From Student SIG to Success: *The Journey of a Student HPC Special Interest Group Towards Sustainable Training and Success in Student Cluster Competitions*

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ABSTRACT

Developing a sustainable High Performance Computing (HPC) workforce pipeline remains a global priority. As access to HPC resources continues to improve in Africa, the shortage of available skilled HPC personnel is a significant impediment to the adoption of advanced research computing infrastructure. South Africa has several workforce training initiatives aimed at developing career HPC system administrators, yet, apart from the annual national Student Cluster Competition (SCC) – an initiative of South Africa's Centre for High performance Computing (CHPC) – there are no other formal training programmes available for the undergraduate student community.

Each year since the inception of the CHPC-SCC the University of the Witwatersrand ("Wits") has entered at least one team. Through the implementation of an array of student-led training approaches using decommissioned HPC hardware, Wits has enjoyed continued success at these SCC events. Moreover, Wits students have been part of the national teams that have achieved six top-3 finishes in international Student Cluster Competitions.

This paper provides an overview of the student HPC Special Interest Group (SIG) formed at the University of the Witwatersrand that focuses on delivering HPC training to the undergraduate student community. The paper outlines the approach towards growing and maintaining the interest group, including teaching and learning strategies to prepare Wits students for Student Cluster Competitions. Insights into the challenges experienced and lessons learned are discussed, particularly with respect to sustainable workforce development. These insights could help develop a structured framework for creating effective and sustainable HPC special interest groups, centred around student involvement.

KEYWORDS

Student Cluster Competition, HPC Workforce Development, HPC Education, HPC Training, Africa

1 INTRODUCTION

Sustainable HPC workforce development is widely recognised as a critical component of effective advanced research computing [6, 11]. Until recently, South Africa did not possess a strong workforce pipeline for HPC. Following the inception of South Africa's first national HPC facility, the Centre for High Performance Computing (CHPC) in 2007, a concerted effort needed to be made towards HPC awareness and outreach initiatives.

As a driver for HPC outreach aimed at undergraduate students at national universities in South Africa the CHPC's national Student Cluster Competition (CHPC- SCC) was launched in 2012. Through the SCC pipeline, South Africa has enjoyed notable success in the ISC Student Cluster Competition, co-organised by the HPC-AI Advisory Council and ISC Group (ISC-SCC).

This paper showcases the University of the Witwatersrand's student HPC Special Interest Group (SIG). The approaches taken towards sustainable student HPC training, the lessons learned, the challenges encountered, and a brief overview of plans for expanding the student SIG model for other universities in South Africa are discussed.

1.1 Importance of HPC Outreach

It is well established that both outreach and education play important roles in accelerating optimal use of advanced research computing resources and ensuring a sustainable workforce pipeline [3]. Hernandez et al. note that the resources encountered during one's collegiate education shapes the tools and techniques that professionals employ throughout their careers [6]. It is important to

https://doi.org/10.22369/issn.2153-4136/16/1/9

expose undergraduate students to HPC concepts as early as possible in their degrees, not only to enhance accessibility to HPC skills and resources, but to inspire undergraduate students to make informed decisions in their course selection to enable the pursuit of careers in HPC.

1.2 Student Cluster Competition

The SCC concept began in 2007 [1] during the SC Conference Series [2] as an educational tool to immerse undergraduate students in HPC [4, 13]. Through the competitive format of the student event, the SCC plays a dual role of HPC outreach and HPC workforce development by introducing participating teams to conventional HPC challenges. Since the initial SC07 event, the SCC has expanded beyond the USA to other international HPC conferences, including Africa [3], Asia [4], and Europe [5].

1.3 CHPC Student Cluster Competition

South Africa's national SCC exposes undergraduate students to HPC in an exciting format and aims to motivate students to consider future careers in HPC.

The CHPC-SCC involves a National Selection Round, held annually in the July winter break, where twenty teams (each of four eligible students) participate in a week of intensive HPC system administration training. The training encompasses both theoretical lectures and practical hands-on labs. The Selection Round covers topics relating to HPC fundamentals, culminating in a final theoretical cluster design project and presentation. The top ten performing teams from the Selection Round progress to the National Finals, held annually in December at the CHPC's national conference [6]. During this round each team is provided with physical hardware and is tasked with assembling a small-scale HPC system and undertaking several benchmarking and performance challenges. The overall winning team of four is crowned the national champions and serves as the foundation of the team to represent South Africa at the ISC-SCC. From the remaining teams, a further two students, as well as two reserves, are selected to complete the national team.

Prior to competing in ISC-SCC, the team travels to the USA for a week of focused technical training and cluster design preparation.

Through its Student Cluster Competition initiative, the CHPC not only develops technical skills in HPC but also cultivates a strong HPC community. Motivating students to pursue careers in scientific computing contributes to a sustainable HPC workforce pipeline in South Africa.

2 WORKFORCE DEVELOPMENT

There are three primary considerations to ensure the sustainable use of advanced research computing:

(1) A user community with the need for, and ability to use, advanced research computing resources.
(2) A skilled technical workforce to deploy, administer, and maintain the resources.

[1]https://www.youtube.com/watch?v=NhSWMSp096c
[2]https://supercomputing.org/
[3]https://scc.chpc.ac.za/
[4]http://www.asc-events.org/StudentChallenge/index.html
[5]https://isc-hpc.com/program/student-cluster-competition/
[6]https://chpcconf.co.za/

Table 1: CHPC Results at ISC-SCC 2013-2020

Year	Result	Year	Result
ISC 2013	1st	ISC-2017	2nd
ISC-2014	1st	ISC-2018	3rd
ISC-2015	2nd	ISC-2019	1st
ISC-2016	1st	ISC-2020	2nd

(3) A pipeline to replenish the workforce and retain the core competencies.

2.1 Building A Workforce Pipeline Through Outreach

The CHPC restricts SCC participants to undergraduate students in the early stages of their degrees to amplify and maximise early curriculum intervention and outreach impact [11].

Prior to the COVID-19 pandemic, from 2012 to 2019, the CHPC-SCC met its national outreach objectives by introducing more than 600 undergraduate students to HPC. In addition, the South African national teams achieved international success at the ISC-SCC, placing in the top three in each of these years (see Table 1). Students from Wits fielded 28 of the 56 (50%) international team members.

2.2 Achieving Outreach Through Student Competition

Adopting a competition model for building a scientific computing workforce provides numerous benefits:

- Competition provides an engaging opportunity for students to work together in teams, strengthening their social and collaborative skills.
- Team assignments closely mirror professional HPC centre scenarios and require students to think critically and work autonomously [4, 5].
- Working closely in their teams against a community of their peers, students are motivated to excel through the high stakes of elimination and reward.

Additionally, the CHPC-SCC is an effective outreach tool because of the attractive opportunity to be selected for the ISC-SCC team. The ISC-SCC team is supported to travel to the USA for additional training and then again to ISC to compete and experience one of the largest HPC conferences.

3 BUILDING THE WITS HPC SIG

Many HPC workforce training initiatives catering for students are organised in a top-down fashion. In contrast, Wits formed a student special interest group dedicated towards HPC training for undergraduate students that is primarily run by the student volunteers [2].

The SIG has matured to perform three primary roles:

(1) Preparing and selecting the University's participating teams for the CHPC-SCC.
(2) Delivering HPC training to undergraduates, with a focus on practical skills that are not typically addressed in the standard Computer Science curriculum.

(3) Developing the student organisers through the experience of leading and training their younger peers.

3.1 The Wits SIG Origin Story

Wits had an established history with HPC prior to the creation of the CHPC in 2007. In 2010, the Wits Mathematical Sciences Support team (MSS) formed several interest groups, including the Wits HPC Interest Group. The group was created to facilitate collaboration and expand access to scientific computing, with a specific focus on leveraging HPC to address complex scientific challenges faced by researchers at the university.

A pivotal moment came with the introduction of the CHPC-SCC in 2012. In the first year of the competition, students entered as individuals and the CHPC assigned them to teams of four. The inaugural winning team included three Wits students. In preparation for ISC'13 the team sought additional computational resources from Wits. Their subsequent victory at ISC'13 brought recognition and secured hardware donations, catalysing the growth of the HPC Interest Group.

Prior to 2021 the group's primary focus was competition preparation and mentorship for the CHPC-SCC. In 2021, the group shifted focus towards a more formal training model incorporating lectures.

The group continues to evolve, relying heavily on mentorship from former ISC participants, under the guidance of the School of Computer Science and Applied Mathematics.

4 A MODEL FOR A STUDENT-LED HPC TRAINING PIPELINE

While numerous HPC student interest groups exist at universities, there is a scarcity of case studies of student SIGs addressing an HPC training pipeline. Pertinently, the Wits SIG, with the Mathematical Sciences Support team, has developed a training model that has been consistently tried and tested.

Due to the continual succession in leadership, the SIG's structure and format has seen incremental evolution over many years. The model presented in this paper focuses on the current approach used by the SIG.

4.1 Creating Awareness for the SIG

A fundamental criterion of success for an organised group is its ability to recruit and maintain members. As members graduate and leave the SIG, a consistent recruitment effort is needed to replenish the membership of the group.

Previously, interest in the SIG was created by past students of the CHPC-SCC targeting undergraduate student mailing lists at various faculties. While this attracted some interest, it was primarily the encouragement from past students who had competed in the CHPC-SCC that enticed their peers to participate during the winter vacation period.

As the SIG has grown into something more than a competition recruitment strategy, new methods of advertising and awareness creation have been introduced. These include: a SIG Discord channel, Instagram account, Linkedin page, WhatsApp group, posters, a website [7], and an exhibition stand at the Science Career Fair. Invitations to join these groups or channels are distributed within university mailing lists by current members and on other social platforms within the university. While creating awareness in this way has brought in some interest, students report that the most interest and participation is still gained by word of mouth.

4.2 SIG Structure and Leadership

The SIG is student-run, with a leadership structure that is more collaborative than hierarchical. There are no formal titles; the group functions on a volunteer basis, driven by its members. Each year, students who were part of the previous year's ISC-SCC team take on the role of organisers, guiding the next cohort of students. Organisers take on a variety of responsibilities, including developing content for talks, managing social media, and overseeing team selection and preparation. This flexible structure has proven effective, allowing the group to easily change its methods to suit the current circumstances. Since there isn't a single figure of authority determining the group's direction, members are more innovative and open to exploring new ideas, where decisions are made collectively.

4.3 Training and Activities

Prior to 2020, the exclusive focus of the SIG was to prepare students for excelling at the CHPC-SCC [2]. A decision was made in 2020 to extend the reach of the SIG to cater for a wider range of interests. Subsequently, general HPC-themed talks and practicals were introduced to expand the group's mission to provide broader HPC education to all interested students. The expanded talks and workshops are publicly available and hosted on a dedicated SIG GitHub repository [8].

The SIG follows the two semesters of the academic year, with weekly meetups held during the campus lunch hour. The first semester focuses on introductory-level HPC talks, with each talk accompanied by a tutorial relating to the content. Presenting content in this format aims to equip students with the practical skills required to use a particular tool or to perform a particular technique immediately. Following the preparatory talks, team selection for the CHPC-SCC Selection Round is concluded with a test (outlined in Section 4.4).

The second semester begins after the CHPC-SCC Selection Round concludes, and the SIG's focus shifts to broader topics with more emphasis on preparing any progressing teams for the CHPC National Finals (outlined in Section 4.5).

The SIG has explored various formats for delivering the training, including traditional SIG-led lectures, guest lectures from HPC experts, practical-styled interactive sessions, and tutorial-styled sessions that combine lectures with practical exercises.

Following feedback and further research into effective practical HPC training, the most recent efforts have focused on tutorial-style sessions, where interactive exercises aim to enhance students' engagement and learning while reducing the volume of lectures presented to participants [10, 12]. For instance, the SIG recently ran

[7] https://github.com/WitsHPC
[8] https://github.com/WitsHPC/HPC-InterestGroup

a hackathon event that tasked students with solving a highly parallelisable programming challenge in the fastest possible runtime. [9]

4.4 Team Selection

Wits commits to sending two teams to the CHPC-SCC Selection Round every year. Team selection begins with a timed open-book placement test, which consists of extensive Linux-based and shell-scripting questions. The highest-scoring students are selected to represent the university. To ensure well-balanced teams, the organisers review students' motivations and transcripts. Once teams are formed, SIG organisers act as mentors, dedicating time to assist with cluster design, setup, and testing at Wits. The SIG has investigated preliminary hands-on training before team selections to allow a larger pool of students an opportunity to be selected by bridging the technical knowledge gap. To complement this, the SIG holds regular practical tutorials that are also considered when selecting teams.

Most recently, the group has experimented with a project instead of a placement test. The project utilises the HPC Ecosystems Project's OpenHPC 2.x virtual lab [8] to set up a local virtual 3-node cluster using Vagrant and VirtualBox. Students had four weeks to run a small custom parallel application on their virtual clusters, including build and run scripts, to simulate aspects of a student cluster competition. Students were scored based on the functionality of their scripts, with a significant allocation to the fastest runtime. The project had several advantages over the placement test: it attracted better-prepared applicants, and it further enhanced their preparation for the Selection Round; however, there were also some drawbacks: participation rates were lower than usual, and organisers had to manually test the run scripts to ensure no hardware advantages impacted the results. Moving forward, the aim is to find a balance between tests and projects to optimise participation and learning outcomes.

The implementation of a multifaceted selection process increases the likelihood of choosing motivated and balanced student teams. Where some students may not have achieved top scores in the placement test, they have an opportunity to demonstrate their willingness to learn and improve through their performance in the hands-on practicals.

4.5 Team Preparation

Following the CHPC-SCC Selection Round, the SIG focuses attention towards preparing the Wits teams progressing to the CHPC National Finals. To facilitate hands-on practice, the teams are provided with access to HPC training systems. The training systems are built from decommissioned HPC production nodes [7, 9].

Hands-on access to physical systems provides a comprehensive learning experience to gain the technical skills required to build, deploy, and optimise an HPC cluster. These skills include, inter alia, operating system installation, network configuration, package management, and Linux shell.

Using their own deployed systems, the teams learn to compile software from source and to run distributed applications. During this training phase, the SIG mentors serve as guides for the students, giving them high-level technical advice and objectives. With this guidance, the teams learn how to identify and control factors affecting application and system performance. The extensive hands-on time produces teams well-versed in competition expectations and capable of solving problems rapidly and effectively [1].

[9] https://github.com/WitsHPC/HPC-InterestGroup/tree/main/assorted/competitions/2023_cuda/problem

5 CURRICULUM

One goal of the SIG is to be as inclusive as possible. To achieve this, training material assumes no prior knowledge or experience in any of the areas relevant to HPC. Accordingly, considerable emphasis is placed on introduction to essential concepts. More advanced topics are left to later stages of the SCC training or for further self-study to avoid overwhelming beginners.

The lessons are designed to be modular and include sufficient theoretical context to provide fundamental understanding. Focus is placed on developing practical skills and providing insights into best practices. This philosophy of learning by doing is well suited to the practice of HPC system administration and performance tuning. The curriculum equips students to excel in the Selection Round of the CHPC-SCC and is shown in Table 2, classified by topic and assessment type.

The curriculum has evolved over multiple iterations through contributions by Wits SCC participants based on areas of interest and available expertise. It accommodates a variety of teaching modalities (online, in-person, asynchronous, talks, practicals, labs, and quizzes) across a wide range of topics at different levels of depth and inherent difficulty.

From 2021 the core course materials are consolidated in the public GitHub repository which contains the SIG talks, tutorials, and materials for self-study. Some of the material is maintained privately out of necessity (for instance, the SIG quizzes). This includes more advanced material, including solutions that are relevant to CHPC-SCC preparations, and content that is central to the team's strategy at ISC-SCC. The GitHub approach facilitates collaboration and accessibility and lends itself to iterative development. The repository contains both original work as well as material collected or reformatted from publicly available sources. Quizzes, student submissions, and student discussions are hosted on Moodle LMS.

6 STATISTICS

The SIG facilitates a virtual community through Discord, and membership stands at 366 past and present students as of April 2024.

Table 3: Wits SIG results in SCC

	1st	2nd	3rd	Total Events
CHPC-SCC (National) 2014-2023	7	5	4	11
ISC-SCC (International) 2013-2023	2	2	1	11

Table 3 shows the performance of Wits participants at the CHPC-SCC and ISC-SCC events. The ISC (International) row shows results from national teams where Wits comprises more than half of the members. The Total Events column reflects the number of SCC

Table 2: Wits SIG HPC Curriculum (1st and 2nd Semester)

Lecture	Topics Covered	Tutorial (T) or Quiz (Q), if any.	
Introduction to HPC	Fundamental concepts of HPC and its applications.	-	-
Linux and shell	Basic shell commands and their usage in Linux.	Use the terminal to answer questions	Q
Hardware Basics	Understanding hardware components and how to make informed decisions about cluster design.	Technical questions about hardware, requiring investigation of hardware specifications and computing centres	Q
Compiling Applications	Building and running applications from source (compiler flags, linking libraries).	Compile a simple application (e.g., \`htop\`).	T
Parallel Computing and MPI	A high-level overview of MPI, OpenMP, and CUDA.	Compile and run a simple MPI-enabled program.	T
Advanced HPC System Tools	Containerisation and module management.	Hands-on implementation of these tools.	T
Benchmarking$^{\alpha}$	Understanding benchmarking applications.	Run HPL.	T
Scripting$^{\alpha}$	Overview of scripting and best practices.	Script a small application installation.	T
Version Control$^{\alpha}$	Using Git and GitHub effectively.	-	-
Makefiles$^{\alpha}$	Creating and using Makefiles.	-	-
HPC Best Practices$^{\alpha}$	Tools, techniques, and approaches relevant to reliable and efficient operation of HPC clusters.	-	-

Key: $^{\alpha}$ denotes 2^{nd} semester

events, noting that Wits had multiple teams at each CHPC-SCC. The strong results reflect the SIG's effectiveness in supporting world-class competencies in HPC system administration and optimisation.

From 2014 to 2023 teams from Wits have won the National Round seven times, with the non-winning Wits teams securing a further five silver and four bronze medals (Wits traditionally sends two teams to the National Round). Over the past ten years, more than half of all members of the CHPC national teams competing in ISC-SCC have been students from the Wits SIG.

Most of the SIG membership originates from two University schools: the School of Computer Science and Applied Mathematics; and the School of Electrical and Information Engineering. The SIG comprises of first to fourth-year students, with the majority being in their second year of study. The organising committee are in their third year of study or later.

In the first semester, weekly talks usually attract 20 students, with as many as 30 students participating in the hands-on tutorials. After the winter break (which coincides with the conclusion of the CHPC-SCC Selection Round), weekly participation drops significantly to around 10 participants on average.

7 CHALLENGES

The predominant challenge faced by the SIG is its sustainability. Sustainability is affected by three primary factors: group membership attrition, leadership succession, and remote delivery.

7.1 Attrition

The SIG experiences a sustained reduction in attendance throughout the course of the year. Feedback alludes to three reasons for student withdrawal:

(1) After final team selection, the unplaced students lose motivation and subsequently withdraw.
(2) As the academic year progresses, students prioritise academic coursework over the SIG.
(3) As topics become more advanced, student interest in the SIG diminishes.

7.2 Succession

As a student body, the organising committee is constantly affected by members graduating and leaving, which necessitates recurring recruitment of new mentors. Ensuring continuity in leadership is a recurring challenge.

To mitigate this challenge, promising students are selected to co-organise with more senior members, who take on a more direct mentorship role. The mentorship model provides a gradual exposure to leadership roles while spreading the workload for the current leadership. Once the inevitable graduation of senior students occurs, the replacement organisers already have the requisite experience.

7.3 Remote Delivery

Remote delivery was adopted during the COVID-19 pandemic, transitioning all SIG activities to online platforms. While the improved accessibility enabled broader outreach and scalability of the SIG's activities, it led to lower engagement levels compared to in-person sessions. Consequently, the SIG delivers most talks in-person on campus. When the goal of an event is to reach a wider audience, the sessions are conducted online.

8 RISKS

The SIG's primary appeal remains the opportunity to participate in the CHPC-SCC and ultimately to compete in the ISC-SCC. The regular success of the Wits teams at the National Finals encourages new students to enrol. With the current succession model of past students returning to mentor the new cohort, the strength of the SIG is closely correlated to the performance of the previous year's teams in the SCC. It is possible that if a cohort fails to emulate the success of the previous year, there could be a reduction in the strength of the mentorship for the subsequent year. Further, it is possible that a relatively poor performance may also discourage students from joining the next year.

While the CHPC-SCC sets diversity requirements for participating teams, the Wits SIG leadership struggles to retain female representation which may pose a threat to long-term retention of female involvement in the SIG.

The SIG enjoys support from the University through access to HPC resources, but the absence of any formal funding does leave the SIG heavily reliant on the continued goodwill of the University for hardware and training resources. In particular, the use of years-old repurposed decommissioned HPC hardware is prone to hardware failures, leading to a diminishing supply of available HPC resources for hands-on practice.

9 LESSONS LEARNED AND REFLECTIONS

Past competitors returning as mentors has proven to be effective in leveraging the firsthand experience gained in the competition, ensuring future teams remain well-prepared and competitive. To strengthen knowledge transfer resilience the SIG has a strong culture of opensource documentation, storing past and current resources in the SIG GitHub.

Under the guidance of past organisers, the leadership handover process has proven crucial to equipping the incoming organising team. Since the new organisers have been participants in the group's activities in the preceding year, they are familiar with the responsibilities and methods of execution.

Notwithstanding all efforts to mitigate interruption in leadership succession, the fact remains that the SIG is operated on a voluntary basis by students whose primary responsibilities are their studies. While the SIG remains primarily led by student volunteers, there is a risk to the SIG sustainability. At the risk of volunteers withdrawing, despite the strengths of a student SIG, the group's longevity is inextricably linked to sustained institutional support.

The current model for recruiting new SIG members depends on the CHPC-SCC to attract students to participate. While there is no indication that ISC-SCC or CHPC-SCC will end, the SIG is cognisant of this inter-dependence.

A perfunctory assessment of the SIG's success at both the CHPC-SCC and ISC-SCC could lead to the conclusion that the Wits SIG is a successful model for building an effective student HPC pipeline. While this may indeed be true, such an assessment fails to consider circumstances at Wits which may be contributory factors to this success. For one, Wits is among the top-ranked universities in Africa and is recognised as one of the top Computer Science and Engineering universities in South Africa [14]. The strength of the Wits academic programme likely attracts good students, and these good students will excel against their peer institutions.

The Wits SIG owes its origins and much of its ongoing popularity to the incentive of participating in the ISC-SCC. Reaching an international cluster competition like ISC-SCC is well beyond the means of most institutions. Likewise, even hosting a local SCC requires significant investment in time, resources, and funding.

10 FUTURE WORK

A natural consequence to students not being selected for the CHPC-SCC is a drop in engagement with the SIG. The organisers hope to improve engagement by undertaking several interventions.

Hosting additional internal competitions throughout the year will enable more students to experience the competition component, resulting in improved student engagement and retention in the SIG.

The introduction of long-term projects may also produce stronger participation and engagement. By encouraging students to consistently invest time throughout the year, they will build incrementally towards a concrete but ambitious end goal.

While local HPC resources are currently reserved for the use of the SCC teams, the goal is to expand access for the general (non-SCC) SIG members.

To maintain engagement throughout the year, the organisers would like to introduce certificates of completion for students who complete the SIG training. Additional non-technical content, such as career panels, will be included in future SIG activities. Organisers currently contribute to the broader HPC community through presentations and collaboration with the HPC Ecosystems Project [7, 9]. The SIG intends to expand its involvement in this project through the development of additional training content for the community.

11 CONCLUSION

The University of the Witwatersrand HPC Special Interest Group is a student group that seeks to provide advanced scientific computing skills to undergraduate students. The SIG focuses on three areas: exposing undergraduate students to general HPC education; preparing teams for Student Cluster Competitions; and equipping students with technical skills in HPC.

The Wits SIG has fostered HPC knowledge and technical skills among the student community for more than ten years. The evidence of both local and international student cluster competition achievements may offer some indication of the strength of the SIG's efforts.

This case study aims to provide insight into how to build a sustainable and successful student HPC community. At the very least, aspects of the Wits student SIG model might be of use to others seeking to contribute to the enhancement of HPC education and workforce development.

ACKNOWLEDGEMENTS

The impact of the Wits student SIG is the result of years of concerted contributions by many individuals. From members of the Mathematical Sciences Support Team to the Student Cluster Competition convenors, past and present, including all the generous sponsors and enablers for the CHPC-SCC and ISC-SCC. In particular, Brian Maistry, Shunmuga Pillay, Senzo Mpungose, Kay Dhlamini, Eugene de Beste, Nick Thorne, Matthew Cawood, Israel Tshililo, Sakhile Masoka.

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