A quantum mechanics educational proposal implemented in the INSPYRE School

Adriana POSTIGLIONE (1), Catalina CURCEANU (1), Marisa MICHELINI (2), Lorenzo SANTI (2), Angelo BASSI (3), Susanna BERTELLI (1)

(1) INFN Frascati National Laboratory, Frascati, Italy
(2) Udine University, Udine, Italy
(3) University of Trieste and INFN Trieste, Trieste, Italy

Abstract. Among the non-formal educational initiatives that enable students to enter places where scientific research is realized, the INFN-INSPYRE is an International School of excellence, reaching more than 600 people from 17 countries around the world since 2011. For its 2024 edition, the school will benefit of the collaboration with the physics education research and outreach community of GIREP and CERN. Here we present the quantum mechanics didactic proposal implemented in INSPYRE 2024 with 40 students of 7 countries and planned in the context of the collaboration between INFN researchers and physics education researchers of GIREP and specifically of Udine Group.

1. Introduction

Educational initiatives proposed by Universities and Research Institutes that allow high school students to enter the environments where scientific research is carried out are particularly remarkable and significant, especially for physics, which nature is founded in the experimental and theoretical interactions. These activities indeed raise awareness of the way in which physics research works and of its numerous applications in everyday life, especially when they allow participants to delve into the research environment, interact with researchers, and directly conduct experimental activities [1]. In addition, the construction and implementation of these initiatives might also provide an ideal space where scientific research, educational research and school come together to confront each other and create new and valuable activities to bridge research and education. The design of these initiatives, in fact, requires reflection on disciplinary aspects, learning processes and conceptual common-sense ideas, the role of lab-based activities in physics and teaching-learning practices. It is within this framework that the INFN Frascati National Laboratory will hold the 2024 edition of the International School INSPYRE, targeted to high school students, and focused on modern physics. The School will make use of the experimental facilities and scientific staff of the Laboratory, its decennial experience in public outreach activities[1], but also of the cooperation with the physics education research and outreach community of GIREP and CERN. Here we focus on the proposal on quantum mechanics (QM), that, starting from an already established educational activity [2-3], has been adapted to the new context and expanded to integrate two seminars, 4 hours of lab-based activity and a debate, to make participants become protagonist of their own learning process.

2. Research and results

INSPYRE (*International School on Modern PhYsics and REsearch*) is a week-long school held at the INFN Frascati National Laboratory since 2011 that reached more than 600 students from 17 countries [4]. During the school, participants are involved in seminars, laboratories, and guided tours, and can thus experience the lab environment by interacting with various scientific figures and touching physics firsthand. The 2024 edition of the School, held in April 8-12, welcomes 40

[1] comedu.lnf.infn.it

students from France, Germany, Italy, Romania, Serbia, Slovakia and Spain. It is titled "*From quantum foundations to artificial intelligence",* as special attention will be dedicated to fundamental QM topics, but also to the latest scientific and technological application, such as quantum computing and artificial intelligence. The choice of these topics is also related to the *Rome Technopole project*[2] that is supporting the school, which sees digital transition as one of its pillars. The QM proposal begins with a seminar introducing problematic issue of QM (properties, state, superposition principle, measurements, entanglement and non-locality). Then, 4 hours of IBLS [2-3] experimental and theoretical Lab on polarization state of light allows students to explore and explore the concept of polarization making use of polarizing filters and bi-refringent crystals, building some hypothesis on single photon polarization state and properties. In the theoretical part of the Lab, they play as theoretician physics planning and analyzing ideal experiments using a simulation open environment based on JQM software. A seminar on the second quantum revolution and on quantum computing will then offer another context and perspective [5]. The path will conclude with a debate where students will discuss the encountered concepts with the tutors of the previous seminars. The debate is an opportunity to bring out the fundamental aspects of quantum way of thinking and second quantum revolution through stimulating questions. Learning results are analysed by means of mixed methods (qualitative and qualitative) and of tutorials and pre- tests. A specific test is dedicated to exploring participants' engagement in the proposal.

3. Conclusion

The INFN-INSPYRE school is a well-established example of a out-of-school educational activity organized by a cutting-edge research centre such as the INFN Frascati National Laboratory, which nevertheless renews itself each year by enriching its program and approach. In particular, the 2024 edition will feature the collaboration of members of GIREP physics education research community and specifically the Udine Group, who is co-designing the QM proposal together with INFN researchers starting from an established proposal but adapting it to the new context. Results of engagement and learning conceptual fundamental elements of QM enable the development of an effective and comprehensive proposal that will explore fundamental topics giving attention both to research in physics and in physics education aspects.

INSPYRE is supported by the INFN National Commission CC3M and by Rome Technopole[2].

References

[1] J. A. Kitchen, G. Sonnert, P. M. Sadler, The impact of college- and university-run high school summer programs on students' end of high school STEM career aspirations, *Science Education* **102** (2018) 529– 547.

[2] M. Michelini, R. Ragazzoni, L. Santi, A. Stefanel, Proposal for quantum physics in secondary school, *Phys. Educ*. **35** (2000) 406.

[3] M. Michelini, R. Ragazzoni, L. Santi, A. Stefanel, *Quantum Physics as a way of thinking: an educational proposal*, in: *Phyteb 2000*, Elsevier, Paris, 2001.

[4] S. Bertelli et al., Experiences in INSPYRE: International School on Modern Physics and Research, *14th International Technology, Education and Development Conference INTED2020 Proceedings*, (2020) 8866-8874.

[5] A. Bassi, S. Ghosh, T. Singh, *Information and the Foundations of Quantum Theory*. In: A. Aguirre, B. Foster, Z. Merali (eds) *It From Bit or Bit From It?*. The Frontiers Collection. Springer, Cham, 2015.

[2] ECS 0000024 Rome Technopole Project, - CUP B83C22002820006, PNRR Mission 4 Component 2 Investment 1.5, funded by the European Union – NextGenerationEU