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Addressing students' reasoning difficulties in thermal physics[1]

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Recent investigations into student learning of thermal physics at the undergraduate level have shown that most students in introductory courses face significant obstacles in mastering fundamental concepts in this area. [M. E. Loverude, C. H. Kautz, and P. R. L. Heron, Am. J. Phys. **70**, 137 (2002); D. E. Meltzer, Am. J. Phys. **72**, 1432 (2004).] Results from a variety of institutions indicate that up to 80% or more of all students fail to complete introductory courses with an ability to use the first law of thermodynamics in problem solving, while related confusion with entropy and second-law concepts is also widespread. Our ongoing investigation of student learning of thermal physics at the advanced undergraduate (junior-senior) level is probing the evolution of students' reasoning as they attempt to integrate the macroscopic and microscopic /statistical viewpoints into a coherent understanding. This work confirms that difficulties with fundamental concepts persist for a majority of students at this level as well. Among the specific difficulties identified are a strong tendency to attribute state-function properties to process-dependent quantities such as heat and work, a complementary failure to recognize the state-function property of entropy in irreversible processes, and confusion regarding the application of the second law to entropy changes in non-isolated systems. I will present data that characterizes these learning difficulties in more detail and reflects their prevalence at different levels of instruction. We have been developing and testing a variety of pedagogical strategies aimed at addressing these difficulties at both the introductory and advanced undergraduate level. I will outline and discuss these strategies along with a preliminary assessment of their effectiveness, and show examples of the curricular materials that are under development.

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