NATIONAL SCIENCE AND TECHNOLOGY FORUM

PROCEEDINGS OF DISCUSSION FORUM
CAREER PATHS FOR RESEARCHERS – WHERE TO IN A CHANGING WORLD?

Dates: 2–3 December 2020
Venue: CSIR International Convention Centre, Pretoria

Table of Contents

OPENING AND WELCOME

Ms Jansie Niehaus (NSTF Executive Director) opened the discussion forum and welcomed everyone. This discussion forum had been organised under the auspices of the Science Councils and Professional Bodies sector of the NSTF.

SOUTH AFRICA'S EXPECTATIONS OF ITS RESEARCHERS – MR MMBONENI MUOFHE, DEPUTY DIRECTOR-GENERAL, DEPARTMENT OF SCIENCE AND INNOVATION

Different stakeholders have different expectations against which they measure the performance of researchers, and researchers have their own perceptions about what they are expected to do. There are certain criteria that may be useful in considering what we expect of researchers:

Excellence: Excellence is not negotiable for researchers. The work that they do cannot be compromised for any reasons. It is globally understood that the knowledge that researchers generate is useful for informed evidence-based decisions and policy informed by facts. Apart from the knowledge that researchers generate, they also have a responsibility not to share misinformation, including the information they may share on social media. People tend to consume the information they are given, and researchers are central to the perpetuation of information. Researchers need to be mindful of the power that they have in this regard. Power in the hands of the wrong people is dangerous. Information from research has to be believable. Excellence is central to what researchers are expected to do.

Relevance: There has to be value in the knowledge that researchers generate. The world cannot afford people who are doing research just for fun, or research for the sake of research. Around the world, people are grappling with a number of serious challenges such as climate change. The duty of researchers is to generate knowledge that is the truth at that time, although the truth changes over time. Researchers cannot allow themselves to operate in research as 'hired guns'. Science must remain the one thing that people can believe in.

Objective: The efforts of researchers, and the honesty with which they do their work, cannot be determined by which government administration is in place. One of the things that the Department of Science and Innovation (DSI) takes pride in is the huge respect it has for the various professions for which it is responsible. The DSI encourages researchers to conduct research and share knowledge truthfully without dictating how they should do so.

Being part of the community: Researchers have to be part of the community. In South Africa, researchers have to appreciate that conducting research is a calling, and that they have a role to play with respect to inclusivity and transformation of the research fraternity. This role has to be carried out by researchers themselves. In the context of transformation, relevance and excellence are not mutually exclusive. We cannot have a research community that is comprehensively male. A nation will not succeed if it leaves behind the majority of its population, namely the women. Any systems that researchers put in place must be responsive to the challenges in South Africa. The exclusion of women is no longer written, but there is still the danger of creating cultures in which women are not welcome. Cultures such as these are sometimes spoken of in jest, but the reality is not welcoming for women.

Training the next generation of researchers: Researchers are expected to reproduce new members of the profession. Each generation should produce better researchers than those of the past. By training their successors, researchers ensure their legacy.

Learning from nature: Researchers need to learn critical lessons from nature, most notably that things are generally not what they seem. Researchers must see themselves as part of the ecosystem that provides sustenance to keep them alive, suggests questions to be probed by generating knowledge and solutions, and offers opportunities to people with different views to act as sounding boards for sharing and shaping new knowledge. By taking such a perspective, researchers will want to contribute to transforming the knowledge that they produce into products and services that will improve people's lives.

Keeping the end in mind: In conducting research, researchers constantly need to keep in mind the end towards which they are working.

Taking responsibility if one makes a mistake: Researchers must be humble and take responsibility for acknowledging any mistakes they may have made.

Speaking with authority and conviction: Researchers must tell people what they need to hear, not necessarily what they want to hear.

Politicians have to take decisions with respect to research priorities in the context of competing demands and limited resources, based on value for money and the prospect of researchers delivering truthful facts.

Discussion

Debbie Schultz: Many of the issues raised are aligned with global thinking about the nature of research and the role of researchers. Is the role of researchers in South Africa defined by legislation or policy in any way?

Question: In terms of ethics, what measures are in place to ensure that researchers abide by a certain code of conduct, since most funding for research in South Africa comes from the DSI?

Mr Muofhe: Researchers make certain commitments related to ethics in research. When the DSI funds research projects, the research proposals have to comply with ethical provisions. For medical doctors, the oath of the profession is inherent in what they do, yet some unethical medical practice still occurs and sometimes goes undetected. Universities do not necessarily equip students for the world of today. Government policy development is sometimes too slow to address particular challenges. Governments still talk about regulating social media, for example, when it has become clear that it would be impractical to try to do so.

A global platform is required for legislation and policy development, because no single nation has the capacity to deal with all the requirements. Even more urgently, existing legislation and policy need to be implemented. South Africa is a signatory to a number of commitments dealing with global challenges, for example the Sustainable Development Goals and climate change. South Africa faces large challenges with respect to implementing the agreements. People have been aware of the impending climate change issues for years without taking any significant measures to address them. The availability of information does not necessarily mean that the information will be acted upon. We have enough information to enable us to do the right things without needing more legislation or policy.

Dr Botha (SACNASP): The South African Council for Natural Scientific Professions (SACNASP) has a code of conduct that is sent out annually for review and revised by researchers themselves. The code of conduct cuts across all 25 fields of science in which researchers can register with SACNASP. Professional scientists take ethics very seriously.

Mr Muofhe: We have huge respect for professional bodies in the natural sciences. In certain other professions, professional bodies have not managed to prevent dishonest members from allowing their profession to fall into disrepute.

Ms Niehaus: It was gratifying to hear that the DSI governs research but allows independence of research. The DSI has proved itself over the years as encouraging independence.

The South African government at one time in the past denied that HIV is deadly, and promoted the view that it could be cured through diet. The Academy of Science of South Africa (ASSAf) conducted a study on the role of nutrition in HIV, and showed through scientific research that HIV could not be cured in that way. The findings of the study directly contradicted the official government position on HIV, but ASSAf was allowed to publish the study without any restraints or recriminations. South Africa is fortunate in this regard.

NRF'S SUPPORT OF POSTGRADUATE STUDENTS AND POSTDOCTORAL FELLOWS – DR MBULELO NCANGO, DIRECTOR: HUMAN AND INFRASTRUCTURE CAPACITY DEVELOPMENT, NATIONAL RESEARCH FOUNDATION

The mandate of the National Research Foundation (NRF) is to contribute to national development by:

- Supporting, promoting and advancing research and human capacity development through funding and the provision of the necessary research infrastructure, in order to facilitate the creation of knowledge, innovation and development in all fields of science and technology
- Developing, supporting and maintaining national research facilities
- Supporting and promoting public awareness of, and engagement with, science
- Promoting the development and maintenance of the national science system and support of government priorities.

In order for the NRF to discharge its mandate, it has a five-year strategy and annual performance plans that address the national priorities of unemployment, poverty and inequality and are aligned with various national policies and international strategies, including the National Development Plan, the DSI's Ten Year Innovation Plan, and the 2030 Agenda for Sustainable Development.

The NRF also serves the national transformation agenda and to this end has a Transformation Framework with four pillars:

- Transforming equity profiles of postgraduate students and researchers
- Transforming the knowledge enterprise
- Transforming science and society relationships
- Building diverse and inclusive learning organisation.

The presentation will focus on the pillar of 'Transforming equity profiles of postgraduate students and researchers'. The NRF recently developed a Postgraduate Student Funding Policy in which the principles of equity of opportunity in relation to access, success and throughput, and representivity were adopted. These principles are underpinned by the pursuit of research excellence in all its dimensions. Research excellence (as ascertained through a review process) and the attainment of certain academic thresholds are requirements for eligibility for NRF postgraduate student funding.

The NRF adopted nine policy clauses to ensure transformation among researchers and postgraduate students:

Policy clause 1: The NRF will include financial need as a criterion for the allocation of bursaries.

In the past, the NRF prioritised the funding of bursaries for students who were financially needy, but this clause makes the principle explicit. Students that will be deemed financially needy (i.e. with a combined family income of less than R350,000 per annum) will include those that are assessed by the National Student Financial Aid Scheme (NSFAS) as being needy. In addition, there may be students that are financially needy but have not undergone a means test. The NRF has partnered with NSFAS and Ikusasa Student Financial Aid Programme (ISFAP) for undertaking means testing and for information sharing. A memorandum of agreement with ISFAP will be finalised. Academic excellence will continue to play a critical role.

Policy clause 2: Financially needy students will be funded without interruption, for postgraduate studies completed within regulation time, at total cost of study. This policy will be restricted to South African citizens and permanent residents.

Financially needy students must obtain a minimum of 65% for major subjects in the final undergraduate year of study for honours bursaries; an average of 65% at honours level for master's bursaries; or an average of 65% at master's level for a doctoral bursary. If a grade is not indicated at the master's level, the application will not be considered for funding by the NRF.

Policy clause 3: To encourage students with disabilities, that meet the academic requirements, to pursue postgraduate studies up to doctoral degree level, students with a disability will be funded without interruption for their postgraduate studies at total cost of study. This policy will be restricted to South African citizens and permanent residents.

Students with a disability must obtain a minimum of 65% for major subjects in the final undergraduate year of study for honours bursaries; an average of 65% at honours' level for a master's bursary; or an average of 65% at master's level for a doctoral bursary. If a grade is not indicated at master's level, the application will not be considered for funding by the NRF. Students with disabilities may apply for additional funding of up to R20,000 for an assistive technology device. This is the maximum amount allowed during the tenure of the scholarship.

Policy clause 4: To encourage the retention of all exceptional academic achievers to pursue postgraduate studies up to the doctoral degree within regulation time, these students will be funded without interruption at total cost of study. This policy will be restricted to South African citizens and permanent residents.

To be eligible, students must achieve a minimum of 75% for major subjects in the final undergraduate year of study for honours bursaries; an average of 75% at honours level for a master's bursary; or an average first class pass at master's level for a doctoral bursary. If a grade is not indicated at master's level, the application will not be considered for funding by the NRF.

Policy clause 5: To encourage higher participation in postgraduate studies, all NRF bursary values for partial cost of study will be adequate and cover at least tuition and accommodation costs.

Students who are not financially needy and do not have a disability may be considered for partial cost of study. To be eligible, students must achieve a minimum of 65% for major subjects in the final undergraduate year of study for honours bursaries; an average of 65% at honours level for a master's bursary; or an average of 65% at master's level for a doctoral bursary. If a grade is not indicated at master's level, the application will not be considered for funding by the NRF. A maximum of 5% of the funds for partial cost of study may be awarded to international students. Students who are funded for partial cost of study at honours level may be moved to total cost of funding if they achieve a minimum of 75% for their honours degree.

Policy clause 6: To contribute to a reduction in the time to completion, the NRF will prioritise funding full-time studies in line with regulation times whilst being sensitive to discipline and societal specific norms.

Support for part-time studies will be limited to individuals employed as knowledge workers, broadly defined as individuals involved in the chain of producing new knowledge, communicating and translation of knowledge into policy and products. Part-time study support will be primarily directed at individuals employed as academics and researchers at public research institutions.

Policy clause 7: To contribute to lowering the age of doctoral completion, the NRF eligibility criteria for bursaries for full-time studies, will have an age limit to achieve doctoral completion by the age of 35.

The maximum age at application will be 28 years at honours level, 30 years at master's level and 32 years at doctoral level, and the anticipated maximum age at completion will be 29 years at honours level, 32 years at master's level and 35 years at doctoral level.

According to the Post School Education and Training (PSET) report for the 2017 academic year, there were approximately 200,000 postgraduate students in the South African higher education system, including 100,000 honours students, 30,000 master's students and 30,000 doctoral students. Of these, the NRF funded between 14,000 and 15,000 postgraduate students, including 5,000 honours students, 3,000 master's students and 3,000 doctoral students.

NSFAS funds students at undergraduate level with a budget of billions of Rands, but the NRF has a budget of only about R1 billion for postgraduate bursaries. There are thus large disparities between the funding available for undergraduate and postgraduate study in South Africa.

Policy clause 8: All postgraduate bursaries across the NRF funding landscape will be allocated as follows: 95% South African citizens and permanent residents; 5% students from SADC countries and the rest of the world; and 55% women. The South African targets are further disaggregated in terms of race as follows: 90% Black (African, Coloured, and Indian); 10% White and 1% students with disabilities.

For the 5% students from SADC countries and the rest of the world, the focus will be on alignment with the African continental agenda and countries with which South Africa has bilateral and multilateral agreements.

In 2018, 80% of the postgraduate students funded by the NRF were black and 60% were female. The targets in terms of race are more difficult to meet at doctoral and postdoctoral levels; only 68% of PhD students and 49% of postdoctoral fellows were black. Of the postgraduate bursars in 2018, 83.1% were South African, 4.1% were permanent residents and 12.8% were international students. The targets with respect to South African students were more difficult to meet at doctoral level (where only 67.7% were South African) and postdoctoral level (where only 49.4% were South African).

Policy clause 9: The majority of student bursaries will be awarded in a directed manner so as to respond to national priorities, vulnerable disciplines and fields important for socio-economic development, as may be identified from time to time

In order for the NRF to realise its goal of contributing to the knowledge economy in South Africa by attaining at least 1% of the global research and development output, the NRF will not fund:
- Undergraduate qualifications, regardless of the NQF exit level
- Postgraduate certificates or diplomas, regardless of NQF exit level
- Master’s by coursework only
- Professional master’s and doctoral degrees.

The value of NRF bursaries is R60,000 for honours, R90,000 for master’s and R120,000 for a PhD. The bursaries have not kept up with inflation. The funding values of a number of other institutions (e.g. SKA, SANBI, CSIR, ARC, SAMRC) are significantly higher than the NRF at honours, master’s and doctoral levels. The NRF is therefore proposing to increase the value of its bursaries from 2021 to R149,000 for honours, R167,000 for master’s and R175,000 for PhD for students on total cost of study, including tuition fees, accommodation, meals, a living allowance and a laptop. Students on partial cost of study will receive funding only for tuition and an accommodation allowance.

Studies have shown that students who receive adequate funding are more likely to complete in regulation time because they do not have to find work in order to supplement their living expenses and thereby sacrifice time away from their research.

When the new bursary values are implemented, the NRF will only be able to fund about 8,000 postgraduate students, compared with 15,000 at present.

The call for postgraduate bursaries will open on 1 April 2020, and applicants will be notified of the outcome by 13 November 2020 for master’s and doctoral bursaries (to allow their supervisors to plan their research programmes), and 29 January 2021 for honours bursaries so that students are informed before they have to register for the new academic year.

Three types of postdoctoral fellowships are available: NRF Free-standing, DST-NRF Innovation and DST-NRF-DHET Scarce Skills fellowships. The intention is to phase out the NRF Free-standing postdoctoral fellowships, because the values are significantly lower than the amounts available for the other two types of fellowships.

Black Academics Advancement Programme

In line with its transformation agenda to changing the profile of the research workforce, the NRF has embarked on a strategic partnership with the FirstRand Foundation to promote the development of black African South African academics to become nationally and internationally recognised researchers.

For researchers on the doctoral track, the award comprises a three-year sabbatical grant. Seventy-five new and continuing awards will be supported over a five-year period. In order to be eligible, applicants must be South African citizens not older than 40 years, in full-time academic employment at a public university in South Africa, and registered for a doctoral degree in any discipline. They must have an approved research proposal, ethical clearance for the research proposal, and have been assigned a supervisor.

For researchers on the postdoctoral track, the award comprises a two-year sabbatical grant. One hundred new and continuing awards will be supported over a five-year period. In order to be eligible, applicants must be South African citizens not older than 45 years (at the time of application), in full-time academic employment at a public university in South Africa, and have completed a PhD within the last five years. This grant may not be held together with an NRF rating.

Conclusions

The NRF funding criteria are underpinned by the pursuit of research excellence in all its dimensions. The transformation of the postgraduate and postdoctoral cohort is the core objective.

The aim is to retain high academic achievers in the system to pursue postgraduate studies up to the doctoral level, as part of a national drive to grow the next generation of academics to sustain South Africa's knowledge enterprise.

The postgraduate policy aims to fast-track the development of postgraduate students in high-impact, priority and vulnerable disciplines that are critical for national socio-economic development.

To encourage students to complete their doctoral studies by their mid-thirties, NRF-funded postgraduate students that complete their degree within the NRF funding period will be funded without interruption from honours up to doctoral level, provided that they meet university entry requirements and minimum NRF academic requirements.

Discussion

Question: Has the NRF considered funding researchers based on government platforms that collaborate with universities?

Response: The NRF Professional Development Programme is open to researchers in the national facilities, science councils and public research institutions that are actively engaged in research, and encourages partnerships between universities and public research entities. In 2013, the Department of Science and Technology issued a directive to the NRF to identify public research institutions that could benefit from NRF funding. The NRF prioritises the funding of full-time students.

Question: How does a researcher apply to the NRF Professional Development Programme?

Response: The NRF issues a call, which is sent to relevant stakeholder institutions.

Question: How were the statistics compiled on the reasons for postgraduate students not completing in regulation time. Did the study include asking students themselves why they did not complete on time?

Response: An ASSAf study on doctoral completion rates found that fully-funded students complete a PhD within an average of 3.5 years, compared with 4.8 to 5 years for students without full funding. The criteria for applying for an NRF postgraduate bursary including already having an approved research proposal and ethical clearance for the proposal, and having been assigned a supervisor. These criteria are not stipulated by some of the other funders that offer doctoral bursaries, with the result that doctoral students who are not funded by the NRF may take longer to complete. A study by Prof Johann Mouton, director of the Centre for Research on Evaluation, Science and Technology (CREST) at Stellenbosch University, found that students whose doctoral studies are not fully funded may be forced to work to supplement their income, which takes time away from their research and hence they do not complete on time.

Question: How many international students are graduating with a doctorate compared to black South African students? It is important to understand the reasons why so few black South Africans are completing doctoral degrees.

Response: Prof Mouton of CREST demonstrated that international students tend to complete a PhD much faster than South African students. The reason is that they are usually bound by conditions or obligations imposed by their country of origin to complete in regulation time. South African students tend not to complete on time because the bursary values are insufficient to cover all their costs and allow then to concentrate fully on their studies.

Debbie Schultz: Where is information on NRF bursaries and research funding available?

Response: In order to inform prospective funding applicants, the NRF has engaged with the Council on Higher Education (CHE), Universities South Africa (USAf), and the national facilities, and will be engaging with the science councils in February 2020. The NRF first has discussions with stakeholders at the highest level (e.g. university VCs and DVCs) in order to get buy in, and will then conduct a roadshow to all universities, national facilities and science councils, specifically targeting students. The NRF's funding framework document is due for publication in April 2020. Information on bursaries and research funding is also available on the NRF website. The NRF would give the NSTF a summary of the available funding to be placed on the NSTF website.

Question: The NRF funding policy for postgraduate studies caters for young scholars. Has the NRF considered funding for financially needy older scholars who are academic achievers?

Response: The NRF has had robust engagement about catering for the older cohort of postgraduate students, especially from the disciplines of education, the social sciences and humanities. However, the NRF aims to transform the system, part of which entails addressing the challenge of the ageing professoriate in universities and the lack of younger successors. The NRF is trying to ensure young doctoral graduates who can be productive in the research system for a long time. The NRF has to use its limited budget to address is aims, given the scarcity of resources. The NRF's annual budget for postgraduate scholarships is R1.1. billion, which is small compared with the NSFAS budget for undergraduate students. The NRF cannot fund all the postgraduate students who apply, and has therefore decided to prioritise scholarships for younger students. Postgraduate students are starting to organise themselves to challenge this approach. The NRF is trying to impress upon the Minister of Higher Education, Science and Technology that it might be necessary to think differently about how to fund postgraduate students. If the NRF's scholarship budget were increased, the NRF could perhaps consider increasing the age restrictions for postgraduate bursaries.

Comment: Many postgraduate students do not see a future in academia and therefore stop at master's level. There could be gaps in filling senior academic positions if the NRF phases out free-standing postdoctoral fellowships, as proposed?

Response: The NRF is not phasing out all postdoctoral fellowships, but only free-standing postdoctoral fellowships, which are of lower value, in order to focus on a new model of more extensive funding for postdocs. The new model will be ready for presentation to the academic community in 2020. The intention is not to fund researchers for postdoctoral fellowships alone, but to develop a long-term programme to fund their development from emerging researchers to established researchers and ultimately international scholars. Unfortunately, increased funding levels would mean that fewer postdoctoral fellows could be supported. The NRF is engaging with the Ministry of Higher Education, Science and Technology to ensure that postgraduate scholarship receives extensive funding.

THE IMPORTANCE OF MENTORSHIP OF POSTGRADUATES AND EARLY CAREER RESEARCHERS, AND HOW TO ENSURE THAT IT HAPPENS – MR MUIMELELI MUTANGWA, FACILITATOR: SYNNOVATION SOLUTIONS

The Centre for Emerging Researchers (CER) brings together a network of Africa's emerging researchers to contribute towards the generation, application and advancement of reliable alternative solutions to Africa's developmental challenges in pursuit of total liberation and complete self-determination. The CER pursues this objective through the facilitation of interdisciplinary research collaborations, sector-specific policy dialogues, capacity building, training and support for emerging African researchers.

Central to the vision of the CER is the determination to grow and empower emerging researchers into Africa's leading researchers, analysts and policy-makers whose work will inform decision-making in the development of public and industrial policies towards attaining South Africa's National Development Goals.

The CER has signed a five-year research collaboration agreement with the University of Johannesburg. Challenges related to postgraduate South African students have been identified, including:

- **Lack of options:** There is a tendency for students to continue to postgraduate studies only because other options seem very limited. The financial rewards for postgraduate students are generally insufficient to meet their family responsibilities. If high-performing students receive a lucrative offer of employment, they are likely to accept it rather than pursuing postgraduate studies.
- **Soft skills more valued in industry than qualifications:** There have been shifts in the areas of competence that are rewarded. People who advance in the corporate world generally do so not because of their academic qualifications, but because of skills such as leadership or other soft skills. Students notice this tendency, and are less attracted to pursue postgraduate studies as a result.
- **Industry perceptions of research and academia:** Industry does not necessarily respect academia because they perceive it as too theoretical. Such perceptions make postgraduate opportunities less attractive to prospective students.
- **Meaning and purpose:** Students need to find meaning and purpose in their research and believe that it is worthwhile if they are to be inspired to continue. Students are not motivated only by the opportunity to publish their research.

From my own experience as a postgraduate student, the NRF funding was insufficient; it covered only tuition and accommodation, but not living expenses. I ended up cleaning shoes for fellow students to raise money, and enjoyed this business venture. Using my chemical engineering knowledge, I manufactured my own shoe-cleaning detergent, which won several awards including an African Innovation Award. I also had the satisfaction of creating employment by having a shop. I started to understand what postgraduate students are looking for. They want to work on research projects with outputs that can be implemented and applied, not just publish their findings in academic papers.

When the CER was established in 2017, it was realised that the new generation of postgraduate students and early career researchers need support in three main areas:
Financial support, including grants, scholarships, travel, tuition and living expenses
Technical support, including academic support, research methodologies and tools of analysis (which can be provided by the supervisor in order to offer depth and rigour)
Mentorship support outside of academic support. The CER works in this area, including:

- Personal mastery, to ensure that students understand who they are, what drives them and what motivates them. This is an important element for success in academia and elsewhere
- Exposure to high-performance culture and professionalism
- Introduction to the 4 Cs of the 21st century: communication, collaboration, critical thinking and creativity
- Linking ambition and passion with career development
- Finding meaning and purpose.

The main activities of the CER are mentoring for postgraduate students, and offering collaborative research consulting services. The CER model is to approach companies and government agencies, listen to the issues that they are experiencing, translate the issue into a research problem, match the issue to the CER's network of researchers who have participated in its mentoring initiative, put together a diverse team from different disciplines, and develop a research solution and recommendations for the client. The corporate world shows appreciation for the kinds of solutions that the CER delivers. The researchers who form part of the network earn money and gain experience through participation.

The CER partnered with the DSI and took part in a five-day training workshop on technopreneurship in Malaysia with 27 participants from 17 developing countries. The participants realised that they were united in their goal of trying to build a better post-colonial society and were experiencing similar challenges of unemployment, poverty and inequality, but their approaches to addressing these challenges were sometimes very different. Some countries were taking on increasing debt, while others were focusing on RDI. The participants agreed that an effective approach might be to develop the respective countries' knowledge economy, which involves generating intellectual property that can be sold, licensed or used to establish knowledge-based spin-off companies.

South African academics are taught to 'publish or perish', but in Malaysia academics are encouraged to protect their research outputs (e.g. through patents or copyright) before publishing a journal paper. Their slogan is thus 'protect, and publish or perish'). The focus is on generating intellectual property (IP) that can be licensed, sold or used as the basis for starting a spin-off company. Research involves creating new knowledge, which is important in order to develop new markets, offer new benefits, sustain and grow the economy, improve the reputation of institutions and build the knowledge economy. If research serves only to improve the reputation of the researcher and the institution and does not serve any other purpose, it is probably not necessary.

One way of ensuring the relevance of research is the approach of end-user driven R&D, in which user behaviour is the starting point for new concepts, and researchers have to justify their proposed research on the basis of the value that the outcomes will add to society. This approach might be usefully considered for South Africa.

The commercialisation process for innovation and building the value of a new technology involve imagining with respect to both the market and the product or process, mobilising interest and endorsement, incubating to define commercialisability, mobilising resources for demonstration, demonstrating products and processes in context, mobilising market constituents, promoting adoption, mobilising complementary assets for delivery, and sustaining commercialisation. At each stage, stakeholders have to be satisfied and mobilised. Important stakeholders of the knowledge economy are government, industry, academia and the community. The community is the source of research questions, and consumer make use of research output.

The ways in which knowledge is transferred show the various career paths that are open to researchers, including consultancy, graduating students, graduating academic members, collaborative research, generating and protecting IP, licensing, service and outreach programmes and establishing spin-off companies. Emerging researchers who are mentored and supported could create their own jobs.

Intellectual property can be protected through patent, trademark, copyright, industrial design or trade secret. In South Africa, the Intellectual Property Rights from Publicly Financed Research and Development Act (Act No. 51 of 2008) governs any IP developed in the course of all research activities that receive any public funding. The Act stipulates the functions of technology transfer offices (TTOs) of institutions:

- To develop and implement policies for the disclosure, identification, protection and commercialisation of IP
- To assess IP to determine commercial potential, the probable success of commercialisation routes and appropriate forms of protection
- To attend to all aspects of IP transactions and the commercialisation of IP.

Researchers need to work more closely with TTOs to ensure that their research is translated into useful output.

The CER joined researchers from the CSIR, the universities of Johannesburg, the Witwatersrand, Free State, Venda and Pretoria, and GIBS Business School for the 4IR academic and innovation visit to Israel, visiting the University of Jerusalem, Tel Aviv University, Yissum Technology Transfer Office and the Hebrew University Centre for Innovation and Entrepreneurship (HUJI-Innovate) in order to explore their approaches to linkages between R&D and industry. There are lessons that South Africa could learn from a country such as Israel with a strong RDI culture.

One of the senior researchers at CER, after completing his engineering degree and MBA, established Lamo Solar, a start-up in the renewable energy sector. Lamo Solar completed a solar-PV mini-grid that has electrified 70 households in Upper Blinkwater in the Eastern Cape. To recover the cost, Lamo Solar partnered with Raymond Mhlaba Municipality, which sells prepaid solar electricity vouchers to households connected on the grid. This is one of the success stories that the CER has been associated with. A senior CER researcher is advising the Presidential Commission on the Fourth Industrial Revolution; another has designed his own watches; and another who is completing his PhD in higher education management at a UK university is part of a CER research team that made a significant contribution to developing the funding model that was accepted for free higher education in South Africa.

Conclusions and recommendations

- Emerging researchers are interested not only in research, but also in development and innovation.
- Mentorship is important for growing and empowering emerging researchers into Africa’s leading researchers.

- Academic and research institutions could outsource mentorship support to a third party such as the CER.
- TTOs or DVC Research Offices need to be capacitated to add mentorship to their functions.

ISSUES OF IDENTITY: AGE, CULTURE, RACE, GENDER, AND LANGUAGE IN RESEARCH INSTITUTIONS – MS NDONI MCUNU, CEO: BLACK WOMEN IN SCIENCE

Ms Mcunu is a PhD student at the University of the Witwatersrand in the field of ecology, biology, climate change and agriculture. She is also involved in civic leadership and social-preneurship and founded Black Women in Science (BWIS). She has done research and written articles for *Nature* and *The Conversation* on how to unify African women and Africans in general to address the issue of their voices not being heard in academia and research.

After completing my master's degree, I struggled to get a job. I realised that the kind of job I could get was not what I wanted to do. I wanted to stand out and have a different voice or identity in science, but I lacked academic support and understanding. It seemed to be assumed that after completing a master's degree, one should automatically continue to a PhD, but I found that assumption problematic, as finishing a master's degree was not celebrated.

Statistics on the research workforce from the *Scientific American* show that in sub-Saharan Africa, only 29% are women, while 71% are men. In the South African population as a whole, 39.9% are African females, but they are severely underrepresented in the R&D workforce at only 12.7%. Most women at South African universities are enrolled for degrees in education or the social sciences, and far fewer are enrolled in science or engineering.

Science, technology, engineering and mathematics are the fields of knowledge that will be driving much of the technological progress predicted for the Fourth Industrial Revolution (4IR), but in South Africa only 13% of graduates in those fields are women. There is a narrative that is not being spoken about diversifying the identify of research. Only 24% of the members of the Academy of Science of South Africa (ASSAf) are women, and only 31% of the governance of ASSAf comprises women. The number of black science doctoral graduates in South Africa is growing thanks to significant investment, but there is a long way to go to achieve balance in terms of both race and gender. The pace of change has slowed in the last three years, but at the current trajectory it would take well over one hundred years to close the gender gap. The African element is missing not only in the statistics for the research workforce and science graduates, but also in the images one sees related to science. We need to become advocates for the identity of women in research.

The aim of BWIS is to improve the quality of science graduates entering the professional, business and academic research sectors. The objectives of BWIS are to:

- Encourage the participation black women in science, technology, engineering and mathematics (STEM) careers
- Focus on historically disadvantaged institutions
- Approach scientific careers in a multidisciplinary way
- Promote postgraduate qualifications.

There are many policies to promote women to pursue STEM qualifications, but the challenge is that we do not know what women want to do because we have not asked them or listened to them. More needs to be done than simply investing money in addressing the issues. We have to know how to attract women to enter and stay in the system.

BWIS works with the NSTF and the DSI, and has some mentorship programmes with the NRF. BWIS has fellowships in Johannesburg and KwaZulu-Natal, with annual selection of 100 BWIS fellows. BWIS has trained over 250 women. The BWIS fellowship has presented three workshops, on 'The business of entrepreneurship', 'Scientific writing and publishing' and 'How to build a proposal and brand yourself as a young black female in science'.

Postgraduate students are still asking what a researcher is. They want their lives to have purpose and relevance, make money from their skills, and have a life beyond academia. A needs analysis of the skills that women postgraduate students want shows that 71% want business development, but this is not covered in the curricula of science degrees. Women scientists are likely to be lost to research as they will seek employment in a multidisciplinary field where they are encouraged to apply their minds. Other competencies for which there is a demand are research skills (71%), public speaking (69%) and scientific writing (62%). Science communication is also not adequately addressed in science degrees to ensure that scientists are seen and heard as people who want to make a contribution.

BWIS developed a model for leaders that involves training in business and attention to social wellbeing for those aspiring to a scientific career. Black women are facing depression and psychological challenges in dealing with their backgrounds and the pressures confronting them.

'Hot' topics are women in research, diversity, the 4IR and young academics. It is important to have a balanced identity in research. There have not been enough case studies, and women in research are not sufficiently celebrated. Ms Mcunu cited some examples to show how women in science have huge potential but are often side-lined:

- An example from NASA is that an all-female spacewalk recently had to be cancelled due to the lack of spacesuits in the right size for women. One of the astronauts said, 'In this case, it's easier (and faster!) to change the space-walkers than reconfigure the spacesuit.' A huge research funder such as NASA is not prepared to do what is required for a symbolic gesture that would showcase women.
- Ncoza Dlova, a black woman professor from the University of KwaZulu-Natal, recently made a scientific breakthrough by discovering a gene that causes permanent hair loss among African women. She became interested in the topic because of her own experience as an African woman. Her research debunks the narrative that has been sold to black women, as well as many of the products on the market that are supposed to prevent hair loss. Research such as this adds the African element to international platforms and influences research interest in topics that affect people from a different background, history and experience.
- Katie Bouman is a 29-year-old woman computer scientist who was behind the first image of a black hole. She led the development of a computer program that made the breakthrough image possible.
- There was a smear campaign against Prof Mamokgethi Phakeng, Vice Chancellor of the University of Cape Town, alleging that she did not have sufficient gravitas to be a senior academic as her PhD is not in pure mathematics but in maths education. The reality is that Prof Phakeng's undergraduate degree is in pure maths, and she decided to pursue postgraduate research in maths education to address the problems of people in her community who had been left behind because they did not understand mathematics. She became the first black female South African to obtain a PhD in mathematics education. She thus understood African needs and redesigned her research to address some of these.

BWIS wants to change the voices of postgraduate women students to say things like:

- I influence knowledge building through research.
- I have collaborated and learnt to publish.
- I was supported through my graduate programme.
- I now approach my research in an interdisciplinary manner.
- My institute, funders and supervisors have given me space to focus on my family.

The take-home points from the presentation are:

- Are we redesigning the models of science to suit and attract a new identity in research?
- Do we understand the modern scientist?
- What is the new identity in research?
- Are we adjusting to the changes?

PANEL DISCUSSION

Are factors such as organisational culture, language, and perceptions of discrimination serious hurdles along the path of researcher development? What is the role of mentorship and counselling?

Debbie Schultz: The following are questions from a group of doctoral students who have asked me to represent them:

- With respect to careers for researchers, they were sold a dream that is not the reality. South Africa does not have much in the way of markets in their field (biotechnology) to offer them a research career in industry.

- They have not had any exposure to the potential to become an entrepreneur, how to develop a business or the avenues for initiating an incubation process.
- A big barrier to any business in the field of biotechnology is the stringent certification requirements.
- There does not seem to be much R&D potential in South Africa. The multinational companies that operate in South Africa conduct their R&D outside of the country. They have a better chance to get a good job outside South Africa than inside, but would like to remain in the country. Their only option if they remain in South Africa seems to be to accept a job for which they are hugely overqualified.
- They have heard about multilateral agreements between countries in many professions but not in biotechnology.
- An undergraduate BSc degree does not equip one for any job, not even entrepreneurship.
- They have been told that education is the way out of poverty, but they realise that it is actually the way into poverty.
- One said he was doing the most relevant research in his field (ground-breaking nanotechnology with a focus on breast cancer), but the only places with industries in the field are in Australia and Canada. Where does one go after graduating?

Mr Mutangwa: There are opportunities at university to develop skills other than those that one is taught in the classroom. Joining the debating society, for example, would start to build confidence in communication and public speaking. One has to work at developing skills.

It is important to recognise other skills that one develops in the journey towards getting a postgraduate qualification, including knowing how and where to find information, understanding the tools of analysis and how to write. One should identify these skills, and explore their value in industry. Graduates with a master’s degree or doctorate could add value in a number of different organisations.

The government is trying to foster entrepreneurship, for example through the sector education and training authorities (SETAs) and various government agencies. Many young people (some of whom do not even have a university qualification) have benefited from various sources of government funding. Unfortunately, these organisations do not communicate or advertise enough what they can offer. Funding is also available through multinational agreements, although there may be a lack of initiatives to accompany the agreements.

Ms Mcunu: The most important skills for a scientist to learn are how to sell yourself, and how to communicate so that people are interested in your research. These are not skills that one is formally taught as a postgraduate student. It is important to surround yourself with friends in a wide variety of fields apart from science.

Firstly, you need to understand your research field thoroughly. Secondly, avoid feeling pressurised to start a business. Becoming an entrepreneur starts with considering how you could sell your research.

Chair: Focus on the 4 Cs of the 21st century: communication, collaboration, critical thinking and creativity. Try to find places where you can achieve deliverables, and approach institutions that could provide you with funding for your research.

Dr Angwe Lekunze (NWU): I am a postgraduate student. The focus of postgraduate mentoring is on writing and publishing, but in that way your become ‘a big fish in small pond’. After completing your doctorate, your supervisor may not have a postdoctoral position for you. You may not know what to do, where to go or whom to speak to. You may have a viable project that will help society and make a difference in the world, and you may wish to take your research further and develop new ideas, but you do not have funding for that. How do you go about it?

Mr Mashiane Mothogoane (SANBI): The statements by the NRF speaker that South Africans continue to postgraduate studies only because they have nothing else to do, and that South African postgraduate students take much longer to complete than international students, and the statement by the speaker from the Department of Trade and Industry (dti) that South Africans are generally lazy seem to be gross generalisations. What evidence is there for these statements? What size sample were these observations based on, and how representative was it? These kinds of statements seem to be part of an unfortunate narrative.

Mr Seth-Frerich Fobian (UP): Would it be possible to implement some skills training (e.g. in entrepreneurship) in the undergraduate BSc curriculum to make bachelor's graduates more employable and position them to start businesses and industries. Buy-in is needed not only from government and academia, but also from industry. Without industry buy-in, entrepreneurship becomes difficult.

Mr Malvin Thabani Tshabalala (UP): The career path for science postgraduates is not as clear as for many other professions such engineering or accounting. We are advised to work at alternatives (e.g. writing, entrepreneurship) rather than expecting to be employed as researchers in our discipline. Is the reality that science graduates are only left with alternatives?

Chair: Supervisors are sometimes spread too thin to be able to provide all the support that a postgraduate student needs. Another challenge is that as one's research progresses as a postgraduate student, one may become more knowledgeable about the topic than the supervisor.

Mr Mutangwa: Networking is a valuable skill for a researcher. It is unfair to assume that this happens naturally, but networking is a skill that can be learned. Networking could be done at a conference or by writing to researchers across the world. By networking, you can meet people who are working in similar areas, discuss your ideas and possibly even involve someone who is able and willing to be a co-supervisor if your supervisor is struggling. As a postgraduate student, you have to take charge of what you need to get your qualification.

Stereotyping South African postgraduate students is wrong, but the comment that South African students tend to continue to postgraduate studies because they have nothing else to do is based on the experience of the Centre for Emerging Researchers (CER), which in late February each year receives many requests for assistance to find a supervisor or funding for postgraduate studies. Most of these people tell a similar story that they had hoped to start working but could not find a job and that they are therefore returning to university for a postgraduate degree. CER conducts university-readiness workshops with school learners and advises them to have an exit strategy from the very beginning of first year, which involves understanding what they want to do when they finish their university studies and what other skills they require apart from a degree. Students should begin taking steps to develop these skills while they are busy with their degree. Another part of an exit strategy is to have an alternative if their first choice does not work out.

Ms Mcunu: Employability is a nationwide problem that is not limited to the sciences. Addressing employability starts in primary school with the way in which children are taught to solve problems. The term 'entrepreneurship' tends to be very loosely used, and does not imply that all graduates should go out and start a business. Perhaps the focus should rather be on creative thinking, and the ways in which children and students are taught to think critically and creatively. At doctoral level, students need to understand the global significance of their research. Developing this kind of approach ought to start at undergraduate level. People can make themselves employable by showing that they have the capacity for critical and creative thinking. You could be creative in approaching companies to identify challenges that you could tackle through your research, and then forming a partnership for that purpose.

It is important always to consider alternatives not only in your career prospects by in life in general. Science students are unfortunately not exposed to the various industries in which they could be employed and use their skills. Graduates need to learn to write their CVs so as to highlight their core skills in ways they may not have thought of (e.g. reading and analysis, project management, supervision of a team, grant management, strategising, executive thinking). You have to consider possible future career paths outside the narrow confines of academia and prepare yourself for a range of different possible positions.

Question: There tends to be a lack of communication with students with respect to alternatives. Could the NSTF establish an online portal of employers and companies in science, what kind of career opportunities are available, and what skills students require for employability.

Dr Rowan Lubabalo Mafu (TIA): A PhD is expected to make a new contribution to knowledge. if doctoral students do not feel they have anything to offer and are stuck in the mindset of looking for a job rather than creating one, they need to reconsider the value of their PhD. If you have technical skills but need additional skills in the corporate world, you would have to work at developing those skills.

Universities are failing students with respect to informing them about opportunities for research funding or seed funding to start a business that is available from the Technology Innovation Agency (TIA) or dti.

With respect to entrepreneurship, you have to consider how you could make money from your research and take advantage of the opportunities. You could approach technology stations at universities with your ideas. There are many platforms for innovation around the country to commercialise research. InvoTech, for example, is positioned to be a leading business incubator in KwaZulu-Natal to convert innovations and new technologies into sustainable and commercially viable businesses.

Question: It is time for the South African research community to look at a different paradigm. Perhaps South Africa is producing too many PhDs for the market, because not all doctoral graduates are interested in entrepreneurship. I disagree with the age limits for PhD bursaries set by the NRF. Often the best doctoral students are those who have been in the work force for several years and have a good idea of a research problem that they want to come back and work on. Such students are very committed. Academics are under huge pressure to take in large numbers of postgraduate students, but we should focus on quality rather than quantity, and not spread ourselves thin but give students all-important mentorship. Minimum standards and criteria should be set in order for an academic to become a postgraduate supervisor.

Ms Anita Engelbrecht (SANSA): A piece of advice to job seekers is to remove your photo from your CV unless you are specifically asked for it, to avoid being judged before a prospective employer has even looked at the CV. You should highlight all your skills on your CV and include outreach or volunteer opportunities that you have participated in even if you do not yet have any formal work experience.

Before embarking on a research project, one should start with end-user research. Is there still room for blue skies research in South Africa, or is all research supposed to be applied?

Ms Naledi Nthite (TUT): We need to expand platforms and programmes for postgraduate student discussions.

Mr Mutangwa: There is space for basic research. Applied research uses the output of basic research, and gaps in basic research are informed by applied research.

Chair: Researchers have to communicate their science.

THE 21ST CENTURY RESEARCH ENTERPRISE AND RESEARCH SKILLS – DR LUCIENNE ABRAHAMS, DIRECTOR, LEARNING INFORMATION NETWORKING KNOWLEDGE (LINK) CENTRE, UNIVERSITY OF THE WITWATERSRAND)

Digital technology is changing the nature not only of S&T but of the world that researchers and scientists occupy, and the types of research that they conduct. Digital technology is, however, not the only area of S&T that is changing the universe. We have become very conversant with digital technologies and use them in everyday life, whether we are researchers or not. Many professionals are becoming digital bilinguals, but the question is whether we are also physics bilinguals. Some argue that physics created the 20th century and is creating the 21st century. The foundational disciplines still underlie the more public science. Nanoscience tends to be a ‘Cinderella science’ in South Africa and many other African countries.

The response to the question of whether the world of the 4IR is changing the research enterprise and the skills required for research is both ‘Yes’ and ‘No’. Digital technologies and their integration with other technologies are changing the nature of research and facilitating things that were previously complex and difficult or even impossible to do, but the world is constantly changing due to a wide array not only of science and technologies, but also demands and ideas. Since the mid-1990s, we have spoken of other ways of interpreting the forces driving change in the S&T environment, including the knowledge economy and the innovation economy. South Africa’s Ten-Year Innovation Plan sets out five ‘grand challenges’, namely biotechnology and pharmaceuticals, space, energy security, climate change and understanding of social dynamics (the nano and digital sciences apply in all these cases). These have become even greater influences in global S&T, but there are also new frontiers.

Scientific thought has continuously been revolutionised over the centuries, for example:

- Biomimicry in the 1400s through Leonardo da Vinci's imitation of birds to produce new technologies. Biomimicry is one of the key sets of ideas underlying S&T today and does not emanate from the 4IR.
- Photonics and the photoelectric effect developed in 1921 by Albert Einstein.
- Quantum physics developed in 1926 by Erwin Schrödinger.
- Theoretical physics and futurism, the brain (the next frontier), neurogames, and the future technologies of the mind (e.g. surrogates or avatars guided by the human brain) developed between 1987 and 2018 by Michio Kaku.
- The second nanotechnology revolution, working at the atomic scale and molecular level, using biomimicry and quantum physics led by Omowunmi Sadik in the 2000s.
- Software today, from analogue to digital in electronics, mobile communications, tech hubs and smart cities, led by people such as Bill Gates, Sumeet Varma and Rajat De.

In exploring the foundations of 21st century research and their value to research today, we need to understand science broadly beyond our own field or niche, and the science, technology and innovation (STI) system beyond our own institution. We also need to know about business.

Nine short conversations about 21st century science, technology and innovation were presented:

1. Enriching science and society (the proverbial holy grail)

Science enriches science and society in numerous ways and has the potential to do so to an even greater extent:

- The exceptional quality of the music played at the All Africa Music Awards (AFRIMA) was due to digital quality sound engineering.
- Literature reviews can be enabled by artificial intelligence to a level approaching precision, without sacrificing theoretical integrity.
- Nano unmanned aerial vehicle (UAVs) can be used in autonomous and semi-autonomous flight for nano-tagging and nanorobotics. This represents a convergence of digital and nanosciences.
- Nanoscience could be effectively used in dentistry to build at the cellular, molecular and atomic levels.
- South Africa's competitor countries are investing heavily in nanotechnology. Russia has a huge nanotechnology venture capital company called Rusnano, and China has a nanopolis (i.e. a city built for the purpose of engaging in nanoscience). South Africa has the National Centre for Nano-structured materials, the DSI/Mintek Nanotechnology Innovation Centre, NanoTech Water Solutions, NanoLand South Africa and seven universities conducting research in the field (with around 1000 master's and PhD graduates and 5000 publications). Despite the large number of institutions involved, South Africa has only 44 patents to date in nanotechnology. We have developed nanoscience and now have to apply this in innovative ways and bring new technology into common use. These are big questions for research managers.
- People need to be digitally bilingual in that they are digitally literate to the same extent that they are language literate.

2. From linearity to complexity to research and innovation entanglement

- We are learning that we need to move away from linearity. The discoveries, inventions and innovations of the future are more likely to come from interdisciplinarity. The question is how to move scientists with a particular set of skills from one sector to another (e.g. moving physicists into digital health, or young people trained in software development into nanoscience, biotechnology or agritechnology).
- The complexities involve issues that reside not only in the physical sciences but also in the human sciences, for example, eco-anxiety because of deforestation, fires, climate change, health risks or cybersecurity risks; the massive responsibility for the recycling of plastics or for the creation of recyclable packaging; significant issues around IP rights and open access to knowledge (patents, licences, copyright), since patents do not just come from clever ideas but are built on prior knowledge, which may be IP protected. As ideas become immensely more complex, and as research management faces more adversity, as collaboration is fraught with challenge, we shy away from complexity rather than inviting, encouraging and embracing it.
- Science production is not simple. The nature of research and innovation today is that of entanglement, involving cross-disciplinary and interdisciplinary research in collaborative institutional settings.

- The economic reality is that research and innovation are always underfunded and cross-subsidised.

3. 4IR or 21st century science

- Science today is not necessarily associated with 4IR. It is not just industrial, but post-industrial and much more complex. There are numerous different units of production and research problems of various scopes, from industrial scale to the need for environmental-scale solutions. The issues relate not only to the power source and how industry is organised, but to the evolution of knowledge. Emerging fields of science and competitive economic activity should not be excluded.
- The terminology used in the South African Science and Technology Foresight Study of 1997 was of a long-term nature; for example, knowledge-based economy, innovation-based economy, techno-scientific revolutions, which been around for many decades. The 4IR terminology gives no added value or additional insight. The term '21st century science' may be preferable for this multiple revolution with many layers and multiple entry points.
- 21st century science is entrepreneurial, requires new skills, and is introducing new jobs, careers and specialisations.

4. Funding, funding, funding, will GERD get to 2% of GDP? And innovation investment

- The Ten-Year Innovation Plan for South Africa set a target of 2% of GDP for gross domestic expenditure on R&D (GERD). In 2018, GERD was only R38.7 billion, whereas expenditure should have been R97.4 billion to reach the 2% target.
- Significantly higher private and public funding investments are needed in R&D.

5. Applications in every area of scientific and research endeavour

- There should be applications in every field of endeavour, including precision agriculture, the future of healthcare, and digital manufacturing and design. There are questions over who owns advanced technologies. Workers at all levels need to be trained in using and advancing precision-agriculture technology. Problems need to be modelled and solved in the digital environment to save time and money. Innovation in financial technologies would, for example, enable insurers to collect lots of data and offer significantly cheaper prices for tailor-made products; for example, insurance just for short periods of high risk.

6. Smart buildings, homes, hospitals, cities, cybercrime and surveillance

- Smart cities are not just about digital technologies. Powerful futures result from the integration of a range of sciences, including environmental science.

7. New parameters for thinking about science, designing science-performing institutions and managing scientific production and IP

- One of the big challenges on the African continent in the 21st century is reliance on the 3TG minerals (tin, tantalum, tungsten and gold) for making digital equipment. Several African countries are rich in these minerals, but the firms that extract the minerals are doing so under conditions of violent conflict. The materials required for every cell phone are being mined at the cost of human life. Nanoscience has not yet progressed far enough to dispense with these minerals and substitute them with more advanced materials, but some of the elements could potentially be built through nanoscience and technology rather than through conflict-based extraction.

8. Producing the 21st century generation of scientists

- Our education systems are failing, not just because of weak teaching, but even more because the 21st century knowledge content is not part of what is taught in the classroom; for example, research skills are not taught from a young age; nanoscience is not mentioned in school textbooks; and the basics of electronics do not form part of the curriculum.
- We no longer need a static 'chalk and talk' approach to teaching. Teachers are being asked to teach with dynamic software applications, but they have not been taught how to do so.
- Pseudoscience needs to be understood, as it has become a huge challenge across the world. Researchers and research managers must question themselves and avoid becoming pseudoscience practitioners themselves.
- We still lead very industrialised lifestyles, generally working from 9–5, or 9–9 or 9–midnight. This is not necessarily a highly productive lifestyle.
- A vegan lifestyle can be very powerful for scientists and researchers, as the experience of a large percentage of the population of India shows.

9. Who is a scientist?

- We still tend to talk in individualistic terms about 'a scientist', but good science today involves collaborative teams, crowd science and citizen science. There are new boundaries to be crossed.
- There are key questions related to the regulation of artificial intelligence (AI)-enabled applications.
- Really simple and creative tasks cannot be taken over by automation. Scientists are not going to be replaced by robots.

Is the 21st century research enterprise about jobs and employment, or about skills, ideas, careers, apps, platforms, patents and research trajectories?

Discussion

Question: A possible counter-question to the question 'Is Africa ready for the 4IR?' might be 'Is 4IR a priority for the global South?'

Dr Abrahams: The term '4IR' is just jargon. The issue is the extent to which countries on the African continent in the global South have engaged, are engaging, and continue to engage in all kinds of science, technology and innovation that are pivotal globally and for Africa. Very few African countries are spending more than 0.5% of GDP on R&D, and many countries are spending as little as 0.1–0.2%; South Africa is spending only 0.7%. The real challenges are related to the consistency of STI practice, the evolution of S&T institutions and the capacity to attract private and public sector funding. These challenges are found in all areas of S&T practice. A CREST study about ten years ago found that in SADC, areas of research strength in terms of publications are plant science, agriculture and subtropical diseases.

We need to continue to invest and seek investment to empower young people with STI skills in a diversity of fields. We need to understand the priorities, and health is certainly one of these. Rather than discussing the 4IR, I would prefer to talk about '21st century science'.

Debbie Schultz: With respect to the notion that creativity is one of the skills that will save humankind in the 21st century environment, recent research has shown that AI is starting to reduce what is seen as creativity.

AN INTEGRATIVE FRAMEWORK FOR ADAPTIVE INDUSTRIAL SYSTEMS OPTIMISATION – MR MTHANDENI LANGA, STRATEGIC TUTOR AND RESEARCHER, UNIVERSITY OF JOHANNESBURG

Society is an integrated cluster that needs to be unpacked in order to contextualise different fields and what they mean in the context of artificial intelligence (AI), computational intelligence or the Fourth Industrial Revolution (4IR), depending on the preferred terminology. The 4IR pursues the integration of production processes and network connectivity to facilitate intelligent behaviour, resulting in machines and corresponding hardware exploiting embedded software capabilities to independently exchange digital information to discover, construct, govern and manage integral industrial processes over cognitive architectures.

In the course of his research, Mr Langa had registered a patent for the integrative principles of systems optimisation. He had coined the term 'context-oriented solutionism' for his approach, which entails trying to come up with a solution that makes sense in the context in which one finds oneself. *Indidiyelo* multiagent optimisationism involves an amalgamation of things. *Indidiyelo* is a Zulu word that means 'integration'.

An integrated cluster is characterised and driven by several variables, with the final outcome being actuation (Figure 1):

- Discovering, which entails an agent discovering where it is located
- Constructing, which involves constructing a preconceived path
- Governing, which involves the creation of governance mechanisms that crystallise what one has discovered and constructed
- Managing, which involves managing through cognitive architecture what one has discovered and constructed.

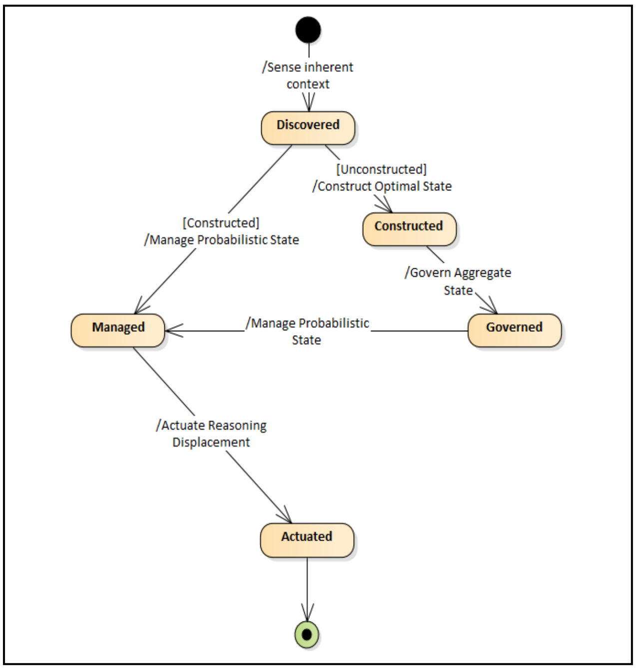

Figure 1: Variables that drive an integrated cluster

We are all agents. An agent is a particle in a computational universe. Its propensity to adapt is subject to internal and/or external factors. Absolutely known factors can be rationalised by determinism, whilst unknown elements can be rationalised by stochasticism. Sustainable organisation reengineering should optimise contextual prevailing factors. In an organisation, people (or agents) at different levels will have different perspectives, from their particular context, on how to resolve an issue.

The integrative framework could be unpacked for optimisation in any context, including a business programme or research performance in any field. We need to consider ways of integrating the various disciplines in order to drive research and knowledge production and stop working in silos.

Discussion

Jansie Niehaus: It was good that the last two speakers introduced opposite points of view. Dr Abrahams challenged the perception that we only work in a digital world, while Mr Langa is living in a digital world and telling the 'inside story'.

Mathematics is powerful in its many applications and indispensable to the algorithms required in the digital world. It is important for learners and students to be equipped with tools such as mathematics and statistics.

Optimisation requires building a mathematical model in which the various factors that are of interest are brought together to create an optimal space in which decisions can be made. Optimisation takes into account that decisions can be variable within that space, with a myriad of possibilities.

PANEL DISCUSSION

Issues of the 4IR – pros and cons. Are 4IR technologies enablers of research? Is there a risk of neglecting other techniques or areas of research due to the availability of such technologies? Is there a risk of fewer researchers being required in the 4IR context?

Mr Langa: My research fuses various philosophies, including behaviourism and functionalism, to consider different permutations and computations derived from a statistical concept, and make it possible to integrate different perspectives and come up with multiple views using information retrieved from disparate databases through key words. 4IR is re-shaping the world through its applications in functions that include sending people to space and autopiloting.

Dr Abrahams: I work in the field of digital innovation and transformation, not in nanoscience. I do not understand why we have to refer to the latest technologies as 4IR. Digital technologies, hardware, software, data, data analytics and a range of applications are enabling capacities and scientific and research activity in almost every field. In the agricultural environment, for example, precision agriculture addresses questions related to the failures of crops and the wastage of scarce resources. Scarce resources such as water can be used economically to produce high-yield crops by applying tools including data analytics and AI-enabled applications to a challenging environment. This kind of analytical perspective can be applied to any aspects of science and technology in any economic or social sector. We are not even scratching the surface with respect to the possible digital applications that can be used. Digital applications are not only changing schools but also universities, which have larger budgets for resources than schools do. South African universities are generally not digitally enabled institutions; for example, they do not use digital technologies to improve the throughput rate at undergraduate level, or to advance the quality of postgraduate knowledge production. We probably have several decades of work to do in order to see digital enablement influence and enhance what happens in the national system of innovation (NSI). One of the challenges is that a large percentage of the NSI is centralised in the City of Tshwane, and the rest of South Africa is excluded. This has been pointed out by a number of scientists and researchers since the publication of the White Paper on Science and Technology: Preparing for the 21st Century in 1996. It is wrong to cluster S&T activity mainly in one small geographic area, but this is the historical reality. However, digital technology makes it possible to invite people from far-flung parts of the country into the room. We have not even begun to explore the possibilities of digital applications and digital innovation. I work in a digital tech hub called Sebologang; there are over 60 tech hubs in South Africa that conduct activities such as producing digital innovation software or hardware, and performing digital fabrication with laser cutters and 3D printers. There are also many business enterprises, sometimes in remote parts of the country or in townships, whose work is enabled by digital technologies and applications. On the African continent, there are over 400 digital tech hubs. We are seeing a transition in which digital technology is major part of new S&T, but not the only one.

Comment: It was good to hear the emphasis on integration and contextualisation. Some of the views at this Discussion Forum have been contradictory. Some believe that the 4IR is coming, while others are of the view that 4IR is already our lived reality. There may be challenges with the way in which 4IR is conceptualised in South Africa. Some people believe that 4IR just involves robots that will take away people's jobs.

Mr Langa: I was trying to highlight that we are not using optimal thinking to look at challenges as an integrated cluster with its own internal properties that can be unpacked, as opposed to the external properties that it is subject to, in order to explore the meaning of 4IR. I am sceptical of the notion of 4IR, and therefore refer to my field as 'computational intelligence'. Artificial intelligence is at least 60 years old, but AI only started making sense when it was coupled with statistics. This gave rise to the field of computational intelligence. We need to spend time understanding the internal properties of a particle, which could be anything, in the environmental context that it is subject to. The internal properties can be optimised in light of what the particle is subject to, but we are not yet at that stage. We want to reach that point, but we continue to keep the human in the loop (e.g. in the case of a drone, there is someone driving it). With computational intelligence, we are trying to remove the human from the loop and posing the questions of whether a particle could programme itself to achieve what it needs to do, and how it could make decisions about what it has to do and what obstacles it should avoid. 4IR is a meaningless buzz word that refers to the integration of software and hardware to optimise our views. We are trying to optimise the way we think, but I am not sure if we will ever reach the stage of removing the human completely from the loop. Even if an agent is operating itself, the designer of that agent was a person. In a theoretical context, there is thus an abstract human in the agent itself.

Dr Abrahams: The issue is what the general researcher needs to know about digital technology and what kinds of digital skills they require. Every member of the South African population needs digital skills and should acquire such skills as early as possible. Children as young as two years old are already playing with simple software. As we develop our specialisations, interests and careers, we need to ask what digital technology we need. Programming is an important skill; for example, we need to learn coding languages similar to the way we learn linguistic languages. This is the nature of the 21st century. We can no longer afford to be ignorant with respect to digital skills; in this sense digital technology is a revolution, but it is not the only one that is happening.

Question: If we are to be aligned with 4IR in our own discipline, what would the end product be? We need a programme assessment to identify our needs and establish a bridge into digital technologies. Participating in a broad platform of applications might not necessarily give us the specific inputs that we need. How can we develop discipline-specific skills?

Dr Langa: Apart from mathematics and statistics, computational thinking is another important skill for comprehending that we live in a computational universe (e.g. the location of every person in a room could be identified using coordinates). In order to be able to conceptualise that kind of perspective, one needs computational thinking. One should know what an algorithm is. One should not just resort to using Google, as the developers of Google are trying to push certain technologies. Python followed by Java are the top programming languages, but in in developing the algorithm for context-oriented solutionism, I want to use Scala, a functional programming language that fuses object-oriented programming as well. If you can program a spreadsheet and have been introduced to object orientation in the context of Java or C++, you can find a way think computationally. This kind of approach needs to be complemented with mathematics, because most applications are mathematically driven. Unless you understand mathematics or statistics, some potential applications will seem far-fetched. In the case of an algorithm that caused planes to descend and crash because it did not allow the pilot to override the algorithm, the abstract humans in the loop, namely the software developers, architects and companies that produce the software, are accountable.

We are living in a computational universe in which everyone needs to be computationally literate and have the ability to think computationally, coupled with philosophy. We need to be able to understand abstract things as opposed to operations, and appreciate how theory influences practical operations. What you believe about yourself at this moment was manufactured a long time ago, and this abstraction becomes reinforced. This is the implication of computational intelligence, which is the reality of the world in which we live.

Question: Nanotechnology makes use of minerals that have been looted. What can researchers do about this?

Dr Abrahams: There are two possible solutions that could operate simultaneously. One solution is technological – as nanoscience develops, it might become possible to build the elements required in the laboratory and not have to mine them in a way that destroys environments, communities and people. This technological solution has been talked about in the literature but the dynamics and economics of such an approach have not yet been seriously explored, or whether it would be possible to create the minerals in sufficient quantities to make it more attractive to produce them in the S&T environment than to extract them through mining. Another solution that applies not only to conflict minerals but to S&T in general is to develop a strong ethical foundation. Throughout the world, ethics in S&T has not yet evolved to a high level.

Question: What are the limitations of nanotechnology? What can it not do?

Question: 4IR must be an integrative approach from various perspectives. The six work streams of the Presidential Commission on the Fourth Industrial Revolution demonstrate the way in which South Africa is approaching 4IR. The work streams focus on hardware and infrastructure, the economic and social sphere, human capital, industrialisation and commercialisation, policy and regulation. 4IR affects not only the programming environment but also the socioeconomic environment. The 30-member commission, chaired by the President, comprises eminent persons from different sectors of society and reflects a balance with respect to gender, youth, labour and business, including digital start-ups as well as digital entrepreneurships. The work streams meet for discussions with stakeholders. One of the work streams considered the skills required for 4IR and submitted a report highlighting that technical skills (including both programming and skills in the particular field of application) as well as soft skills are required, and that the soft skills are the most important; for example, problem-solving, critical thinking, people-management, communication, creativity, empathy, caring, decision-making, cognitive ability, emotional intelligence, negotiation and entrepreneurship.

Dr Abrahams: The most important skills required for success in the 21st century are considered to be critical thinking, creativity, collaboration, communication, information literacy, media literacy, technology literacy, flexibility, leadership, initiative, productivity and social skills.

Mr Langa: An integrative framework requires computational thinking. Practitioners in all fields need to embed a computational approach into their perspective. The word 'impossible' has no reality. Everything is possible. We are trying to optimise computational thinking to develop algorithms that can contextualise their environment and understand what they are trying to do without being operated by humans. This approach requires soft skills. Ultimately, the human can never be removed from the loop, because the human comes up with the designs. The word 'programming' tends to intimidate people and place 4IR beyond the scope of ordinary people. We need computational thinking rather than programming.

Question: The comment was made that South African universities are generally not digitally-enabled institutions. What can be done to catch up and prepare for the future? Are universities doing enough to develop the competencies that students will need to be competitive in the work environment?

Dr Abrahams: Universities are only partially equipping students with the skills they need for the future. We no longer live in a linear world where students have to finish university and graduate before they go out into the world. They need to explore the world while they are at university. This is one of the key changes that the 21st century allows. Higher education needs to equip students to function in parallel universes of learning and application, whatever that might be. The linear approach can only be broken if students at university, whether at undergraduate or postgraduate level, are learning the kinds of things that allow them to operate simultaneously in multiple universes. This is not a dream for the future; this is what is actually happening on campuses today. Students in a wide range of creative fields across the world are being gathered together, for example the Converse shoe brand is inviting students from many different countries to design new apparel, thus using the creative ideas of students rather than employees. This kind of approach could operate in many different fields. Students in nanoscience, for example, could not only write research papers but also engage in nanoscience production. Knowledge developed in the course of a master's or doctoral degree could be used to create artefacts.

Question: Every current development has side effects. Law cuts across disciplines in order to regulate and prevent negative consequences in future. Does regulation have any place in relation to 4IR?

Dr Abrahams: Many of the effects resulting from digitisation are already being regulated; for example, privacy and data protection, as unimaginable volumes of personal data are collected by virtue of people leaving a digital footprint as they operate in the digital space. The EU General Data Protection Regulation (GDPR) has evolved as a highly complex attempt to regulate something that is very difficult to regulate. The South African Protection of Personal Information (POPI) Act (No. 4 of 2013) touches on just a few of the issues contained in the EU GDPR, although it could be interpreted in context of the EU GDPR. Lawyers and regulators need to be aware of the implications and challenges of digitisation; for example, consultants to an organisation are typically required to sign an MIE consent form in order to be paid, and in this way give away their rights, and the personal information that they have to provide could be used by a third party; or the consent requested for a medical procedure could include giving consent to use one's medical information in conference presentations or for advertising purposes. Such practices are against the law. One of the principles of law, namely that of minimality (i.e. that one has to provide only the minimum amount of information needed for a particular transaction) is often not applied. Much work is needed in the legal and regulatory environment with respect to compliance with existing law and global legislative change.

Mr Langa: In a situation with the three variables of patent, partaking and dissertation, each of the variables could be aligned with economics, education, health, justice and media. This results in 60 different perspectives. The next step is to consider intent optimisation; this example would conservatively yield 9.6615×10^{34} combinations. The permutations are even larger at 8.093×10^{160}. Since it is not possible for the human brain to make sense of astronomical figures of this magnitude, AI could help.

RESEARCHERS VS ENTREPRENEURS: WHO DRIVES INNOVATION? – DR ANTONEL OLCKERS, CEO: DNABIOTEC

I came from a full-time academic career molecular human genetics and now have a business career. I am grateful to my PhD supervisor and co-supervisor and my research collaborator and mentor who taught me how to lead a research team, and to those who taught me the difference between pseudoscience and science. My academic career began as a student, and by the time I left academia I had been head of the Molecular Biology Unit in the Department of Human Genetics at the University of Pretoria and director of the Centre for Genome Research at North-West University. I graduated over 30 master's and doctoral students, and since I left academia I have had two extraordinary professor positions.

I attribute the success of my company DNABiotec to all the members of my team who have taken the business from concept to profit over the last 18 years, and especially to my husband who is the other director of DNAbiotec, Paul Olckers, an electronic engineer and CEO of 5DT, who taught me all I know about business and how to lead a business team by sharing his business knowledge and skills and setting an incredible example for me as an entrepreneur.

I founded DNAbiotec in October 2001. The business has three main income-generating activities:
- Forensic science (e.g. DNA expert in court cases)
- Biotechnology, involving research in human genetics at the start of the company. The business model has changed over time, and now the company is more involved in business and innovation-related services.
- Training in science, business and forensic portfolios.

Patents are extremely effective tools for IP protection, but as an entrepreneur with 18 years' experience in a successful company, I do not own any patents. When I left academia, I discovered that there were certain things I could do extremely that the market was willing to pay for. The business is essentially the translation of business capital into market capital.

Researchers and entrepreneurs have different mind sets and perspectives with respect to the world. The question is whether these mind sets are mutually exclusive. The traditional role of a researcher in the academic sector was to focus on research, generate knowledge and publish papers. Such researchers would typically have no interaction with the private sector, and would interact with the public sector when needed. The academic sector believed that academia drives innovation through research and the knowledge that it creates. I used to be that kind of researcher more than two decades ago. By comparison, the entrepreneur of the past would typically focus solely on business, create products and services and push these into the market, and make a profit. Such entrepreneurs would generally have almost no interaction with the private sector, and with the public sector only when absolutely necessary. They believed that the private sector alone drives innovation through its products and services. Making money is a noble endeavour, since you cannot help anyone unless you have money. The traditional belief in the separate nature of research and entrepreneurship created an 'us' and 'them' mentality between researchers and entrepreneurs, which existed when I entered the innovation space. There was a so-called 'innovation chasm' between industry and academia. At the national level, this stifled opportunities and there were many missed opportunities. Each sector believed that they were the only one that could see the truth. There is potentially much more value in viewing things from the perspective of both research and industry. It is essential to look at the entire innovation network, clarify the respective roles of entrepreneurs and researchers, and then decide who drives innovation, and even if this is the right question to ask.

Innovation can be defined as the smallest number of activities or aspects. DNAbiotec tested this model with many SMMEs as well as several large international corporations, and they all agreed that this is how they innovate. Traditionally innovation began with a concept, and continued to research, development, productisation, manufacturing and commercialisation. The realisation grew that the flow of information in the innovation network is not in one direction only, but bidirectional, with every node in the network connected to every other node.

There are numerous considerations and frameworks to be taken into account in innovation. If innovation is to be sustainable, it has to be ethical. The legal and policy frameworks will have an impact on innovation.

Seventy-five per cent of existing scientific knowledge is in the form of patents only, not scientific literature. The value of know-how tends to be underestimated, but if you document your learning curve in developing innovation, other people may also find it useful. The DSI incorporated our model of innovation into the Bio-economy Strategy. DNAbiotec also developed a portfolio of three short courses.

We unpacked what the knowledge economy means for the bio-economy, and what it means for DNAbiotec in particular, as an SME in the bio-economy sector. Inventions require research and they cost money, while the innovation of products and services traded in the market makes money. We found that innovation remained fragmented. The research and entrepreneurship sectors were both working very hard, but not necessarily together with an innovation mind set. Each sector on its own cannot fix the innovation fragmentation at national level. The silo thinking of the past is no longer relevant and is not an enabler of innovation. A new paradigm is needed. There is no 'us' and 'them', only 'us', and our fates are linked in South Africa. An illustration of the way in which the sectors are linked is shown in the flow of fiscal funds. The private sector can license technology and use it to make a profit. Taxes on the profit are paid to the South African Revenue Service (SARS), which pays the funds into the fiscus. National Treasury allocates a budget to each government department from the fiscus, including the Department of Science and Innovation, which in turn allocates a budget to the National Research Foundation (NRF). The NRF funds research grants to academia, which uses the grants to generate the technology that gives rise to the innovations (including products and technology licences) that the private sector uses to make a profit. Logic thus dictates that we should work together to achieve the common goal of a strong national economy. Each sector has tried and failed to drive innovation on its own. Innovation needs both research and entrepreneurship to drive it. Each sector, with its own innovation mind set, and bearing the entire innovation network in mind, needs to enter into a high level of engagement with the other. As we go forward, we need a new mind set towards innovation that grows the economy. We require entrepreneurial researchers, and researcher entrepreneurs.

An entrepreneurial researcher has to be aware of their role in innovation and cultivate an entrepreneurial mind set, for example, looking for opportunities and funding in unconventional places, including outside the country. The research of the entrepreneurial researcher must feed into innovation, with applied research leading to products and services. An issue to be addressed is what is funded at national level. The entrepreneurial researcher must be able to communicate with both the private sector and government (the public sector).

The researcher entrepreneur has to be aware of their role in innovation. They cannot concentrate only on commercialisation, but needs to cultivate a research mind set, for example, by basing decisions on scientific fact. A business approach that uses the scientific methods will contribute to the sustainability of the company. The products and services of the business will flow from inventions. The researcher entrepreneur must be able to communicate with both academia and government (the public sector). For the researcher entrepreneur, the brutal truth is to see the world as it is, not as one wishes it to be. Researcher entrepreneurs can write up their experience in the form of papers for publication in the academic literature.

DNAbiotec has documented its know-how in research and in specific technologies and generates income from the IP that resides in this documentation, which is used to present short courses in science, business and forensic practice. The DNAbiotec portfolios include:

- The Essential Business Portfolio includes business practice, IP management, science project management, grant-writing and science-writing, ethics in science, social responsibility, innovation, entrepreneurship and business start-up.
- The Essential Forensic Portfolio covers DNA evidence, cross-examination and statistical analysis of DNA evidence. It is used to train thousands of attorneys and advocates on how to deal with DNA evidence in court proceedings, and forensic laboratories in how to add statistics to their business model.

Many people believe that R&D can revive the South African economy, but only innovation can grow an economy, and R&D is just a part of innovation. South Africa has been funding R&D for a long time, but the rest of the innovation chain has received far less attention and investment.

The major threats to innovation at national level are not using all our national resources, and not educating for the future. We do so at great risk to the national system of innovation and the country. South Africa has high levels of unemployment especially among the youth and those without any form of higher education, but even graduates may be unable to find a job. Unemployment leads to depression and has thus become a mental health issue.

We need to educate for the future by including entrepreneurship and financial education in school curricula so that people become increasingly self-reliant. Many young people are drowning in debt because they have not been taught to manage their own money or about the devastating effect of interest. In my science career, I expected to be required to apply hard technical skills every day, but I did not expect to also have to read legislation, come to grips with complex ethical frameworks, learn about IP, master soft skills or assist government in multiple committees. Depending on one's scientific field, one might also have to adapt to the digital world, learn to code, understand robotic workflows and become an expert in another field (it is no longer enough to be specialised in just one academic field).

President Ramaphosa would like to see entrepreneurship taught in schools from an early age in order to develop a culture of self-employment, as there is no alternative for South Africa to succeed. He commented that too often citizens are risk-averse with respect to entrepreneurship, preferring the so-called comfort of gainful employment to the perceived insecurity that comes with self-employment. However, the reality is that an entrepreneur with a successful company may have more financial security than employees in academia or in other people's companies. President Ramaphosa recommended changing the direction of education to develop relevant skills for the 4IR. He commented that technology is replacing workers, and that the impetus for economic activity is shifting from very large enterprises to smaller individual-led companies. He recommended that ideally 70% of graduates should be in science, technology, engineering or mathematics (STEM). He stressed the importance of getting the basics right earlier in the lives of children, and the crucial role of secondary education in inculcating the critical thinking skills of problem-solving and reasoning.

Statistics from the USA show a correlation between unemployment and postgraduate enrolments; in other words, graduates tend to enrol for postgraduate studies if they cannot find a job. Similar trends are evident in South Africa. In order to counter this trend, the education system must produce graduates that are market ready. It is unimaginable that in 2019, there is no digital portal in South Africa to link students seeking jobs to companies that are hiring.

For innovation to succeed, the skills required by both the entrepreneurial researcher and the researcher entrepreneur are no different, including complex problem-solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, judgement and decision-making, service orientation, negotiation and cognitive flexibility.

Characteristics of the world today that present a host of opportunities include superstructured organisatons, the computational world, extreme longevity, the rise of smart machines and systems, new media ecology and the globally connected world.

Graduates should stop asking the question of who will employ them, and instead ask 'How can I empower myself, and perhaps create jobs for a few other STEM graduates?' The public have to be educated about innovation. There are many citizen innovators without any education. Non-traditional careers have to be considered. It is a conundrum that universities train engineers to be ready to work for themselves when they graduate, but the same campus also trains scientists who are not ready to work for themselves upon graduation. What happens in engineering school is not happening in science schools. This ought not be difficult to fix.

You need to find your role in innovation and drive it wherever you are. The only way to create a sustainable innovation system is to create an innovation culture at all levels, from primary school to secondary school, tertiary education, postgraduate education and among supervisors.

Nobody knows what lies ahead, but four certain aspects of the future will be digital technology, AI and machine learning, robotics, 5G and beyond. You have to understand the implications for your particular field. Once you have found your niche in innovation, you should pass your passion on to the next generation as the innovators of the future. If you cannot find your path in innovation, you might consider creating your own.

CAREER PATH AS A RESEARCHER- WHERE TO IN A CHANGING WORLD? – DR KOUSAR BANU HOORZOOK, RESEARCH COORDINATOR: PROCESS, ENERGY AND ENVIRONMENT TECHNOLOGY STATION, (PEETS), UNIVERSITY OF JOHANNESBURG

Researchers face both opportunities and hurdles. There are two main types of career paths for researchers: namely, within academic and research institutions, or outside of these institutions in industry. From my experience of lecturing students in biochemistry at honours level, fewer than five from a class of 20–30 indicate that they want to continue with postgraduate studies. Feedback from students who want to go into industry is that there are financial constraints for them to continue to postgraduate studies, and furthermore that they are under financial pressure to provide for their family once they have graduated. Those who obtain a PhD are often considered overqualified when they leave academia and try to pursue a career in industry, and companies cannot afford to pay people who are qualified at that level. An honours degree is the usual entry-level qualification in industry. Falling pregnant is a hurdle for women postgraduate students due to the stringent timelines for completion.

The issue is where to continue to after completing postgraduate studies and possibly also a postdoctoral fellowship. The cross-cutting skills that researchers develop in the course of their studies could become useful at this stage, for example, community engagement, teaching and training and science engagement through giving local and international presentations. I would like to illustrate the challenges by referring to my own experience.

I completed my honours project at the Water and Health Research Centre at the University of Johannesburg (UJ). In order to develop passion and appreciation for one's research, our professor encouraged us to collect our own water samples, become involved in fieldwork and engage with the community. We drove through rivers and across mountains to collect our own water samples; we set up make-shift laboratories in the field to test our samples; and we engaged with communities and presented our results to them. Our professor made sure that we became involved. During my master's and doctoral studies, I mentored and trained many students at the University of Venda and UJ, developing their skills in microbiology and molecular biology so that they could further their research, complete their studies and obtain their degree. We had the opportunity to present and showcase our research at local and international conferences, and to collaborate with international researchers who wanted to test their methodologies on South Africa water sources. Through my postgraduate experience, I became an innovator. One of my innovations was to develop a faster method to test for diarrhoea-inducing *E.coli* bacteria in drinking water. My second innovation, a mobile water-testing laboratory that addressed a gap in South Africa, was presented at the Moola for Amanzi competition in 2007, which was a collaboration between the Netherlands and South Africa. This business idea was one of the top five in the competition. After ten years of discussion and negotiation between the UJ technology transfer office and the Technology Innovation Agency, a seed fund grant was awarded to develop the mobile water-testing laboratory. It took ten years of determination not to give up in order to reach that point. The need for and value of the proposal have increased in the intervening period. The lesson is never to give up on your idea and your dream.

In 2018, I graduated with my PhD and completed the building of the mobile water-testing laboratory. We shared our experience in addressing Sustainable Development Goal number 6 (Clean Water and Sanitation) with the World Health Organisation in Ghana. The mobile lab was launched in early 2019 with the assistance of the Process, Energy and Environment Technology Station (PEETS) at UJ, TIA and the DSI. Guests from industry, universities, government and municipalities were invited to the launch. The innovation was well received and was published in several newspapers, and we were invited to talk about it on a number of radio stations.

Discussions are currently under way with UJ to create a business entity within the university to sell the mobile labs and create a service to hire out the lab for water testing. To respond to the question of what postgraduates should do after completing their qualification when they consider whether to go into industry or stay in academia, I decided to stay at UJ not as an academic but as a project manager. I am inventing my position in UJ. I am a research coordinator at PEETS, which forms the link between SMMEs and faculties in the university. We take IP from the technology transfer office (in the form of patents and products) to companies. This role has been lacking at the university in the past ten years. I have found my niche and drive in assisting innovators and researchers to take their products to the market. The focus of PEETS is on energy, water and the environment. I am a scientist specialised in biotechnology, but I collaborate with engineers to manage projects in the field of water, including the management of water quantity and quality, and water filtration, treatment and purification.

Conclusion

- To stay in academia and complete postgraduate studies, you need to have passion, perseverance and determination. You need to do it for the love of it.

- Bursaries for postgraduate studies will need to compete with industry financials. People want stable jobs with a stable income, not to depend on grants. Postgraduate study does not provide financial security or job surety unless you are studying via a company.
- Research does not limit you; you are always learning, trying and keeping up with technology and other life skills.
- Universities need to re-look at how research is conducted and how students are taught in order to equip them with skills for 4IR. This would include doing more responsible research that will contribute to addressing the needs of the country.

Recommendations

- Students must be made aware during their undergraduate studies of the possibilities and opportunities available after finishing postgraduate studies in terms of innovation, patents and entrepreneurship.
- We need to align postgraduate studies and skills development towards 4IR, as this is our future.
- Publication incentives are needed for students to publish more, and supervision incentives to co-supervise more projects.

PANEL DISCUSSION

Possibilities beyond the university walls

Question: What is important for me to venture into research enterprise? Should I look at the value of the IP that I am trying to create, or are there other aspects that I should focus on?

Dr Olckers: If you are considering migrating from academia to the private sector, the first issue to think about is whether there is a market for the IP in the form of the product into which it is packaged. The first node of the innovation network is idea evaluation. When I was in academia, I spent less time on that node, but when I started to conduct research with my own money, that was the node on which I spent the most time in order to cull ideas. I believe that if an idea is to fail, one should fail fast. The ideas are rigorously tested from a theoretical perspective before they progress to the research stage. In the idea evaluation stage, one of the questions to be asked is whether there is a market for the product, what the market is willing to pay, what the anticipated future is for that product, who will constitute the market in the short, medium and long term, and who the competitors in the field are. As an innovator, one is constantly scanning the field for new markets and the entry of new competitors. It is more pragmatic to consider the value of IP in terms of what the market is willing to pay than in terms of the value estimated by an IP lawyer.

Question: The mobile water-quality laboratory could be deployed rapidly. Do you work with municipalities when they face water-quality crises? Is the mobile water-quality laboratory accredited, or are you working towards accreditation?

Dr Hoorzook: In the past we used to work with municipalities and the Department of Water and Sanitation and test their samples. Samples were sent to both our mobile laboratory and an accredited laboratory in order to test the reliability of our results through comparison. The mobile water-quality laboratory has only recently been launched, and field testing is still being done. Municipalities have shown an interest in the mobile water-quality laboratory, but unfortunately most of them lack funding to invest in such a lab. We are trying to get funding from government so that we could take the mobile lab to sites ourselves and collect and sample water-quality samples, especially in places where water-quality crises are occurring. We can collect water samples in problem areas and bring them back to the lab for testing. We are reluctant to take the lab into areas experiencing a water-quality crisis, as that might sow panic among the people.

Question: Have you worked with the South African National Defence Force (SANDF) on the Vaal river?

Dr Hoorzook: No, but the UJ rescue team has worked on projects on the Vaal with the MEC, and we intend to take the mobile lab to the Vaal early in 2020 to assist with water testing.

Question: Many science students are scared of the notion of becoming an entrepreneur. When you went into entrepreneurship, what was your biggest challenge? Would you have considered going into business any sooner?

Dr Olckers: One thing that kept me in academia for a long time and prevented me from going into the private sector was my fear of failure. When I initially decided that I should establish a business in biotechnology, I was almost paralysed by fear that it would fail. At that time (in 2001), statistics showed that three out every four biotechnology start-ups failed in the first three years. One day I realised that fear is due to the ego, and that if I failed I would have to acknowledge that I had not been able to make the business work even though I had been successful in science. Once I realised that, I got over the fear. You gain humility through experience.

I would not personally have considered going into business any sooner, because I was very happy in academia and thought I would retire from there. When I started the company, I initially had dual roles as head of an academic department and CEO of the company, because I wanted to train a generation of students who were not afraid of the private sector, and have people in the private sector working in very close contact with academia. Eventually it became too much to continue with the dual role, as both the academic and the business entities became too big for one person to manage and I had to choose between them. Another factor was that the university closed the department in which I was working. If that had not happened, I would probably have stayed in academia. Most entrepreneurs would advise starting out in business many years earlier than I did. If you ask me whether starting my own business was worthwhile, I would reply that migrating from research in academia to entrepreneurship in my business is the most difficult thing I have done in my career, but also by far the most rewarding thing I have ever done.

Question: South Africa has defined 4IR in its own context as ‘an era where people are using smart connected converged cyber physical and biological systems and smart business models to define and bridge the social, economic and political spheres’. This definition places equal emphasis on the human and technological aspects. What are the implications to researchers in the genomic environment of defining 4IR in this way?

Dr Olckers: Knowing a lot about genomics is no longer enough. New knowledge has to be integrated with one’s existing knowledge, and one has to keep adapting. If you are working in genomics and not using machine learning, for example, you are so far behind that you cannot hope to catch up. You have to embrace new technology and actively use it, which goes beyond just knowing about it.

MULTIDISCIPLINARITY IN SCIENCE AS WE ENTER THE FOURTH INDUSTRIAL REVOLUTION – MS JESSICA GROBLER, REGISTRATIONS MANAGER: SOUTH AFRICAN COUNCIL FOR NATURAL SCIENTIFIC PROFESSIONS (SACNASP)

The South African Council for Natural Scientific Professions (SACNASP) is a statutory body established under the Natural Scientific Professions Act (Act No. 27 of 2003). The council was formed to provide for a credible professional registration and regulatory body for natural scientists to establish, direct, sustain and ensure a high level of professionalism and ethical behaviour in the natural scientific sector, and to improve standards of services rendered by professionals, maintain their integrity, enhance their status and manage liabilities attendant to the practice of natural science professions. The Act requires that all practising natural scientists in South Africa be registered with SACNASP.

The definition of a ‘scientist’ is changing. A scientist used to be considered to be a person who studied a scientific discipline and works in it. The disciplines were clearly defined, and careers were usually within the one or two disciplines studied. A scientist has now become someone who studied a natural science or a mix of natural sciences. The boundaries between disciplines are blurred, and there are constantly new disciplines. Scientists cross fields, change fields and work with non-scientists.

With respect to what the Fourth Industrial Revolution needs, the Institute for the Future identified the following skills that will be essential in this time:
- Novel and adaptive thinking: proficiency in coming up with solutions and responses beyond those which are by rote or rule-based;
- Computational thinking: the ability to translate vast amounts of data into abstract concepts and to understand data-based reasoning in order to make sense of this information;
- Cognitive load management: the ability to discriminate and filter information for importance, and to understand how to maximise cognitive functioning using a variety of tools and techniques;
- Transdisciplinarily: literacy in and the ability to understand concepts across multiple disciplines;

- Virtual collaboration: the ability to work productively and drive engagement as a member of a virtual team; and
- Technological literacy and technical entrepreneurial skills: the capacity for a new partnership with the new smart machines that will enter offices, factories and homes.

Science career paths are different today in several respects from the traditional career trajectory of a scientist in the past. The days of studying one thing and doing a job for 40 years are passing. Scientists study multiple disciplines, mix their studies with commerce and humanities or switch during their studies. Many scientists move out of the realm of science when they start working or during their career. Many collaborate in multidisciplinary teams. Many switch disciplines during their working lives. Adaptation is the flavour of the day.

SACNASP currently has 13,500 registered scientists, and registers scientists in three categories: Professional Natural Scientist, Certificated Natural Scientist or Candidate Natural Scientist, but the conventional definitions are becoming less relevant. SACNASP works with 25 defined fields of practice, but constantly finds scientists that do not fit neatly into any of the defined fields, which are shown in Table 1.

Table 1: SACNASP fields of practice

Agricultural Science	Including Forestry and Wood Science
Animal Science	
Aquatic Science	Includes Marine Science
Atmospheric Science	Includes Climatology and Meteorology
Biological Science	
Botanical Science	
Chemical Science	Includes Industrial Science
Conservation Science	
Earth Science	
Ecological Science	
Environmental Science	
Extension Science	
Food Science	
Geological Science	
Geospatial Science	
Materials Science	Includes Metallurgical Science
Mathematical Science	
Microbiological Science	
Physical Science	Includes Radiation Science
Soil Science	
Specified Science	Fire Origin and Cause Investigation
Statistical Science	
Toxicological Science	
Water Resources Science	Includes Hydrological Science and Water Science
Zoological Science	

Recognition of Prior Learning provides a mechanism for individuals with insufficient formal qualifications to register with SACNASP once they have at least ten years of relevant work experience. Work experience is full-time work experience in a relevant scientific field. The duration of the work experience is calculated from the date of graduation, with the highest qualification being considered. Work experience obtained prior to the highest qualification will not be counted except in exceptional circumstances. Teaching experience, even at tertiary level, is not considered. For registration as a Professional Natural Scientist, at least some of the work experience must be in a position of responsibility.

SACNASP uses a peer-review system to assess applicants for registration. All individuals applying for registration as Professional or Certificated Natural Scientists must nominate referees to submit confidential reports on them to SACNASP. Referees should have personal knowledge of the applicant's scientific work; they could be superiors, colleagues or clients but not subordinates. Referee reports should describe work performed as part of employment not studies. Referees should be registered Professional Natural Scientists or individuals of equivalent qualifications and experience (e.g. potential registered Pr. Sci. Nat. or Pr. Eng.). Referee reports must be the original work of the referee; no copying and pasting is permitted, especially not from text that the applicant wrote. SACNASP requests reports directly from referees; they get a unique link to upload their report directly on to the SACNASP system. You do not have to referee for someone just because you have been requested to, and your report does not have to be positive.

SACNASP launched the Continuing Professional Development (CPD) Programme on 1 April 2017. To comply with SACNASP's CPD policy, registered scientists need to accumulate 25 CPD points over a five-year period in order to be eligible for re-registration. These points can be gained through a number of activities including attending conferences, belonging to a voluntary association, assisting SACNASP as a referee or as a member of a committee. Substantial effort has been put into explaining to voluntary associations how the system works. SACNASP is also hosting workshops around South Africa to address the concerns of registered natural scientists. Consideration has been given to whether the CPD programme could be used to deal with applicants who do not fully meet the requirements for registration because of the interdisciplinary nature of their work, so that they could use CPD points to build up the aspects that they are missing for registration.

All SACNAPS-registered scientists are regulated by a code of conduct for the protection of registered professionals and the public. The code of conduct speaks to the professional behaviour of registered professionals, who are required to conduct themselves in such a way as to uphold the dignity, standing and reputation of the natural science professions. One of the requirements of the code of conduct is that the professional undertakes only to perform work for which they are competent. This raises issues in the present-day world where fields of competence are very blurred, and whether one should trust professionals to know what they are capable of doing and what they are not able to do, as the Engineering Council of South Africa does.

Recommendations

- SACNASP needs criteria for defining and recognising scientists that fit the new era, which would involve less rigidity in how we define fields and more space for adaptation during the course of a career.
- Another issue to be considered is whether we should trust a professional's own judgement of their competence.

STATUS OF POSTGRADUATE RESEARCH TRAINING IN ENGINEERING IN SOUTH AFRICA: A CONSENSUS STUDY BY ASSAF – PROF BEA LACQUET, DEAN AND PROFESSOR, UNIVERSITY OF THE WITWATERSRAND)

The Academy of Science of South Africa (ASSAf) was tasked with conducting a study on the status of postgraduate research and training/education in engineering in South Africa to assist the Department of Science and Innovation (DSI) by providing detailed information and data to be able to assess the state of doctoral training, and identifying possible systemic challenges or shortcomings. The results of the study were published about a year ago.

Introduction and context

The background context for the engineering profession in the country includes South Africa's young and growing population. South African industries produce mainly low- to medium-technology products, which is perhaps not the industrial sector that the country would aspire to. Critically, industrial production is declining and the country is importing more than it should. South Africa has a respected tertiary education system, and a government that is supportive of science and technology. South Africa needs economic growth and international competitiveness. In order to achieve higher growth targets, South Africa would have to boost postgraduate training in engineering to support active participation in research and development, position the country as an attractive destination for global participation, support transition to high-technology manufacturing, and improve international competitiveness.

Talent in the country is a top driver of competitiveness. In order to foster talent, we need appropriate training and life skills, and strong, integrated and practical infrastructure. The quality and availability of highly skilled workers (from artisans to specialist practitioners) is critical for a shift towards innovation and advanced manufacturing.

The future demand for high-level engineers is expected to be in the following areas: water, the Square Kilometre Array (SKA), renewable energy, smart cities, sustainability, the energy/food/water nexus, infrastructure technology for developing environments, industrial engineering, systems engineering, IT engineering, animation and gaming, big data, asset and facilities management, and asset management in process industries.

With respect to South Africa’s research capabilities, the country has respected academic and public research institutions, which need to be used correctly. The country’s researchers are engaged in international cooperation and impact to a significant extent. R&D spending in South Africa is not optimal. The contribution from the private sector is declining. South Africa spends 0.73% of GDP on R&D, which is the lowest percentage among the BRICS countries. A growing danger in some sectors is that industry is moving its research efforts to other countries, which reduces the environments in which high-level engineers can work in South Africa. Another challenge is that South African research lacks outward orientation. International companies are sometimes considered a threat, but working with such companies can be a very enriching experience provided that South African IP is protected. In becoming more outward looking, South Africa could begin by looking towards SADC countries.

Postgraduate research programmes are needed in order to build capacity in an integrated education system supporting undergraduate education, reverse the outflow of talent, attract international talent, develop and commercialise, and promote small high-tech firms.

Postgraduate engineering education landscape at South African higher education institutions
Fourteen higher education institutions in South Africa offer postgraduate engineering qualifications; these comprise eight universities, five universities of technology and one distance education institution. They offer a broad range of programmes. It might be argued that these programmes should be rationalised and reduced, but the diversity of programmes creates considerable potential for interdisciplinarity, which is intensified when the possibility of working with scientists in a range of fields is also taken into account. Research is constrained by the relatively low numbers of staff with a doctorate, which also limits supervision capacity. The numbers of higher education staff with a doctorate in engineering need to be increased.

Postgraduate student training at South African higher education institutions
Since 2009, there has been an average annual growth of about 10% in the number of master’s enrolments and 12% in the number of doctoral enrolments in engineering, which is gratifying. Since 2000, there has been steady growth in the percentage of African, Coloured and Indian master’s and doctoral engineering students and graduates compared with white students, which is positive evidence of transformation of the engineering profession. Students take an average of three years to complete a master’s degree in engineering, and 4.3 years to complete a doctorate, which compares favourably with many engineering programmes abroad.

Gender dimension of postgraduate engineering training
Only about 22% of postgraduate engineering students are women, compared with 45% of the undergraduate engineering class being women at the University of the Witwatersrand, for example. Factors that inhibit female participation in postgraduate engineering programmes include lack of adequate funding (although this is equally true for male students), negative stereotypes, discriminatory sentiments from male peers and an unthinking industry, lack of female visibility in engineering, women’s isolation and the scarcity of female mentors and role-models, the pressure on black women of the ‘black tax’ (i.e. supporting their family or giving back to their community who supported them in their university studies), and the existence of many other rewarding careers to pursue.

The report suggests a number of interventions that address these barriers and aim to break the pattern related to the paucity of women in postgraduate engineering.

Employability and demand for postgraduate engineering graduates
South Africa’s low- and medium-technology industries see little need for engineers with a postgraduate qualification. South Africa therefore loses many young engineers with a postgraduate qualification to employment opportunities abroad. If South African industries were to move towards higher-technology

projects, more international firms are likely to be attracted to South Africa due to the potential to work with local labour. South Africa is not presently seen as an attractive research and innovation destination.

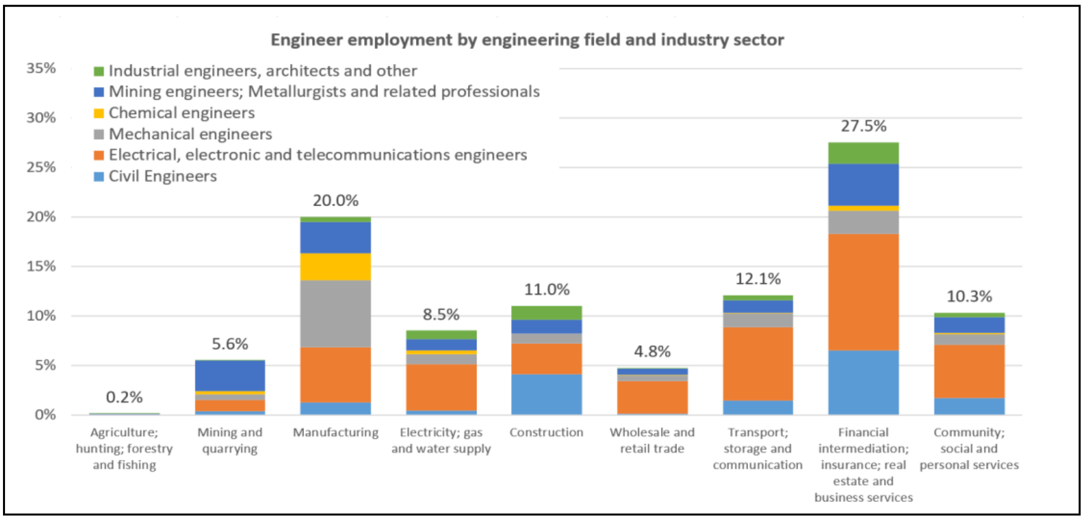

Figure 2: Engineering employment by engineering field and industry sector

Figure 2 shows the industries in which engineers in different fields are employed. The largest groups of engineers are electrical, electronic and telecommunication engineers, followed by civil engineers and mining engineers. The financial sector employs the most engineers, followed by the manufacturing sector.

Industry needs to be educated about the value that engineers with postgraduate training could add, including lateral thinking and advanced problem-solving skills; research, development and innovation skills; and specialised leading-edge skills. They could also stimulate outward-looking innovative industries. Major technology-intensive projects could be used to move industry to a higher level.

International comparison of efficiency and effectiveness of postgraduate engineering training

South Africa was benchmarked against eight comparator countries (Brazil, Russia, India, China, Germany, Republic of Korea, Malaysia and Mexico) on several indicators of efficiency and effectiveness. The findings included:

- Participation: In 2008, only 15% of youth in South Africa were participating in higher education, and this increased to 19% by 2017. This was the lowest participation rate among the comparator countries. The participation rates for the other countries in 2017 were Malaysia 26%, India 27%, Mexico 30%, China 43%, Brazil 51%, Germany 68%, Russia 80% and Korea 93%. China and Brazil doubled the participation rate over the period 2008–2017. China is producing 1155 engineering graduates per year per million population compared with 1968 in Korea, 1114 in Germany, and only 265 in South Africa. Addressing this challenge presents an opportunity.
- Progression: South Africa has a conversion rate of only 14% of bachelor's graduates to master's studies, and 31% conversion rate of master's graduates to doctoral studies, compared with Malaysia's 42% conversion rate from bachelors to master's and 39% from master's to doctoral, for example.
- Completion: In South Africa, the postgraduate completion rate for engineering master's students is 77% and for engineering doctoral students 52%, compared with 86% and 65% respectively in China, 86% and 80% in Mexico, and 82% and 54% in Korea.
- Educational system efficiency: Only 23% of academics in South Africa had a doctoral degree compared with 64% in Russia, 63% in Korea, 35% in Brazil and German, 26% in Malaysia, 23% in China, 12% in Mexico and 9% in India.

Conclusions and recommendations

- South Africa has 14 higher education institutions that offer postgraduate programmes in engineering. The top four produce 78% of both master's and doctoral graduates.
- There is a current shortage of supervisory capacity for postgraduate students in engineering.

- Expensive infrastructure is required for research at postgraduate level.

Recommendation:
1. The creation of new postgraduate engineering programmes is not currently recommended.

Research foci
- There are large numbers of research groups at the various higher education institutions (e.g. 32 at UCT, 29 at UP and 23 at Wits.
- There are very few inter-institutional research initiatives.
- Most of the universities have extensive cooperation with industry.

Recommendations:
2. Inter-institutional collaboration should be strengthened to improve critical mass.
3. Research productivity and critical mass should be evaluated in order to guide future investment from DSI.

Women in engineering
Women make up 21% of master's and 13% of doctoral engineering graduates. There has been a steady increase in female enrolments over time, but the numbers are still low.
Recommendation:
4. The involvement of women in postgraduate engineering programmes should be promoted.

Supervisory capacity
Supervisory capacity is a major constraint. There is a serious shortage of highly qualified engineers.
Recommendations:
5. Ways need to be investigated to make academic careers in engineering disciplines more attractive.
6. The internationalisation of engineering education needs to be increased by relaxing immigration requirements and encouraging international PhDs to stay on in postdoctoral and teaching positions.
7. Urgent steps should be taken to increase the number and proportion of PhD-qualified staff and address demographic challenges.

Partnerships with government and the private sector
Alignment with the needs of partners is promoted. Major industrialisation and supporting programmes could be vehicles for developing major R&D programmes. There is a serious shortage of highly qualified engineers.
Recommendation:
8. Strategies need to be developed for the reindustrialisation of South Africa, with a common vision and cooperation.

Vision for postgraduate engineering
South Africa needs to take a regional and global position on what postgraduate engineering is supposed to achieve, especially the role in increasing industrial participation in high-tech industry. The country needs a well-educated workforce to support the transition and become an attractive destination, since investment follows high-level skills.
Recommendation:
8. Government should take the initiative to develop a vision and implementation plans for postgraduate engineering to position South Africa as a competitive destination.
9. Higher education institutions must support the transition to high-tech industries by offering appropriate postgraduate education.

PANEL DISCUSSION

Scarce qualifications and multidisciplinary qualifications: What difficulties are there, and what should be done to resolve them?

Question: What is the impact of fusion degrees on registration with professional bodies?

Ms Grobler: It has always been difficult to register graduates with a fusion degree, but SACNASP is improving its approach to such qualifications. Graduates with a fusion degree in fields that are both within the natural sciences are registered in either or both of the two fields on a case-by-case basis.

There are still difficulties with those who step outside the natural sciences, and they tend to be registered at a lower level.

Question: How can the registration of professionals be enforced in the science fraternity?

Ms Grobler: SACNASP is working on an MoU with the South African Police Service with a view to enforcing registration, since it is a criminal offence for a practising natural scientist not to be registered.

Prof Lacquet: There might be implications with the Competition Commission of the requirement that one cannot practise as a natural scientist without being registered.

Ms Grobler: An issue for SACNASP to look into is whether the requirement to register in order to practise limits the opportunities of natural scientists, but at the same time SACNASP functions to uphold the law in this regard.

Question: Why are South African engineers less enthusiastic to do a PhD than scientists?

Prof Lacquet: There are a number of jobs available to engineers after completing a bachelors or especially a master's degree. Many engineering graduates are enthusiastic about research but lack the finances to continue to a PhD. One of the challenges is how to retain good students unless bursaries are available. Another factor is that many engineers get married soon after completing their initial degree, and therefore have an additional incentive to start working.

Question: Do difficulties in registering with the with the Engineering Council of South Africa (ECSA) impact on the numbers of certified engineers, and how could the process be improved to ensure more qualified engineers?

Prof Lacquet: The criteria for registration with ECSA are clear and well defined, and candidate engineers have to comply. There are fewer candidate engineers than there might be because it is not obligatory to register if one does not want to, since the Competition Commission rejected ECSA's application for exemption of its rules from the requirements of the commission.

Prof Khathutshelo Nephawe (SACNASP): The draft SACNASP Amendment Bill is before Parliament. The draft bill has been discussed with the Competition Commission, and they do not consider that it contains any anti-competitive behaviour. President Ramaphosa, in his inaugural speech, urged professional bodies to take action against those who are practising without registration. Regulators in South Africa have a clearly defined role to protect the public. A medical doctor, for example, could not practise without being registered with the relevant professional body.

Question: Natural scientists are legally not permitted to practise unless they are registered with SACNASP. What is the level of compliance with the law regarding SACNASP registration among natural scientists working in government departments, science councils and universities? Natural scientists who are contracted to work with government (e.g. those who conduct environmental impact assessments) would be compelled to register. SACNASP has ways of monitoring levels of compliance, as well as mechanisms to encouraging people to comply. Many advertisements for jobs for natural scientists in government stipulate SACNASP registration as a requirement, but other advertisements do not.

Ms Grobler: SACNASP acknowledges that a significant incentive for natural scientists to be registered is when their employer requires them to do so and it impacts on their salary. SACNASP has had discussions with government departments, many of which have incorporated SACNASP registration into the occupation-specific dispensation.

With respect to mechanisms in SACNASP to monitor natural scientists who are not registered, this information often emerges in cases of malpractice. SACNASP can only regulate professionals who are registered. SACNASP points out to employers that requiring registration is part of good governance, and that failure to register could give rise to problems with professional indemnity, insurance pay-outs and demonstrating that the organisation has competent staff.

With respect to the level of compliance, SACNASP does not have a good source of data on the number of natural scientists working in South Africa.

Question: What is SACNASP doing to motivate natural scientists working in government departments to register? Natural scientists who are registered have to pay their annual dues to SACNASP, but they do not see any benefits in return, and there do not seem to be any penalties for those who are not registered.

Ms Grobler: There are many benefits to SACNASP registration, including access to a network of professionals. SACNASP registration is a stamp of approval of one’s competence and a guarantee to one’s customers. SACNASP is considering adding mentors to help young scientists to grow professionally. It is important not to lose sight of the fact that SACNASP is a regulator, and that registered natural science professionals are paying for legal compliance, rather than for a service. The annual SACNASP fees are comparatively lower that for many other professions. Accountants are not required to be registered with their professional body, for example, but many do so for the sake of prestige.

Question: If SACNASP registration is compulsory, why does government not subsidise the annual registration fee?

Ms Grobler: SACNASP is not supported by government but is self-funded through the registration fees. Government provides some funds to SACNASP for projects. The South African government does not have a model of supporting professional bodies; for example, the Health Professions Council of South Africa is funded by the fees paid by medical professionals. If there is a need for a different model for natural scientists, this should be motivated by government.

Prof Khathutshelo Nephawe (SACNASP): The focus of the previous SACNASP Act was on regulation and compliance. In the new draft SACNASP Bill submitted to Parliament, the focus has shifted to creating an enabling environment; for example, scientists who participate in science engagement activities will be awarded CPD points by SACNASP. SACNASP is engaging with all government departments, and natural scientists working in some government departments do not qualify for promotion without SACNASP registration. One of the biggest benefits of SACNASP registration is the CPD programme through which natural scientists can participate in a lifelong learning experience, and continue developing the graduate attributes that will be required in the future. Natural scientists who are registered with SACNASP can demonstrate that they have subscribed to the code of conduct.

Prof Lacquet: The South African Constitution should be the foundation for acting ethically and doing the right thing in one’s profession. Professionals should be registered, but should not be forced to do so.

Question: There is a shortage of PhDs in engineering, and South Africa is trying to positioning itself as an attractive destination for international students and staff and reversing the outflow of talent from the country. Yet international students who graduate from a South African university have to return to their country of origin on completion of their studies. This seems to be a contradiction.

Prof Lacquet: We need political guidance in order to change the approach to international students and staff. The more people with different backgrounds and perspectives that are involved, the better the solutions that can be developed. South Africa cannot afford to be inward-looking but needs to position itself in relation to Africa and the rest of the world. We need to attract talent from elsewhere to work in South Africa and help to grow the economy.

Question: In 2019, the chairman of the Portfolio Committee on Higher Education and Training made a pronouncement about introducing a quota for foreign students and staff at South African universities, which many vice-chancellors opposed. What is the view of this proposal from the perspective of engineering at higher education institutions?

Prof Lacquet: Some people believe that there are too many international students and staff at South African universities, but South Africa is in transition and it takes a while for the system to reach a new state of equilibrium. It is not true that foreign academics and students are taking away anything that is due to South Africans; instead they are making significant positive inputs. We need everyone to help build the country, including bringing in role models from abroad who are passionate lecturers and researchers. We should rather fix what is wrong than try to limit participation.

Question: What can South Africa to do to position the country as an attractive destination for international students and staff and reverse the outflow of talent from the country given the challenges, which include the lack of supervisory capacity, adequate funding and expensive infrastructure.

Prof Lacquet: Universities are involved in various initiatives to address the lack of supervisory capacity. The New Generation of Academics Programme (nGAP), for example, is a programme of the Department of Higher Education and Training to recruit capable scholars as new academics. We do not always need the most expensive equipment to achieve research objectives. South Africans are very creative and generally able to use their ingenuity. People tend to be more creative if there is a deficit in what they require. One of the ways of addressing the supervision capacity is to start supervising students in groups with similar interests. Another benefit of such an approach is the enrichment that comes from interaction within the group. In order to address the challenges, everyone needs to contribute as and how they can.

Ms Niehaus: An important reason why scientists should register with SACNASP is to address the current huge scepticism about science and scientists and the misinformation that is circulated without any form of approval. Since the basis for scientific research is integrity, it should make a difference with respect to the credibility of information when a scientist speaks.

Prof Lacquet: It would be better for people to be more aware of the South African Constitution and committed to living up to it than to try to police them to do the right thing.

Question: There seems to be convergence in the work of scientists and engineers in many of the fields that are becoming important, such as big data, water and nanotechnology. Does it make sense to have two separate professional bodies for the registration of scientists and engineering if the purpose is to protect the general public, or should we consider more generic professional registration for science, engineering and technology, which might help to address multidisciplinary issues?

Prof Lacquet: Engineers and scientists do different kinds of work, with different ways of approaching a problem. Engineering qualifications are accredited by ECSA based on specific outcomes, which are different from qualifications in the natural sciences. There are many overlaps between careers in science and engineering, such as lifelong learning, the need to focus on ethics, and the need for an understanding of the sociology related to one’s discipline, but I do not believe that we are ready for a single registration body for scientists and engineers, even though they may often work in the same space. Many nurses perform similar work to scientists in certain fields, but we would not consider a single registration body for these two groups of professionals. Depending on the type of work in which engineers are engaged, they may have more than one professional registration, since the South African Council for the Project and Construction Management Professions (SACPCMP) insisted that engineers involved in project work must register as project managers. A variety of professional bodies are being formed and trying to find ways of regulating professions within their sphere. It is too early to consider amalgamating the professional bodies for engineering and science.

Question: Given the reasons provided for the necessity of professional registration and regulation of natural scientists, would it make sense to regulate social scientists as well?

Prof Lacquet: Many social scientists are already regulated within their own professions, for example, journalists, social workers or psychologists.

Question: Perhaps the DSI should limit its funding to science practitioners who are not registered with SACNASP, and ultimately not grant non-registered scientists any funding, in order to encourage registration.

Ms Grobler: This is a suggestion that SACNASP could consider.

TRIPLE HELIX

What does a systems approach tell us about Triple Helix collaboration? – Mr Bernd Oellerman, Director: Regional Industrial Development, Department of Trade and Industry

Everywhere one goes, there is reference to a system, complexity, networks, multidisciplinary approaches, collaboration and so on, all of which are characteristic of what a system is as described by systems theory. Examples of systems include:
- Biology and physiology: nervous system, digestive system, immune system
- Ecology: ecosystem
- Astronomy: solar system
- Transport: transport system, brake system
- Education: school system
- Society: heating system, metric system, public address system, sound system.

The term 'system' is often used without much understanding of what it actually means. There are various definitions of a system. The following definition covers the key aspects of what constitutes a system: 'A group or combination of interrelated, interdependent, or interacting elements or components forming a collective and complex whole, that share a common purpose and which work together in a certain way.'

Systems theory is based on the development of General System Theory by Karl Ludwig von Bertalanffy in the 1930s, but insights and understanding of systems existed much earlier, as evident from the study of the solar system by Galileo and Kepler, the development of counterpoint and harmony in music, and the building of highways and aqueducts by the Roman civilisation.

Systems theory is based on concepts that the whole is more than the sum of its parts, that systems relate to the whole and the parts and their relationships, and that systems can be open or closed. One of the areas of application of systems theory is in management and organisational development, where learning, knowledge, relationships, networks, adaptation and complexity become important. Because management and organisations are central to the topic of innovation and industrialisation, my research involved a literature study on prior research where systems theory overlaps with management sciences.

The application of a systems approach to organisations involves some of the following aspects:
- The function of the system and its interrelated components is more important than structure.
- Understanding is more important than knowledge.
- A systems approach requires explaining rather than describing the different parts.
- A systems approach involves looking out of instead of looking into.

The Triple Helix (TH) model was established by Henry Etzkowitz and Loet Leydesdorff about 30 years ago. It describes the dynamics of the relationships between three core groups, namely government (public sector), industry and academia (e.g. universities). A fourth helix has been posited, comprising civil society, the media and culture-based community, or a societal helix of innovation users. A fifth helix was also added related to the environment and an ecological approach.

Much has been written about the Triple Helix, and it has been applied among others to:
- Industry, academia, government, civil society and the environment
- Relationship and stakeholder management
- Collaboration and networks
- Actors and intermediaries
- Self-organisation
- Cross-pollination of roles and functions.

It was discovered early in General System Theory that a system that does not allow continuous feedback and adjustment will die.

A system approach has four core elements that apply to collaboration:

Components and elements, which could include institutional frameworks, companies, government departments, associations and business chambers, academic and research, development and innovation (RDI) institutions, unions, non-governmental organisations (NGOs) and community-based organisations (CBOs). By applying a systems approach, it has become clear that institutional frameworks and the setting up of institutions are generally well addressed.

Collective complex whole, which could include RDI institutions, industry or government, labour, community and others. South Africa aspires towards being a collective and complex whole, but there are a number of challenges preventing this, some of which are not recognised, including tensions between big business and small and medium enterprises; national, provincial and local government; government and industry; industry and labour; community, government and industry. A collective and complex whole is clearly evident in terms of complexity, but the collectiveness is not as strong as expected in terms of inclusivity.

Interaction and relationships, where significant limitations and insufficient efforts were found within the system as well as outside the system. This is ironic as human beings are by definition made to communicate, and exist in relationships of all kinds to their environment and to others. Yet, it may seem that we prefer to focus on our differences, own agendas and selfish ambitions instead of working together and allowing space for others to engage with us in a positive manner. These interactions and relationships are established at many levels based on the function or roles of people, their organisations and the systems within which they find themselves, including RDI; education and training; funding and finance; policy and regulation; production; marketing and other functions; logistics, procurement, trade; management; total quality management (TQM) and other processes.

Shared or common purpose, where provisional evidence of significant constraints was found. Various components or elements often purport to share a common purpose, but the actions of most actors within the various systems seem to indicate the opposite. This is clear from the plethora of media statements, articles and other literature in which the need for partnerships, coordination and collaboration are articulated and where distrust and different agendas are blamed for lack of working together.

Areas that lack a common purpose include education, learning, knowledge, economic benefit, policy, politics, growth, development and employment. Intermediaries are required to pull the various components and elements together. Given the complexity of the technological developments anticipated in the coming decades, we will need many more people who can act at the interfaces.

When the definition of systems theory is applied to collaboration, the shortcomings in collaboration start to become evident; for example, researchers excel at research but are not expected to understand how government operates. Intermediaries are needed to draw the various parties together at an interface that translates the research or technology to others in the collaborative ecosystem in government or industry. Government views life and the world through a certain lens, taking into consideration policies and relationships from its perspective. Collaborative systems often do not work because we fail to recognise that we are not doing well in translating in a way that each of the components understands, and hence not achieving a shared purpose. Collaboration collapses due to lack of a common purpose. We could all agree that the common purpose should be innovation, but we have not shared our outlook on innovation with others. We need to spend more time aligning and understanding each other, which requires talking and listening to other people. We are part of a greater system.

To add to the complexity and difficulties faced in dealing with the system, there are multiple levels or angles from which to view this, but it is important to recognise the various levels at which a systems approach can be applied, including sectors, groups, associations, entities; departments, divisions, units; and even individuals who influence one another.

The primary gaps identified in systems are to have a shared or common purpose, as well as interactions and relationships. A system functions best when the four core elements intersect and overlap (Figure 3). If the core elements are separate, it means that we do not understand the importance of each of them and therefore cannot address them. Analysing each of the core elements of a system that is not functioning properly should reveal where the problems lie.

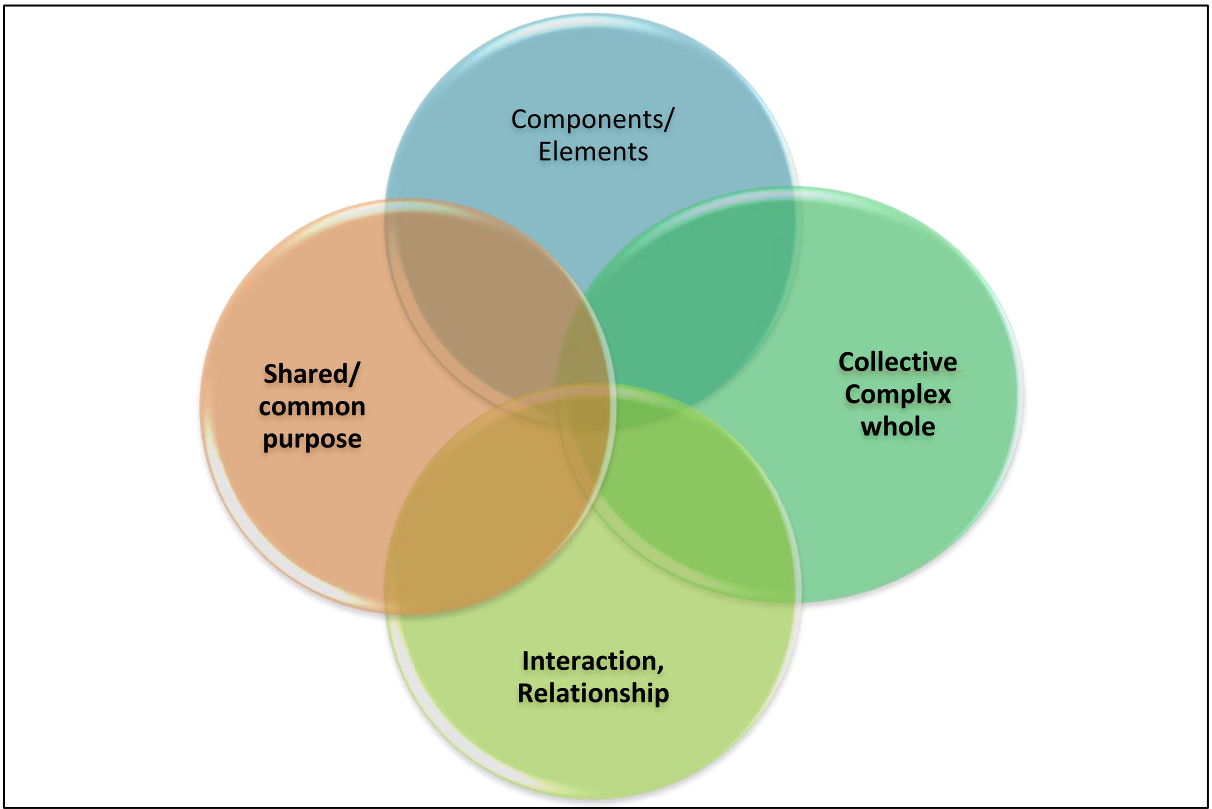

Figure 3: A systems approach

For collaboration to succeed, there must be the intention and willingness to work together. The inevitable question is: 'Were we not made for a time such as this, to break down silos and cross boundaries?' We have been born at this time because we have something to contribute to the system. Collaboration will improve if we take this kind of approach. We are at a juncture in the history of the world where we have to work together now more than ever. If someone wanted to mine gold or diamonds in South Africa at the end of the 19th century, no environmental impact assessment was needed, and very little thought was given to the impact of mining on people or the environment. Yet, the impact was no less than it is today. Rather, our thinking and paradigms had not developed to such a level where the importance of a systems approach was recognised and understood. More than a century later, it is almost impossible to address a problem without taking into consideration at least a number of other stakeholders or elements that may be affected. Examples of this include building a bridge or a road, developing a syllabus, planning a new mine or establishing a new business. No individual person can avoid affecting other people in everything that they do, since everyone forms part of a system. One can only become optimally effective, as we were designed to be, by engaging and interacting with that system. One cannot believe or assume that one functions on one's own in the world.

The United Nations Economic Commission for Africa (UNECA) endorses and encourages collaboration, observing:

> Economies that have industrialised have at their core – regardless of policies – institutions and processes to promote strategic collaboration between the private sector and the government…Successful industrial policy requires close government–private sector collaboration that ensures its relevance and effectiveness…More successful countries understand, however, the need for systematic coordination and regularly co-opt the private sector and encourage super-ministerial collaboration (UNECA, 2014)

The Department of Trade and Industry (the dti) has various initiatives to support collaboration between academics, researchers, scientists, technologists, innovators and others in the system. The dti's Industrial Parks programme intends to achieve a number of aims in support of collaboration, including:

Research, development and innovation (RDI): One of the key success factors for industrialisation and industrial parks internationally is an intentional activity by government and the other players in the Triple Helix to foster collaboration between the RDI community and industry. South Africa has not performed well in this regard, but there are improvements and the dti is doing much to foster collaboration.

A useful example of the way in which industry can benefit from RDI collaboration comes from Italy, which used to be a world leader in textiles three decades ago before competition from China rapidly destroyed the Italian markets. The textile industry in Italy was characterised by a number of small companies that were often family-run. In the face of the Chinese competition, many of these companies went bankrupt. Italy analysed the situation and concluded that one of the features of their industry was that different family members might work for different competitor companies. They concluded that if they were to collaborate and conduct basic research that could benefit the whole industry, the Italian textile industry could become competitive again and regain their market share. The Italian government started to initiate programmes. It took 15 to 20 years to recover their market share, and Italy is again a forerunner in the international textile industry.

Skills development: Academics need to participate in skills development for business and industry. It cannot be assumed that business will know exactly which skills it needs. Academics and business need to collaborate to address this. There are complaints that universities are not producing graduates that industry can use. This kind of disjuncture results from making assumptions about what industry requires instead of sitting down, talking to them and working together to invest in skills development.

Capacity building: Industry and academics have different perspectives. It is important to understand these different perspectives in order to work together. Intermediaries are required in order to translate the needs in light of what is available, and to help the various parties to work together to address capacity building. Industry needs capacity in the form of people who are able to do the job and want to work.

Continuous improvement: Any institution needs continuous improvement in order to become and remain successful.

Digital Hubs, shared services and facilities: The Digital Hubs are a Presidential programme with the aim of establishing 100 such hubs across South Africa. The initiative is driven by the Department of Small Business and several other players, and resides within the Presidency. The dti contributes to the initiative as far as it relates to the Industrial Parks. In the Digital Hub shared facilities within an Industrial Park, the dti would like to provide an opportunity for people with academic and R&D capacity to offer their services to companies. This would be a mechanism to foster the building of relationships, provide additional revenue for academic research, and make industry more competitive.

Other initiatives of the dti include:

Innovation and Commercialisation Unit, which works closely with the DSI. Incentives to support innovation are being investigated, especially in the so-called 'last mile'. There are various sources of support (including the DSI and the Technology Innovation Agency) for development up to the prototype stage, but support for commercialisation tends to be lacking. This is an area that the dti is starting to address and would like to involve academics to a greater extent.

Industrial Sector Master Plans, which are being developed by considering what needs to be done to support each identified industrial sector in the country in order to make and keep it competitive and to guard against and respond to job loss due to Fourth Industrial Revolution (4IR) interventions. This initiative requires academic research.

Curriculum design and re-skilling is another area to which academics are invited to contribute from a collaborative systems perspective and to work with other parties to develop solutions.

Flexibility and adaptability, which people tend to be scared of because they think it will mean that they might have to let go of what is precious to them, but this is not the case. If you focus too much on trying to please other people, you might never discover your own purpose. Once you know who you are, it is much easier to be flexible. Identity is crucial.

Public–private partnerships: Everyone has value to add and should take the initiative to do so. Building a society requires everyone's contribution.

National System of Innovation and transformative innovation policy: This is being driven by the dti and is another area in which academics could become involved.

Sometimes it requires a catharsis, or a Rubicon to cross, before you know who you are. As R. Buckminster Fuller said, 'There is nothing in a caterpillar that tells you it will be a butterfly.'

The international Triple Helix Association: who we are – Ms Maria Laura Fornaci, Executive Director, Triple Helix Association

The Triple Helix Association (THA) is a not-for-profit, non-governmental association with scientific purpose and a global reach. It originated with an informal movement built around a series of international workshops and was established as a legal entity in 2009 by leading international scholars in innovation and entrepreneurship to promote the study of the interactions among academia, industry and government through the Triple Helix open access journal. Some of the milestones in the history of the THA include:

- In 1996, the first Triple Helix Workshop was held in Amsterdam, which marked the start of the Triple Helix movement, launched by Prof Henry Etzkowitz and Prof Loet Leydesdorff.
- In 2009, the Triple Helix Association (THA) was established in Turin, Italy, with its headquarters at Fondazione Rosselli, chaired by Prof Henry Etzkowitz with Prof Loet Leydesdorff and Prof José Manoel Carvalho de Mello as vice-presidents.
- In 2014, the association was professionalised and the organisational structure was developed with five operational committees. The association developed its new vision and mission, value proposition, business model and extended portfolio of services, and multi-stakeholder governance, growing to 120 members and 3000 readers in seven THA chapters (Brazil, Peru, Russia, South Asia, Kazakhstan, Greece, Germany), with more expected to join.

The THA aims to advance scientific knowledge and operational capacity to ignite and manage university–industry–government interactions (Triple Helix) to foster research, innovation, entrepreneurship and regional sustainable development. The THA's positive and effective interaction models and mechanisms between governmental institutions, academia and industry could have a dramatic impact on the innovativeness of firms, cities, regions and countries. The model involves offering solid scientific knowledge based on theoretical models and good practice, combined with an international reach for dissemination, promotion, peer learning and partnership development.

THA activities for knowledge generation and co-design include:

- **Promoting research, debate and knowledge sharing at international level on the Triple Helix theory and practices:** The activities include the TH Conference and Summit series. The Triple Helix international conference was held in South Africa in 2019. The next conference will be held in Tampere, Florida in June 2020 on the topic of 'The future of innovation and innovation for the future'. The TH Summit 2020 is scheduled for November 2020 in Bologna, Italy on the topic of 'Designing globally connected innovative regions'.
- **Stimulating new knowledge generation and codification:** THA has seven special interest groups, awards, an online repository and publicly funded projects.
- **Facilitating networking and cooperation among the Triple Helix actors at international and local levels,** through an online members' gallery, TH post, TH talks and onsite TH chapters.
- **Supporting the translation of academic models into practical achievements** through THA special events, webinar series, the TH Academy for Chapters and publicly funded projects.

THA activities for dissemination and awareness raising include fostering wide dissemination of scientific findings and practical results. This is done through the TH Journal, Helice Magazine and TH best practice series.

The motivation in favour of establishing a TH Chapter in South Africa include:

- International exposure and national recognition
- Getting access to the latest TH studies and cases

- Opportunities for international networking and cross-fertilisation with other innovation ecosystems through the exchange of scholars, web events and study visits
- Opportunity to participate in the capacity building programme to prepare the staff of the Chapter and local Triple Helix actors to work together to build their local innovation ecosystems via the Triple Helix model.

Measuring innovation ecosystem dynamics and the Triple Helix – Prof Emanuela Todeva, Professor of International Business Strategy and Innovation, St Mary's University (by Skype from the UK)

Researchers are the most precious commodity in society, and we would like to see them in high positions as decision-makers and orchestrators of our economic development. Over the years, I have built competence in managing multi-stakeholder correlations and business clusters.

The Triple Helix Association is addressing the challenges of ecosystem dynamics. There is a strong drive for partnerships and collaboration, but very often these collaborations are sought in dynamic relationships. Multi-stakeholder relationships are much more difficult to manage.

The Triple Helix model is a three-dimensional spiral comprising government, industry and knowledge-producing institutions. The human body, which is very complex, is constituted by the double helix. The level of complexity increases enormously when there are three entangled spirals. Our understanding of the Triple Helix is still evolving. I would like to introduce the current state of knowledge of the Triple Helix model and ecosystem dynamics. The implementation of this model in South Africa could be explored in the discussion session. I would also like to highlight a workshop that I organised at St Mary's University on 'Innovative place-based Triple Helix properties: regional developments with smart specialisation strategies'.

The Triple Helix model is often described as three overlapping circles constituting actors that are trying to understand the knowledge of the other circles and to reach out to them. University professors are trying to advise government, or they are working on collaborative or contract research for industry. Businesses are reaching out to university researchers for new products and services. Businesses and government are working together to support small entrepreneurial firms. Small areas of overlap start to emerge (Figure 4a) because of the efforts of the actors in government, industry and universities to reach out to one another. However, there is still a gap in the middle between the three circles, which is known as negative overlap due to gaps in communication, understanding, consensus and working together. As relationships improve, positive overlap grows between the three circles (depicted as the black area in the middle of Figure 4b), when all three stakeholders have established consensus and a common agenda, and share objectives, concepts, knowledge and frameworks. The Triple Helix does not relate only to innovation policy, but involves consensus, dialogue and joint decisions. Ultimately, the aim of the Triple Helix model and the activation of actors is to create behaviour in each of the helices to compromise and try to reach consensus. These complex relationships require very sophisticated orchestration.

The Triple Helix is a complex model. The three spheres of university, industry and government are very far apart (Figures 4a and 4b). Within the government, which is developing policies and exercising political leadership, the dominant process is a political one. Actors within the government sphere are driven by their roles in this political process. Industry is subjected to serious global competition, and the market process drives the decisions and choices of industry players. Industry holds resources and capabilities, which it has to channel. In addition to working for competition, industry engages the political and innovation processes. University researchers are motivated by the innovation process to publish articles and conduct academic research, and there are few incentives to reach out to industry and government. The forces that act to pull the Triple Helix apart are still very strong. Personal motivation is required to overcome the forces of separation.

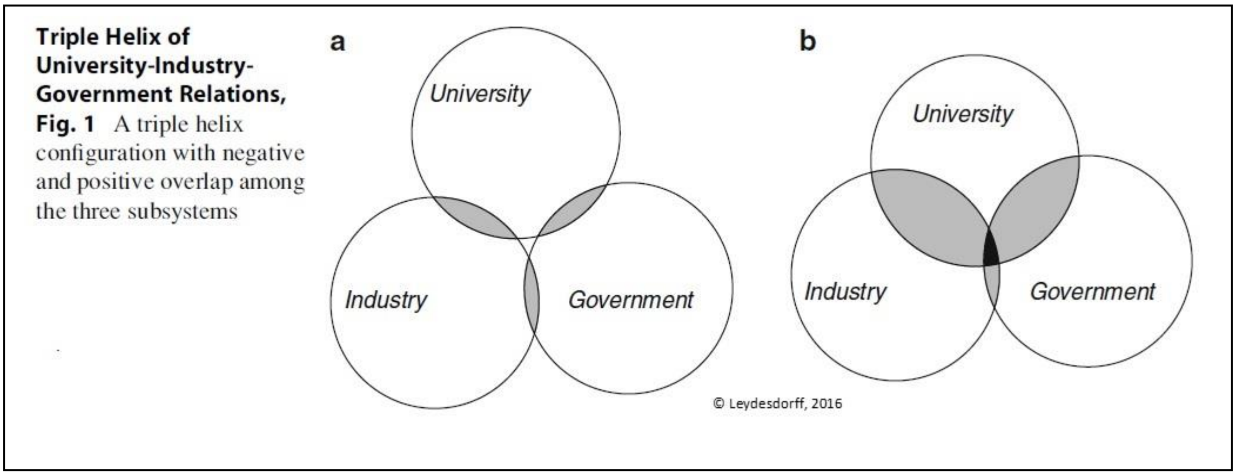

Figure 4a and 4b: Triple Helix university–industry–government relations

The main challenges facing Europe have been identified as:
- Future fitting the economy
- Industry 4.0
- Creating new jobs
- Economic growth
- Increasing GDP
- Value creation from new economic areas
- Developing more entrepreneurs
- Energy transformation
- Creating new high-tech companies
- Building entirely new industries
- Shifting local economic activities into the knowledge-driven economy
- More spin-outs from universities
- Digitalising local industries
- Improving industry collaboration
- A lack of unicorns (in the venture capital industry, a unicorn refers to any tech start-up company that reaches a US$1-billion-dollar market value as determined by private or public investment).

These challenges face not only the European Union but countries around the world. The agenda for stakeholders is to overcome these challenges. Ultimately, the purpose of the triple helixes is not just to understand one another, but to address these challenges in the complex ecosystem. The Triple Helix movement embraces these challenges and the Sustainable Development Goals, and searches for complex solutions to complex problems by using knowledge and capacity through multi-stakeholder coalitions to address the global challenges.

With respect to the definitions of open innovation ecosystems:
- An ecosystem is a constellation of diverse actors, coalescing around a particular challenge and collaborating to deliver a complex solution. Competitive forces are obstructions to healthy ecosystems. If the actors in an ecosystem adopt a selfish agenda for profit-maximisation rather than optimisation of benefits, it is not possible to create healthy ecosystems.
- The components of an ecosystem are talent (labour), capital, innovators, clusters, creative hubs, science and technology research parks, infrastructure, accelerators, connectors, facilitators, promoters and influencers who shape opinions, consensus-building, compromise, coalition building and optimisation within the system.
- Coordination, facilitation and orchestration are critical for managing complex ecosystem dynamics.

Figure 5 shows the first layer of an ecosystem as comprising the stakeholders and their associated roles. The second layer is made up of coordination and strategic co-alignment to address the overarching challenges and goals of the ecosystem. The Triple Helix provides a platform to go beyond individual interests and incentives and to search for consensus over the definitions of the challenges and the formulation of goals and objectives. The third layer recognises the legacies and opportunities that shape the ecosystem. It is recognised in the literature that every ecosystem is path-dependent, which means that it depends on its history and foundations. Building new foundations for a new industry or new regional growth is very important, but it is also important to transform existing regions and communities that are dependent on their past history. The three layers are interconnected. The actors emerge from the past and have to envision the future. The actors are thus the connecting element between the past and the future, and have to engage in strategic co-alignment. Ecosystem actors are those visionaries that can see beyond themselves and their roles within government, industry and academia, and who can lead the ecosystem towards consensus and strategic co-alignment.

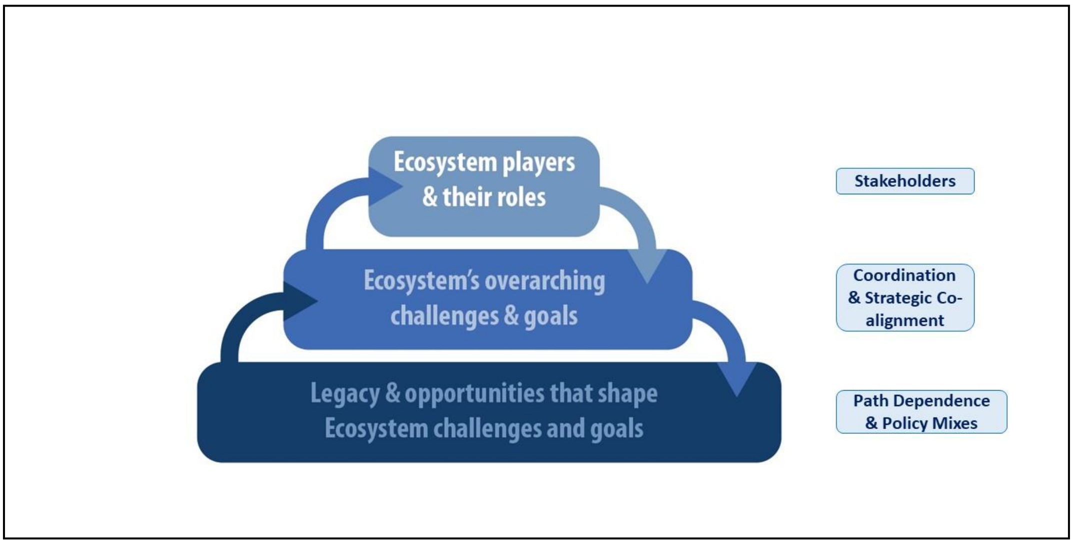

Figure 5: Ecosystem Functions and the Triple Helix

Figure 6 shows the Triple Helix and the way in which it can be activated, which requires finances as well as entrepreneurial discovery and development. The simple model of the Triple Helix does not show the main factors of production, namely labour, capital, the policy and legal framework, entrepreneurship and knowledge, as well as land, technology and market access. The pink squares in the figure are the drivers of ecosystem dynamics.

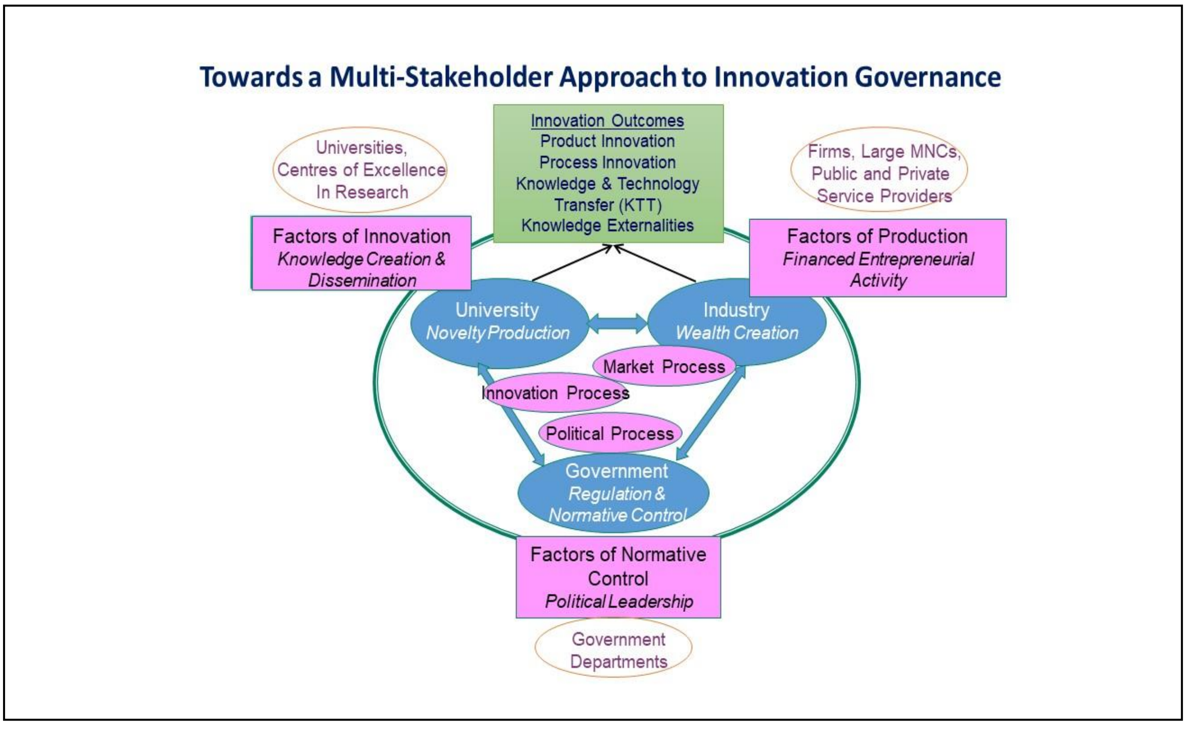

Figure 6: Towards a multi-stakeholder approach to innovation governance

People are committed to developing the land or a territory. New technologies are constantly evolving and can revolutionise the global economy and our understanding of it. Technologies are an essential part of the solutions, but they are only one component. We cannot expect technology-driven solutions unless the human actors have reached consensus. This is one of the lessons of the work on the Triple Helix. Market demand is critical. Without the circulation of knowledge, labour and capital, it is difficult for the Triple Helix to function.

A South African Triple Helix Chapter: proposal – Ms Jansie Niehaus, Executive Director, NSTF

The Triple Helix is not only a model but an academic discipline, primarily in the social sciences but not limited to that sphere. Academics in this field study the dynamics among Triple Helix players. In South Africa, we would refer to such research as innovation studies. South Africans who are studying the science system or the National System of Innovation might be regarded as Triple Helix researchers. Ms Niehaus posed the question whether the Triple Helix model is useful for studying innovation.

The South African White Paper on Science, Technology and Innovation was launched in 2019 as government policy to replace the Science and Technology White Paper of 1996. The new White Paper establishes innovation as a priority for the South African government. This is emphasised by the fact that the Department of Science and Technology has been renamed as the Department of Science and Innovation.

The role of a Chapter of the Triple Helix Association would include participating in a capacity building programme for the local innovation ecosystem. Another focus would be to look at specific regions including cities, special economic zones and industrial parks, and to get researchers involved in working to enhance them.

A Triple Helix Chapter has to be established through an existing organisation such as the NSTF, which would serve the role of the local interface with the THA, and a centre of THA debate in South Africa and development of local interactions with and among TH actors.

The THA has both individual and organisational members. There are many organisational members across the world, both inside and outside countries where a THA Chapter exists (i.e. Brazil, Peru, Russia, South Asia, Kazakhstan, Greece, Germany). South Africa does not necessarily need to establish a chapter in order to be involved with the THA. For example, the 2019 Triple Helix international conference was held in South Africa.

The THA consists mainly of academics studying the dynamics of triple or quadruple helix relationships. In South Africa, studies of innovation usually involve players in the triple or quadruple helix. The question is whether to establish an official THA Chapter as a ‘community of practice’ for those that study innovation or the TH players. This would need wide consultation to involve as many players as possible.

The NSTF already exists to represent all stakeholders, including researchers, industry/business and government and thus represents the Triple Helix in relation to science, engineering, technology and innovation in various sectors. The NSTF includes civil society, making it a quadruple helix organisation. The NSTF has more member organisations from the private sector than from the public sector.

The vision of the NSTF is a transformed country where science, engineering and technology (SET) and innovation contribute to a high quality of life for all who live in South Africa, where the profile of SET professionals is representative of the profile of the general population, and where the education system is effective, particularly in terms of performance in SET subjects and promoting innovation.

The NSTF plays a niche coordinating and unifying role, making it easier to get an overview and navigate the National System of Innovation, which comprises the small but complex SET community with many role players. NSTF activities are inclusive and collaborative, reflecting openness, independence and collaborative energy. The NSTF has a wide network involving a variety of role players, and communicates with over 10,000 people.

The question is whether South Africa needs a chapter of the Triple Helix Association and whether it would benefit the country. If so, should the NSTF as an intermediary use its platforms and network of contacts to establish a chapter of the THA and coordinate the activities related to the THA?

Discussion

Ms Niehaus posed the question of whether the Triple Helix was a good model for South Africa, whether it had any limitations, and whether there were any alternatives that would be more suitable for South Africa's National System of Innovation.

Comment: The Triple Helix approach is not new to South Africa; the NSTF is already using a similar model in working with the business, education, government and civil society sectors. The roadmap for RDI in South Africa already speaks to the principles of the Triple Helix. A specific example of the sectors working together is the professorial chairs with objectives that support government initiatives. The stakeholder participation models used in South Africa already function according to the quadruple helix.

Debbie Schultz: It seems that the Triple Helix model would address the nature of collaboration rather than the structures. National and international development goals require collaboration, but models for collaboration have not been altogether successful. The Triple Helix does not seem to claim to have solved this issue, but building pathways and potential mechanisms to make collaboration happen is extremely useful at every level.

Jansie Niehaus: The issue of people working in silos, not sharing their knowledge and not wanting to work together is raised at every Discussion Forum. The issue is what to do about this.

If we accept the Triple Helix as a useful model, where should a chapter of the Triple Helix Association be based? It need not be located at the NSTF but could reside within a university or research institution. The THA requires that a chapter be lodged within an existing institution.

Comment: The elements of the Triple Helix already exist in South Africa, but the challenge is how to enable them. The dti presentation spoke about gaps in the system. There are gaps that can be addressed in order to formalise the Triple Helix model and ensure buy-in for implementing it to avoid people working in silos. The DSI is doing a lot in this regard and forming partnerships, for example, with the Water Research Commission. Perhaps we need a national dialogue to identify where the gaps lie and what can be done to address them.

Debbie Schultz: The CSIR did an analysis of collaboration related to achieving the SDGs. It might not be wise to place Triple Helix collaboration under the government umbrella to avoid the initiative becoming caught up in political issues. The NSTF might be a suitable home for a South African chapter of the THA, given its links to researchers who are trying to collaborate more effectively.

Comment: I agree with that suggestion. There is some collaboration among government departments, but the focus is on agreements and high-level talks, and the information does not filter down to practitioners. We need the involvement of people on the ground who will implement what has been discussed at collaborative inter-governmental meetings.

Comment: Young scientists are discouraged by the lack of job opportunities after master's level. They are generally directed either towards sales or remaining in academia. There ought to be more information available about opportunities in industry. There is perhaps a need for coordination to make information about potential careers for postgraduates more readily available.

Ms Niehaus: Information is available on the internet, but it is scattered in different websites and difficult for students to find. There might be a need to coordinate this kind of information and make it available.

Comment: Collaboration needs a shared purpose. Incentives for collaboration would facilitate breaking down silos; for example, if there were an incentive for government agencies to work with researchers, it would be possible for postgraduate students to work on translational research that would advance what government agencies are doing. The Triple Helix model, whether managed by the NSTF or another suitable organisation, could perhaps incentivise the breaking down of silos between sectors.

Ms Niehaus: It is worth investigating what can be done.

Comment: The Triple Helix seems to be a good model to inspire collaboration and innovation. The discussions on the Triple Helix should be extended to involve industry and government beyond the academic circle.

Ms Niehaus: The Triple Helix international conference was very academic, apart from invited speakers from industry and business. It would be a challenge to get industry and business interested and involved in this kind of collaboration. The NSTF will develop a model of how a THA Chapter could work and how key stakeholders in the system could be consulted.

APPENDIX 1: LIST OF ACRONYMS

3D	Three-dimensional
4IR	Fourth Industrial Revolution
AI	Artificial intelligence
ARC	Agricultural Research Council
ASSAf	Academy of Science of South Africa
BRICS	Brazil, Russia, India, China and South Africa (an association of five major emerging national economies)
BSc	Bachelor of Science
BWIS	Black Women in Science
CEO	Chief executive officer
CPD	Continuing professional development
CREST	Centre for Research on Evaluation, Science and Technology
CSIR	Council for Scientific and Industrial Research
DHET	Department of Higher Education and Training
DSI	Department of Science and Innovation
dti	Department of Trade and Industry
DVC	Deputy Vice Chancellor
ECSA	Engineering Council of South Africa
EU	European Union
GDP	Gross domestic product
GDPR	General Data Protection Regulation
GERD	Gross domestic expenditure on R&D
HIV	Human immunodeficiency virus
IP	Intellectual property
ISFAP	Ikusasa Student Financial Aid Programme
IT	Information technology
MBA	Master of Business Administration
MEC	Member of the Executive Council
MoU	Memorandum of understanding
NASA	US National Aeronautics and Space Administration
NRF	National Research Foundation
NSFAS	National Student Financial Aid Scheme
NSI	National system of innovation
NSTF	National Science and Technology Forum
NWU	North-West University
PEETS	Process, Energy and Environment Technology Station, University of Johannesburg
PhD	Doctor of Philosophy
Pr. Eng.	Professional Engineer
Pr. Sci. Nat.	Professional Natural Scientist
PV	Photovoltaic
R&D	Research and development
RDI	Research, development and administration
S&T	Science and technology
SACNASP	South African Council for Natural Scientific Professions
SADC	Southern African Development Community
SAMRC	South African Medical Research Council
SANBI	South African National Biodiversity Institute
SANSA	South African National Space Agency
SET	Science, engineering and technology
SKA	Square Kilometre Array
SME	Small or medium enterprise
SMME	Small, medium or micro enterprise
STEM	Science, technology, engineering and mathematics
STI	Science, technology and innovation
TH	Triple Helix
THA	Triple Helix Association
TIA	Technology Innovation Agency
TTO	Technology transfer office

TUT	Tshwane University of Technology
UJ	University of Johannesburg
UNECA	United Nations Economic Commission for Africa
UP	University of Pretoria
US/ USA	United States of America
VC	Vice Chancellor

APPENDIX 2: LIST OF PARTICIPANTS

Name	Institution
Mr Thabiso Mudau	Agricultural Research Council (ARC)
Dr Linda Fick	Academy of Science of South Africa (ASSAf)
Dr Tebogo Mobotha	ASSAf
Dr Thabang Mokgethi-Morule	Bind Biotech
Ms Ndoni Mchunu	Black Women in Science (BWIS)
Ms Dineo Liuma	CapeBio
Ms Mpho Nkosi	Council for Scientific and Industrial Research (CSIR)
Dr Andrew Smith	CSIR
Ms Pinda Sifunda	CSIR
Dr Mandla Khumalo	CSIR
Mr Julius J Komba	CSIR
Ms Patience Mphumbude	Department of Agriculture, Forestry and Fisheries (DAFF)
Mr Mathala Mokwele	DAFF
Ms Precious Kgomotso Mokgope	Department of Agriculture and Rural Development
Mr Moses Rampele	Department of Military Veterans
Mr Whinsky Alkema	DNAbiotec
Mr PG Erasmus	DNAbiotec
Dr Antonel Olckers	DNAbiotec
Mr Héctor Galván Susaña	Dominican Embassy (Ambassador)
Mr Mmboneni Muofhe	Department of Science and Innovation
Mr Bernd Oellerman	Department of Trade and Industry
Ms Sanari Malele	Limpopo Department of Agriculture and Rural development
Mr Teddy Mnisi	Limpopo Department of Agriculture and Rural Development
Mr Kgwadi Quintin Molepo	Mokumong Foundation
Ms Tebogo Sole	South African Medical Research Council (SAMRC)
Ms Fungai Mapumba	SAMRC
Ms Phindile Ngobese	SAMRC
Ms Zama Mzobe	SAMRC
Ms Sikhethiwe Masuku	SAMRC
Mr Gudani Mukoma	SAMRC/Wits Developmental Pathways to Health Research Unit
Dr Tebello Mahamo	National University of Lesotho
Dr Maretha Fourie	South African Nuclear Energy Corporation (Necsa)
Ms Rebaone Mokate	Necsa
Ms Nkateko Makaringe	Necsa
Mr Litha Yapi	Necsa
Dr Mpho Lekgoathi	Necsa
Dr Mbulelo Ncango	National Research Foundation (NRF)
Ms Busisiwe Sibiya	NRF
Ms Kgaogelo Molepo	NRF
Prof Elvis Fosso-Kankeu	North-West University (NWU)
Mr Tom Mosiane	NWU
Dr Angwe Lekunze	NWU
Mr Takudzwa Wakasemwa	Pearson High Institute of Technology
Dr Esper Jacobeth Ncube	Rand Water
Ms Emma Makozho	South African Chemical Institute (SACI)
Dr Gerda Botha	South African Council for Natural Scientific Professions (SACNASP)
Ms Sarah van Aardt	SACNASP
Prof Khathutshelo Nephawe	SACNASP
Ms Jessica Grobler	SACNASP
Dr Duduzile Molefe-Khamanga	SADU Scientific Analysis and Research Consultant
Mr Kabelo Rapholo	South African Institute of Industrial Engineers (SAIIE)
Mr Mashiane Mothogoane	South African National Biodiversity Institute (SANBI)
Dr Janine Victor	SANBI

Name	Institution
Ms Bridget Nduna	SANBI
Dr Theresa Sethusa	SANBI
Dr Nkateko Ncube	Sanineat
Mr Dime Kekana	South African National Space Agency (SANSA)
Ms Anita Engelbrecht	SANSA
Prof Michele Miller	Stellenbosch University (SUN)
Dr Rowan Lubabalo Mafu	Technology Innovation Agency (TIA)
Ms Lucy Moleko	TIA
Ms Naledi Nthite	Tshwane University of Technology (TUT)
Ms Maureen Ramaube	TUT
Dr Nqobile Xaba	TUT
Dr John Onolame Unuofin	TUT
Dr Leonard Kachienga	TUT
Dr Renay Ngobeni	TUT
Dr Sidonie Tankeu	TUT
Dr Maxleene Sandasi	TUT
Ms Veronica Maphanga	TUT
Dr Helene Fotouo	TUT
Ms Khumo Rampa	TUT
Mr Luhlelo Nxumalo	TUT
Mr Legohu George Molepo	United Nations Educational, Scientific and Cultural Organization (UNESCO)
Prof Nkopodi	University of South Africa (UNISA)
Dr Kebede Kefeni	UNISA
Prof Hugo Lotriet	UNISA
Mr Gregoire Sadiki	UNISA
Dr Emmanuel Mbuyi	UNISA
Mr Louis-Charl Coetzee	University of Johannesburg (UJ)
Mr Muimeleli Mutangwa	UJ
Dr Kousar Banu Hoorzook	UJ
Mr Mthandeni Langa	UJ
Ms Lorraine Mthethwa	UJ
Mr Seth-Frerich Fobian	University of Pretoria (UP)
Ms Tracey Lebepe	UP
Mr Clement Mashaba	UP
Mr Malvin Thabani Tshabalala	UP
Mr Donald Kubayi	UP
Mr Michael Bosch	UP
Mr Sifiso Nsibande	UP
Ms Mashudu Munyai	UP
Mr Petrus Joubert	UP
Dr Dan Molefe	UP
Ms Florence Shange	UP
Ms Nurain Aboo	UP
Ms Chantelle Howlett-Downing	UP
Ms Matete Phala	UP
Mr MC de Beer	UP
Dr Katarina Medger	UP
Ms Tshinakaho Malesa	UP
Mr Jaco Nel	UP
Ms Jane Ramaswe	UP
Ms Lesego Gaolatlhe	University of the Witwatersrand (Wits)
Dr Lebogang Mokotedi	Wits
Mr Zaahid Khan	Wits
Ms Siwaphiwe Peteni	Wits
Ms Charlotte Mthethwa	Wits
Dr Lucienne Abrahams	Wits

Name	Institution
Prof Bea Lacquet	Wits
Dr Christine Sterninger	Wits

APPENDIX 3: SUMMARY OF POLICY ISSUES RAISED AT THE DISCUSSION FORUM

NRF FUNDING FOR POSTGRADUATE STUDENTS AND POSTDOCTORAL FELLOWS

The NRF would give the NSTF a summary of the available funding to be placed on the NSTF website.

The new regime for sponsoring postgraduate students and postdoctoral fellows is welcomed, acknowledging its aims of transforming the postgraduate and postdoctoral cohort; retaining high academic achievers in the system to pursue postgraduate studies up to doctoral level; growing the next generation of academics; and fast-tracking the development of postgraduate students in high-impact, priority and vulnerable disciplines that are critical for national socio-economic development. The new funding regime will make NRF bursaries more competitive with other scholarships for postgraduate studies and with the job market.

There is concern about the decision to prioritise scholarships for younger students to the exclusion of mature postgraduate students, especially at doctoral level. Many potential doctoral students only find their research interest after several years in the workforce.

MENTORSHIP AND ISSUES OF IDENTIFY FOR POSTGRADUATE STUDENTS

Mentorship is important for growing and empowering emerging researchers. A more formalised approach might be needed to ensure that mentorship takes place in academic and research institutions. The suggestions included outsourcing mentorship support to a third party, or capacitating DVC Research Offices or technology transfer offices to add mentorship to their functions.

Models of science may need to be redesigned or adapted to attract and retain new identities of researchers.

Developing a skills set for the 21st century is important and needs to start from primary school onwards. The most important skills required for success in the 21st century are considered to be critical thinking, problem-solving, reasoning, creativity, collaboration, communication, information literacy, media literacy, technology literacy, flexibility, leadership, initiative, productivity and social skills.

The most important skills for a scientist to learn are how to sell oneself, and how to communicate so that people are interested in one’s research.

Students need to appreciate the value of the many marketable skills they develop on their postgraduate journey apart of the strictly discipline-related skills, and to work at using available opportunities to develop a suite of skills for the future role that they envision for themselves after they finish their studies.

Graduates with a master’s degree or doctorate should realise that they could add value in a number of different organisations by using their skills; for example, knowing how and where to find information; understanding and using tools of analysis; writing for various kinds of audience; teaching and training; communication, public speaking and science engagement; networking; and community engagement.

DIGITAL TECHNOLOGIES

We are living in a computational universe in which everyone needs to be computationally literate and have the ability to think computationally. Every member of the South African population needs digital skills and should acquire such skills as early as possible.

There may be challenges with the way in which the Fourth Industrial Revolution (4IR) is conceptualised in South Africa, since people believe that 4IR just involves robots that will take away people’s jobs. 4IR refers to the digital technologies, hardware, software, data, data analytics and a range of applications that are enabling capacities and scientific and research activity in almost every field, in which the human agent remains implicit.

Programming is an important skill. People need to learn coding languages similar to the way in which they learn linguistic languages.

INNOVATION

It is important for South Africa to create an innovation culture at all levels, from primary school to secondary school, tertiary education, postgraduate education and among supervisors. We need to educate for the future by including entrepreneurship and financial education in school curricula so that people become increasingly self-reliant.

The major threats to innovation at national level are not using all our national resources, and not educating for the future.

The silo thinking of the past is no longer relevant and is not an enabler of innovation. A new paradigm is needed. There is no ‘us’ and ‘them’, only ‘us’, and our fates are linked in South Africa.

We require ‘entrepreneurial researchers’, and ‘researcher entrepreneurs’. There is potentially much more value in viewing things from the perspective of both research and industry. It is essential to look at the entire innovation network, clarify the respective roles of entrepreneurs and researchers, and then decide who drives innovation.

Entrepreneurship must be taught in schools from an early age in order to develop a culture of self-employment, as there is no alternative for South Africa to succeed.

Universities must produce graduates that are market ready. Students need exposure during their studies to the potential to become an entrepreneur, how to develop a business or the avenues for initiating an incubation process. Exposure to the potential for entrepreneurship should begin as early as the undergraduate BSc curriculum to make bachelor’s graduates more employable and continue through postgraduate training to position them to start businesses.

Graduates should stop asking the question of who will employ them, and instead ask ‘How can I empower myself, and perhaps create jobs for a few other STEM graduates?’ Students must be made aware during their undergraduate studies of the possibilities and opportunities available after finishing postgraduate studies in terms of innovation, patents and entrepreneurship. They must be given confidence in the value of their skills so that they are not scared of the notion of becoming an entrepreneur or paralysed by fear of failure.

Universities train engineers to be ready to work for themselves when they graduate, but scientists are not trained to be ready to work for themselves upon graduation. What happens in engineering school is not happening in science schools. This ought not be difficult to fix, and would include doing more responsible research that will contribute to addressing the needs of the country.

R&D is just a part of innovation. South Africa has been funding R&D for a long time, but the rest of the innovation chain has received far less attention and investment.

ENGINEERING TRAINING

The quality and availability of highly skilled workers in South Africa (from artisans to specialist practitioners) is critical for a shift towards innovation and advanced manufacturing.

South Africa needs to prepare itself to meet the demand for high-level engineers the following areas of anticipated future growth: water, the Square Kilometre Array (SKA), renewable energy, smart cities, sustainability, the energy/food/water nexus, infrastructure technology for developing environments, industrial engineering, systems engineering, IT engineering, animation and gaming, big data, asset and facilities management, and asset management in process industries.

Postgraduate supervision capacity is constrained by the relatively low numbers of academics with a doctorate.

R&D

R&D spending in South Africa is not optimal, and the contribution from the private sector is declining.

A growing danger in some sectors is that industry is moving its research efforts to other countries, which reduces the environments in which high-level engineers can work in South Africa. South Africa needs to position the country as an attractive destination for global participation, support transition to high-technology manufacturing, and improve international competitiveness.

Another challenge is that South African research lacks outward orientation. International companies are sometimes considered a threat, but working with such companies can be a very enriching experience provided that South African IP is protected. In becoming more outward looking, South Africa could begin by looking towards SADC countries.

Higher education research is constrained by the relatively low numbers of staff with a doctorate.

REGISTRATION OF NATURAL SCIENCE PROFESSIONALS

SACNASP needs criteria for defining and recognising scientists that fit the new era, which would involve less rigidity in defining fields and more space for adaptation during the course of a career.

Continuing Professional Development (CPD) points could perhaps be used to build up the aspects that a natural science professional is missing for registration.

All government departments, science councils and universities should require the natural science professionals that they employ to be registered with SACNASP, and should stipulate this in job adverts for such positions.

There might be implications with the Competition Commission in relation to the requirement that one cannot practise as a natural scientist without being registered with SACNASP.

ETHICS

The ethical foundation of science and technology will have to evolve to an even higher level to address increasingly challenging ethical issues.

CV WRITING FOR GRADUATES

Graduates need to learn to write their CVs so as to highlight their core skills in ways they may not have thought of, including skills developed in the course of their studies that are not necessarily related to their specific discipline.

Participation in outreach or volunteer opportunities should be included in the CV as evidence of experience even if one does not yet have any formal work experience.

A tip from someone in human resources management is to remove one's photo from the CV unless one is specifically asked for it, to avoid being judged before a prospective employer has even looked at the CV.

POSTGRADUATE DISCUSSION FORUMS

Platforms and programmes for postgraduate student discussions need to be expanded.

TRIPLE HELIX

The concept of the Triple Helix was introduced and the idea of forming a South African chapter of the International Triple Helix Association was discussed.

The Triple Helix model could perhaps incentivise the breaking down of silos between sectors and inspire collaboration and innovation. The discussions on the Triple Helix should be extended to involve industry and government beyond the academic circle.

The NSTF will develop a model of how a THA Chapter could work and how key stakeholders in the system could be consulted.

NSTF WEBSITE

Suggestions to be included on the website:

- An online portal of employers and companies in science, what kind of career opportunities are available, and what skills students require for employability.
- A summary of the available NRF funding for postgraduate students and postdoctoral fellows.