers
  - 3 Modules
  - Heat and Temperature Unit
    - 26 Hours of Instruction
- Instruction
  - Teaching by inquiry
    - Students perform experiments, exercises in small groups
  - Check-outs with TA's
- Provides the data for this project

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- PEG- An Introduction to the Physics Education Group
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  - Prior Research
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The Cooler Question (2005)

"A block of wood and a block of aluminum, both of identical size, have been in a cooler with a bag of ice for a long time. The temperature of each block is measured with a thermometer. Is the temperature of the wood block *greater than*, *less than*, or *equal to* the temperature of the aluminum?"

Administered by Matthew Cochran in the algebra-based physics sequence at UW

- Results (N=57)
  - $T_{wood}=T_{Al}$ 45%✔
  - $T_{wood}>T_{Al}$ 25%
  - $T_{wood}<T_{Al}$ 30%

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- PEG- An Introduction to the Physics Education Group
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  - Prior Research
  - First Research Task
- Suggestions for Future Research

The Ruler Question (2011)

A student takes a metal ruler and a wooden ruler from his pencil case. He notices that the metal one feels colder than the wooden one. Explain why.

- Administration
  - Second day of class- all students had completed section of module which showed that everything in a room is room temp.
  - Occurred on a "pretest" but tested material from previous day.

The Ruler Question (2011)

A student takes a metal ruler and a wooden ruler from his pencil case. He notices that the metal one feels colder than the wooden one. Explain why.

- Correct Response
  - Both rulers are at the same temperature; they are in thermal equilibrium with the room.
  - Sense of touch is not a good indication of temperature.

"The two rulers, assuming they have been in the pencil case for a long time, are the same temperature. However, metal is a conductor while wood is an insulator which means that heat transfers to and from the metal more quickly than the wood. Since the ruler is colder than the student's hand, heat transfers from the hand to the ruler quickly making it feel colder. Heat still transfers from a hand to wooden ruler but at a slower rate."

The Ruler Question (2011)

A student takes a metal ruler and a wooden ruler from his pencil case. He notices that the metal one feels colder than the wooden one. Explain why.

- Results
  - Both rulers are at the same temperature; they are in thermal equilibrium with the room- 30%
  - Sense of touch is not a good indication of temperature- 60%
  - Indicated both- 25%
- Common Reasoning:
  - Conductivity of the metal- 60%
- No responses said it was actually colder

Student Ideas About Thermal Conductors

"The wooden one transfers heat to other objects more quickly than metal. Therefore the wood feels warmer because the heat transfer happened more quickly."

"The surface area in contact with any given section of your skin is greater, more energy is transferred to the metal. It is a better conductor."

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- PEG- An Introduction to the Physics Education Group
- Student Understanding of Thermal Equilibrium
  - Prior Research
  - First Research Task
  - Second Research Task
- Suggestions for Future Research

The Popsicle Question (2011)

A student takes a Popsicle out of a freezer, where he had placed it the day before. He notices that the Popsicle feels colder than the stick and concludes that the stick must be at a higher temperature than the Popsicle.
Do you agree with him? Explain your reasoning.

- Administration
  - Final exam for Summer Institute
  - Only two students had started the thermal conductivity module

The Popsicle Question (2011)

A student takes a Popsicle out of a freezer, where he had placed it the day before. He notices that the Popsicle feels colder than the stick and concludes that the stick must be at a higher temperature than the Popsicle.
Do you agree with him? Explain your reasoning.

- Results
  - Popsicle and stick are at the same temperature; they are in thermal equilibrium with the freezer- 85%
  - Sense of touch is not a good indication of temperature- 70%
  - Indicated both- 55%

Student Ideas About Specific Heat

- Confusion between specific heat and conductivity- 25%

"The popsicle feels colder because it has a lower specific heat than the stick- meaning it takes less calories per gram to raise the temp by 1°C. It is absorbing heat from the hand faster than the stick and therefore feels colder. (The change in temp is greater for the popsicle than the stick for the same amount of time.)"

"What the student may be noticing is a difference in specific heat between the ice & wood. Specific heat reflects how many calories a substance needs to raise 1g of it 1°C. It sounds like the wood needed fewer calories/g to raise its temperature which is why it felt warm. (Less heat left his fingers in his thermal exchange)."

Student Ideas About Specific Heat

- Confusion between specific heat and conductivity- 25%
  - Use of specific heat of water as specific heat of popsicle

"The popsicle feels colder than the stick because the water in the popsicle requires more calories per gram to raise its temperature (1 cal/g/C°) than the wood does (0.42 cal/g/C°)."

Student Ideas About Specific Heat

- Possible Reasons
  - Table of specific heats did not include ice
  - Module does not state how specific heat changes in phase

Temperature (degrees Celsius)	Heat capacity of one gram of water (calories/Celsius degree)
0	1.007
10	1.001
20	0.999
30	0.998
40	0.998
50	0.999
60	0.999
70	1.001
80	1.002
90	1.004
100	1.007

"The most striking feature of the preceding table is not the differences but the almost perfect equality of the numbers. We will ignore small differences, and in this module we will treat heat capacity as a constant."

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Future Research

- Conductivity
  - Probe variation in student ideas about conductivity
  - Create a pretest for Conductivity section
- Specific heat and conductivity
  - Emphasize in curriculum that specific heat does not indicate sense of touch
  - Write a pretest question
- Specific heat and phase changes
  - Add specific heat of ice to appendix
  - Discuss in module how phase changes specific heat

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