Introduction of the concept of probability in physics for the training of physics teachers

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Abstract. We present a way of introducing the concept of probability in statistical mechanics and in quantum mechanics, for physics teachers in training with the purpose of consciously developing non-deterministic ways of explaining.

1 Introduction

Quantum mechanics is an area of physics of immense importance in modern technology, which has led in recent decades to a growing interest in its teaching into introductory physics courses at university and high school level. However, the learning of quantum mechanics is considered a very difficult topic, which implies seeking changes in teaching practices that enable a better conceptualization (Greca & Freire, 2014).

This work addresses the historical and epistemological development of the concept of probability seeking to highlight the change of the pattern of explanations of classical mechanics (determinism) to quantum mechanics (probabilistic). The proposal is aimed at training physics teachers.

2 Patterns of explanation in physics

The different patterns of explanation of the sciences can be understood as conceptual frameworks that articulate the ways of understanding the world, thus constituting what is called scientific knowledge. If it is recognized that this knowledge is a historical process, the way it has been constituted can not be separated from the way in which the research questions are formulated and the construction of answers to them is faced. So, determining what a scientific explanation is can not be answered in an abstract way, through a general philosophical characterization. It requires understanding the historical contexts in which the question has been posed, as well as the problems and thought traditions that have contributed to its examination (Martínez, 1997).

It is assumed that a pattern of explanation in the sciences is a certain way of explaining something scientifically, under particular ways of understanding the notions of causality and law of nature, as well as the type and scope of the inferences that can be made from the study of experience.

The explanations formulated within the framework of Newtonian mechanics can be characterized as part of the pattern of explanations by laws enunciated in Martínez (1997). Its distinctive core lies in the idea that explaining consists of showing how certain phenomena follow certain laws. This pattern of explanation evolved and extended to other fields of physics during the eighteenth and nineteenth centuries, such as optics, hydrodynamics, the theory of electricity and magnetism. Until that moment the concept of probability was absent in physics, dedicated rather to the construction of scientific knowledge with an axiomatic character from the perspective of mechanics (Hacking, 2005).

In the nineteenth century, the scope of explanations by mechanistic and determinist laws was questioned, and the first mechanistic theories that incorporated contingent aspects of the world

emerged, in terms of historical and probabilistic concepts in their explanations. An example of this is the statistical mechanics of Boltzman which addresses the problem of systems of many particles in order to obtain their collective properties without the individual study of each particle; this implies introducing the concept of probability, which implies a change in the nature of the elaborated explanations, that is, moving from explanations with a deterministic character to a probabilistic character.

3 Thinking about the notion of probability for the training of physics teachers

In the framework of classical statistical mechanics, a common problem is that of distributing N particles in r states, corresponding to the most probable distribution with a fixed total energy. In this way it is possible to introduce the concept of probability in order to encourage non-deterministic reasoning.

The study of this problem is done through a spreadsheet using $N = 4000$ particles to distribute in three states of energies ε, 2ε and 3ε, fixing the total energy. Subsequently it is shown that this partition complies with the distribution law of Maxwell-Boltzman by making the adjustment to an exponential curve that is elaborated in the spreadsheet.

In the case of quantum mechanics, the concept of probability is introduced through the study of the Stern-Gerlach experiment, which allows us to show one of the properties exhibited by elementary particles: spin. It is emphasized that the spin in one direction is a variable that is incompatible with the spin in another direction perpendicular to the first, so it is impossible to simultaneously measure the spin in these two directions.

4 Conclusions

Given the diversity of physical theories and their differences in the ways of explaining the phenomena that they address, to think the formation in quantum mechanics for physics teachers supposes to introduce the concept of probability assuming that its use implies a style of reasoning and a way of explaining differently the one that underlies the explanations by deterministic laws.

References

[1] I. Greca & O. Freire, Meeting the challenge: Quantum physics in introductory physics course. In *International Handbook of Research in History, Philosophy and Science Teaching*. Springer, New York, 2014.

[2] S. Martínez, *De los efectos a las causas. Sobre la historia de los patrones de explicación científica*. UNAM, México, 1997.

[3] I. Hacking, *The emergence of probability*, Cambridge Univerity Press, New york, 2006.