Investigating the Beliefs of Experts and of Teachers on Teaching Quantum Physics at Secondary Schools

Marco DI MAURO (1), Luca S. PERLI (1), Pasquale ONORATO (1), Stefano OSS (1), Massimiliano MALGIERI (2), Denis COGO (3)

(1) University of Trento, Physical Science Communication Laboratory, Department of Physics, Via Sommarive, 38050, Povo (Trento), Italy
(2) University of Pavia, Department of Physics, Via Bassi, 27100, Pavia, Italy
(3) University of Padova, Department of Physics and Astronomy, Via Marzolo, 35121, Padova, Italy

Abstract. In this contribution, the results of a series of questionnaires conducted both with expert researchers and active high school teachers of physics, concerning aspects of the teaching of quantum physics at the secondary school level, are reported and compared. The addressed issues were the overall appropriateness of this teaching, the (quasi-)historical approach, the necessary mathematical tools and the specific topics that should be included. Some foundational and controversial aspects of quantum physics, which concern potentially includable topics, were addressed as well.

Introduction

The teaching of Quantum Physics (QP) at the secondary school level is one of the most pressing issues being faced by researchers in Physics Education and by teachers [1,2]. The need is usually justified in the light of the importance of this wide subject in contemporary and future scientific research and technology, which can hardly be overestimated, but also on the huge cultural significance of a topic which deeply revolutionized our view of the world. The challenges to teaching this subject come primarily from the fact that it requires fundamental changes in the way the physical world is understood, conflicting with the classical thinking of students confronting with it for the first time, especially considering that, from the conceptual point of view, there are interpretational issues that remain controversial after almost a century. An additional challenge concerns the fact that a full working understanding of even basic quantum mechanics requires mathematical tools that are unfamiliar to high school students. In fact, sometimes the appropriateness of addressing QP at the pre-university level is even denied, as such difficulties are seen as insurmountable.

According to the widely used Model of Educational Reconstruction [3], the first step in designing a science curriculum is the clarification and analysis of the science content. This clarification includes the analysis of significant topics, related applications, and their scientific and philosophical implications. Accordingly, several groups are currently conducting Delphi studies with experts and teachers to investigate these matters [1,2,4].

In this contribution we will report on our own study, which is currently being performed, in which we aim at investigating and comparing the views of experts and teachers about the overall appropriateness of teaching QP (**RQ1**: whether), the motivation (**RQ2**: why), the possible contents and topics to be taught (**RQ3**: what), the pseudo-historical approach which is currently the most common, and the role of mathematical knowledge and skills in learning some aspects of QP (**RQ4**: how). Some additional questions referred to some relevant conceptual aspects of QP which are still controversial and object of foundational studies, such as the fundamental nature of light quanta and their role in explaining physical effects, the complementarity and uncertainty principles. In the first round (cf. [5] for the results), 17 expert researchers were interviewed. Then, similar questions were subsequently proposed in the form of a questionnaire to 31 more experts. Currently, the same questionnaires are being proposed to a number (165 at the time of writing) of Italian high school teachers. Although they may lack the scientific background of experts, it is essential that the study be extended to teachers, as they have of course a deeper understanding of the situation a typical student or a typical class are found in.

Previous and future results

Previous results, obtained with experts, are reported in [5]. Experts were in general found to agree with the appropriateness of teaching QP at secondary school level. As could be expected, all experts agree that the main obstacle to teaching QP is an inadequate knowledge of mathematics.

In motivating the appropriateness of teaching QP at school, the experts emphasised the cultural relevance of the topic and aspects related to scientific literacy, while they mostly downplayed technological topics and quantum technologies. This was reflected in the topics which were recommended to be included in the curriculum, which are largely those included in traditional courses, such as atomic energy levels and quantisation, spectral lines, the photoelectric effect, the particle behaviour of light, and Heisenberg's uncertainty principle. On the other hand, concepts typically associated with the "second quantum revolution", such as quantum state, quantum measurement, entanglement, and applications like quantum information and quantum computers, were generally excluded.

Almost all the experts considered the presentation of the cornerstone experiments that ushered in QP to be appropriate. However, some experts criticised the choice of the traditional quasi-historical approach, because it necessarily overlooks the full historical complexity of the developments, with the additional risk of giving students wrong ideas about Nature of Science, and also because it can lead students to confuse between quantum mechanics and old quantum theory. A further reason is that this roundup of experiments is not usually supported by adequate laboratory activity.

Regarding the foundational and controversial aspects, our results confirmed, perhaps unsurprisingly, the absence of consensus among scientists.

The results obtained with teachers are currently being analysed, and will be presented at the conference, together with a detailed comparison with the results obtained with experts.

References

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