Approaching Quantum Technologies for Secondary School Students and Their Teachers

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Abstract. The incorporation of quantum technologies into secondary school curricula is of growing importance. Nevertheless, this necessitates that high school teachers acquaint themselves with these topics as well. This paper presents insights gained from a series of short-term lectures and long-term courses on the fundamentals of quantum technologies, aimed at upper-secondary school students. A course for in-service physics teachers is currently being prepared based on this experience. The contribution will include specific ideas as well as approaches that can be used to cover the topic at that basic level.

Introduction

Quantum technologies are a rapidly developing branch of science and industry that are increasingly integrated into our daily lives. International projects such as QTEdu and QWorld aim to train individuals capable of working with these technologies and to educate the public on their principles, including their integration into upper secondary school curricula.

Quantum physics is often considered a difficult subject, both because of the mathematical apparatus involved and because it represents a completely new approach to describing the world around us. However, advancements in computer graphical representation have provided an alternative to complex mathematical equations. Furthermore, the younger generation is already accustomed to various forms of simulated reality, making it easier for them to accept the peculiar behaviour of micro-objects. Therefore, I believe it is worthwhile to introduce quantum physics and technologies to high school or even younger students.

Approach and methods

Interactive teaching has become the basis of the approach. The publication [1] is the exception. This requires us to create our own activities for our classes. As previously stated, we utilise a range of applets, simulations and graphical representations. The IBM quantum circuit simulator is particularly useful. We also frequently employ games to support the concept that *kids who grow up playing quantum games will acquire a visceral understanding of quantum phenomena that our generation lacks.* [2]

Implementation

A 90-minute lecture was prepared and presented to high school students at several schools. The introductory part discussed the importance of understanding the principles of quantum technology and its potential applications in students' future career. This was followed by an explanation of the basics of physics, specifically the peculiarities of quantum behaviour. The lecture concluded with a demonstration of a real quantum algorithm. Students were asked for their opinions on quantum technologies at the beginning and end of the lecture by a short online questionnaire.

Besides a single lecture, a long-term course has been offered as an extra-curricular activity for vocational school students. Eleven students have attended a 90-minute lesson once a week for four months. The course content has covered basics of quantum physics for technologies (superposition, quantum measurement, probabilistic behaviour, qubit state description, various gate representation…), selected advanced quantum topics (EPR paradox, Bell inequities …), quantum cryptography (quantum key distribution, BB84 protocol…), examples of quantum algorithms (Grover algorithm, concept of

Shor algorithm…). The course will be repeated in July 2024 during the two-week summer camp for upper-secondary students, who are particularly focused on STEM subjects. Moreover, a seminar with a similar content is also being piloted as an elective course for future physics teachers in the summer semester 2023/2024.

Examples of activities

Figure 1. Quantum Tic-Tac-Toe is a well-known application that demonstrates how superposition and measurement work in quantum mechanics. However, as a hands-on activity, it provides a clearer understanding of these concepts.

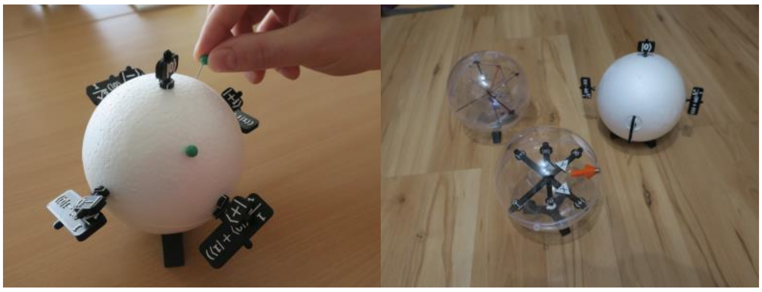

Figure 2. The Bloch sphere is the representation of the qubit state as a point on the sphere's surface and the geometrization of gate effect on it. This eliminates the need to introduce complex numbers to students. The hands-on approach was found to be much easier for students compared to drawing pictures or using computer animation.

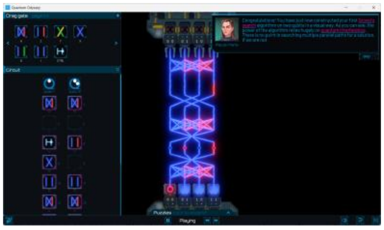

Figure 2. Screenshot of the Quantum Odyssey [3]. This computer game provides a graphical representation of qubits and gates using coloured circles and lines, making the study of quantum algorithms more accessible and engaging (as puzzles).

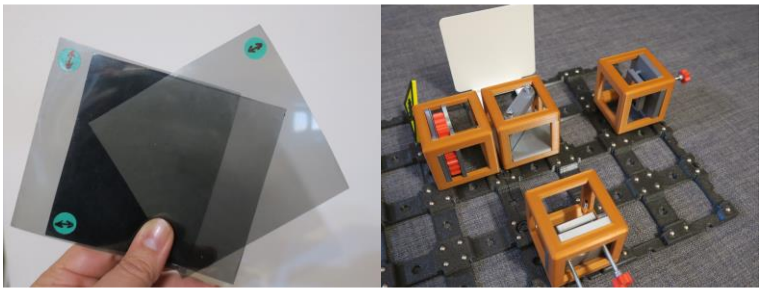

Figure 4. Photon polarisation is often used as the physical realisation of a qubit. At the start of the course, students can become familiar with it through simple experiments with polarising film. Subsequently, a self-built low-cost interferometer [4] can be used as a "quantum computer".

Conclusion

The experience gained so far shows that quantum technologies are highly attractive to high school students. They are willing to pursue them in their spare time. Additionally, interactive and graphical representations of quantum states have been shown to aid in understanding the basic concepts of both the technologies and the underlying quantum physics. The involvement of students in the learning process through various activities, mainly games, has been found to be key. The same approach is planned for the teacher training course, but it may be necessary to address initial concerns about the perceived difficulty of quantum physics.

References

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[3] *Quarks Interactive*. https://www.quarksinteractive.com/
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