Inaugural Quantum Computing School in Lesotho: Its impact and the Lessons Learnt

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Abstract.

This paper reports the events and impact of a two-day Physics Without Frontiers (PWF) quantum computing School that took place on the 14^{th} and 15^{th} of November 2020 at the National University of Lesotho (NUL). Sponsored by the International Centre for Theoretical Physics (ICTP) and aimed to run annually, the School was intended to introduce quantum computing; using existing open-source quantum computing platforms, to undergraduate students in Lesotho as well as to highlight how quantum computing can be used as a driver for the Fourth Industrial Revolution (4IR). The School was also intended to encourage students to consider furthering their study in quantum computing and related disciplines. This (hoped-to-be annual) event will potentially unite the NUL, the Lesotho government and the ICTP in a long-term relationship; to the benefit of young Basotho scientists and students. The November 2020 event was, in and of itself, a success on several response measures including good and consistent attendance over the two days, as well as being influential based on several students' requests for postgraduate reference letters following this event. The outreach approach used here can be replicated elsewhere, especially in Africa, in order to capacitate students with quantum computing skills. Challenges encountered in this event will also be discussed in the paper.

1. Introduction

The first quantum revolution started in the early $1900s$; with the birth of quantum mechanics. Quantum mechanics probes the world at a sub-atomic level. During the second half of the 20^{th} century; in the $1970s$, the second quantum revolution was born [1]. The second quantum revolution is characterized by the use of concepts from quantum physics in order to process information. This use of quantum mechanical concepts in order to process information is referred to as quantum information processing (QIP) [1, 2, 3].

Some of the sub-fields of QIP include quantum cryptography [4] and quantum computing [5]. Quantum cryptography uses quantum mechanical concepts such as the *no-cloning theorem* and Heisenberg's *uncertainty principle* in order to enable secure communication of information. On the other hand, quantum computing makes use of quantum mechanical concepts such as *interference* and *superposition* in order to perform computations in a manner that offers computational advantage over conventional computing paradigm [1]. Coincidentally, in addition to being one of the sub-fields of the second quantum revolution, quantum computing is also one of the driving technologies of the fourth industrial revolution (4IR) [6, 7]. As a consequence, quantum computing has gained some traction beyond the academia.

Despite the growing popularity of quantum computing in other parts of the world [8], there are other parts of the world where the awareness of quantum computing is still limited. These parts are predominantly in the global South. This limited awareness of quantum computing in the global South can be addressed through science communication approaches such as outreach and public engagement activities [9].

In this paper, we provide a report on the two-day quantum computing outreach activity that was held in Lesotho in November 2020. The goals of this outreach activity were:

- to introduce quantum computing to undergraduate students in Lesotho; and
- to encourage these students to consider pursuing their studies in quantum computing.

The remainder of this paper is structured as follows. The next section provides the background information on quantum computing and science communication. This is followed by Section 3, which outlines how the quantum computing outreach activity discussed in this paper was conducted. Furthermore, Section 4 discusses the outputs of the outreach activity, including the lessons learnt from this quantum computing outreach. Finally, Section 5 concludes this paper.

2. Background Information

2.1. Quantum Computing

As already stated earlier in this paper, quantum computing uses quantum mechanical concepts in order to perform computation. Additionally, in order to process information, quantum computing uses a quantum bit (qubit) as a unit of information [1]. A qubit is analogous to a binary digit (bit) in conventional computing paradigm. Additionally, a qubit can exist in superposition of two quantum computational basis states, namely $|0\rangle$ and $|1\rangle$.

Mathematically, a qubit can be represented as [1, 10, 11]:

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle, \tag{1}$$

where α and β, which are known as probability amplitudes, satisfy the condition:

$$|\alpha|^2 + |\beta|^2 = 1. \tag{2}$$

In order to implement quantum computing on the existing noisy, intermediate-scale quantum (NISQ) computing devices [12], various quantum computing software frameworks can be used. These frameworks include [7, 13, 14]:

- QuTiP;
- IBM‘s Qiskit;
- Google‘s Cirq and TensorFlow Quantum;
- Amazon‘s BraKet; and
- Xanadu‘s StrawBerry Fields and PennyLane.

2.2. Science Communication

Besides communicating with peers through the publication in scientific journals, scientists can also communicate directly with the general public [9, 15]. Various approaches can be used by scientists to engage with the general public. These approaches include [9]:

- outreach activity;
- public engagement;
- diversity and inclusion promotion activity; and
- knowledge exchange.

The communication approach that was used in the work reported in this paper is the outreach activity. The details of this outreach activity will be provided in the next section.

Table 1. Summary of Topics Covered on Day 1.

Topic	Speaker
Introduction to Quantum Computing	Makhamisa Senekane
Quantum Computing and the $4IR$	Makhamisa Senekane
Introduction to Python	Makhamisa Senekane
Navigating Through Google Colab	Naleli Matjelo
Hands-on Introduction to QuTIP	Makhamisa Senekane

Table 2. Summary of Topics Covered on Day 2.

Topic	Speaker
Hands-on Intro. to QISKit	Makhamisa Senekane (MS)
Hands-on Intro. to Cirq and TensorFlow Quantum	Naleli Matjelo (NM)
Hands-on Intro. to BraKet	MS
Hands-on Intro. to PennyLane and Strawberry Fields	NM
Careers Opportunities in Quantum Computing	MS and NM

3. The Quantum Computing Outreach Activity

The two-day quantum computing outreach activity was held at the National University of Lesotho's Roma Campus, Lesotho, from the 14^{th} November 2020 to the 15^{th} November 2020. This outreach activity was organized by the International Centre for Theoretical Physics (ICTP) Physics Without Frontiers (PWF) and the National University of Lesotho (NUL). The ICTP PWF provided both the technical and the financial support, while the NUL hosted the event and prepared the learning material for this activity.

As already stated, this outreach activity was intended to introduce quantum computing to undergraduate students studying in Lesotho. Therefore, in order to prepare for the event, invitations were sent out to the three universities in Lesotho; namely the NUL, Botho University, and Limkokwing University of Technology. Students who were familiar with computing and/or physics were requested to apply for the event electronically, and successful candidates were notified via an e-mail. Consequently, 34 students were invited to attend this event.

The topics that were covered on the first day of the quantum computing outreach activity are provided in Table 1. In essence, the first day was intended to introduce the students to Python programming language [16] and quantum computing. Additionally, students were exposed to cloud-based programming environment using Google Colaboratory/colab [17]. Finally, they were briefly introduced to one of the quantum computing frameworks, namely QuTiP framework.

On the other hand, the topics covered on the second day are provided in Table 2. These topics were mainly geared towards exposing the students to different types of quantum computing frameworks. Finally, the students were exposed to the career opportunities in quantum computing. Originally, more speakers were invited to give lessons in this School. However, due to various challenges, especially owing to the fact that the School took place on a weekend, ultimately, only two speakers were able to give lessons in this School.

Through-out this two-day event, the students were using their own computing devices and using Google Colab to run their codes, while the free internet access was provided by the National University of Lesotho. Furthermore, the students were permitted to discuss the quantum computing exercises provided with their colleagues. Figure 1 shows students sharing ideas during one of the exercises.

Figure 1. Students engaging with the exercises during the quantum computing outreach event.

4. Outreach Activity Outputs

In total, 34 students registered for the quantum computing outreach activity. These students came from two of the three universities in Lesotho, namely the NUL and Botho University. Figure 2 provides an overview of the students who attended, and their institutions. As can be observed from the figure, majority of the participants were from then National University of Lesotho. This might be due to the publicity that this event received within the National University of Lesotho, as opposed to two other universities.

Figure 3 shows participants when dis-aggregated by gender. It can be observed from the data that when dis-aggregated by gender, the list of participants paints a very gloomy picture. This gender disparity underlines the necessity to pay attention to gender representation during the admission process of the participants. Furthermore, the disparity underlines the need to further mainstream gender equality, especially in the quantum computing community.

At the end of the event, the students who successfully attended all the sessions of this two-day event were awarded with certificates of participation. Of the 34 students who were invited to attend the quantum computing event, 32 were awarded with the certificates of successful completion. Figure 4 shows the design of the certificate of participation that was awarded to the students upon successful completion of all the activities.

The first goal of the quantum computing outreach activity was to introduce the undergraduate students in Lesotho to quantum computing. This goal was met, even though the attendance of the students was dominated by one university. Furthermore, the attendees were predominantly male.

On the other hand, the second goal of the outreach activity was to encourage students to consider pursuing a career in quantum computing. After the completion of the event, several students have approached the event organizers (the authors of this paper), requesting reference letters for postgraduate studies.

As stated earlier, this quantum computing outreach initiative was a result of a collaboration of the ICTP PWF and the National University of Lesotho. This collaboration underlines the necessity of the resource-constrained countries to explore the possibility of joining hands with

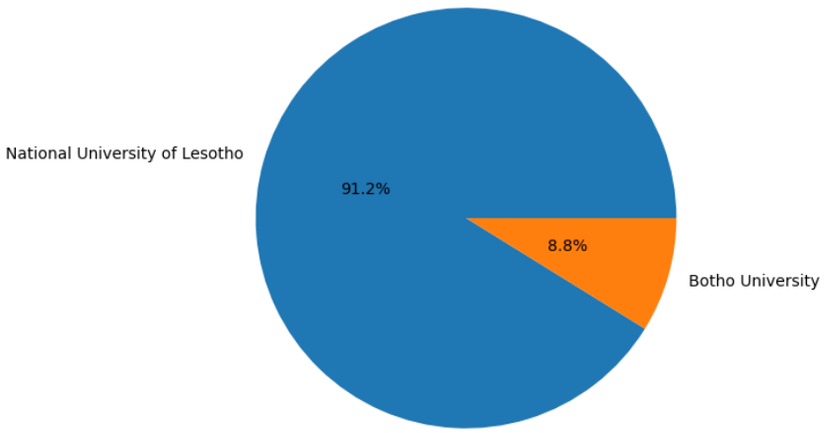

Figure 2. Quantum computing outreach activity participants, by institution.

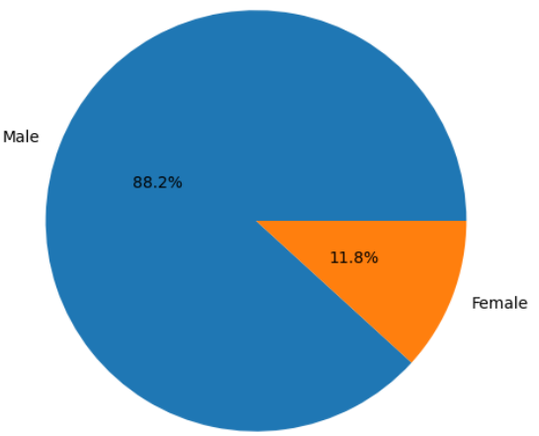

Figure 3. Quantum computing outreach activity participants, by gender.

the established entities in order to up-skill and develop their communities. Furthermore, the learning material produced in this collaborative work can be used by other resource-constrained countries as a tool to introduce quantum computing to the undergraduate students.

This is to certify that

attended the

ICTP Physics Without Frontiers

School on Quantum Computing.

National University of Lesotho

14th - 15th November 2020

Prof. Bobby Acharya
Co-Coordinator of PWF

Dr. Molefe Makhele
Head of the Department of Physics

Figure 4. Upon the successful completion of all the sessions of the event, the students were awarded with certificates of participation.

5. Conclusion

In this paper, we have discussed the details concerning the two-day quantum computing activity that was held in Lesotho in November 2020. Additionally, we have discussed the challenges that this activity faced, and the lessons learnt from hosting the activity. We have also reported on the impact of the event. Finally, we have argued that the approach used in organizing and hosting this activity can be replicated elsewhere in a resource-constrained country, especially in Africa.

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