Simulations as scientific research tools: an insight into explanations of high school students

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Abstract. Computational simulations have increasingly been used as real research instruments in scientific practices, and own a controversial epistemological role between theoretical models and experiments. Moreover, their central role in scientific communication make them an important tool for citizenship. The present study aims at investigating high school students' explanations of simple simulated phenomena, as to make emerge their stances on the reliability on simulations as research tools. 20 interviews were carried out and analyzed, showing that different types of simulations invoke different degrees of reliability, as well as different kind of explanations.

1 Simulations as models/experiments: scientific research, high schools and citizenship

While in the past *computational simulations* only played the role of powerful tools for analyzing and representing results in the context of known and explored theories, they are nowadays considered as real research instruments, and there is a still open epistemological debate about the relationship between simulations, models and experiments [1].

Following Grune-Yanoff and Weirich [2] we can distinguish *equation-based* simulations - if imitate a system by using equations that describe the behavior of the whole system - and *agent-based* ones - if imitate a system by generating its dynamics through the imitation of its micro-constituents that behave as dictated by local rules. Whether these simulated systems can be regarded *models* themselves is a discussed issue, as the two cited above *"differ from models mainly in their temporal expansion* […] *as well as in their epistemic opacity*" [2]. The results of these kind of simulations, in fact, are not *analytically* predictable, because they simulate complex systems. In this sense, they have been compared to real *experiments*, with the limit that we interact with a *model* rather than with reality.

All these peculiarities make computational simulations epistemologically complex to settle, as they have brought new ways of explanations into the scientific community. Most of high school curricula do not provide an introduction to the deep change that computational simulations have brought in scientific practices; students are used to think about *experimental work* as a matter of *observation* of new phenomena, *verification* of physical laws or *application* of the latter to new contexts [3]. Some proposals have been made to introduce computational simulations in high school for promoting *procedural knowledge strategies* for modeling real complex phenomena [4]; however their educational implications are by now underexplored. Furthermore, this lack of confidence with such an important tool can contribute to the widening of an "epistemological gap" between science and citizenship [5], as they have become increasingly important also for the communication of scientific results with social implications. In the present work, we investigate high school students' explanations of some simple simulated phenomena, to answer the following research questions:

1. how do the students collocate simulations with respect to the experimental work they are used to do at school? to what extent do they consider the results of computational simulations reliable?

2. what kind of knowledge do they account for giving explanation of the simulated phenomena? does it depend on the epistemological peculiarities of computational simulations?

2 Design of the pilot study and research methods

After a review of the literature, four different applets were selected: i) an agent-based simulation about Schelling's segregation model; ii) an equation-particle-based simulation about the predator-prey dynamic, built on Lotka-Volterra equations; iii) an equation-field-based simulation about global warming; iv) an applet showing the behavior of ideal gases according to the state equation (http://phet.colorado.edu). This last was chosen for comparison; *didactical simulations* are micro-worlds in which students can play with a limited set of variables to explore deterministic physical laws/models, but differently from scientific computational simulations the result of moving these variable is always predictable.

We prepared a semi-structured interview protocol to follow the students' 'experiential path' from the first exploration phase to the phases of interpretation and explanation of a phenomenon, finally asking them to evaluate, in general, the reliability of the simulation and its potential use to address real societal or scientific issues.

The analysis of the audio-recordings of 20 interviews has been carried out with a qualitative strategy [6], and to look into students' words we chose to adopt the framework provided by Braaten and Windschitl [7] about scientific explanations, who have identified five models of explanations argued to be relevant for science education: *covering law*; *statistical-probabilistic*; *causal*; *pragmatic*; *unification*.

3 Analysis and preliminary results

According to students, the reliability of simulations results seems to depend more on *what* is being simulated (human society in Shelling simulation, *predator-prey* population in Lotka-Volterra), than on *how* the simulation evolves; moreover, the *quantity of data* available with the virtual laboratory is considered as a factor of higher reliability, even if the relation between experimental and virtual data is perceived sometimes in a naïve way. The agent-based and equation-based simulations seem to provoke *causal* kind of explanations; this recall the characteristic temporal expansion of computational simulations. The didactical simulation of ideal gases, instead, seem to invoke a *covering law* explanation, based on argumentations about laws and variables, more than about processes. Some explanations, especially with respect to climate models, include statistical reference. Thus, the data reveal that different types of simulations generally invoke different degrees of reliability, as well as different kind of explanations.

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