Investigating and Addressing Learning Difficulties in Thermodynamics

Abstract

Study of thermodynamic principles forms a key part of the basic curriculum in many science and engineering fields. However, there are very few published research reports regarding student learning of these concepts at the college level. As part of an investigation into student learning of thermodynamics, we have probed the reasoning of students enrolled in introductory and advanced courses in both physics and chemistry at a large Midwestern university. The total sample size was over 1800 students in the physics courses alone, and approximately 90% of these students were engineering majors. Part of this work included examination of learning difficulties encountered by physics and engineering students enrolled in an upper-level (junior/senior) thermal-physics course. We used a combination of free-response diagnostic questions administered in written form, and hour-long clinical interviews with individual students in which they explained their reasoning while solving problems. We found that up to 80% of the introductory students were unable to make practical application of the first law of thermodynamics in problem solving even after instruction had been completed, and many had a seriously flawed understanding of the meaning of heat and work. In addition, a large majority retained significant confusion regarding the role of entropy within the context of the second law of thermodynamics. In many cases, part of the difficulty could be traced to interchanging the roles of state functions on the one hand with process-dependent quantities on the other, to overgeneralization of conservation principles in inappropriate contexts, or with confusion regarding the meaning of commonly used terms such as “system” and “surroundings.” We found that a majority of the upper-level students at the beginning of their course retained most of the specific learning difficulties seen among the introductory students. We have attempted to address these difficulties through learning strategies that emphasized working in small groups on research-based guided-inquiry worksheets. Our experience in probing and addressing these learning difficulties may provide insights into analogous pedagogical issues in upper-level courses in engineering which focus on the theory and applications of thermodynamics.