Bridging the Quantum Gap: Addressing Challenges in Training Individuals in Quantum Computing Using Self-Guided Learning Resources

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ABSTRACT

The convergence of quantum technologies and high-performance computing offers unique opportunities for research and algorithm development, demanding a skilled workforce to harness the quantum systems' potential. In this lightning talk, we address the growing need to train experts in quantum computing and explore the challenges in training these individuals in quantum computing, including the abstract nature of quantum theory, or the focus on specific frameworks. To overcome these obstacles, we propose self-guided learning resources that offer interactive learning experiences and practical framework-independent experimentation for different target audiences.

KEYWORDS

quantum computing, interactive learning environments, education

1 INTRODUCTION

As quantum technologies inch closer to practical applications, there is a pressing need to train a new generation of experts capable of harnessing the power of quantum computing systems effectively and advancing the research around quantum computing. As anticipated use-cases of quantum computing overlap strongly with existing applications of high-performance computing (HPC) [3], there is increased demand in the HPC world in providing training and learning opportunities to support a workforce equipped with the knowledge and skills to exploit quantum systems' potential [6].

In this paper, we delve into the challenges faced in training people in quantum computing such as the abstract nature of quantum theory, including superposition and entanglement, which pose a steep learning curve for individuals transitioning from classical computing paradigms. To address these challenges, we introduce the concepts that guided the development of a comprehensive learning platform aimed at facilitating the training of individuals in quantum computing. The proposed self-guided learning resources provide interactive and immersive learning experiences, encompassing theoretical foundations and practical implementations.

We believe that the self-guided learning resources can help bridge the gap in quantum computing education, enabling individuals to acquire the necessary skills to contribute to the emerging quantum landscape. Through a combination of accessible learning resources, practical experimentation, and a collaborative ecosystem, this platform can empower learners to harness the full potential of quantum computing and accelerate the advancement of quantum technologies in the HPC domain.

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2 CHALLENGES IN PROVIDING QUANTUM COMPUTING EDUCATION

Educating a wide range of high-performance computing (HPC) users in the field of quantum computing poses several challenges. Quantum computing is a rapidly evolving field that combines elements of physics, computer science, and mathematics and is considered to be counterintuitive, making it difficult for individuals to grasp its fundamental concepts.

2.1 Diverse Backgrounds

HPC users come from various backgrounds, including computer science, physics, mathematics, engineering, chemistry, meteorology and material science with initiatives to expand to the vast array of social, behavioral, or economics disciplines [8]. Educating such a diverse audience requires finding common ground and conveying quantum concepts in a manner that is accessible and understandable to individuals with different backgrounds. This is especially true in view of the frequent use of physics vocabulary in the field of quantum computing.

2.2 Abstract Nature of Concepts

Quantum computing operates on principles that deviate significantly from classical computing. Concepts like superposition, entanglement, and quantum algorithms can be abstract and counterintuitive [11], making them challenging to grasp for newcomers. Translating these abstract concepts into tangible and relatable examples is crucial to facilitating understanding among a wide range of users.

2.3 Rapid Technological Advancement

Quantum computing is a fast-paced field with frequent breakthroughs and advancements. This challenge is compounded when educative initiatives focus on learning a specific quantum computing framework or application programming interface (API) that is subject to change. Quantum computing frameworks such as Qiskit, Cirq, or Forest, are essential tools for developing and running quantum algorithms. However, these frameworks often undergo updates, improvements, and even major revisions to accommodate advancements in hardware, algorithmic breakthroughs, or community feedback. As learners show difficulties in semantic transfer on constructs with different syntax but same semantics [9], relying solely on a specific framework or API can limit adaptability and hinder the ability to keep up with the rapid evolution of the field.

3 EDUCATING A WIDE RANGE OF USERS IN QUANTUM COMPUTING USING SELF-GUIDED LEARNING RESOURCES

Different self-guided learning resources (e.g. [4, 10]) have been proposed to address the challenge of providing quantum computing education to a wider audience either by offering direct learning opportunities or by being used as an additional resource in in-person training. However, many of these options tend to presuppose prior knowledge, resemble technical documentation for specific frameworks, or delve excessively into advanced physics concepts. These characteristics can impede the accessibility and comprehension for beginners and non-experts. To this end, we have developed self-guided learning resources available through IQM Academy[1] addressing the aforementioned challenges as outline below.

3.1 Focusing the Underlying Principles and Concepts of Quantum Computing

It is crucial for learners to develop a solid foundation in the underlying principles and concepts of quantum computing, allowing them to understand the fundamental building blocks that drive various frameworks and APIs and that stay relevant in the long term. By focusing on core concepts and gaining a broader understanding of quantum computing principles, users can adapt to changes in frameworks and APIs more effectively, enabling them to navigate the evolving landscape of quantum computing with greater flexibility and agility.

3.2 Low Floors and High-ceilings

In order to cater to *diverse backgrounds* of learners, the resources should cater different levels and be easy to pick-up for beginners, but also provide challenging content for advanced learners – this is often referred to as having low floor and high-ceilings [5] and can be facilitated through fine-grained modularization. Following the style of exploratory learning [7], IQM Academy provides interactive applets that invite learners to first experience the concepts hands-on, which also helps to overcome the *abstract nature of concepts*.

3.3 Using Different Frameworks to Highlight Concepts

In learning, code serves particularly as a tool for thought during the learning process, allowing individuals to mold and articulate ideas. However, fixating too much on particular aspects of a programming framework can obstruct the understanding of the fundamental concept. Therefore, for any curriculum striving for profound learning and transfer, it is crucial to deliberately integrate strategies that promote transfer [1]. By avoiding excessive focus on a specific framework and instead utilizing implementations in different frameworks presented next to each other to illustrate the concept (see fig. 1), we enable a comparison of various ways to express the same idea. This approach facilitates a deeper understanding and appreciation of the underlying principles in the context of *rapid technological advancements* [2].

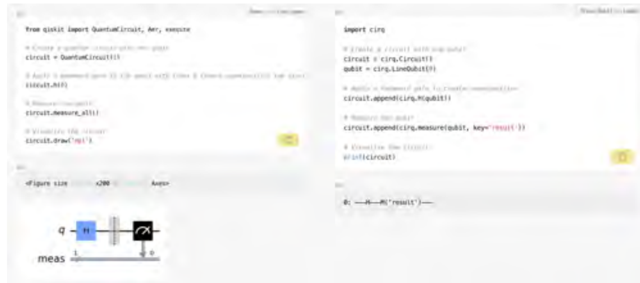

Figure 1: Parallel support for Qiskit, cirq and QASM (not displayed) fosters deeper understanding of underlying ideas.

4 CONCLUSION

While educating a wide range of HPC users in quantum computing may be challenging, it is an essential endeavor to unlock the full potential of this technology. With concerted efforts and effective educational strategies, we can bridge the gap and empower a broader community to explore, understand, and contribute to the exciting world of quantum computing. IQM Academy is addressing this educational need by following above concepts and is available for free.

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[1] IQM Academy is available via https://www.iqmacademy.com.