# Simulation design for the students' conceptual understanding of introductory thermodynamics

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**Abstract**. This study refers to the design principles of an educational simulation for introductory physics and their application on a newly constructed simulation (IGasES) for classical thermodynamics. These principles rely on convergence of three modeling aspects (physics education, learning and simulations). This study also reviews the issues of the simulations that are commonly used for the introduction of the basic processes of ideal gases and the first law of thermodynamics. We choose the energy chain model for mediating between the phenomenology and the formula of the first law of thermodynamics to enhance the students' conceptual understanding.

## 1 Introduction

Computer simulations are widely integrated in numerous formal science instruction settings and particularly in physics teaching and learning [1]. A straightforward definition of an instructional simulation is 'an interactive representation of the system to be studied, based on a model of the system' [2]. This kind of educational software has drawn many researchers' attention, with some equivocal results [3, 4]. There is much discussion regarding the instructional design for facilitating the simulation's goals. The question that remains unanswered is if we should attribute part of the ambiguous results to the software itself.

## 2 The three aspects of modeling for the design of the simulation

In the definition of educational simulations, the concept of 'model' is central. Our perspective refers mostly to this key concept in a three-folded way; the proper combination of the three fields described below can result to a powerful, yet user-friendly, educational tool for the teaching and learning of physics:

a. epistemological engagement of models in physics education, which primarily deals with the reductive representation of reality (the 'pragmatic' approach [5]),
b. didactical aspects of models in physics learning, which promote the explanatory mechanisms of models (the 'constructivist' approach [5]), and
c. the integration of the above in physics simulation modeling, forming a structure meant to generate the behaviour of a physical situation based on the user's decisions [2].

## 3 Introductory classical thermodynamics instruction with simulation scaffolding

In the context of physics, classical thermodynamics suggests a macroscopic theory that specifies the energy forms during physical phenomena. However, the students bear many alternative frameworks for the key concepts and the laws of the theory [6]. Educational simulations took up the challenge for promoting accurate conceptual knowledge of introductory thermodynamics. However, the existent software render epistemological (i.e. blending of classical and statistical thermodynamics, depreciation of qualitative modeling), didactical (i.e. conceal of the underlying conceptual knowledge, disregard for the students' linear reasoning) and philosophical issues (i.e. promotion of positivistic approaches).

In order to tackle such issues, we put into effect the three-dimensional principles of modeling for the design of an educational simulation for thermodynamics. We apply the proposed theoretical basis in IGasES (Ideal Gas Educational Simulation), a newly constructed simulation for the field of classical thermodynamics for students of the upper secondary school level and university beginners.

## 4 Application of the design principles in IGasES

IGasES operates the main four thermodynamic processes of the ideal gases (isothermal, isochoric, isobaric and adiabatic) and links them to the first law of thermodynamics. Considering the prime 'pragmatic' aspect of the modeling, it presents a deliberate reduction of the respective phenomenological (macroscopic) field of ideal gases (qualitative) and it also embeds the first law of thermodynamics in its mathematized form (quantitative). In order to bridge these 'pragmatic' modeling representations, IGasES exposes the underlying conceptual model through an intermediate 'constructivist' model, the energy chain model (semi-quantitative) [7], which depicts the transformations of energy within the system. A snapshot of the simulation in processes is illustrated in Fig. 1.

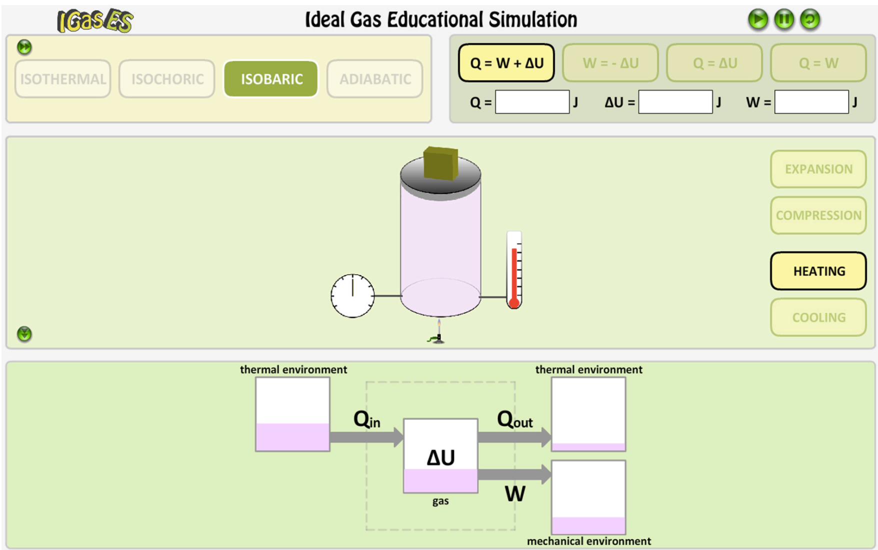


Fig. 1 Snapshot of IGasES: isobaric heating at equilibrium state

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