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חומר רך: עיצוב תוכנית לימודים לתלמידי תיכון בנושא מדעי עכשווי ובינתחומי

Soft matter: Curriculum design of a contemporary, interdisciplinary science course for high school students

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Abstract

High school and first year college students usually encounter the concepts and approaches of physics in a traditional curriculum that focuses on simplified systems such as the mechanics of point particles or thermodynamics of ideal gases. Such students rarely have the opportunity to study contemporary, interdisciplinary topics in which physical models are used to analyze complex real-world, interacting multi particle systems. This dissertation describes a design-based research of a curriculum that introduced such an inter-disciplinary topic – the study of soft and biological matter to 11^{th} and 12^{th} grade students.

The first part of the dissertation addresses how the topic of soft matter, typically taught in graduate courses, is adapted to the introductory student level. We begin by introducing the fundamental tenet of soft matter systems analysis: the use of microscopic models, such as the lattice-gas, to quantify macroscopic properties utilizing principles of statistical thermodynamics (e.g. free energy minimization). We then describe how we make the topic accessible to students: first, by presenting it in the curriculum as a generic modeling process analyzing diverse phenomena in a unified manner; and second, through instructional activities such as using concept maps for organizing knowledge and troubleshooting tasks to learn from common mistakes.

The dissertation continues with two empirical studies that focus on two key aspects of student learning in the program: 1. The evolution in students' use of fundamental principles of statistical thermodynamics (such as the 2^{nd} law of thermodynamics) as the complexity of the systems that were studied and the level of quantitative analysis has increased. 2. The perceptions of scientific modeling that students acquired as they studied soft matter systems in the lessons and after they participated in independent, inquiry projects.

Our analysis of learning in the program is based on authentic classroom data from diagnostic questions, videos of lessons and interviews. In order to provide a comprehensive analysis of student learning, and the role of prior knowledge and epistemology in it, we focused on the statements of case study students, whose performances represent common learning pathways in the program.

We found that several students believed that phenomena in which the entropy of system decreases, contradict the 2^{nd} law of thermodynamics. We suggest that this deficiency is related to student difficulties in integrating energy related concepts, and to an epistemology that allows fundamental scientific laws to be overridden by others. In addition, we found that many students were inclined to interpret the process of modeling soft matter phenomena as a mathematical pro-

cedure and disregarded its simplification aspect which precedes the mathematical derivations. We suggest that the simplification aspect did not sufficiently capture the students attention and was therefore disregarded while the mathematical aspects were naturally difficult and provoked student interest. In addition, this deficiency can be related to student perceptions of modeling as a process of replicating real systems in a mathematical form, which might have rendered approximations and simplifications as undesirable.

In the spirit of design-based research, the findings were interpreted in light of the instructional activities and were used to propose strategies to improve instruction in future developments of a similar, interdisciplinary program. In addition, the findings contribute to the understanding of themes such as modeling and statistical thermodynamics that extends beyond the context of this specific design.