Quantum Algorithms in Action: A Student's Exploration of Shor and VQE

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Introduction

What does the future of computing look like? As a high school student venturing into quantum computing, I discovered that the answer lies at the crossroads of mathematics, computer science, and research. With tools like Qiskit and algorithms such as Shor's Algorithm and the Variational Quantum Eigensolver (VQE), I began a journey into one of the most exciting frontiers of technology. From algorithms that could reshape cybersecurity to simulations that might support sustainable innovation, each step revealed new possibilities. This is my story—where curiosity meets computation, and student research connects to real-world impact.

1. Discovering Quantum Computing as a High School Researcher

Exploring quantum computing felt like stepping into another dimension. My passion for mathematics and computer science found new expression in qubits, superposition, and entanglement. My first exposure came through online workshops and the Qiskit platform, which allowed me to run quantum circuits on real devices. Writing Python code that manipulated qubits turned abstract theory into tangible experiments. The more I learned, the more I realized that this field was not just about technology but about reimagining what computation could be. Discussions with peers and mentors deepened my understanding. Concepts like decoherence and error

correction, once intimidating, became tools to explore. This growing expertise led me to implement Shor's Algorithm and apply VQE for molecular simulations—two experiences that shaped my research ambitions.

2. Shor's Algorithm and the Future of Cybersecurity

Shor's Algorithm is famous for its ability to factor large integers exponentially faster than classical methods. Since modern RSA encryption relies on the difficulty of factoring, Shor's work revealed a vulnerability that could transform cybersecurity. Learning about this was thrilling—and unsettling. If quantum computers scale, they could break much of today's encryption. This raised new questions for me: How do we design post-quantum cryptography resilient to quantum attacks? How do we balance innovation with security? For me, Shor's Algorithm wasn't just a technical breakthrough; it was a call to think critically about the social consequences of quantum progress.

3. VQE and Molecular Simulation for Sustainable Innovation

While Shor's Algorithm looks backward—challenging current systems—VQE looks forward, enabling new possibilities. The Variational Quantum Eigensolver uses hybrid quantum-classical methods to approximate the ground states of molecules. I explored how VQE could model molecular interactions for biopesticide design, aiming to reduce environmental harm compared to traditional chemicals. This project showed me how quantum computing might one day accelerate the discovery of sustainable materials and pharmaceuticals. By blending chemistry, computer science, and mathematics, I witnessed firsthand how interdisciplinary innovation can address global challenges like food security and environmental health.

4. Lessons Learned and Vision for the Future

These projects taught me that algorithms are not just lines of code—they are stories about possibility. Shor's Algorithm told the story of vulnerabilities in digital security. VQE suggested new narratives for sustainability. Along the way, I learned

resilience from debugging quantum circuits, perspective from collaborating with peers, and creativity from weaving math into computation. Looking ahead, I see quantum technologies transforming fields from medicine to national security. But I also see the urgent need for ethical leadership to guide this transformation.

5. Ethical Reflections and Responsible Innovation

With great power comes great responsibility, and quantum computing exemplifies this. The same algorithm that secures data could also expose it. The same molecular simulation that designs life-saving drugs could design harmful compounds. This dual-use nature demands that future scientists ask not only 'Can we?' but 'Should we?'. Working on biopesticide design reminded me that innovation must prioritize human well-being and planetary health. As students, we must cultivate both technical skill and moral courage. Only then can quantum technologies evolve into tools that serve society equitably.

Conclusion

My exploration of quantum algorithms was more than an academic exercise—it was an initiation into the responsibilities of discovery. Shor’s Algorithm revealed the fragility of today’s security. VQE opened the door to sustainable chemistry. Together, they reshaped how I view computing, ethics, and innovation. This journey confirmed that the future of quantum computing belongs not only to experts in labs but also to students willing to imagine, experiment, and question. I hope to carry this spirit into my future studies, contributing to a world where curiosity drives responsible progress.

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