Early Promotion and Dissemination of Quantum Computing in Young Venezuelan Students

Dafne Carolina Arias-Perdomo, Universidad Central de Venezuela, Venezuela

The Paris Conference on Education 2024
Official Conference Proceedings

Abstract
This project addresses the educational challenges faced by secondary and diversified education levels in Venezuela, particularly in teaching physics and advanced scientific concepts like quantum computing. Quantum computing is an exciting field at the crossroads of physics and computer science. Given the shortage of specialized teachers and the late exposure to fundamental physics concepts in Venezuela, this initiative seeks to engage high school students, especially girls, in quantum sciences early on. This project aims to showcase the teaching process for young Venezuelan girls who are 15-20 years old while also working with a mix group of high school students aged 14-17. Through virtual and face-to-face activities, students were introduced to the core principles of quantum computing, fostering curiosity and understanding. The first results indicate a significant improvement in students' conceptual grasp and interest, with progress among female students. This project highlights the importance of early and inclusive STEM education in developing future innovators and closing the gender gap in scientific fields.

Keywords: Quantum Computing, STEM Education, Gender Inclusivity, Venezuelan Education, Physics Education

Introduction

Navigating the educational challenges of teaching Science, technology, engineering, and mathematics (STEM) subjects in Venezuela involves numerous factors. In particular, teaching physics at secondary education levels faces significant obstacles, including a shortage of specialized teachers [1-3]. This deficit results in many students encountering fundamental physics concepts for the first time at the university level, which is considered too late. Previous studies have documented this issue, further exacerbated by massive emigration [4]. Efforts to foster scientific curiosity in young people often need more mathematical and pedagogical tools. Although children are familiarized with basic principles like force, energy, and movement from a young age, a comprehensive and formal classroom approach remains rare.

As we can see, the shift to higher education reveals a significant gap, with students often needing better preparation for scientific fields. Besides this issue, the shortage of specialized teachers is compounded by students' need for more interest in scientific disciplines, as careers like physics are often perceived as not lucrative. Job prospects and financial rewards tend to influence vocational choices, diverting interest from scientific disciplines. However, this perception is far from reality since it is essential to note that physicists, thanks to their ability to solve complex problems, find opportunities in diverse fields, where they apply theoretical and experimental models to practical situations [5]. Integrating long-standing physical and computational concepts into the curriculum can inspire more students to explore scientific and technological areas, including quantum computing.

Quantum computing represents a technological revolution capable of transforming industries, justifying significant investment. For Venezuela, introducing young people to this technology early is relevant for developing human capital and preparing future innovators in other areas, such as cryptography or healthcare. Given the complexity of quantum computing, which requires a deep understanding of physics and mathematics, initiatives like the work done in this project are essential for demystifying and disseminating this knowledge among high school students and young people.

Finally, encouraging the inclusion of girls in physics and science is essential for several reasons [6]:

- Interactive teaching reduces the gender gap in learning outcomes, fostering higher academic achievement among female students.
- Despite existing barriers, women's equal presence in academia indicates untapped potential.
- Representing women in teaching and research positions challenges gender stereotypes and contributes to a diverse and inclusive academic environment.

In Venezuela, while there is no exclusion of women from any career, female participation in research and development decreases at higher levels, with about 30% presence in specific research centers [7]. Encouraging girls' inclusion in physics and related fields is not just a matter of equality but a necessity to close the gender gap, harness all talented minds, challenge gender role perceptions, and design equitable work environments.

With this in mind, we designed an educational approach to introduce the concept of quantum computing to students through a series of one-hour talks. These sessions began by contrasting classical/Newtonian mechanics with quantum mechanics, highlighting the limits of our current classical computers. From there, we delved into critical topics such as qubits, superposition, entanglement, and the practical applications of quantum computing with their leading actors. This approach aimed to make complex quantum concepts accessible and engaging for students and show the current applications.

The foundational knowledge required for understanding quantum computing is rooted in quantum physics. The topics covered in these sessions are illustrated in Fig. 1.

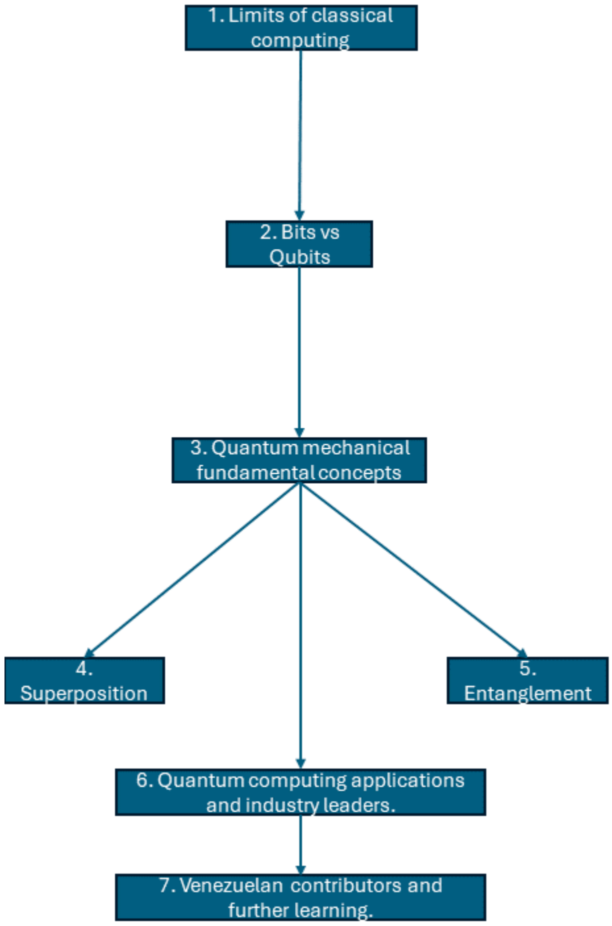

Figure 1: Flowchart of Cover Topics During the Project.

Methodology

The project employed a comprehensive methodology combining virtual engagement and face-to-face activities to introduce quantum computing concepts to young girls and high school students—this multi-faceted approach aimed to address diverse learning needs and maximize student engagement.

During the virtual engagement activities, young girls created videos before and after the lectures on quantum computing, fostering expectation and active participation and evidencing progress in their conceptual learning. Strategies included stratified sampling to select diverse participants and performing pre- and post-intervention assessments.

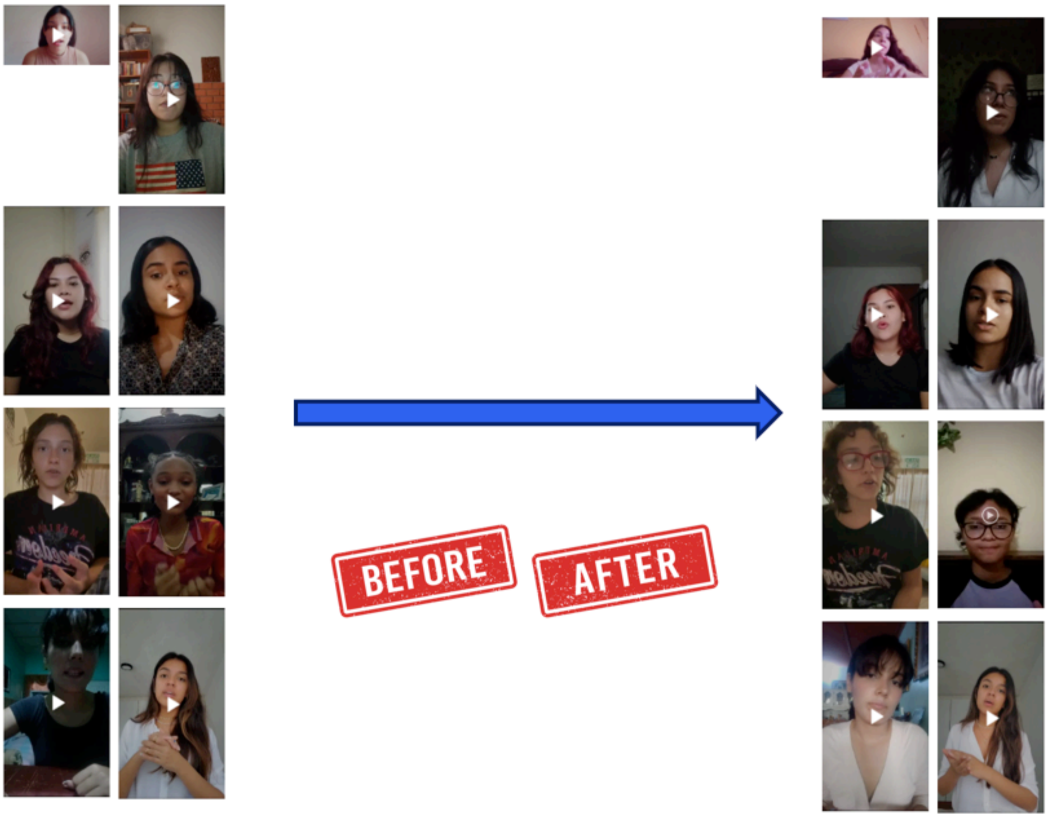

Figure 2: Girls Created Videos Before and After the Lectures on Quantum Computing, Fostering Active Participation and Demonstrating Their Progress in Conceptual Learning Through Virtual Engagement Activities.

The face-to-face activities were carry on at the "*UEPC Nuestra señora de las Mercedes de Aragua*" in Maracay, Venezuela, on October 2023. We targeted third-year middle school students, first-year high school students, and second-year senior high school students. Each session introduced fundamental quantum computing concepts, such as qubits, superposition, and entanglement, tailored to students' educational levels and prior knowledge, as agreed in Fig. 1.

Group	**Age Range**	**Total Students**	**Girls**	**Boys**
Third-Year Middle School Students	14-15	23	10	13
First-Year High School Students	15-16	14	5	9
Second-Year Senior High School Students	16-17	29	9	20

Table 1: Students Groups Attending Presential Lectures.

Due to the diversity of the class (see Table 1), a traditional teaching mode was adopted, followed by class discussions, which fostered enthusiasm among students.

Despite initial skepticism, students' curiosity and participation increased as the lecture progressed. In the case of the First-Year High School Group, female students asked insightful questions about the limitations and career paths in quantum computing. Also, during the Third-Year Middle School Group, female students showed heightened interest when the Grover Algorithm was explained using the video game "*Among Us*," indicating the effectiveness of using culturally relevant and engaging examples to capture attention. Last, in the Fifth-Year Senior High School Group, the male students expressed significant interest in job opportunities related to quantum computing and the presenter's professional journey.

Figure 3: A Face-to-Face Class at ‘UEPC Nuestra Señora De Las Mercedes De Aragua’. The Sessions Targeted Various Student Groups and Introduced Fundamental Quantum Computing Concepts Such As Qubits, Superposition, and Entanglement, Tailored to Their Educational Levels.

Further studies are still needed, mainly designed surveys to assess the program's effectiveness in greater detail.

Discussion

This comprehensive methodology underscores our commitment to transforming educational paradigms and empowering young people, especially women, in Venezuela through quantum science literacy.

To understand the basics of quantum computing, participants are already motivated to learn more, as evidenced by their active engagement and enthusiasm during virtual and face-to-face sessions. The main obstacle at this point is to expand the curriculum to include more technical aspects, particularly the mathematical foundations required for a deeper comprehension of quantum computing concepts.

In a school context, mathematics is one of the subjects that inspires the most fear [8]. This fear often arises from a need for more understanding and the perceived complexity of mathematical concepts. Recognizing that these advanced topics require a solid mathematical foundation, the curriculum will include a comprehensive introduction to mathematical techniques essential for quantum sciences, such as linear algebra. A first proposition is made in Fig. 4. These skills equip students with the tools to navigate and excel in these challenging yet captivating subjects.

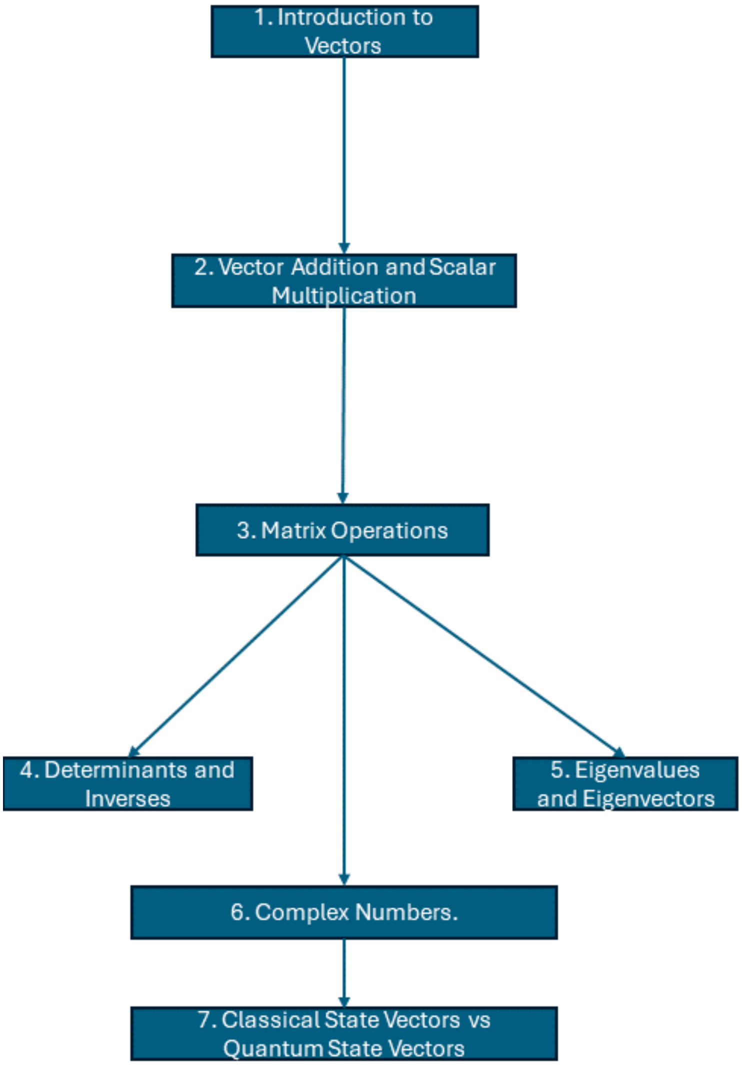

Figure 4: Flowchart of Possible Topics to Include a Comprehensive Introduction to Mathematical Techniques Essential for Quantum Sciences, Based on the Projects Qubit by Qubit [9] and QWorld [10]. These Concepts Require Multiple Lectures to Cover Thoroughly and Cannot Be Completed in a Single Session.

An essential aspect of our approach involves addressing and overcoming the fear of studying math. One girl from the virtual activities shared her perspective, highlighting the everyday anxieties and negative perceptions about math, especially at her age and grade level. She noted that seeking help, finding instructional videos, and utilizing various resources can significantly alleviate these fears. This testimony reflects a broader sentiment that, despite the intimidating nature of math, with the proper support and resources, students can overcome these barriers.

Mathematics is essential for understanding and applying concepts in quantum computing. For these concepts to take root and be applied, they must first be understood and valued by the target community. Although the topics outlined in Fig. 4 up to point 4 are part of the Venezuelan high school curriculum, we propose a more focused approach toward quantum computing. This approach will include practical activities integrating programming, highlighting its significance in the field. Programming deepens the understanding of quantum computing concepts and empowers students, particularly women, by providing valuable skills and opening up diverse career opportunities [11].

Conclusion

The project has addressed some of the significant educational challenges faced by secondary and diversified education levels in Venezuela, particularly in teaching basic quantum computing concepts. The first findings of this work indicate a significant improvement in student's conceptual understanding and interest in quantum computing. Including practical activities and culturally relevant examples, such as the Grover Algorithm explained through the video game "*Among Us*," effectively engaged students and fostered curiosity.

The implications of these findings suggest that early and inclusive STEM education is vital for developing future innovators and closing the gender gap in scientific fields. Introducing students to quantum computing concepts early on and providing a supportive learning environment can inspire a new generation of scientifically curious and technologically adept individuals.

However, the study also identified limitations, particularly the need for more specialized teachers and a more comprehensive curriculum that includes the necessary mathematical foundations for understanding quantum computing. As mentioned, the main obstacle now is to expand the curriculum to incorporate more technical aspects, particularly linear algebra and programming. Programming deepens the understanding of math concepts and empowers students, especially women.

Further research is needed to assess the long-term effectiveness of this educational approach, including designed surveys to gather detailed participant feedback. These studies will help refine the curriculum and teaching methods, ensuring that the initiative continues to meet the learning needs of students and contributes to closing the gender gap in STEM fields.

Acknowledgements

The success of these activities was supported by various individuals and organizations, including Unitary Funds for further developing this project in <*Quantum*|*Chamitas*>, a pioneering initiative focusing on accessible, high-quality quantum education in both Venezuela and France for girls in STEM. The teaching staff of "*Las Mercedes de Aragua*": Prof. Ana Mercedes Ocha, Prof. Edalis Martinez Saavedra, Cecilia Anis, Prof. Maryit Flores, Prof. Rubén Briceño, Prof. Nérida Jiménez, Prof. Ana Pacheco, Prof. Blanca Valderrama, and Dr. Zulay Perdomo. Thanks also to the Womanium organization. Thanks to Mélissa Vaca provided invaluable support throughout the project, and to Prof. Dr. Pio José Arias González which is currently helping develop the math curriculum.

References

[1] Calatrava, C., & Martínez, L., et al. (2022). Informe 2021-2022 del Sistema de Evaluación de Conocimientos en Línea (SECEL). [Video]. YouTube. https://www.youtube.com/watch?v=x6dIpj1WK40

[2] Planchart, E., & San Blas, G. (1995). Enseñanza de la ciencia en Venezuela: un reto al futuro. *Gac Méd Caracas, 103*(3), 213-230.

[3] Flórez, R. E., & Chaparro Becerra, L. A. (2019). Crisis en Venezuela en términos de educación. *Shimmering Words: Research and Pedagogy E-Journal, 8, 177-187*. Retrieved from http://revistas.ustatunja.edu.co/index.php/shimmering/article/view/1805

[4] Gamboa, D. G., & Anjel-van Dijk, L. (2022). Academic freedom and the untold story of Venezuelan scholars under pressure. *The Academy in Exile Book Series, 2*, 249.

[5] Mulvey, P., & Pold, J. (2023, July 26). New Astronomy Bachelors and Masters: What Comes Next. Data from the degree recipient follow-up survey for the classes of 2018, 2019, and 2020. Retrieved from https://ww2.aip.org/statistics/new-astronomy-bachelors-and-masters-what-comes-next

[6] Adegoke, B. A. (2012). Impact of interactive engagement on reducing the gender gap in quantum physics learning outcomes among senior secondary school students. *Physics Education, 47*(4), 462–470. https://doi.org/10.1088/0031-9120/47/4/462

[7] Canino, M. V., & Vessuri, H. (2003). La otra, el mismo: El género en la ciencia y la tecnología en Venezuela. *CDC, 54*(54).

[8] Di Martino, P., & Zan, R. (2013). Where does fear of maths come from? Beyond the purely emotional. In *Proceedings of the eigth congress of the European Society of Research in Mathematics Education* (pp. 1309-1318). Middle East Technical University.

[9] The Coding School. (n.d.). Qubit by Qubit. Retrieved from https://www.qubitbyqubit.org/

[10] QWorld. (n.d.). QClass 23/24. Retrieved from https://qworld.net/qclass23-24/

[11] Contreras-Ortiz, S. H., Ojeda Caicedo, V. V., Marrugo-Salas, L. M., & Contreras-Ortiz, M. S. (2021, October). A model for the development of programming courses to promote the participation of young women in stem. In *Ninth International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM'21)* (pp. 126-132).

Contact email: carolina@quantumchamitas.com