Research based design of an instroctural unit Statistical mechanics - model of the diffusion phenomenon

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A research based introductory curriculum was developed to build the conceptual framework offered by physics to explain complex phenomena that are of interest to material and life science. The curriculum was implemented, evaluated and refined in a course for interested and capable high-school students (10^{th} to 12^{th} grade) offering 5 unit matriculation credit.

The research-based development of the curriculum followed the Model of Educational Reconstruction (MER) (Duit, 2007) framework considering three interrelated components: (1) The analysis of content structure - the selection of central ideas and their organization into a coherent knowledge structure aligned with students' prior knowledge and the rational for the program; (2) The construction of instruction - consisting of the implementation of pedagogical principles to design a learning environment given the constraints of implementation (time, resources, etc.); (3) The study of students' achievements and difficulties, allowing to identify achievable learning goals for the program.

To meet students' limited prior knowledge students first (in 10^{th} grade) analyzed particle diffusion by means of step-by-step evolution of many-particle-systems. The construction and analysis of computational dynamical models allowed to justify and concretize the shift from Newtonian dynamics to random-walk. The abstract statistical thermodynamics treatment of non-interacting systems in equilibrium was first presented in 11^{th} grade in a unit focused on spatial configurations. The "statistical thermodynamic of spatial configurations" unit built the equal a-priori probability of all microstates postulate based on students' former acquaintance with particle dynamics - random walk. The unit followed with analysis of distributions, entropy and the second law in the spatial context. The unit set the stage for later analysis of thermal contact (configuration in energy space) and systems with interactions relevant to life sciences.

The Thesis focus on the "statistical thermodynamic of spatial configurations" unit. Diagnostic problems and interviews served to study students' understanding of the central principles and concepts following completion of the unit, as well as changes in students' perceptions and their

preferences regarding various models (particle dynamics vs. statistical thermodynamics) for particle diffusion several months after completion of the unit. The analysis show that students have largely succeeded in properly implementing the concepts and principles they have learned, so that the teaching unit in its format achieves most of its goals. The change in students' perceptions is expressed in the model they use to predict the phenomenon - dynamic or/and statistical mechanics, but their point of view in which they describe the phenomenon: micro- the particles random walk; macro- the average on area and/or on time of the local density; probability- the probability for certain value of the local density, does not change.