Interdisciplinary approach to Quantum Technologies: a teaching - learning experience for high school students

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Abstract. Quantum Technologies will have fundamental social and economical implications in the next future. Therefore is urgent to make new generations aware of disruptive potential of these technologies so they can fell part of the second quantum revolution. Using an interdisciplinary approach, we designed and implemented a teaching learning sequence for high school students about the core concepts of quantum physics and the tenets of quantum computation. The intertwining between logic and physics enables students to understand the new way quantum computers manipulate information. In this paper, we present the design principles and the encouraging results of its implementation.

1 Education in the Second Quantum revolution

In recent years we have witnessed an important growth in the research on quantum technologies (QT). Many strategic plans have been presented by various countries that invest in these new technologies in order to face “the Second Quantum Revolution”: the European Union with the Quantum Flagship has started an investment of €1 billion in 2018 [1]; China has just declared QT one of the new high techs in its 14th Five-Year Plan (2021-2025) [2]; in the USA, IBM, Google, Microsoft and Intel have been focusing on QT and have already achieved significant results.

Alongside this great challenge, there is another very important one: the educational challenge to prepare the next generations of experts, technicians, and citizens for the wide and deep societal impact that this second quantum revolution is expected to produce [3].

Within this framework, we have developed a project aimed to explore the second quantum revolution as a context to make the secondary school students aware of the role of quantum physics in the development of QT.

2 Research Project and activities

We present a teaching - learning sequence (TLS) developed by the University of Como together with the University of Bologna and the University of Pavia. The TLS has been implemented in a Late - Summer School, hosted by the University of Como and held online due the pandemic. The school involved about 37 very motivated secondary school students (17/18 years old) from September 08 to 11, 2020.

The main thread was the computation and the interdisciplinarity between mathematics, computer science and physics. Starting from the "spin-first approach" and the concept of quantum qubit [4], we introduced the main features of quantum physical systems, that is state preparation, evolution and measurement and we reconceptualized them in terms of input information, processing, and output, triggering an analogy between the physical and the computational perspectives. Going then into the substance of how the quantum logic gates, circuits, and algorithms work, we switched on the mathematical perspective that intertwined with the other. This intertwining of three different levels has created a sort of fabric, on which the various topics are inserted: entanglement, quantum circuits, quantum protocols, the Grover's algorithm, and their implementation on Qiskit [5] .

We addressed the following research questions:

> RQ1: How does our interdisciplinary approach support students understanding of the main characteristics of QT, in particular the Quantum Computation?
>
> RQ2: How does our interdisciplinary approach support students to familiarize with the main difference between classical and quantum computation?

3 Results

To answer these questions and evaluate the impact of the course, we collected different kinds of data: questionnaires, interviews and worksheets completed by the students during the activities. We are qualitatively analyzing the questionnaires, completed by 30 students out of 37. We are investigating students' reflections and how they perceive the connection of the three disciplines and the QT through a top-down and bottom-up approach.

As for RQ1, most of the students has grasped the essence of our approach. Students realized the relation between physics and computation. They appreciated the goal of unpacking the logic that stays beyond physical laws and using it to manipulate information.

As for RQ2, most of the students recognized the role of the superposition principle embodied in the new basic unit, that is the shift from the Bit to the Qubit. They associated to the superposition principle the amount of information that can be processed. Furthermore, the students highlighted the possibility of quantum computers to make calculation in parallel and to solve different kinds of problems than the classical one.

References

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