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Student learning of upper-level thermal and statistical physics: The derivation and use of the Boltzmann factor¹
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As the Physical Review Focused Collection demonstrates, recent frontiers in physics education research include systematic investigations at the upper division. As part of a collaborative project, we have examined student understanding of several topics in upper-division thermal and statistical physics. A fruitful context for research is the Boltzmann factor in statistical mechanics: the standard derivation involves several physically justified mathematical steps as well as the invocation of a Taylor series expansion. We have investigated student understanding of the physical significance of the Boltzmann factor as well as its utility in various circumstances, and identified various lines of student reasoning related to the use of the Boltzmann factor. Results from written data as well as teaching interviews suggest that many students do not use the Boltzmann factor when answering questions related to probability in applicable physical situations, even after lecture instruction. We designed an inquiry-based tutorial activity to guide students through a derivation of the Boltzmann factor and to encourage deep connections between the physical quantities involved and the mathematics. Observations of students working through the tutorial suggest that many students at this level can recognize and interpret Taylor series expansions, but they often lack fluency in creating and using Taylor series appropriately, despite previous exposure in both calculus and physics courses. Our findings also suggest that tutorial participation not only increases the prevalence of relevant invocation of the Boltzmann factor, but also helps students gain an appreciation of the physical implications and meaning of the mathematical formalism behind the formula.

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