Introduction of an IBT approach for nuclear physics education in high schools: a case study.

Paolo TERUZZI, Marina CARPINETI, Nicola LUDWIG

State University of Milan, Department of Physics, A. Pontremoli, via Ceoria 16 Milano 20133 Italia

Abstract An educational experiment on nuclear physics topics developed in fourth and fifth grades of an Italian scientific high school is presented. The ten-hour nuclear physics (NP) program was carried out following an innovative energy (IE) related path in two groups of penultimate year classes formed by students selected on a voluntary basis. The first group followed a traditional teaching approach while the second followed an IE approach. The teaching and satisfaction results and limitations of the experiment are discussed. The results of the experimentation were later used to redesign and propose a similar course to a fifth grade class.

The state of the art of nuclear physics education in Italy: problems of the contest

An adequate introduction of the fundamentals of nuclear physics at the high school level enriches the preparation of students, introducing them to issues related to basic research, health and industrial applications, and issues related to energy sustainability, which are also the basis of a conscious culture of citizenship. The teaching of NP is, moreover, provided for Italian high schools, although little practiced [1]. When carried out, this is old style way on a simple description of phenomena and a listing of laws. This implies that NP teaching produces notional, at best instrumental learning, aimed at solving more or less complex exercises and problems.

A pragmatistic approach for Inquiry teaching of NP

We propose the introduction of nuclear physics with an Inquiry Based Teaching (IBT) approach [2], where the didactic innovation is, aimed at enhancing learning through more or less complex problems and through intuitive and inferential procedures.
The cornerstones of this new design of an NP lecture course can be summarized as follows. Taking into account that a widespread laboratory practice is not easy to apply, it was preferred to set up the course by exploiting a different route. In order to foster an IBT approach, it was decided to approach NP by theoretical problems aimed at the formulation of concepts, in agreement with a pragmatistic approach. In this IBT way, in which students build concepts step-by-step [3] through the stages of engagement, exploration, and explanation [4], can be achieved. The authors conducted a pilot study of this approach with three high school classrooms.

Contents and methods

The contents of the course are thus dictated by the goal of giving students the tools for a deep understanding of the variety of NP phenomena and by the methodological choice just outlined. To the description of nuclear phenomena in axiomatic form (nucleons, isotopes, law of radioactive decay, description of fission and fusion processes, applications), it was preferred to lead students to the identification of the causes that determine them (characteristics of the nuclear bond, potential barrier, quantum effects). A course of this kind, aimed at investigating the deep reasons that explain NP phenomena, requires a long time for its implementation, especially if active participation of students is required at each stage of the teaching practice. For this reason, application-related content (dosimetry and radiation effect, energy production from fission and fusion, applications in art and archaeology, nuclear accidents) has been only partially covered, so comprehensive bibliographic references can be provided.

Outcomes

The course thus designed has been tested on three groups of students. A survey of prior knowledge of atomic physics and NP was initially conducted through questionnaires later discussed with the students. After an introduction related to the fundamentals of NP, an exposition of some simple phenomena (deuteron analysis, e- - e+ annihilation, p-p cycle) allowed for the introduction of the mass-energy problem, based on conservation considerations. A detailed analysis of the deuteron, allowed the concept of bond energy to be formalized and, later, the step-by-step construction of the semi-empirical mass formula. A second step concerned the building of a nuclear potential. At this scholarship level it could be shown only by qualitative graphical representation.

Through this and some general considerations concerning the relationship between mechanical energy, potential and the classical possibility of an event, more complex phenomena were then addressed, giving a complete explanation as far as the algebraic calculation allowed, elsewhere only a qualitative one (decays and tunneling effect, nuclear reactions, fission, activation energy and energy conditions, fusion and problems relating to the realization of a fusion reactor).

Following this pragmatistic path, the examples, questions, and problems generated surprise in students, useful in fostering the will to understand more. In this way, learning became the outcome of an experience driven by the desire to fill the gap between reality and expectations. It became apparent that the process of abduction, construed as a creative endeavor encompassing both inference and intuition, and essential according to the pragmatist perspective, is necessary for the structured logic framework where intuitive elements can be accommodated [5].

Perspectives

We designed and implemented a course that provides an example for the renewal of NP teaching. To make this approach effective is only possible in the presence of adequate teacher training. Therefore, after the test of the educational path with classes, we are planning to conduct a training course for high school teachers, with the aim of disseminating the practices of the test on NP teaching carried out.

References

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