NELSON MANDELA
UNIVERSITY

Faculty of Science

Shaping the future of Science
at Nelson Mandela University

The Faculty of Science seeks to Inspire, Engage, Educate and Employ the next generation of scientists, explorers and innovators.

This publication is a strategic overview of the Faculty of Science led by the Executive Dean, Professor Azwinndini Muronga. The content serves to offer insight into Prof Muronga's leadership, and to guide the faculty's strategy, goals and work, now and into the future. Prof Muronga has drawn on examples and narratives from his own experience as a researcher, science communicator and educator. Hence, several of the examples used to emphasise fundamental, strategic issues reflect Prof Muronga's areas of expertise. However, they apply to science in general and therefore to the whole Faculty of Science.

For more about the Faculty of Science go to ***science.mandela.ac.za***

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Executive Summary

Background

The past few years at Nelson Mandela University have seen significant strategic growth and direction for the Faculty of Science. Concurrent with the expansion and diversification of our teaching and learning offerings, the Faculty of Science is making considerable strides towards expanding our activities in novel research. Science has long been the leader for research activity at Nelson Mandela University and the Faculty of Science is unquestionably more research-intensive than it was five years ago.

This document is based on the Executive Dean of the Faculty of Science, Professor Azwinndini Muronga's interaction with the Faculty of Science, the broader university, and external stakeholders. It offers the long-term strategic direction for the faculty to ensure the growing role for science, technology and innovation in a more prosperous and inclusive society. It focuses on developing a faculty strategy that emphasises the use of Science, Technology and Innovation (STI) for the benefit of society in a sustainable manner.

The need for the faculty's new strategy is motivated by:

1. **Rapid and fundamental global changes.** Drivers of these changes are socio-economic and geopolitical (e.g. demographic shifts, urbanisation, rising inequality and youth unemployment), scientific and technological (e.g. the blurring of lines between the physical and digital spheres as a result of information and communication technologies and the Fourth Industrial Revolution [4IR]), and environmental (with climate change having serious consequences for the world's most vulnerable people). These changes have profound implications for the Faculty of Science. Inter- and transdisciplinary knowledge is increasingly important, and research is becoming increasingly data-driven. Our success in responding to the 4IR will depend on how well we leverage the pivotal role of information and communication technology (ICT) and harness the potential of big data. Furthermore, the faculty has a fundamental role to play in achieving the United Nations Sustainable Development Goals.
2. **A coherent, inclusive science.** In addition to centring learning and teaching, research, training and innovation, and engagement in the faculty, interventions aimed at improving transformational systems and processes as well as the governance of the faculty will be introduced. Among these is the establishment of a task team on Structures, Systems and Processes which will look at the current structures within the faculty and recommend new and enhanced fit-for-purpose structures, systems and processes.
3. **The need to assess our undergraduate enrolment.** Over the past few years, while the faculty's undergraduate enrolment has remained constant, the overall numbers of students taught in the faculty has significantly increased. A major contributor to this is the increase in new programmes in the university's service faculties, which urgently needs to be accommodated in the planning of the institution and the faculty.
4. **Expanded capabilities and support for the knowledge enterprise.** To develop the full potential of knowledge, the faculty strategy should aim to expand research outputs and transform the research landscape, such as through programmes to improve the performance of historically disadvantaged groups and inactive research bases. The research system's output of human resources should be improved (for example, through developing the human resources pipeline, providing increased support for students and staff, increasing supervisory capacity, and transforming the demographics of the professoriate). In addition to research and PhD outputs, the strategy will support a diversity of post-secondary education opportunities and the prioritisation of the development of technical skills for the economy, including a focus on education and training for future digital jobs. The strategy should emphasise the support for a diversity of knowledge fields, a greater focus on inter- and transdisciplinary research and the contribution of the humanities and social sciences to addressing complex societal problems. The adoption process of research themes should be transparent and the research focus areas will be aimed at opportunities to meet the government's National Development Plan's objectives. The strategy should support the upgrade and expansion of teaching and research infrastructure, including cyber infrastructure.
5. **Science engagement.** The realisation of the strategy should in part depend on building an innovation culture in society and developing a science-literate and aware citizenry. The strategy should therefore pay attention to skills and faculty arrangements to support and coordinate science-engagement initiatives. Building on our record in developing African and international partnerships, the strategy should also introduce a systematic approach to expanding the Africanisation and internationalisation of science. The strategy should seek to add new niche areas, following national and global trends.
6. **Resources stewardship.** Very few of the ambitions of the strategy will be realised without adequate funding, infrastructure and human resources. The faculty should rethink resourcing its strategy in the 21st century.

Over the next decade, the Faculty of Science should continue to prioritise growth in terms of its physical infrastructure so as to permit expansion of our teaching and learning, and research activities.

One of our highest priorities should be ensuring our offerings continue to prepare students for 21st century careers and further education, while also investigating possible new specialisations or programmes. To ensure our programmes remain relevant and enhance the employment readiness of our graduates, we must constantly review them. Entrepreneurship should be introduced and enabled.

As a faculty, we recognise that support for research goes through cycles. It is generally acknowledged that the current funding climate in South Africa increasingly favours programmes intended to benefit our national economy through shorter-term applied research, rather than the traditional investment in longer-term basic and fundamental research that has historically benefited our departments and schools. In order to continue to thrive in the current climate, we should enhance the support required for funding applications over the next 10 years as a means through which to increase the diversity of funding received by the Faculty of Science. Additionally, we should work internally to improve our allocation of resources and strengthen internal opportunities to

support research. The faculty should rethink the current funding model for research and postgraduate publication purposes.

A key challenge facing the faculty at the moment is the limited space available for research. Despite our significant need for a Teaching and Learning Complex, for the foreseeable future we will remain unable to accommodate more faculty members and postgraduate students. To this end, we envisage the creation of a new, research-focused Science Complex on the university's Port Elizabeth Campus and on the George Campus that will attract researchers of the highest calibre to the faculty. Only by continuing to expand our professoriate and postgraduate student capacity, in concert with developing best practices for grant applications and diversifying funding sources, will the Faculty of Science make truly great strides towards increasing our standing in national and international research communities, and make a great impact on society. Our successes in raising our research profile will, by extension, contribute to elevating Mandela University's overall positioning and thus resonate with the university's strategic goals.

Over the next 10 years, we should support our teaching excellence, research capacity, diversity of funding sources and capital investment, and prioritise the improvement of science as a whole, by enhancing our visibility and sense of community. Working with both internal and external goals in mind, the faculty should emphasise the enhancement of our communications strategies in order to increase the visibility of our excellent academic programmes and research strengths. Our primary aim in this respect should be to establish a reputation for science at Mandela that is truly commensurate with our accomplishments, many of which are not yet widely known. The benefits of increasing our visibility and reputation will no doubt include increased enrolment of top students from across South Africa, Africa, and beyond, along with increased visibility to potential partner organisations interested in supporting research.

We should also work to strengthen the Science Faculty from within so that our people are well connected and operations within the faculty are transparent and conducive to a sense of responsiveness and community. To this end, we should improve our internal communications so as to ensure individuals are properly supported and recognised for their contributions. With regard to how a sense of community applies to our students, it should be our goal to develop more lasting relationships with our graduates as they transition into their lives after Mandela. By strengthening our larger network of alumni and other external stakeholders, we will increase future opportunities for the Faculty of Science as we continue to benefit society through the expansion of scientific understanding.

Scope of Strategic Planning

The Faculty of Science Strategic Plan will serve as a guide for the next 10 years in terms of the areas in which we are dedicated to effecting positive change and strengthening our faculty, thereby enabling us to build on the outstanding education offered to our students and increase societal benefit through research, teaching and learning and engagement. The scope of this document is not exhaustive, nor is it meant to be prescriptive of new ideas that might be identified during its 10-year life cycle. The strategy document will be complemented by operational planning with regard to teaching and learning, research, training and innovation, engagement, resources stewardship, transformational systems and processes, student and staff access for success, as well as other areas, as needed. Our operational plans will be updated regularly to ensure we are holding ourselves accountable and realising our strategic goals through specific and measurable actions. In 2021, the strategy document will allow us to critically reflect on our progress and inform the next round of strategic planning.

Planning Process

In 2019, the Faculty of Science will undertake self-assessment of our performance metrics for enrolment trends, success rates, programme offerings, research revenue and output, and resource allocations, as well as structures, systems and processes. This is done in parallel with the "As Is" process of the organisational redesign. There will be consultations with our departments and schools, at which time each department will be asked to address how the faculty's six foundational pillars – teaching and learning excellence, research, training, and innovation excellence and impact, engagement excellence, transformational systems and processes, student and staff access for success – apply to their activities, and to identify their areas of greatest research intensity. This process will be conducted using a variety of methods, including interviews, facilitated discussions and subcommittees of task teams, ultimately leading to feedback that will inform us as to potential goal areas and issues of relevance to the faculty. This self-assessment process will culminate in Strategic Planning Retreats, to be held throughout 2019, where faculty representatives will be invited to share feedback from their groups.

After the retreat, a draft strategic plan will be prepared by the planning executive committee, a subset of the larger Science Faculty planning committee, who will synthesise the feedback from the planning discussions and retreat. This draft will then be progressively revised, allowing for internal consultation within the faculty and with our on-campus partners, as we articulate the faculty's strategic priorities for the next 10 years. The final strategic plan will be operationalised from the start of the second quarter of 2020. From 2021, there will be annual reviews of our progress towards realising our strategic goals.

Unique Opportunity in the Faculty of Science Redesign

The higher education sector is in a state of transition. We, as Nelson Mandela University, believe it is up to us to define the trajectory we take in the context of emerging and pressing national, continental and global challenges.

Essential to this trajectory is a fundamental question: What are universities for? This question has confronted higher education for centuries. In terms of our own posture, our scholars and researchers have to be prepared to experiment with alternative models that are rooted in communal legitimation of knowledge, and which tap into the wisdom of all people.

This has informed our university's Institutional Organisational Redesign. The Faculty of Science, progressively led by Executive Dean Azwinndini Muronga, is leveraging the organisational redesign to holistically review and assess whether its present faculty structures, work flows, procedures and systems are strategically aligned and fit for purpose.

In Prof Muronga's presentation to Council last year, he made the point that the redesign needs to capacitate the faculty to meet its goals and to assist in streamlining operational disjuncts between the faculty and the support units on which it depends for its optimal functioning.

He explained that the organisational redesign offers several advantages for the faculty, and its students and staff. In his words: "It will maximise effectiveness and efficiency in our faculty and enable the faculty to better respond to the complexities of our size and shape, the need for resources, access and success for our students and staff, engagement with our internal and external stakeholders, and diversity and inclusion in the sciences."

Prof Muronga anchors transformation in the philosophy of diversity and inclusion in the sciences, using the holistic definition of diversity, including diverse ideas, demographic diversity in the student and staff composition, processes, systems, selection committees, committee structures and programme offerings. It also talks to the need for the ongoing decolonisation of the curriculum process, including introducing the history of science, technology and medicine, which adds to diverse knowledges in the curriculum.

The pursuit of diverse knowledges in this era of the Fourth Industrial Revolution (4IR) includes maximising the opportunities and addressing the challenges of the 4IR, and we are looking to the Faculty of Science to lead the institution in addressing this, in collaboration with our other faculties. It includes grappling with the question of how to be human in the 4IR. This is another important dimension of transformation, as is the inclusion of science entrepreneurship or 'sciencepreneurship' and innovation in the curriculum. It is about preparing our students for the jobs of the future, as many of the jobs they are being prepared for today will no longer exist by the time they graduate. Research and the curriculum need to be reviewed within this context.

In the same vein, our new institution-wide research themes – which are the product of a wide consultative process – speak both to the present and the future, namely, our existing knowledge asset base, as well as our aspirations. They speak to what we have chosen to be and how we are positioning ourselves in terms of our research priorities in the higher education sector. As a university we have settled on the following organising themes to steer our differentiating scholarly contribution:

- Ocean and Coastal Sciences
- Social Justice and Democracy
- Environmental Stewardship and Sustainable Livelihoods
- Innovation and the Digital Economy
- Origins, Culture, Heritage and Memory, and
- Humanising Pedagogies

"In the process of transformation and internationalisation we are exploring new models and research fields, and we are growing our research partnerships with universities across the continent and globe."

Photo credit: Dr Stephanie Plön, Ocean Health Researcher, AEON-Earth Stewardship Science Research Institute, Nelson Mandela University

In the process of transformation we are exploring new models and research fields, and we are growing our research partnerships with universities across the globe. Important to our redirection is the focus on advancing the African footprint of our internationalisation, research and engagement strategies that frame our relationship with our continent as an African university.

We will be deliberately growing our African collaborations and partnerships to align with Madiba's own intellectual and social justice project, which was first and foremost framed around his African identity. We already have several African partnerships representing all our faculties and most research Chairs. Professor Mike Roberts' SARChI Chair in Ocean Science and Marine Food Security in the Faculty of Science creates a bridge of marine scientists and doctoral fellows that extends from Nelson Mandela University to universities along the eastern coast of Africa (known as the Western Indian Ocean or WIO), to Southampton University in the UK.

These scientists are directly engaging with communities who rely on the oceans for food, at a time when the oceans are warming, the marine environment is deteriorating from high levels of pollution and overfishing, and food insecurity is rapidly rising. To find answers on how to address this requires an intensive inter- and transdisciplinary research approach.

As Prof Muronga emphasises, for all inter- and transdisciplinary research, as well as engaged research, to be successful, we need strong disciplinary knowledges – this is discussed in this publication with reference to the fundamental, basic sciences. And we need strong community engagement. A fine example is the research led by Distinguished Professor of Zoology Graham Kerley from our university's Centre for African Conservation Ecology (ACE) and ACE affiliates Dr Sharon Wilson and Dr Dave Balfour. In 2018 they published a world-first book titled: *Livestock Predation and its Management in South Africa: A Scientific Assessment.*

Scientists partnered with farmers, communities, wildlife managers, the Department of Environmental Affairs; the Department of Agriculture, Forestry and Fisheries; Cape Wools; and the SA Mohair Growers Association to produce a scientific assessment of the issue of predation on livestock in South Africa. This will inform new policy frameworks, based on an adaptive, more holistic approach to the management of livestock predation, that is missing in the current legislative framework.

Engagement for the university is equally important to scholarly output and success, as are teaching and learning and research. The university supports the call by the Faculty of Science to establish an Engagement Committee within the faculty, as this is in line with the aspiration of Nelson Mandela University to be known as a community-engaged university.

The envisaged 'Science Shop' of the Faculty of Science is all about engagement and very much in line with the university's strategy for Hubs of Convergence, where the university and the community come together to engage on any issue. The 'community' includes the government, industry, private sector and civil society.

The Science Shop will be a meeting place for all members of the Faculty of Science and its stakeholders to engage, in particular on science-related transdisciplinary issues, and, importantly, to engage with young people about future career paths and articulation routes in science, in line with the 4IR.

All this offers some of the answers as to what universities are for, namely, the expansion of human understanding: pushing forward the frontiers of knowledge in all sciences and the humanities to cultivate humanity and to contribute to the well-being of our city, our province, our nation, our continent, our world.

The key challenge facing all South African universities is to develop a strong postgraduate pipeline and to sustain the development of the next generation of academics. Research capacity and culture has to be inculcated early at undergraduate levels, a quest made more difficult by the fact that many students entering higher education are often insufficiently prepared due to the generally poor schooling system.

This has required of us to strengthen instructional support and foundational programmes, as well as to enhance existing early warning systems to ensure that all our students are in a conducive environment not only to complete their qualifications on time, but for many of them to achieve high quality passes that position them to access postgraduate studies, thus strengthening our pipeline.

The Faculty of Science is already embarking on strategic initiatives in this regard, such as the development of tutors and lab demonstrators, the National Institute for Theoretical Physics (NITheP) internship programme, and the participation of undergraduates in the Global Undergraduate Awards, which forms part of the research experience in the undergraduate programme. The university is firmly behind the development of an honours pipeline and will make provision for this ahead of 2020.

It is pleasing to note that the Faculty of Science is rethinking its honours programme, from its admission process in line with the philosophy of diversity and inclusion in the sciences, to supporting and encouraging honours graduates to go on to pursue master's and doctoral studies within the faculty. This needs augmented supervision capacity and resources such as laboratory spaces and advanced scientific computing facilities to conduct their research.

Our university's ambition from first year to the professoriate is to evolve a scholarship that will truly change the world. We enter the next decade with bold innovations and strategies; it's an exhilarating time for all of us, and we look forward to taking the journey together.

Introduction by the Executive Dean of the Faculty of Science
Professor Azwinndini Muronga

Looking to the future: The Soul of the 21st Century African Faculty of Science

The Faculty of Science at Nelson Mandela University is at a crossroads. Having been part of a relatively young merged university, less than 15 years old, we are in the process of reshaping our identity and assessing our role as the largest service faculty within Nelson Mandela University.

On 20 July 2017 the institution became Nelson Mandela University, carrying the honour of being the only university in the world to officially carry the global icon's name.

It is a fitting time to reflect on our journey and pause for a moment to consider where we are and where we want to go. In doing so, the Faculty of Science needs to heed the call of President Cyril Ramaphosa in reshaping our future to truly become a 21st century African Faculty of Science.

At Nelson Mandela University's naming ceremony, President Ramaphosa said:

A new university is born today. At its birth … it is challenged to redefine higher education in our country … From now on, the many thousands of students passing through these gates will have the name 'Nelson Mandela' in their résumés. Will they too go on to become unifiers, innovators, internationalists? Will they too dream of a new society founded on equality and the pursuit of human happiness? And will they have the skills, the knowledge, the consciousness to strive together to build such a society? A new university is born today.

Our new university is being taken into the future by three distinguished leaders: the Chancellor, Dr Geraldine Fraser-Moleketi; the Chair of Council, Ms Nozipho January-Bardill; and the Vice-Chancellor, Professor Sibongile Muthwa. The Faculty of Science is excited to work with these leaders in pursuit of our university's central tenet, as explored in the Vice-Chancellor's inaugural address on 17 April 2018: *Taking Nelson Mandela University Boldly Into The Future in Service to Society*. The title and the VC's speech resonate well with the goals of the Faculty of Science in re-shaping its future to become a 21st Century African Faculty of Science.

Of particular interest in the inaugural address is:

1. The notion of transformational and transformative leadership; and
2. The identity of the university experienced through the faculties, with growing connections between the natural sciences, the humanities and the social sciences through transdisciplinary research and partnerships in solving local and global challenges.

Standing at the crossroads and looking at the clock, I realise that we are entering the third decade of the 21st century. Globally, social and political systems are acceding to the notion of a post-truth world. Right here at this crossroads, in this precarious political and social context we face both the opportunities and the challenges of a range of powerful, emerging technologies – from artificial intelligence, to biotechnologies, from advanced materials to quantum computing – that will drive radical shifts in the way we live in the era of the Fourth Industrial Revolution (4IR).

While standing at this crossroads for our world, university and faculty, I am reminded of the most extraordinary moment in the history of science – the picture of gravitation, space-time and

"Everything we do as a faculty needs to be forward-thinking because our graduates must survive and thrive in the 21st century and the rapidly evolving Fourth Industrial Revolution, which will bring with it careers and opportunities that do not yet exist."

matter embodied in Einstein's General Theory of Relativity. It fundamentally changed how we understand space and time, and energy and mass. From this theory a fundamental link between space and time emerged, unified into space-time, and the relationship between mass and energy emerged as mass-energy conservation. To achieve this, Einstein had to think radically by stepping away from the tradition of thinking about space and time separately; instead, he unified them, similarly energy and mass.

It took Einstein nearly eight years to find the final and correct form of the General Relativity (GR) theory which connects matter (mass-energy) and space-time. It takes us back 100 years to 29 May, 1919 when the first tests for Einstein's GR were performed during the longest (six minutes long) total solar eclipse of the 20th century from the island of Principe (off the west coast of Africa). When the New York Times published the news of the results confirming the prediction of GR theory on 7 November, 1919, Einstein became a household name overnight. Since that most important eclipse off our continent, Einstein's GR has been tested in many other ways, each time proving that his view of the warping of space and time is very much the universe we live in.

The latest test was the detection of gravitational waves (predicted by Einstein's GR theory in 1916) that have been travelling across the universe for 130 million years, arriving on Earth on 17 August, 2017. I am proud that South Africa and Africa participated in the detection and observation of these gravitational waves through MeerKAT and SALT. This detection gave birth to a new scientific research field known as Multi-messenger Astronomy/ Astrophysics.

At the time of writing of this publication, a historical breakthrough happened – the first ever image of a black hole was released by the Event Horizon Telescope collaboration on Wednesday 10 April, 2019. The existence of black holes was predicted by Einstein more than 100 years ago, and this is a confirmation of the test of Einstein's theory once again.

Standing at these crossroads means we bear a huge responsibility to shape the future of the Faculty of Science at Nelson Mandela University and we are compelled to think out of the box as Einstein did if we want to better understand our world and the cosmos. I would like to refer my colleagues to the book *The Structure of Scientific Revolutions* by American physicist, historian and science philosopher, Thomas S. Kuhn. He explains that the history of science teaches us that major scientific breakthroughs only happen because of radical thinking away from the norm or traditional scientific thinking.

Kuhn challenged longstanding linear notions of scientific progress as he argued that transformative ideas do not arise from the day-to-day gradual processes of experimentation and data accumulation, but rather through the revolutions in science – those breakthrough moments that disrupt accepted thinking and offer unanticipated ideas outside of normal science.

These examples, albeit from physics, are instructive in our infotech and biotech age where the phrase *paradigm shift*, popularised by Kuhn, gave it the meaning it has today. I am using the analogy of scientific revolutions because most scientists are familiar with and aware of them. As the Faculty of Science we will need to think radically away from the day-to-day thinking in order to achieve our vision, mission, values, graduate attributes and strategic priorities and objectives.

This requires moving out of our comfort zone. It means phrases like 'this is how it has always been done' will have to give room for new, diverse and inclusive ideas.

It means that systems and processes that stand in our way will have to be dismantled, and just like in Einstein's theory, where the concept of time and space needed to be unified, it might be necessary to dismantle the silos in the faculty and emerge with unified entities that will be fit for purpose and for our identity.

A major lesson we have learnt from Einstein's theory is that it has stood the test of time; therefore our strategy will need to stand the test of time for the next ten years or so, and just as we test hypotheses in science, our strategy will need to be tested against fit-for-purpose monitoring and evaluation standards. As the title of the book by venture capitalist John Doerr states: *Measure What Matters.* The question then is what matters for us?

The analogy of the Einstein scenario necessitates that all our students should have a knowledge of the history and philosophy of science, to explore *What is Science?* and *How is Science Done?* (the Scientific Method). Once the history and philosophy of science is included in our curriculum, we will be able to articulately address the question of diverse knowledges, new knowledges and the relevance of the curriculum.

While we are at the crossroads there is an expectation by the university and society at large, local and global, that the Faculty of Science should play a leading role in navigating the Fourth Industrial Revolution (4IR). Thus, as we shape the future of the faculty, this future will also be shaped by our understanding and participation in shaping the future of the 4IR.

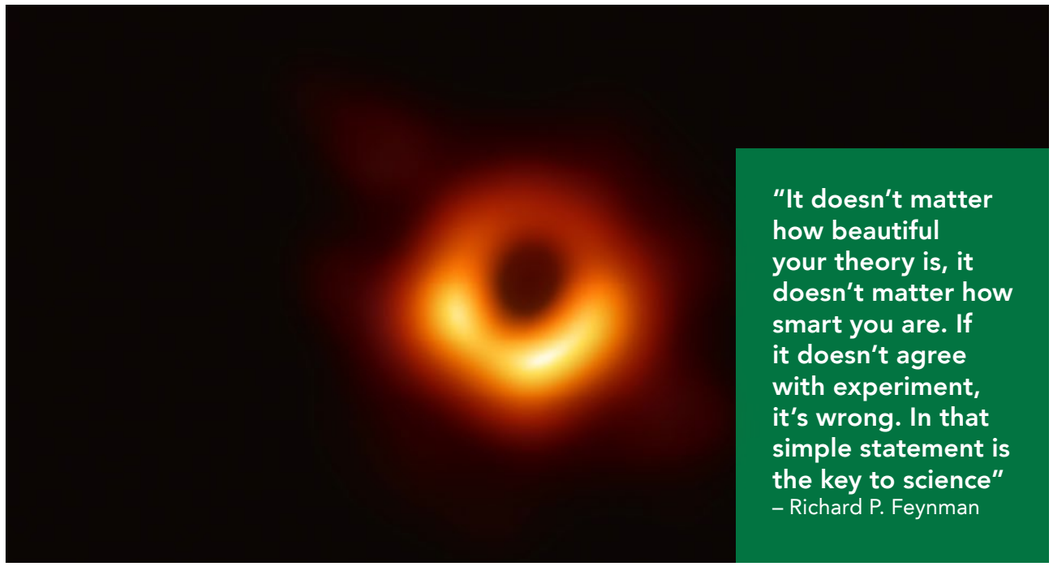
The convergence of data with the advent of computational storage and cognitive power will transform industry and society at every level, thereby creating opportunities that were once unimaginable – from education and health to agriculture, manufacturing and services.

The faculty should lead in the approach to and preparedness for the convergence of several important technology shifts, such as mixed reality, artificial intelligence and quantum computing.

The Faculty of Science should rise to the importance of the 4IR and shape it for the benefit of all, guided by our vision of becoming a 21st century African Faculty of Science. This will require new ways of thinking and a broad understanding of different technologies that will impact individuals, communities, our institution and the society at large. The 4IR will indeed be a new chapter in human development, on a par with the First, Second and Third Industrial Revolutions.

If we miss this window of opportunity to shape the future of science, technology and innovation, and in ways that promote the common good, enhance human dignity and protect the environment, the chances are that the challenges we face today of inequality, poverty, unemployment and environmental degradation, will only become worse and compromise the well-being of all.

The good news is that the evolution of the faculty is entirely within our power. Everybody can and should have a say about how we shape the future of our faculty, and we are in the fortunate position of having a very supportive top leadership of the institution. In shaping the future of our faculty, our mission, vision, values, graduate attributes, strategic priorities and objectives should reflect the university's strategic direction, the National Development Plan (NDP), the Sustainable Development Goals (SDGs), and be aligned with Agenda 2063 and the White paper on Science Technology and Innovation (STI).



"It doesn't matter how beautiful your theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong. In that simple statement is the key to science"
– Richard P. Feynman

The first ever image of a black hole shows the supermassive black hole in the heart of galaxy M87. Photo credit: The Event Horizon Telescope

About the Executive Dean of the Faculty of Science Professor Azwindini Muronga

Prof Muronga joined the Faculty of Science at Nelson Mandela University on 1 April 2016. He holds a PhD in Physics from the University of Minnesota, United States, an honours and master's in Physics from the University of Cape Town, and a BSc from the University of Venda. He was a postdoctoral fellow at the University of Frankfurt and at the GSI Helmholtz Centre for Heavy Ion Research in Germany.

Prior to taking up his post at Nelson Mandela University, Prof Muronga was an Associate Professor of Physics and the founder and Director of the University of Johannesburg (UJ) Soweto Science Centre where he was based from 2010 to 2016. From 2005 to 2010 he was a senior lecturer of physics at the University of Cape Town.

Prof Muronga is the past President and current International Liaison Councillor of the South African Institute of Physics (SAIP). He is a member of the C11 Commission of the International Union of Pure and Applied Physics (IUPAP); the Board of the South African National Space Agency (SANSA); the South African Council for Natural Scientific Professions; the National Institute for Theoretical Physics (NITheP) steering committee and the organiser and host of the NITheP internship programme, and Chair of the judging panel for the mathematics and physics category in the Global Undergraduate Awards.

In June 2018, Prof Muronga gave a series of lectures to students from the continent who attended the fifth biennial African School of Fundamental Physics and Applications, hosted by Namibia. The first school was hosted by South Africa; the next school will be held in Morocco in 2020.

In July 2018 Prof Muronga attended the International Conference on High Energy Physics (ICHEP) in South Korea as a member of its international advisory committee and the IUPAP C11 Commission. He presented on Diversity and Inclusion in Science, and Education and Outreach.

The attendance of the Namibian and South Korean conferences is part of the faculty's Africanisation and internationalisation strategy.

Prof Muronga's research field lies at the intersection of nuclear physics, particle physics, astrophysics and cosmology, studying the nature and properties of matter under extreme conditions such as those in heavy ion collisions and astrophysics.

He is deeply involved in research activities in these fields and has started building activities in the Eastern Cape, through the NITheP Internship Programme, and recruitment of international postdoctoral researchers.

There is growing interest nationally and internationally in partnering with Nelson Mandela University, as demonstrated by the hosting of the SA-CERN board meeting on 10 September 2018 at the university – it was the first time it was held outside of the Western Cape.

In February 2018, the faculty hosted Russian scientists from the Joint Institute for Nuclear Research (JINR), Dubna, to establish collaborations. A collaboration proposal on nuclear physics, particle physics and astrophysics has since been submitted to the National Research Foundation (NRF) by Prof Muronga who is a member of SA-JINR. The collaboration will include scientists from South Africa (Nelson Mandela University and the University of Cape Town), Poland, Brazil, Russia and Germany. Through this collaboration students from the Faculty of Science will have the opportunity to participate in exchanges with JINR.

The faculty will also be partnering the JINR on celebration of the International year of the Periodic Table, which was formulated by Russian chemist and inventor, Dmitri Mendeleev.

In December 2018, the renowned physicist, Distinguished Professor Ulrich Heinz from Ohio State University, visited the Faculty of Science and gave a seminar in the Department of Physics.

In January 2019 for the first time the Faculty of Science hosted the international High Energy Particle Physics Workshop, which is traditionally organised by scientists from Wits University.

All these and other activities are geared towards capacity building in the Eastern Cape for research in nuclear physics, particle physics, astrophysics and cosmology.

The goal is for Nelson Mandela University to participate in large collaborations, such as the SKA, CERN, IThemba LABS, and environmental research at a national and international level.

The 17 SDGs, adopted by the United Nations (UN) General Assembly on 25 September 2015, form the core of the UN's 2030 Agenda for Sustainable Development. They balance the economic, social and environmental dimensions of sustainable development. In reshaping the Faculty of Science we should outline the role of science, technology and innovation in achieving the SDGs.

The NDP Vision 2030 was introduced by government in 2011 to serve as South Africa's long-term planning framework. The aim of the NDP is to address a set of core outcomes covering 14 focus areas: education, health, safety and security, economic growth and employment, skills development, infrastructure, rural development, human settlements, local government, environment, international relations, public sector, social protection, nation-building and social cohesion. In reshaping the Faculty of Science we should outline the role of science, technology, and innovation in achieving South Africa's NDP.

In addition to the access and success of staff and students, the three focus areas (Learning and Teaching; Research; Training and Innovation (RTI); Engagement) and the cross-cutting enablers of the faculty strategy (structure, systems and processes and resources stewardship), the reshaping of the faculty should include:

- Harnessing the potential of big data;
- Exploiting the pivotal role of ICT;
- Harnessing the Fourth Industrial Revolution;
- The promotion and protection of the basic sciences;
- Strategically harnessing African collaborations;
- Advancing the interconnections and complementarity between the natural sciences and the humanities and social sciences;
- Embracing inter- and transdisciplinarity and evolving research systems;
- Selection of key/focus/thematic research areas;
- Foregrounding science engagement;
- Increased human capital and expanded knowledge enterprise;
- The African and internationalisation strategy;
- Diversity of knowledge fields;
- Effective monitoring and evaluation of the faculty strategy;
- Coherence and integrated approaches (systems and processes aligned with the strategy); and
- Governance structures.

Also at the crossroads we are facing the Ocean Sciences Campus and the Medical School, which will have an impact on the faculty strategy and present the faculty with challenges and opportunities in the three focus areas. Without clear strategies, the new entities pose a risk to the Faculty of Science due to uncertainty. We need to carefully strategise around this, including governance and the role of the Science Faculty. The programmes on the Ocean Sciences Campus also need to be truly transdisciplinary and the campus should be considered as a user facility for all disciplines, while the human resources remain in their home faculties.

Ocean Sciences and the Medical School need to clearly articulate their strategy to the Faculty of Science. Without a clear strategy, it brings uncertainty to the Faculty of Science and creates confusion around roles and responsibilities. There needs to be clarity and communication around this. There also needs to be clear communication that the Ocean Sciences Campus is a postgraduate campus. Providing clarity will enable the Faculty of Science to communicate and guide students and parents appropriately.

The Faculty of Science should be looking at a better approach and fit-for-purpose ways of establishing entities, including units, centres and institutes within the faculty to ensure they are constituted in sustainable ways and we should clearly elaborate on how the entities relate to other faculty divisions, such as departments, and the faculty as a whole.

Another issue that needs to be addressed is that 18 000 undergraduate students from other faculties are serviced by the Faculty of Science, with exploding enrolments, but without fit-

Prof Azwinndini Muronga and final year BSc, and maths and physics postgraduate students on the National Institute of Theoretical Physics (NITheP) Internship Programme in December 2017.

for-purpose resources in the faculty. This is a disaster waiting to happen. The faculty in reshaping its future strategy should address its own shape and size in conjunction with the vastly enhanced numbers from other faculties. The big question with which the faculty needs to grapple is where the balance lies between growing the discipline of science and being the largest service faculty in the university.

At the moment, and with our current resources, the faculty is heavily a service faculty and is not growing the science disciplines. If this continues, the faculty will be unable to lead the institution in navigating the 4IR and other scientific endeavours. Thus, the reshaping of the Faculty of Science strategy is as good as the available resources. It is not just a case of 'getting on with things', we need to acknowledge that the rise of numbers as a result of fee-free education will increase year on year, and it requires careful planning and resources allocation. As part of this, we urgently need to replace inadequate, old and deteriorating equipment that is simply not suitable for a 21st century science faculty.

What needs to be addressed is that while the numbers of students and postgraduates have continued to swell since the time of the merger in 2005, the resources have either stayed the same in quantity and quality or have deteriorated. Under these circumstances, the question of quality has to be legitimately questioned, including the impact on high-level safety and security and health, which is part of our faculty's flagship values. The quality of education also needs to be questioned and our vision can realistically only be realised if we have the means and resources with which to achieve it.

The faculty is already addressing these challenges through various initiatives, such as re-curriculation and articulation redesign, faculty structures redesign, the establishment of an Engagement Committee, Science Education Forum, Computational Sciences Forum, Transformation Task Team (also known as the Diversity and Inclusion Task Team) and the establishment of the following portfolios, identified as gaps in the optimal functioning of the faculty: the Faculty Manager post, Faculty Planning Portfolio, Faculty Resources Stewardship Portfolio, Faculty Undergraduate Affairs Portfolio and Faculty Postgraduate Affairs Portfolio. Other initiatives include the introduction of the Undergraduate Research Experience Programme, participation in the Global Undergraduate Awards, hosting of and participating in the annual FameLab competitions, co-hosting of Science Communication Workshops for the Eastern Cape province, participation in the annual National Science Week activities and African and international science events. In 2019 we are organising events in celebration of the International Year of the Periodic Table of Chemical Elements and the International Year of Indigenous Languages.

The faculty, in reflecting on its vision and how we address the challenges and opportunities we face, should continuously address the following questions:

What makes us a good 21st century African Faculty of Science?
What should we be good at? What are we currently good at?
What should we be good for? What are we currently good for?

These are the questions that have also been asked by Chris Brink in his book, *The Soul of the University: Why Excellence is Not Enough*.

The question, 'What are we good at?' addresses excellence, while 'What are we good for?' addresses purpose. The faculty should pay close attention to what we are good for, and address this with the same determination that we pursue what we are good at. We have not been paying sufficient attention to the parity between the two guiding questions that further address both the 'true' and the 'good'.

Professor Stephen Hawking and Nelson Mandela met in May 2008 to discuss the Next Einstein initiative, aimed at discovering and nurturing great mathematicians and scientists throughout Africa. The initiative stemmed from the success of the Cape Town-based African Institute for Mathematical Sciences (AIMS)

Excerpt from the address by President Cyril Ramaphosa at the renaming of the Nelson Mandela University, 20 July 2017

In naming this university after Nelson Mandela, you are shouldering a great responsibility – to encourage, educate and nurture the new generation about which Madiba wrote.

You are shouldering the responsibility of giving life to Madiba's dream of social equality.

That means that this university must be at the forefront of efforts to make higher education accessible to the poor and marginalised.

While we have made huge strides in making higher education accessible, many capable and deserving young people are still not able to enter universities.

Many of those who do gain enrolment struggle to succeed.

Many study in substandard living conditions.

The support they receive is not sufficient.

Too many drop out.

These are the challenges that a university named after Nelson Mandela will have to confront.

It will also have to confront the challenge of harnessing, as Madiba put it, the collective wisdom of humankind.

This means looking at what we teach and how we teach it.

We must decolonise our higher education system.

We need an education system that will see Africans as worthy contributors to the development of curriculum content.

A university that associates itself with Nelson Mandela must necessarily review its curriculum and examine the subtle layers of colonial and neocolonial norms that underlie its thought systems.

It will have to liberate the minds of the oppressed and awaken them to the potential of African scholarship.

It will have to remove the cloak of institutionalised racism and sexism.

It will have to promote an African renaissance and contribute, through teaching and research, to the making of the African Century.

It must remain rooted in answering the challenges that confront our society in a global economy.

This must be an African university that serves the continent and her people.

By naming this institution after Nelson Mandela, you are making the commitment that out of your teaching will emerge African scholars and academics that can bring a diversity of thought to traditional knowledge systems.

It will have to build partnerships for African scholarship through knowledge sharing.

It will have to be deeply rooted in its African identity.

When students walk onto the grounds of this university they should feel the humanism of Nelson Mandela.

This should be a place where diversity is a strength.

This should be a place where differences of opinion, ideology, culture and interest are able to thrive and contest.

This should be a place where there is respect for the cultural, linguistic, and ethnic diversity that characterises the beauty of our people.

By recognising the legacy of Madiba, by studying what he stood for and what he means to our people, you will fully realise the transformative value of higher education.

From now on, the many thousands of students passing through these gates will have the name 'Nelson Mandela' in their résumés.

Will they too go on to become unifiers, innovators, internationalists?

Will they too dream of a new society founded on equality and the pursuit of human happiness?

And will they have the skills, the knowledge, the consciousness to strive together to build such a society?

A new university is born today.

We have been focusing on the 'true' – in other words, the pursuit of knowledge for its own sake, and this is not sufficient for addressing the needs and demands of civil society – the 'good'. This will need innovative ideas and paradigm shifts, starting with the challenges of civil society, local and global, and we should do so with a clear understanding of when the pursuit of knowledge should be challenge-led rather than curiosity-driven and how these two approaches interact and differ from each other.

We should think in multi-dimensions, where, in this case, the two questions co-exist in a coordinated landscape with one axis being for excellence and the other for societal relevance. As a faculty we should determine our coordinates and ask ourselves 'which subjects do we wish to be good at?', and 'what contributions do we wish to make to address the challenges facing society?'. Then we will not be trapped by academic debates as a series of binary oppositions, of 'excellence' versus 'purpose' or of 'true' versus 'good'. Instead, we should talk about excellence and purpose, knowing the true and pursuing the good, and we can delight in both as each reinforces the other and opens us to new ideas and new niche areas, including infosciences, biosciences and data sciences, and new programmes, such as a master's in data science.

For our three core focus areas we should think in an interconnected, interdependent three dimensional landscape. For the benefit of society, the faculty should be good at all three areas, and make sure that all three are treated inclusively in how we operate, such as through incentives, awards and promotions.

Being at crossroads has given me time to reflect. As a faculty we should collectively pause and reflect. As scientists we are living through exciting scientific times. I have been at Nelson Mandela University for only three years and major scientific breakthroughs have happened within this short time. The detection of gravitational waves from far away galaxies as a result of the black hole collisions and neutron star collisions led to a Nobel Prize in 2017. What should be exciting for us is that South Africa and the continent once again played a role in the observation and detection of the gravitational waves in 2017 as the continent did in 1919 when the bending of light by full solar eclipse was measured off the west coast of Africa. Both these events saw Einstein's theory of General Relativity passing the test. The detection of gravitational waves by the Laser Interferometer Gravitational-Wave Observatory (LIGO) on 17 August 2017 has shown us the future of major scientific breakthroughs. Firstly, the advent of technology has enabled humanity to detect waves that have been travelling towards Earth for about 130 million years from a distant galaxy. Secondly, it took instruments around the world to confirm what the LIGO detectors were seeing and this happened in real time. This latter point about the future of major breakthroughs is an indication of the need to break the silos and utilise our resources effectively.

I am just starting on my fourth year here at Nelson Mandela University and another breakthrough and historic event has already recently taken place. On 10 April 2019 the first ever photograph of a black hole was revealed at a press conference in Brussels. Humanity had never had a glimpse of a black hole until now. This particular black hole, which is a super-massive object at the centre of Messier 87 galaxy (M87), is really a monster. It resides 55 million light-years from Earth and has a mass 6.5 billion times that of the sun. Everything unfortunate enough to get close to it falls in and never emerges again, including light itself. It is a point at which every physical law of the known universe collapses.

Once again we could view this first ever photograph of M87's black hole as a testament to the ingenuity of our species, our infinite curiosity and our capacity to wonder. It is a result of collaboration of nations around the world. The Event Horizon Telescope is a combination of eight radio telescopes around the globe into a composite telescope the size of the Earth. As the planet spins and orbits, the target black hole rises into the field of view of component telescopes around the planet. To render a precise image, the telescopes need to operate as one, which involves sensitive time corrections so that one global eye looks toward the black hole.

Taking the first ever photograph of the black hole was done so that we may learn more about the fundamental laws of nature and, in doing so, better understand who we are. Looking at this picture of the black hole I am amazed at the fact that we are actually looking at the black hole as it was 55 million years ago, because it is so far away and light takes that long to reach us. Over those millions of years, as the light from M87 was on its journey towards our planet, our species was emerging here on Earth, along with our myths, differentiated cultures, ideologies, languages, and varied beliefs. And now we are living through ecological breakdown, and appalling inequalities. It feels as if we are being pulled to the darkness of a black hole.

To humanity this breakthrough gives us greater insight to the strangeness of the universe. This also shows us that the possibilities for our species are endless. All this shows us that we exist in a vast and unknown cosmos, and we are at the very beginning of understanding it. With all the achievements so far, we know so little, and we have done so little. We should be humble. My research field has made me humble. To know that in the grandness of space and time I am just a blip. I am much smaller and less significant to the cosmos than a single grain of sand is to the entire Earth. Despite this the thirst for scientific discovery, for new knowledge, and for a better world, means that I should traverse my smallness in a quest for the truth. It means I should defy my own limits to learn and explore. Back here on Earth my own research field, involving large diverse collaborations, has made me realise that scientific discoveries transcend humanity's differences, such as gender, race, histories, cultures, ideologies, languages, and beliefs.

This scientific breakthrough of the first ever picture of the black hole in M87 should remind us of what we can achieve through inter- and transdisciplinary collaborations. This moment should also remind us that we are more capable of building a better life for all human beings on Earth today and in the future. There are no laws of science that demand poverty, inequality, and destruction. These are human-made phenomena and humans can end them. The photograph is a symbol of our capacity to do that. In our faculty we could also end a hostile environment to pave the way for safe and conducive spaces for students and staff. The first ever image of the black hole, is a beacon of hope. It gives us permission to hope for a better world, and to know that one is possible. It gives us hope that we can be the best 21st century African Faculty of Science.

1 Overview of the Faculty of Science

The departments offer a range of diploma and degree-based programmes in the natural sciences, chemistry and agricultural disciplines.

The Faculty of Science is one of seven faculties at Nelson Mandela University and is comprised of the Departments of Agricultural Management, Biochemistry & Microbiology, Botany, Chemistry, Computer Science, Geosciences, Mathematics & Applied Mathematics, Mathematical Statistics, Oceanography, Physics, Physiology, Textile Science, and Zoology.

Each of the faculty's entities is engaged in ground-breaking research and the education of students from undergraduate and professional degrees through to graduate studies. In addition to the traditional three-year BSc degree, a four-year BSc degree is also offered (currently known as BSc Extended).

The departments on the Port Elizabeth campuses are situated within three schools, namely Biomolecular and Chemical Sciences (Biochemistry & Microbiology, Chemistry, Physiology, Textile Science), CMPS (Computer Science, Mathematics and Applied Mathematics, Physics, Statistics), and Environmental Sciences (Botany, Geosciences, Oceanography, Zoology).

On the George Campus the faculty includes the School of Natural Resources Management, which offers the following programmes: Higher Certificate in Veldfire Management, Diploma and Advanced Diploma in Agricultural Management, Game Ranch Management, Wood Technology, Forestry, and Nature Conservation.

The Agricultural Management Department on the Port Elizabeth campuses also offers the Diploma and Advanced Diploma in Agricultural Management and Game Ranch Management. The Chemistry Department on the Port Elizabeth campuses offers the Diploma in Analytical Chemistry, and Chemical Process Technology and the Advanced Diploma in Analytical Chemistry.

School of Biomolecular & Chemical Sciences

- Biochemistry and Microbiology
- Chemistry
- Textile Science
- Physiology

School of Computer Science, Mathematics, Physics and Statistics

- Computing Sciences
- Mathematics and Applied Mathematics
- Physics
- Statistics

School of Environmental Sciences

- Agriculture and Game Management
- Botany
- Geosciences
- Zoology
- Oceanography

School of Natural Resource Management (SNRM), George Campus

The science programmes currently being offered to about 700 students in the SNRM at George Campus are:

- Forestry
- Wood Technology
- Veldfire Management
- Nature Conservation
- Agricultural Management, and
- Game Ranch Management

Our Mission and Vision

Our mission is to offer a diverse range of pure and applied science-based educational and research experiences to contribute to a sustainable future.

Our vision is to be a dynamic and engaged African science faculty, recognised for generating relevant, leading-edge knowledge for a sustainable future.

Our Three Focus Areas

- Teaching and Learning
- Research, Training, and Innovation (RTI)
- Engagement

The three are intertwined, so that all respond to and feed into each other. Like the three-legged African pot, if you remove one leg the pot will fall. Before the time of the three-legged pot we used three rocks as pillars around the fire for cooking. Like the legs or rocks we want to strongly anchor the three pillars and give them equal attention. All of three are elaborated on within this publication.

Our Values

- Excellence
- Ubuntu
- Integrity
- Responsibility
- Respect for diversity
- Respect for the natural environment
- Health and safety

High percentage of national leaders in their disciplines

The Faculty of Science is renowned for its high percentage of national leaders in their disciplines, recognised by external international agencies who rank them among the best in in South Africa.

The faculty's professoriate includes 135 permanent academic staff members who, along with our lab technicians, lab assistants, tutors and demonstrators, our dedicated contract and part-time academic teaching personnel, are involved in the delivery of nearly 500 courses to 18 000 undergraduate and 220 postgraduate students, all of which is supported by 81 permanent Faculty of Science Professional and Administrative Support Staff (PASS) staff members. The faculty is proactively recruiting additional academic staff members in specific fields.

PhDs	55% academic staff (with an increase year on year)

Employment Age	Less than 35 years	35–55 years	More than 55 years
	32	132	52

	African		Coloured		Indian		White	
	M	F	M	F	M	F	M	F
Demographics	32	23	16	10	4	5	76	50
International	5				1		3	

Gender	
M	F
128	88

Appointment Type	
Permanent Contracts	Long-term Contracts
182	44

Nationality		
South African	Permanent Resident	Work Permit
207	6	3

Dedication to internationalisation

The faculty reflects Nelson Mandela University's dedication to internationalisation, with 37 percent of our postgraduate students and five percent of our undergraduates coming to us from countries outside South Africa. The majority of our international students are from the rest of the mother continent, Africa.

In terms of the international diversity of our faculty, in the past years, three quarters of the new staff members we have recruited have trained internationally at a postgraduate or postdoctoral level. With these new additions, the faculty has added to its collective experience the benefit of training from leading institutions in 14 different nations, helping to create a truly international community for academic and research excellence.

Postgraduates and Postdoctoral Researchers

In 2018 the faculty's postgraduate cohort included 131 honours students, 239 MSc/MCom/MTech students, and 196 PhD/DTech students. In addition, there were 48 postdoctoral students.

The BTech, MTech and DTech is being phased out. From 2020 the articulation will be from Diploma to Advanced Diploma to Honours, MSc and PhD.

Postgraduate Master's and Doctoral Programmes

MSc

1. Agricultural Management
2. Game Ranch Management
3. Biochemistry
4. Microbiology
5. Botany
6. Chemistry
7. Computing Science
8. Geology
9. Geography
10. Mathematics
11. Applied Mathematics
12. Mathematical Statistics
13. Nanoscience (Biomed)
14. Nanoscience (Chemistry)
15. Nanoscience (Physics)
16. Oceanography
17. Physics
18. Physiology
19. Nature Conservation
20. Forestry
21. Textile Sciences
22. Zoology

PhD

1. Agricultural Management
2. Biochemistry
3. Microbiology
4. Botany
5. Chemistry
6. Computing Sciences
7. Geology
8. Geography
9. Mathematics
10. Applied Mathematics
11. Mathematical Statistics
12. Oceanography
13. Physics
14. Physiology
15. Nature Conservation
16. Textile Sciences
17. Zoology

Postgraduate Honours Qualifications

Bachelor of Commerce Honours

5 Streams

- Mathematical Statistics
- Computer Science and Information Systems
- Information Systems and Accounting
- Information Systems and Auditing
- Information Systems and Business Management

Bachelor of Science Honours

15 Streams

- Applied Mathematics
- Biochemistry
- Botany
- Chemistry
- Computer Science
- Environmental Geography
- Formulation Science
- Geographical Information Systems
- Geology
- Mathematical Statistics
- Mathematics
- Microbiology
- Physics
- Physiology
- Zoology

Undergraduate Qualifications

Although the Science Faculty has among the highest entrance requirements at the university, undergraduate students entering the faculty are often under-prepared for university level studies, especially in terms of maths competencies, English literacy and written skills. This is attributed to the recognised challenges facing many of the primary and secondary schools in South Africa today.

In spite of the students' under-preparedness however, the faculty recognises the potential of many of our incoming students. A range of interventions is in place to assist them to overcome the challenges they face as they pursue their tertiary education. Our strategic plan includes addressing the needs of all our students in this regard.

Four-year Bachelor of Science (BSc) Degree (currently known as BSc Extended)

4 streams

- Biochemistry, Chemistry, Microbiology and Physiology extended
- Biological Science extended
- Environmental Sciences extended
- Geosciences extended

Three-year Bachelor of Science (BSc) Degree

6 Streams

- Biochemistry, Chemistry, Microbiology and Physiology
- Biological Sciences
- Computer Science
- Environmental Sciences
- Geosciences: Geography and Geology
- Physical Sciences and Mathematics

Our Six Strategic Priorities

To determine the faculty's strategic priorities, we initiated focus groups of staff and students in the faculty, chaired by appointed staff members. Their feedback is integral to the roll out of the faculty's overall strategy and strategic priorities, discussed in this publication.

Strategic priority 1

Teaching and learning (access for success)

The focus of our teaching and learning is on undergraduate education.

Strategic priority 2

Research, training, and innovation (RTI)

The faculty needs to participate in large-scale research development such as the SKA and SA-CERN. From the undergraduate level, research and innovation is encouraged in all fields, and includes the full spectrum – from science for sustainability to blue-sky. By the end of 2019 the faculty will have established its new and revised research themes.

Strategic priority 3

Engagement

Engagement is often associated with community engagement, which is key for us, but we also extend this to include engagement with society at large, with industry and with the national and global scientific community, to enhance the outputs, reputation and visibility of the faculty. This is partly achieved through the marketing of our faculty, including our internationalisation and Africanisation strategy and achievements, our public engagement and networking and our engagement with all our stakeholders.

Strategic priority 4

Transformation

Transformation includes the focus on diversity and inclusion in the faculty, and it speaks to the transformation of systems, curricula, policies and processes that we need to address on a sustained basis.

Strategic priority 5

Resources stewardship

We need to assess our physical, financial and human resources to determine what we need, where our shortfalls lie and how to address these.

Strategic priority 6

Staff and students, experiences and wellness

We need to constantly strive to enhance our students' experience of the faculty, and to focus on staff wellness as part of the overall functioning and performance of the faculty.

Our curriculum drivers should respond to:

1. Achieving in-depth disciplinary knowledge as the foundation and platform for pursuing transdisciplinary, multidisciplinary and interdisciplinary knowledge, in order to understand and address global sustainability challenges;
2. Developing social awareness and responsible citizenship, diversity, equality and social justice;
3. Encouraging adaptive expertise and global talent mobility; our staff and students need to be able to operate in flexible or virtual digital work spaces and collaborate in networks and partnerships;
4. Enhancing creativity, innovation and entrepreneurship;
5. Developing problem-solving and critical thinking ability;
6. Developing intra- and inter-personal skills;
7. Developing communication skills;
8. Building knowledge of the Internet of things, virtual reality and artificial intelligence;
9. Developing computational and programming skills;
10. Service to society and community;
11. Ethics, accountability and integrity;
12. Literacy, numeracy and abstract thinking.

Our strategic priorities should respond to:

1. Sustainable development goals;
2. The needs of our economy and industry;
3. The national development goals;
4. Decolonisation and transformation;
5. Sustainable futures;
6. Technological advances;
7. Social justice, diversity and equality;
8. Widening access for success.

Faculty structural and organisational redesign

In support of our focus areas and strategic priorities, and the university's Institutional Organisational Redesign Project the faculty is rethinking its structural and organisational design to address key needs for optimal functioning, such as a faculty planning portfolio. Other new portfolios to be created will include the faculty resources stewardship portfolio, the postgraduate affairs portfolio, and the undergraduate affairs portfolio. A faculty manager would need to be appointed to manage these and other faculty planning portfolios.

Within the faculty planning portfolio, of immediate importance is to have a data analyst who will use the data within the faculty for strategic interventions, such as in student success and research directions.

The faculty resources stewardship portfolio will address fiscal infrastructure, financial sustainability, third stream income and human resources functions.

The postgraduate portfolio will include the honours programme, tutors and demonstrators, master's and PhDs, postdocs, research associates and SARChIs.

The undergraduate portfolio will look at the undergraduate students' experiences – from attraction and recruitment all the way to graduation. This portfolio will include teaching and learning, the curriculum, the extended programmes, BSc programmes, diploma programmes and service modules.

Ten-year strategy

Give the current status quo within the Faculty of Science the faculty needs to map a 10-year strategy which addresses the following questions:

1. The size and shape of our faculty in the 21st century.

We need to look at our enrolment numbers and infrastructure capacity, and question whether we want to be a heavily service-orientated faculty or do we want to grow the disciplines in the faculty?

Our numbers have been steady over the past 10 years – do we want to grow the numbers?

2. The number of enrolments

The number of enrolments in the other faculties we service has dramatically increased and is currently pressurising the faculty to be a service-orientated faculty instead of nurturing future science innovators, explorers, inventors, science entrepreneurs (sciencepreneurs), and growing the science enterprise. We currently have 3000 science students but we service 18 000 students.

This needs to be discussed with the university leadership and the other faculties, as servicing the other modules does not rely on the Faculty of Science alone. Essentially this is about balancing the growth in the Faculty of Science's disciplines.

3. Transformation in the faculty

The status quo needs to reflect the philosophy of diversity and inclusion in the sciences. This means changes in demographics, changes in our governance structures, systems and processes (the way we do things) and changes in the three pillars: Teaching and Learning; Research, Training and Innovation (RTI); Engagement.

The faculty also needs to address the question of access for success of its students and staff through, for example, a complete student and staff value chain, including attraction, a welcoming culture and atmosphere, and retention through support and development of both students and staff.

4. We need to address the status of research in our faculty and decide where we want it to be in the next five to ten years.

6. We need to address whether we are happy with the way we do teaching and learning in a 21st century Faculty of Science.

7. The question of engagement – how does the faculty want to engage with all of its stakeholders, internal and external.

All of these need to be answered in order to develop the 10-year strategy.

2 Teaching and Learning in the Faculty of Science

In the 21st century what it means to be an academic is markedly different from what it meant even as recently as the latter part of the last century. This change is certainly driven by whom we teach, but it is also a result of a change in who is doing the teaching.

The current era requires a more diverse academic profile, which, in turn, contributes more diverse opinions about the changing culture of academia. These demographic and cultural changes will yield rich student outcomes and graduate attributes. And whether we are ready for them or not, these changes are already happening.

As part of the diversity of who, what, when, where and how students learn, there is no longer such a thing as 'a typical professor' in the 21st century. No matter how much certain academics might cling to 'the good old days', there is no going back. We all need to embrace the possibility and challenge of creating a new kind of academic environment.

Coupled with this, our university has made a public commitment to increase access for success on our campuses and we will also see more online and blended education – technology-assisted education. To achieve this, we need to look at ourselves as academics and change the way we do certain things, including changing attitudes that perpetuate a failure mentality. It is not acceptable to tell students that our courses are very difficult and that only a few of them will pass. Instead, we need to achieve an overriding success rate of high-achieving students by investigating whether our policies, methods and approaches are still relevant, and change those that do not serve a 21st century dynamic, engaged, African science faculty.

We need to abandon outdated traditions and notions of "this is the way we have always done things" if they no longer serve us, such as how we assess our students and whether high numbers of rote-learning tests are appropriate. A 21st century faculty of science has to move with the times, with the Fourth Industrial Revolution, including embracing technology-assisted learning, and change our policies to include new and more appropriate forms of assessment. We need to introduce experiential learning as part of assessment – linking assessment to the real world, where, for example, a student studying wood technology goes out there and actually cuts wood and innovates; a student studying chemistry spends time in industry and innovates. Students in agricultural programmes should be able to feed hungry communities and students. For this type of assessment, the students write about their experience, and recommend which innovations they think could be improved upon or better applied.

As part of the faculty's 2019 strategic planning sessions, a focus group on teaching and learning has been established, which will map out the strategic framework on teaching and learning matters, including student access for success, undergraduate education and postgraduate education. The core of the group's discussion will include the science curriculum.

Curriculum innovation

At all times, we should strive to include entrepreneurship and innovation in the curriculum. Preparing our students for the Fourth Industrial Revolution also includes preparing them for the jobs of the future, as many of the jobs they are being prepared for today will no longer be there by the time they graduate. Hence, the curriculum needs to be reviewed in the context of the Fourth Industrial Revolution.

As we all know, curriculum change requires a huge amount of energy and resources, and takes approximately three years, as it has to go through the DHET approval process. But change we must, and the great advantage we have as a faculty, and given our university's recent name change, is that we have a unique opportunity to transform the way we do things, including the curriculum.

The curriculum must be of an integrated nature and it must be enabling for the students to articulate in a diverse range of opportunities.

Tutoring and Lab Demonstration

There is no formally co-ordinated, faculty-wide tutoring programme in the Faculty of Science at Nelson Mandela University and this needs to change. As part of this, our tutors and lab demonstrators (demis) need to be remunerated for tutoring and lab demonstration work. They also need to undergo intensive tutor or demi training before they can become part of the academic project in the faculty. The training programmes are vital as they are where we develop new academics and successful graduates.

A formalised programme is necessary for accountability and responsibility. It is also beneficial to postgraduate students in financial need. Those who are struggling financially, especially postgraduate students, use the money from tutoring and lab demonstration work to supplement the cost of their studies.

The tutors and demis have been funded since 2016, and the faculty will formalise this programme in 2019. This will be instrumental in assisting postgraduate students for whom the move to free higher education has not been addressed.

Our faculty is building a strong tutoring and lab demonstration programme, I want it to become known as an excellent programme by academic staff and students alike, and we will expect high professionalism and responsibility from our tutors and demis. This programme will be the backbone of the academic programme as it is the ideal forum where students can ask the tutors for help. In particular, students from under-resourced schooling backgrounds need someone to talk to, as some of them may be scared to talk to the professor or lecturer, but feel they can approach the tutors.

We will be creating a Tutoring Centre where tutors are available to students at all times and we will need to find the resources to fund this, as we will need to hire more tutors, given that we also service other faculties.

In our tutoring and lab demonstration teams we need to ensure the demographics are diverse and inclusive, as it is not productive for students to only experience one kind of tutor or demi. It has been shown that tutors and demis who can speak the students' home languages help students to feel comfortable about asking questions, including in their home language. The issue of language in tutor and demi programmes will therefore be important.

We would like to see tutors and demis becoming part of the academic staff and being included in the tearoom discussions of the academic departments, where they can discuss the issues the students are facing. Departments will be expected to have strong tutor and demi programmes.

The programme will also help to prepare future academics when they go for interviews, because of their experience as tutors and demis. I also want to see our tutors and demis being promoted to the rank of teaching and lab assistants as they progress with their postgraduate studies, as this will encourage more of them to remain in the academy. This will be the faculty's contribution to its own capacity development programme.

Who, why, what, how and where we teach

With greater access and fee-free education our university has seen a surge in the number and diversity of applicants. Such shifts in student demographics have had at least one clear result: they've changed the academy – who we teach, why we teach, what we teach, how we teach, and where we teach, and who is doing the teaching.

Who we teach

The faculty should be asking itself who are the students in the classroom, and this will inform us about the why, what, how, and where we teach. Our academics should be taking it upon themselves to find out about the students they are going to teach each year; this will assist them in preparing for their engagements with the students. Line managers, such as the heads of departments, are also taking note of who is in various classes, so that they can assign academics to teach accordingly.

The question of who we teach should be looked at not only from a numbers perspective but, importantly, from everything that has to do with the curriculum, because the curriculum is not just the content. The curriculum includes a range of different knowledges and the manner in which assessment is conducted. It also talks to conducive environments, methods and pedagogies. It involves the cultures, philosophies, ideologies, values, beliefs, histories, societies, and, very importantly, the contexts of all of these. It is important for our academics to be socially aware of who our students are and important issues that are happening in their lives. This includes external factors beyond their control – such as NSFAS paying late, which means that the students may not have textbooks, and may not have eaten before they come to lectures or tutorials.

Universities are no longer singularly committed to knowledge production for the sake of it. Academia has shifted towards helping students to use knowledge in specific new ways towards innovation.

Why we teach

Perhaps at one time, a notable percentage of students came to university to broaden their intellectual horizons and figure themselves out. Today, this is only part of it. Far more students now attend university for specific reasons and goals, including professional advancement, academic advancement, and entrepreneurial advancement, as well as to become the job creators of the future.

Vocational motivations for degree attainment are driven in part by projected job growth in industries like technology and the health sector, where there is a pressing need to solve 21st century problems and prepare students to take up jobs relevant to the Fourth Industrial Revolution, such as big data and artificial intelligence.

Universities are no longer singularly committed to knowledge production for the sake of it. Academia has shifted towards helping students to use knowledge in specific new ways towards innovation, and at this university, the Faculty of Science should be playing a leading role in this.

Over and above this, the faculty should consider the reason why we teach: for the public good, the betterment of society and a sustainable future.

What we teach

With changed goals comes changed content, which speaks to changes in the curriculum. Solving contemporary social issues requires that we view traditional teaching content from new perspectives. The end of the last century marked the beginning of a shift in which scholars from different scientific disciplines collaborated to form interdisciplinary fields such as biochemistry and geophysics, to mention two. Many academics still struggle to accept the validity of interdisciplinary fields, but 21st century students have no such restrictions. This raises the next question: are we designing curricula for ourselves as academics or for our students?

We are in the process of redesigning our curriculum requirements to ensure that all students take courses that emphasise diverse perspectives. Such additional requirements mean that certain areas of study will get a smaller piece of the curriculum than before. These shifts signal our intention to include relevant curriculum transformation.

Changes required in the curriculum at institutions of higher learning were highlighted by the student protests of 2015/16. The majority of our students want to learn about, and through, diverse perspectives; this is evident in the major cultural shift under way.

The Journey to Mathematics

By Ms Mulalo Makuvha who joined the Department of Mathematics as a New Generation of Academics Programme (nGAP) lecturer in 2018

I was born and raised in a village called Lwamondo in Limpopo, just outside Thohoyandou. I started my education journey at a school in our village called Maphuphe Junior Primary School. After I performed exceptionally well in Grade 4, the principal at the time recommended that I move to the best public school in town called Makwarela Primary School where I did my grades 5 to 7.

Just like any child in Venda, I wanted to go to Mbilwi Secondary School, which produces a 100% matric pass rate. Unfortunately, I never made it because in that year the school was flooded with applications and they made us pick a ticket with either a 'yes' or a 'no', and luck was just not on my side, so I enrolled at a school at home.

I started liking mathematics in Grade 10 after my mother hired a tutor to help me when I had failed horribly in a mathematics test. My tutor, the late Mr Mufandilani, made mathematics fun and interesting and my grades picked up, which built my confidence in my school work. I successfully matriculated in 2007 in the top three of my class.

Ideally, a pupil in grade 12 should have figured out the career path they will follow, unfortunately for me that was not the case. At that time I was so sure of what I didn't want to do. I knew by then that I didn't want to be a doctor or a nurse because of my fear of blood. Ironically I now want to be a doctor, but in philosophy.

My journey to mathematics started with a degree in electrical engineering, which I never completed, but which helped me see that mathematics was the only thing that made sense to me. In 2010 I registered for a BSc degree majoring in mathematics and statistics at the University of Venda, followed by my honours degree at Stellenbosch University.

Short-sightedly, I then decided to get a job at a bank. Working there made me realise my passion and I registered for an MSc degree specialising in Bio-mathematics at the University of Venda.

In 2018 I joined Nelson Mandela University as an nGAP scholar and associate lecturer in the Department of Mathematics. This gives me an opportunity to teach and to focus on research that blends well with my intention to register for my PhD in Applied Mathematics in 2019. My focus area is using mathematics to find ways to control, eliminate and eradicate the persistence of environmentally transmitted diseases affecting humans. This intention is to save lives and improve people's lifestyles in the most cost-effective manner.

When I become a professor one day, my heart will be where it's supposed to be because I will have contributed to helping students to love mathematics, and through my research, to coming up with solutions to real life problems.

How we teach

The notion of "the sage on the stage" is going out of style. Being a lecturer or a professor once meant standing on a podium, holding forth to auditoriums of sleep-deprived students. Now, more and more undergraduates all over the world are hungrily utilising online platforms to learn, and many hardly see their lecturer or professor face-to-face.

As a faculty we need to incorporate both forms of learning: online, and face-to-face – where discussions and other forms of student-centred learning are still required, such as laboratory and theory discussion courses. Further, as a faculty, we need to move towards modernised, digitised laboratories and away from traditional ways of conducting laboratory courses. This will be more efficient, effective and time-saving.

In the current era, we need to change the way we teach, in order to correct the pervasive problem we see in all too many students: a tendency to think they can just memorise facts, and that this counts as learning. Memorisation is no longer enough, if indeed it ever was. Students need to be able to do something with the knowledge they ingest, not just to swallow it and regurgitate it for exams. We therefore need to be focusing our pedagogy on cultivating higher-order cognitive skills and gravitating toward experiential education that emphasises the application, evaluation and creation of knowledge.

The academic environment is no longer the sole source of information, which is widely available. Academics are becoming facilitators of knowledge, helping students to approach, assimilate and work out how to use knowledge.

Labs have always been part of courses in the natural sciences. Students need to be doing textual analysis and original research in the labs from undergraduate level. Undergraduate students should be encouraged to analyse, synthesise and critique other perspectives while developing their own ideas about concepts.

The Journey to Statistics

By Ms Lesego Sepato who joined the Department of Statistics as a New Generation of Academics Programme (nGAP) lecturer in 2018

I completed my undergraduate studies at North West University (NWU), majoring in mathematics and statistics. I didn't know anything about statistics when I first enrolled at university, but I knew I wanted to do mathematics, as this was the subject I found most challenging and interesting during my high school years.

As the year progressed, I found that I had developed a passion for statistics. I then went on to complete my BSc Honours (cum laude) in Statistics. In 2013, academia 'chose me' and I was appointed as a contract junior lecturer at North West University. I later registered for an MCom in Statistics at NWU and completed my studies in 2017. My MCom dissertation was titled *A comparative analysis of ARCH and GARCH type models before and after the removal of outliers.*

In June 2018 I took up an nGAP lectureship in Statistics at Nelson Mandela University where I am registered for my PhD. My area of focus will be on data science and machine learning. I am currently part of a programme with AIMS South Africa, which is a PhD preparatory programme for students doing their doctoral studies in data science. I will be working under the co-supervision of the head of the Department of Statistics, Dr Warren Brettenny, and Dr Mark Nasila, FNB's Chief Analytics Officer in Consumer Banking and the Chief Risk Office, who has a doctorate from Nelson Mandela University, where he also lectured. My PhD will be a collaborative project with FNB.

The nGAP programme comes with a lot of opportunities to uplift my professional skills. I have attended workshops that have enriched my research career and enriched me in postgraduate supervision. I have also been assigned a mentor, Professor Gary Sharp in the Department of Statistics, who will guide me through my PhD and professional journey. Given the enormous opportunity the nGAP programme has given me and the support I have been given by my colleagues in the Statistics Department, my goal is to complete my PhD in 2021.

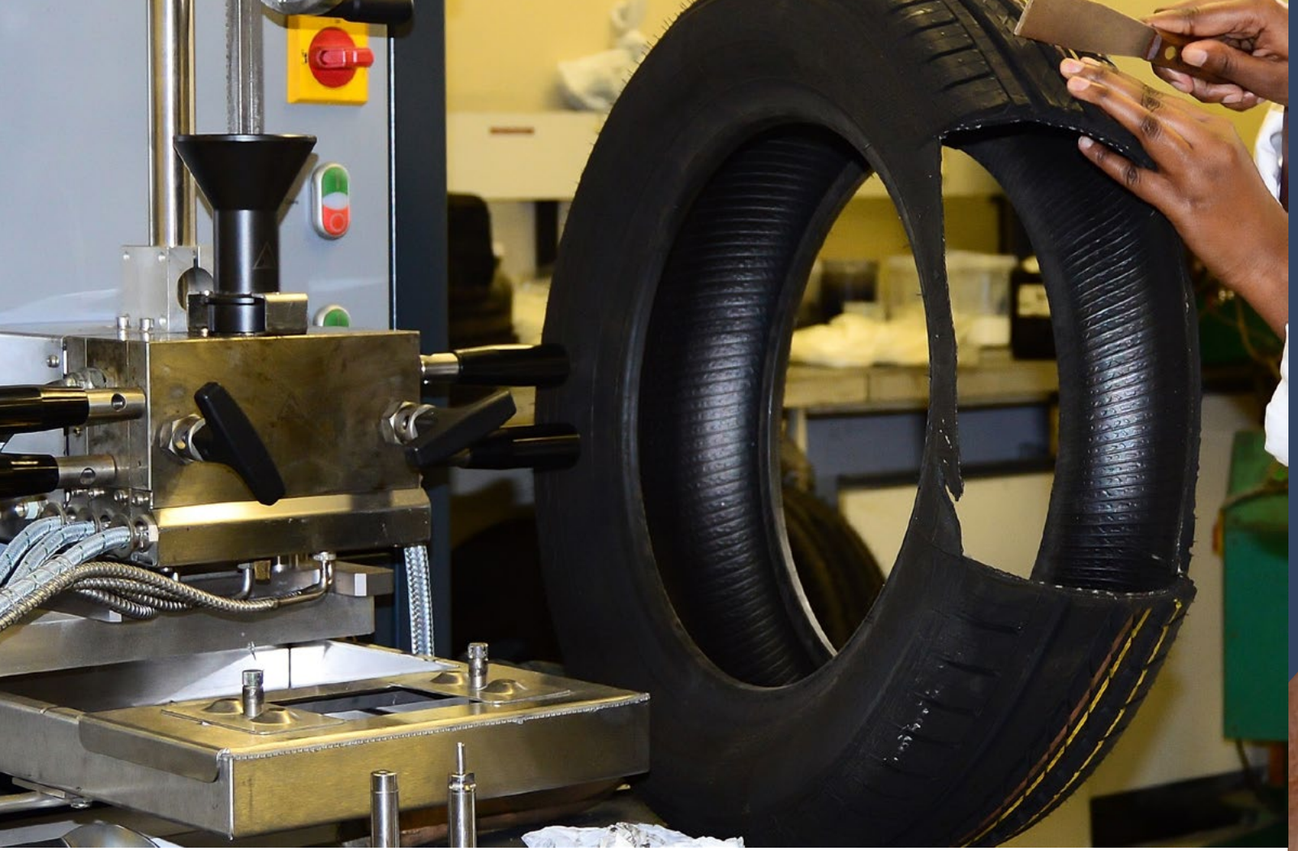
The complexity of the learning process demands equally complex assessments. We can therefore no longer rely solely on final exams to measure students' learning. We need to have more authentic assessments that require students to generate solutions for real-world problems.

The presence of more diverse people and ideas in our classrooms has also led to a focus on cultivating students' 'soft' skills, that is, non-technical, interpersonal and communication skills. We should encourage online discussion to help students practise their written communication skills. We will encourage group projects to foster the collaboration and teamwork required in most workplaces. We should develop and maintain blogs and websites to ensure that students gain experience in writing and speaking to a variety of audiences; hence our inclusion of science communication in the curriculum.

Where we teach

Where we teach needs to address the needs of a 21st century African faculty of science, such as suitable laboratories and classrooms in terms of size and shape: digitised classrooms and laboratories.

It is extremely important to create safe engagement spaces for students and staff alike in the faculty, where they are able to voice their concerns and unhappiness without prejudice.



3 Research and Postgraduate Studies in the Faculty of Science

The faculty will have to create safe spaces, and will be appointing an academic advisor with whom both the students and staff will feel safe to discuss their academic issues and work on appropriate ways to address them.

The postgraduate environment within the Faculty of Science is not conducive enough at present for postgraduate students to feel at home, and this is sometimes due to external factors beyond their control, such as the unhealthy social cohesion that often develops in academic spaces. This results, for example, in students being excluded from certain laboratory or academic spaces, which is not acceptable.

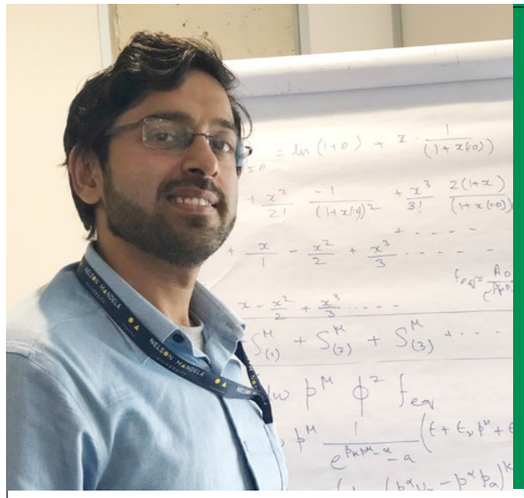
We need to proactively address this issue of academic prejudice, between academics and line managers, as this impacts psychologically and academically on their postgraduates' progress and success. This is completely unacceptable.

Further to the postgraduate issue, the faculty is going to introduce a memorandum of understanding (MOU) between each student and their supervisor, to protect both of them, and to ensure accountability in the progress of the postgraduate students.

Creating and advancing scientific knowledge and understanding

Our faculty is producing about 40% of the research output of the university. However, we should approach this achievement from a different angle, and examine our standing compared to other science faculties nationally and internationally. SciVal and Scopus are two tools of analysis and assessment that will reveal what our faculty is known for in terms of specific fields or disciplines – and this gives us an indication of what we specifically want to focus on.

These are the same tools that other universities such as the University of Johannesburg use to prominently position themselves, with certain departments elevating themselves internationally. This approach will help us to focus on marketing our recognised, existing strengths and at the same time drive specific new niche strengths in 21st century research by looking at some of the interdisciplinary, transdisciplinary and multidisciplinary opportunities in the faculty, such as in the biosciences space (including biomathematics, biostatistics, biophysics and bioinformatics).



Understanding our universe

Dr Mohammed Younus: postdoctoral fellow and research collaborator with Professor Muronga

In June 2018 Dr Mohammed Younus joined the faculty as a postdoctoral fellow and research collaborator with Professor Muronga. Dr Younus completed his PhD in high energy physics, focusing on quark-gluon plasma at the Variable Energy Cyclotron Centre in Kolkata, India, which collaborates with CERN. This level of research collaboration is destined for significant breakthroughs.

"We are trying to understand how our universe has evolved, how the different elements and matters have formed, how they got mass, how they behaved from the initial big bang of quarks and gluons and protons to form all the systems in the universe, 96% of which (notably, dark matter and dark energy) is invisible to us," Dr Younus explains. "We need to try and understand how it separated from visible matter. We don't know yet. All visible matter, including the Higgs particle, comes under the standard model conceptualised by Nobel Physics laureates, Glashow, Weinberg and Salam. Now the new thing is that people are trying to look beyond the standard model to understand dark matter and the absent 96% of total energy. There are a lot of CERN collaborations looking at different types of particles that are not included in standard models – these are yet unnamed, super symmetric particles, about which we can still only conjecture.

"The research that Prof Muronga and I are currently pursuing is part of this. It is in relativistic hydrodynamics, which has vast implications in the study of fluid mechanics in many different systems. It requires looking at how the early universe evolved to produce such dense systems as neutron stars, and we want to link this to part of the evolution of the universe.

"In our research we have to comply with the preservation of causality as described in Einstein's theories, because his theory of relativity is the only theory that hasn't yet been proved wrong. Physicists I. Müller, W. Israel and J. M. Stewart through their calculations in the 1970s tried to alleviate this problem of violation of Einstein's causality theory, which came into the picture with the theory of Eckart on relativistic hydrodynamics. Contemporary researchers like Prof Muronga are also researching the shortcomings of these theories and looking into many incomplete segments. Plenty of aspects have been calculated by other groups but there are some that are still not calculated, which we are working on, and our calculations so far are looking very good. At the moment I'm comparing my calculations with Prof Muronga's and if they are the same, then we will have some preliminary results."

Current Research Areas

From the records, the the faculty's current research areas include:

- Abstract Algebra
- Coastal and Marine Science
- Conservation and Ecology
- Disease Mechanisms and Novel Treatments
- Electron Microscopy and Analytical Science
- Financial Modelling
- Food Security and Rural Development
- Novel Materials, Products and Processes
- Renewable Energy for the Future
- Science, Maths and Technology Education for a Changing World
- Scientific Computing Solutions
- Sustainable Environmental and Natural Resource Management

By the end of 2019 the faculty will produce an appropriate, sizeable list of research themes for 2020 to 2030. As part of the faculty's 2019 strategic planning sessions we have established a focus group on research and postgraduate studies to drive the strategic framework for the faculty's research from 2020 to 2030. The focus group includes the the faculty's research, training and innovation (RTI) committee.

The faculty's new research themes will include several new niche research areas, some of which are already developing organically, and should be established as fully fledged areas from 2020. These include: material sciences, biosciences, astrosciences, theoretical and computational sciences, science education, and the history and philosophy of science.

The faculty encourages inter- and transdisciplinary collaborations, and its approach to this is based on the philosophy of an in-depth disciplinary foundation. The faculty should create additional resources to incentivise leading edge inter- and transdisciplinary research. The focus should be on new niche areas and emerging fields.

Research focus

We need a research focus that will still be relevant at the end of this century. Towards this, we need to look nationally and internationally at the big scientific projects, and to develop our research chairs to be of national and international interest, such that academics, postgraduates and students from South Africa and internationally will come to Nelson Mandela University to be part of them.

One of the biggest scientific projects in South Africa today is the Square Kilometre Array (SKA), which is going to venture into new areas of studying the universe that other scientific instruments have not been able to access. Universities that are not participating in the SKA, will, by default, be left out of future scientific discoveries. As the host of the majority of the SKA dishes, this is where the country and the Department of Science and Technology has committed to investing.

MeerKAT radio telescope. Photo courtesy of South African Radio Astronomy Observatory (SARAO)

At Nelson Mandela University, we have to foreground and develop niche SKA-related transdisciplinary research, from engineering to the basic sciences, and we need to work futuristically in this regard by putting in the groundwork towards future discoveries. Our faculties should form a Mandela SKA Chair or consortium that can grow and attract government and international investment.

Another area in which the government is significantly investing is Operation Phakisa for the 'Blue Economy', where ocean sciences play an important role. The Faculty of Science is substantially supporting and is substantially involved in the Ocean Sciences Campus and its programmes. This is self-evident, considering that the majority of our university's ocean sciences researchers are within the Faculty of Science. We are not only interested in the research side; we are also interested in capacity building, through the creation of an ocean sciences stream within our diverse faculty programme offerings.

In all research areas our staff and postgraduate students need to collaborate with peers at other universities. This includes the historically black universities, as collaboration and co-supervision ensures that all our universities interact with the best in South Africa and internationally. At the same time this reduces the brain drain of top students from the historically black universities, which are typically situated in the rural areas. With today's technology this collaboration is achievable.

Given that we are Nelson Mandela University, the onus is on us to partner with historically disadvantaged research universities. Through this engagement our university can benefit from the rural universities' niche research areas, and they can benefit from ours, such as ocean sciences. Specific research programmes can complement each other, as can relevant research collaboration with other African universities on the continent. This will be in line with our intended Africanisation and Internationalisation Strategy in the faculty.

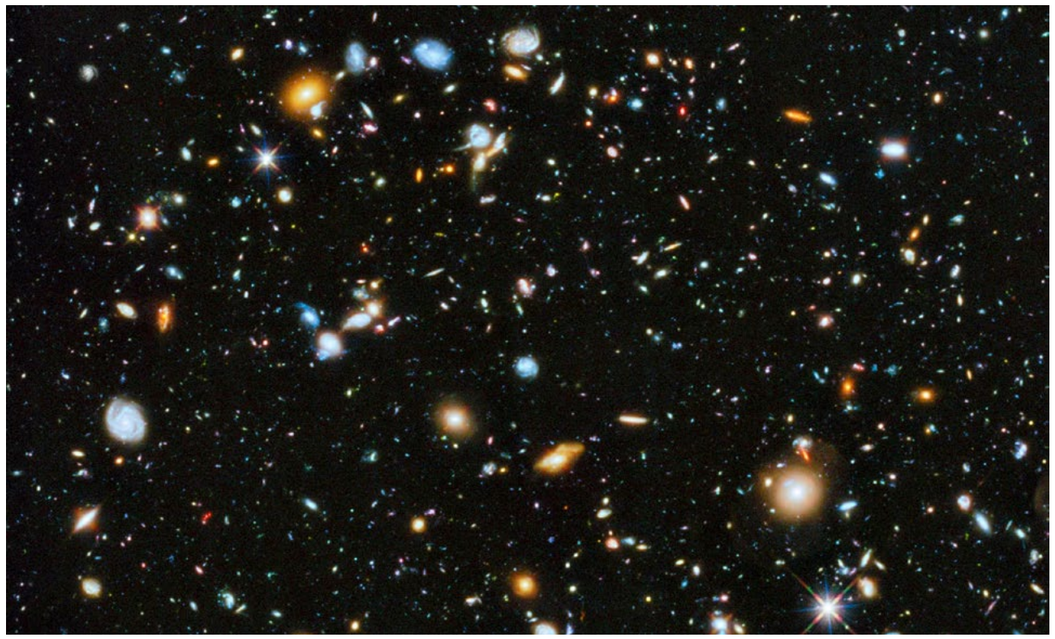
With today's technology, national and international collaborators can come to our university physically or by using digital platforms. Co-supervision is very important in this regard, and we will be addressing the stumbling blocks to what students and postgraduates need to achieve this. University systems need to be more robust to accommodate joint programmes and postgraduate qualifications that can be awarded from two or more universities. We are not there yet.

Scientific Discovery through Advanced Computing

Imagine exploring the inner workings of nature – from the structure of fundamental subatomic particles to the structure and reactions of atomic nuclei and of the properties of dense neutron stars. Imagine discovering new and exotic states of matter, and laws of nature. Imagine travelling through time to observe Earth's global climate as it changes, or travelling through the cosmos as we explore how it came about, how it is evolving and how it will end. Imagine finally understanding the inner workings of the brain, the fundamentals of genomic systems.

Scientists today can explore these realms thanks to the advent of computing power. The availability of high performance computers, graphic workstations, and high-speed networks, coupled with major advances in algorithms and software, has brought about a revolution in the way scientific and engineering investigations are carried out.

At the heart of advances in computing lie innovations in materials, assemblies and architectures that we use to process, store, manipulate and interact with information. ***(continued on page 38)***



Frontiers of the Basic Sciences

The basic sciences include the biological sciences, chemistry, physics, mathematics, statistics, computer science, and geological sciences (or clustered broadly as mathematical, physical, and life sciences). The basic sciences are important in the provision of a fundamental understanding of natural phenomena and the processes by which natural resources are transformed. The basic science disciplines underpin and are essential for the development of the emerging research areas and technology-intense applied sciences. In addition, the basic science subjects are often those required, at least in the first year, for every Science, Engineering and Technology (SET) degree.

As a faculty we have a duty to protect and nurture the basic sciences, and this is an international concern. The United Nations Educational, Scientific and Cultural Organization (UNESCO) has highlighted that they are being neglected worldwide.

While there has been a strong focus on developing emerging research areas in the country (such as nanotechnology, biotechnology, etc.) and technology-intense applied sciences (space science, information and communication technology, and energy), the support to the basic sciences discipline currently requires interventions to ensure their sustainable development.

Neglect of basic science support has led to a state of serious vulnerability of some disciplines. In some cases (e.g. mathematics and statistics), employers cannot find qualified candidates for jobs that require these, and there is a lack of senior academic staff to teach the subjects, especially at postgraduate level.

New scientific knowledge is essential not only for fostering innovation and promoting economic development, but also for informing good policy development, and as a sound foundation for education and training.

The current DST White Paper on Science, Technology and Innovation (STI) emphasises the protection and promotion of the basic sciences.

The International Council for Science (ICSU) has published a statement which states that the demarcation between basic research and applied research is not at all clear-cut. In reality they are inextricably intertwined. Strong scientific disciplines and strong collaboration between them are necessary both for the generation of new knowledge and for its application. Underdevelopment of basic sciences leads inevitably to the stifling of innovation and application.

Development of capacity in the basic science disciplines would enable the transformation of an economy from one that is dependent with regard to the knowledge required to exploit resources, to the successful independent exploitation of such knowledge to aid the conversion of the available resources to products, services and processes for the benefit of national economies.

In 1945, at the end of World War II, the Director of the Office of Scientific Research and Development in the United States, Vannevar Bush, wrote a report called *Science: The Endless Frontier*. He said: "Scientific progress on a broad front results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown." This has triggered major, ongoing debates about curiosity- and technology-driven research. If we put the question to ourselves today, can the faculty and country afford to pursue curiosity-driven research, when the call is for immediate spin-offs for the economy? The faculty should pursue both curiosity-driven and challenge-led research. Curiosity-driven research has produced fundamental advances of transformational power in the last approximately 150 years, such as quantum mechanics, genomics, antibiotics, plate tectonics, nuclear fission and fusion, the x-ray, and the theory of evolution. Many will read this document on the World Wide Web, invented not to solve a perceived problem in mass communication, but rather as an incidental by-product of particle physics research at CERN, with the aim of addressing the information sharing needs of academics. In reading this document, most of us will be using a high-speed wireless device that makes extensive use of technology developed by radio astronomers interested in processing confused, faint signals from the depths of space.

The fruits of curiosity-driven research into the unknown have often been magnificent. The recent discovery of gravitational waves or ripples in space-time, which is an experimental confirmation of Einstein's theoretical work from a century ago, was the culmination of research by large teams of scientists, with billions of dollars of research funding and government investment. It offers new ways of seeing what happens in space and detecting events

that leave little to no observable light, such as black hole collisions.

Space exploration has yielded knowledge about our solar system, such as evidence of flowing water on Mars. Anthropologists and geneticists have used genome sequencing technologies to offer evidence that early humans interbred with two other hominin species.

The list of spinoffs from curiosity-driven research is long. In the 21st century, we are entering a new stage of quantum information technology. This will be due to the evolution of quantum mechanics as a knowledge domain. In its early years it was driven primarily by intellectual curiosity. In its middle years it was symbiotic with a wide range of technologies, including the transistor.

In the context of 21st century research, trans-science will become increasingly important. Trans-science, coined by American nuclear physicist Alvin Weinberg, is science that looks into questions that are too complex for science alone to answer, such as the brain, a species, a classroom, the economy or the climate.

Trans-science, importantly, also looks into science itself, and the sociopolitical and industrial ecosystem in which it operates. It will be important to note that in doing science, we should proceed by inspecting the evidence, acknowledging our limitations, and renewing our determination to improve the connections between science and the world beyond the laboratory.

There is a virtuous symbiosis in which technology helps to push the boundaries of science while scientific breakthroughs open the way to entirely new technologies. True technological innovation often relies on the purest of curiosity-driven science, in the least predictable ways. When 19th century English physicist Michael Faraday, who made a major contribution to the early understanding of electromagnetism, was called to account for what use it had for society, by William Gladstone, who was responsible for the national budget, he replied: "Why, sir, there is every probability that you will soon be able to tax it!" In other words, charge for electricity.

Today we are indeed paying for electricity but had it not been for blue-sky research we would still be in the dark. Faraday was doing basic science, but he had the foresight to realise that through applied research his findings could one day be developed into something that would take society forward and be taxable – the electric light. Faraday had a sense of the potential of his blue-sky research and at the same time he appreciated that basic science alone is not enough. We should therefore not speak of basic and applied science as if they are binary and we have a choice. We should not have to choose. We need to foreground both for future prosperity and we need to ensure that knowledge is shared between the two in an interconnected way. This is also reflected in our faculty mission and vision statement.

Describing this interconnection, 19th/20th century English physicist and Nobel Laureate G P Thomson said his father J J Thomson, also a physicist and Nobel Laureate (the discoverer of the electron), often used the following analogy: "If government laboratories had been operating in the stone age, we would have wonderful stone axes but no one would have discovered metals." In other words if we only focus on applied science, we would have good technologies but we would not have made the giant scientific leaps of the basic sciences. The basic and fundamental sciences, very importantly, also attract bright young student scientists, whose curiosity is their driver.

Curiosity-driven research is research in pure science – research done without any application to industrial matters, but solely with the view of extending our knowledge of the laws of nature. As part of supporting curiosity-driven research, the faculty aims to establish the Institute for Theoretical and Computational Sciences. The Department of Science and Technology's new White Paper on Science, Technology and Innovation (STI) recognises the need to support, promote and protect the basic sciences.

MeerKAT radio telescope. Photo courtesy of South African Radio Astronomy Observatory (SARAO)

Shaping the Fourth Industrial Revolution

"We stand on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before. We do not yet know just how it will unfold, but one thing is clear: the response to it must be integrated and comprehensive, involving all stakeholders of the global polity, from the public and private sectors to academia and civil society." — Klaus Schwab, Founder and Executive Chairman, World Economic Forum

The Fourth Industrial Revolution (4IR) is a new chapter in human development, on a par with the First, Second, and Third Industrial Revolutions, and once again is driven by the increasing availability and interaction of a set of extraordinary technologies.

The 4IR is based on three sets of megatrends – physical, digital and biological – and involves a convergence of technologies and disciplines that is having a multisystem impact. Understanding the likely impact of the 4IR, both positive and negative, and preparing for these collectively and strategically, will be key to South Africa's future resilience.

The First Industrial Revolution used water and steam power to mechanise production. The Second used electric power to create mass production. The Third used electronics and information technology to automate production. Now, the Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century. It is characterised by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres.

The Faculty of Science will have to adopt a values-based approach to the 4IR. We will need to identify the values first; we will also need to understand how the 4IR will impact humanity on a daily basis, and determine how best to influence and shape the development of the 4IR in our local context.

We need to make sure that the outcomes of the 4IR will indeed be beneficial, and distributed fairly across all stakeholders. We need to adopt the multi-stakeholder approach in order to successfully participate and shape the 4IR. In adopting this approach we need to consider the often overlooked and left out stakeholders, and note that amongst the stakeholders are communities still struggling to reap the benefits of prior industrial revolutions, as well as considering the environment and natural world in general.

The multi-stakeholder principle makes it possible to find solutions to complex global challenges. The 'multi-stakeholder' includes business, government, civil society and academia. We further need to focus our engagements on the younger generations in our collaborations, starting with our own Faculty of Science students.

The multi-stakeholder approach to the 4IR should, in addition, be adopted by the faculty in all three pillars of our core business, namely Teaching and Learning, Research, Training and Innovation, and Engagement. This will assist the faculty in our quest to address the question of decolonisation. For example, in our curriculum we should be careful of the language used to describe emerging technologies, such as the so-called 'smart cities' as this can be seen as marginalising those living in rural areas. We don't talk about 'smart rural villages'. Why not? As a faculty we need to be mindful of being inclusive in our terminology. To not do so, goes against our quest to decolonise the curriculum.

As a Faculty of Science at Nelson Mandela University we need to understand and guide the way that the 4IR influences the world around us. To do this, the way we view and discuss emerging technologies that are shaping our world needs to change. We should not think of technology simply as some external force that will inevitably determine our future. Nor should we take the opposite view of technology as simply a tool we can choose to use in whichever way we want. Instead, we need to deepen our understanding of the way in which the new technologies connect with one another and influence us in various ways.

The faculty should take this topic of the 4IR seriously. Recently, the president of South Africa has set up a commission on the 4IR, and faculty alumnus Baxolile Mabinya and Adjunct Professor, Andile Ngcaba have both been appointed to it. The faculty stands to significantly benefit from establishing and developing new niche research areas which will shape the 4IR in accordance with our values and our context. This gives us the opportunity to develop our curriculum, which will address the opportunities and the challenges of the 4IR. The way we carry out engagement will be shaped by the 4IR, and vice versa, our engagements will make the 4IR topic popular.

Understanding the opportunities and challenges presented by the 4IR will assist us in planning our faculty strategy appropriately. Our vision, mission, graduate attributes, curriculum, research, engagement, and the enabling systems, should all reflect our understanding of the 4IR.

(continued from page 34) These cluster into fields, such as centralised cloud computing, quantum computing, neural network processing, biological data storage, optical and mesh computing. These approaches are leading to software development and new forms of cryptography. They are creating and solving cybersecurity challenges, enabling natural language processing and promising huge efficiency gains in areas such as healthcare applications and the simulation of physical and chemical processes. New computing technologies can solve some of the trickiest challenges we face.

Computational science has emerged as a powerful method of analysing a variety of problems in research, product and process development, and manufacturing. Computational simulation should be considered as a third methodology in scientific research, complementing the traditional approaches of theory and experiment. Computer simulations provide both qualitative and quantitative insights into many phenomena that are too complex to be dealt with by analytical methods or too expensive or dangerous to study by experiments.

Computational and data science offer substantial opportunities for scientific breakthroughs that cannot otherwise be realised. At many of the research frontiers, computational approaches are essential to continued progress and will play an integral and essential role in much of 21st century science and engineering. Success in these endeavours, however, requires many new tools of discovery. There will be a need to perform massive computations on an unprecedented scale and to collect, store, and analyse complex data sets at never-before-seen rates and volumes.

Undergraduate Research

We introduce the undergraduate students in our faculty to research in order to offer them this experience and to excite them to the possibilities for new discoveries and knowledge advancement. The programme supports active research participation by undergraduate students in any of the areas of research within the Faculty of Science.

Undergraduate students will present their research projects during an annual Undergraduate Research Symposium where prizes will be awarded for the best presentations in oral and poster form.

The university, through the Faculty of Science, is now an affiliate of the international Undergraduate Awards (UA), and the faculty is participating in the awards to encourage a culture of excellence in our undergraduate students.

In the next decade there will be a phased transition in terms of basic science data flows. New accelerators and telescope and observation facilities will come online and the landscape will change dramatically.

These facilities will be operating and producing data samples on unprecedented scales. Data sizes produced each year could be 200 times greater than what is being produced by today's operating experiments. In addition, these new experiments will each require a simulation programme that dwarfs what we are doing today, in order to take advantage of the expected improvement in statistical precision. Such new facilities will include SKA, as well as ocean sciences and earth observation instruments, such as satellites.

To address the computational challenge, more than hardware is needed. New algorithms to take advantage of the increase in computing power, new programming paradigms, and new ways of mining massive data sets are needed as well.

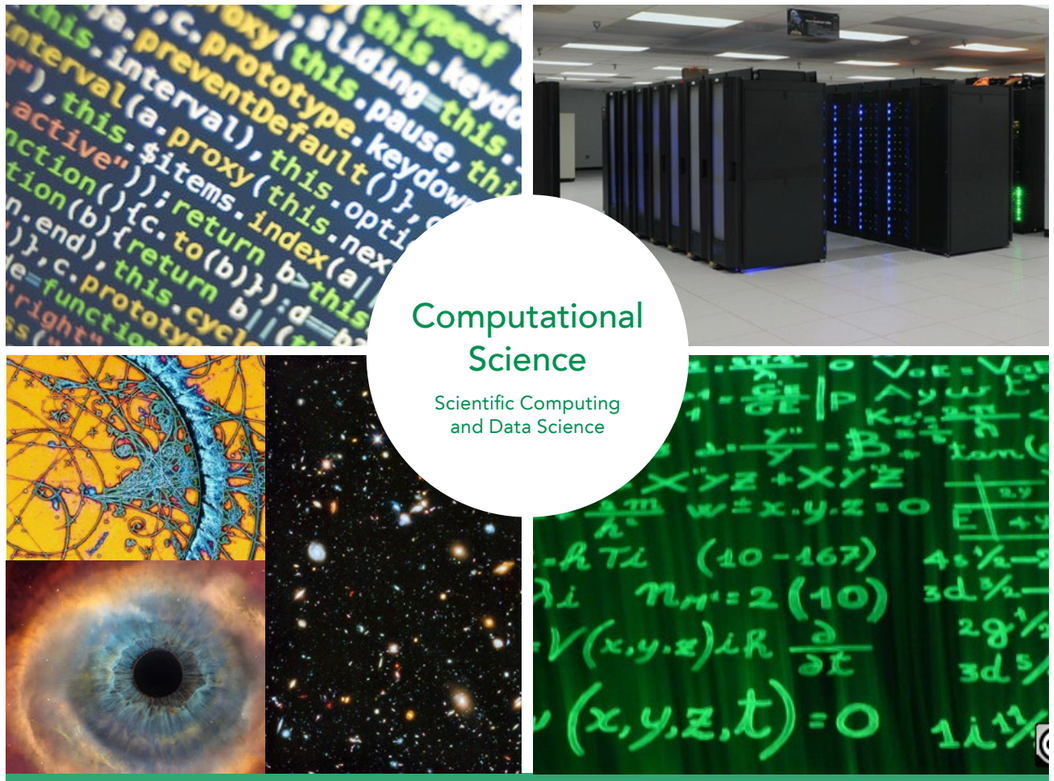
A computational sciences forum has been established in the Faculty of Science. This forum will discuss the computational needs in the faculty, as well as discussing the possibility of a Centre for Advanced Scientific Computing.

The forum will bring together many of the faculty's researchers and students to to tackle some of the the most challenging scientific problems. We anticipate a merger of the Advanced Scientific Computing Centre and the Centre for Basic Sciences to form an Institute of Theoretical and Computational Sciences (ITheoCompSi) within the Faculty of Science. Such an institute will be diverse, inclusive and transdisciplinary.

The beauty of such an institute is that we don't have to wait for it to happen sometime in the future. Our departments and entities can already grow it from the ground up in their existing clusters, and, as our needs and resources grow, it can be expanded to meet these needs. I cannot emphasise enough that if we want to play in the space of very important discoveries, such an institute is imperative.

As we know, South Africa has the High Performance Computing (HPC) community and it is good to leverage these networks but at the same time what we want to do is to train the next generation of youngsters who want to pursue scientific computing, and create jobs for the 21st century, such as big data management by data scientists, which is already huge. If we look at the SKA as an example, the SKA central computer will have the processing power of approximately one hundred million PCs.

The faculty needs to seize the opportunity of growing a niche area in big data as a fourth paradigm in research. Historically we had two dominant paradigms for scientific discovery, namely theory and experiments or observations, with large-scale computer simulations emerging as the third paradigm. Recently, there has been a boom in data science and big data. Big data has become the fourth paradigm on its own. Analysis of large volumes of complex data to derive knowledge will require data-driven computing where the data drives the computation. The faculty should assist its students to graduate with the knowledge of how to navigate the new world of data, in particular how to make sense of the big



Computational Science

Scientific Computing and Data Science

Breakthrough discoveries through advanced scientific computing

Computational science plays a key role in answering some fundamental science questions today. It is required to interpret experimental data and thus return maximum results from investments in experimental facilities, and to translate these results into new knowledge. Imagine exploring the inner workings of a supernova or travelling through time to observe Earth's global climate as it changes. Scientists today can explore these realms thanks to a 100-fold increase in computing power delivered over the past five years, and to the software and algorithms developed to harness the power of these forefront computers.

data that will be all around them in the world. As an example, the SKA will face the challenge of how to transport, store and process 14 exabytes of data which will be gathered by the antennas every day. In simple terms, the SKA will generate enough raw data to fill 15 million 64 gigabyte iPods every day. A single day's data would take almost two million years to play back on an iPod.

The interdisciplinary and transdisciplinary research principle will come alive when we embrace and utilise advanced scientific computing in our research. This will need healthy collaborations between the various disciplines. In essence, we have to move away from thinking that in 'my corner' I will discover something immense; in Nobel discoveries today, people are coming in threes, it is not about individual discovery, it is about collaborations and contributing each of our strengths locally and internationally, and sharing resources for the great discoveries.

The Faculty of Science should position itself and prepare its graduates to contribute to the big data challenge. The White Paper on STI proposes the establishment cyberinfrastructure. Facilities such as the SKA, CHPC, SARAO, SAEON, SANSA are already aligning themselves to contribute to South Africa's big data challenge.

Our task as a faculty is to ensure the next generation of graduates at our university are in the league of Nobel prizewinners who can be employed at high-level institutions anywhere in the world.

Looking into The Future

As scientists the future is out there waiting for us to discover. This future is about the future of our planet, which includes climate change, our biosphere, our demographics and the future of us as humans, which speaks to the future of medicine, genomics and genetic engineering, synthetic biology, and the future of the digital world. This includes artificial intelligence, quantum computing, the cloud, the internet of things, and cyber security.

As the Faculty of Science we need to be part of creating the future, from smart materials to clean energy, transport and robotics.

Our teaching and learning framework as well as our research and engagement should be aligned to the needs of the Fourth Industrial Revolution (4IR).

As a faculty that will increasingly be playing an important role in Africa, we need to play a leading role in the 4IR. Our curriculum and our research, and the way we do things should reflect this embracing of the 4IR. We need to embrace artificial intelligence and machine learning as part of our processes, in our curriculum, research and engagement.

In the spirit of supporting and protecting fundamental research or the basic sciences, we also need to be looking into the future in terms of asking fundamental, futuristic questions, such as about teleportation and time travel, are we 'alone' and what is our purpose in the universe?

4 Snapshot of Some of the Faculty of Science's Centres, Chairs, Institutes, Units and Departments

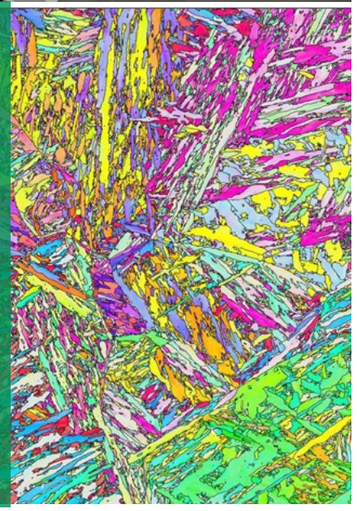
Opposite: CHRTEM PhD candidate, Samkelo Ngongo (left), with specimen preparation assistant, Nkululeko Mfuma.
Centre: High-resolution image of a diamond platelet defect showing the structure of the platelet. Defects in diamonds are of interest because of their effect on a diamond's optical and electrical properties, which have sought-after applications in fields such as quantum computing.
Left: Double aberration corrected transmission electron microscope – the only one of its kind on the African continent – enables atom-by-atom imaging resolution and atom-to-atom chemical mapping of materials.

Centre for High Resolution Transmission Electron Microscopy (CHRTEM)

The CHRTEM is a flagship facility for advanced electron microscopy within the Faculty of Science at Nelson Mandela University – and it is the only place in Africa where scientists can see atoms! "The Centre houses four state-of-the-art electron microscopes, together with the enabling infrastructure for specimen preparation and data processing. It also houses the only double aberration corrected transmission electron microscope in Africa and is the leading facility for advanced microscopy on the African continent," says the director of the centre, Professor Jan Neethling.

This multimillion-rand Department of Science and Technology and National Research Foundation funded centre was established in 2011, with the main aim of providing the enabling equipment infrastructure and expertise for nanoscale materials research and innovation in South Africa. "Such a facility is vital to support technology development and innovation in line with national imperatives such as minerals beneficiation, the transformation towards a knowledge-based economy, and energy security, as well as the support of long-term nanoscience research," Prof Neethling explains.

"We use electron microscopes to 'look inside' materials such as metal alloys, ceramics, powders, semiconductors and minerals, as well as biological and biomedical specimens. Studying how materials are put together, the nature of their atoms and the bonds between atoms, gives us an idea of why they behave like they do. This knowledge enables us to predict when materials will fail, and to develop new materials that suit our needs."



Electron Backscattered Diffraction (EBSD) map showing grain size and orientation information for a steel sample taken from one of Eskom's coal fired power plants. During high-temperature high-stress operations these grains grow in size and the material strength decreases. This EBSD map allows researchers to gain important information about the microstructure of in-service steels that can be used to assess the remaining life of critical power plant components.

Since its launch in October 2011, the CHRTEM has established itself as a leading international research facility, and has contributed to the publication of over 100 peer-reviewed articles in accredited journals, including the likes of *Nature Communications*, *Nano Letters*, *Nature Materials* and *Nature Scientific Reports*. By combining state-of-the-art microscopy facilities with expert industry and academic partners, researchers at the centre are supporting research in strategic areas including the study and development of power plant materials, nanoparticle catalysts, ultra-hard materials, optoelectronic devices, platinum and titanium alloys, novel materials and devices, and biological applications.

The centre has also made a significant contribution to human capital development through the provision of electron microscopy support and training to students, postgraduates, scientists and operators from over 70 institutional departments, including local and international universities, science councils and industry. Since its establishment, the centre has supported over 140 postgraduate degrees (~60 % black, ~40 % female), and has provided microscope training to a large number of postgraduate students through honours and master's degree training programmes, as well as MSc and PhD research projects. The centre has also provided operator training to industry members from Sasol, Eskom, Hulamin and Element Six, and to operators from electron microscopy units at universities across the country. https://chrtem.mandela.ac.za/

The Research Chair in Microfluidic Bio/Chemical Processing

An example of research conducted in the faculty that directly addresses health and wellness in our society is the Research Chair in Microfluidic Bio/Chemical Processing's project to locally produce key drugs.

"We're looking specifically at generic AIDS, TB and malaria medication. None of the Advanced Pharmaceutical Intermediates (APIs) for these medications are made locally, which also makes these drugs incredibly expensive," says Research Chair, Professor Paul Watts, who explains that over the past 10 years, South Africa's health sector has spent R120 billion importing the APIs needed to make generic medicines to treat AIDS and other diseases. And yet one in five AIDS patients goes without this life-saving medication because there's simply not enough to meet the country's huge demand for it.

"Our vision is that the new technology we have researched and developed will be used within South Africa to manufacture the APIs and generic drugs locally. This has several positive implications: it would mean that we would not need to tender overseas and we could create jobs and a new manufacturing industry within the country," continues Prof Watts, who collaborates widely with other researchers in his field in Europe and the United States and who is the recipient of Nelson Mandela University's Innovation Excellence Award.

The University has partnered with a Johannesburg pharmaceutical manufacturer, with the aim of establishing a large commercial manufacturing plant. With government approval the project will receive substantial funding from the Industrial Development Corporation (IDC).
http://research.mandela.ac.za/Research-Chairs/Chair-in-Micro-fluidic-Bio-Chemical-Processing

The Department of Chemistry

The chemistry department has established a proud reputation for its research and graduates in industrial and academic circles alike. The department hosts between 60 and 70 postgraduate students at South and North campuses as well as at InnoVenton and CSIR (PE). The department is also proud to host a South African Research Chair in the area of microfluidic bio/chemical processing which is occupied by Prof Paul Watts (research.mandela.ac.za/Research-Chairs). The department has contributed extensively to industry in the form of process chemistry and products that have made it to commercialisation. An example is a resin for the platinum industry that was produced by the Unit for Metal Ion Separation (previously headed by Prof Jan du Preez). The latest Intellectual Property Portfolio produced by InnoVenton (a research and engagement entity of Nelson Mandela University that incorporates the Downstream Chemicals Technology Station and was previously led by Prof Ben Zeelie) is that of Coalgae®, with patents ranging from processing of microalgae, to coal fines beneficiation using microalgae. The chemistry department is also privileged to be associated with the Centre for Rubber Science and Technology (CRST) under the directorship of Dr Percy Hlangothi. CRST is involved in the recycling of waste tyres into value-added materials such as polymer composites and oils. Other active areas of research in the department include; battery chemistry, polymer chemistry, solid state transitions, metal ion separation, nanomaterials, analytical chemistry, microalgae technologies, catalysis, fuel chemistry, supramolecular chemistry, bioinorganic chemistry and natural products chemistry.
https://chem.mandela.ac.za/

The Ocean Sciences Campus and SARChI Chairs

By Professor Janine Adams
Chairholder of the SARChI Chair in Shallow Water Ecosystems

Four SARChI Chairs in the Faculty of Science are located on the Ocean Sciences Campus, the first in South Africa. Launched in 2017, it will position Nelson Mandela University as the leading marine and maritime university on the continent.

The SARChI Chairs lead research in a number of strategic areas, notably marine spatial planning, law of the sea, food security and shallow water ecosystems. Funding is provided for student bursaries, running costs and equipment for a five-year period. This provides for dedicated student training and progress on addressing key research questions.

An important activity of the Chairs is transfer of knowledge through participation in policy-making advisory boards and management structures (e.g. SANParks, Department of Environmental Affairs (DEA), DEA Oceans & Coast, Department of Agriculture, Forestry and Fisheries). In 2018, for example, we had a successful estuary management course with Garden Route National Park participation and we have been asked by CapeNature and the Western Cape Government to develop a new short learning programme on the management and monitoring of coastal water quality.

Graduates from the Faculty of Science occupy a number of important positions around the country in government departments, academia and consulting companies. Innovative marine science is ongoing, with our marine laboratory, Algoa Bay, on our doorstep. Our researchers are investigating a number of areas to be included in a Marine Spatial Plan for Algoa Bay. The research involves a wide range of collaborators, for example a team of eight different institutions working together. This is funded through the NRF Communities of Practice programme.

Our university has world leaders in estuarine research currently investigating blue carbon storage, land–sea interactions and responses to climate change. In 2018, we produced the first comprehensive blue carbon assessment for South Africa's coastal habitats, and a number of postgraduate students were involved in this.

Other research includes equipment set up in key estuaries to establish whether salt marshes are eroding or keeping pace with sea level rise. These coastal habitats play an important role in protecting the land–sea margin from sea storms and erosion. Our abundance of estuaries in South Africa provide important comparative sites to conduct globally relevant research on climate change.

Coastal and marine activities and research are coordinated through our university-wide Institute for Coastal and Marine Research (CMR). The institute plays an important role in promoting transdisciplinary research on campus, in South Africa and internationally, and provides a highly stimulating environment for collaborative research and debate.

Institute for Coastal and Marine Research (ICMR): http://cmr.mandela.ac.za
Ocean Sciences Campus : http://oceansciences.mandela.ac.za

Left: Prof Nadine Strydom underwater

Our George Campus

By Associate Professor Keith Little
Senior Lecturer and researcher, School of Natural Resource Management

Through a nearly century-long tradition at our George Campus, the Faculty of Science, represented by the School of Natural Resource Management (SNRM) and the Sustainability Research Unit (SRU), has been recognised as a key knowledge catalyst for sustainable futures in the disciplines of natural resource management and environmental stewardship.

The SNRM is focused on teaching and research in the fields of forestry, wood technology, nature conservation, game ranch management, agriculture, and veldfire management. The SRU is mainly focused on research on the sustainability and resilience of social-ecological systems.

The George Campus offers a range of formal programmes that allow a student to progress to the highest levels of academic training: from National Certificates and Diplomas that provide a basic foundation, to MSc and PhD postgraduate degrees.

The programmes within the SNRM provide career-focused training with a strong focus on the practical application of the knowledge and skills necessary for a professional and entrepreneurial career in the natural resource-related industries.

Being a relatively small campus, and with many closely linked programmes within the SNRM, means that students are not only exposed to a range of social, environmental, ecological and management disciplines, but also to working with natural resources in a more holistic manner

The setting of the campus in an environment bounded by forestry (natural and indigenous), conservation areas (mountains, Karoo and coastal), agriculture, industrial and urban interfaces, enhances the principles shared in the course content of SNRM, which have relevance both nationally and internationally.

Collectively, the diversity of disciplines offered on the George Campus provides an ideal environment for cross-disciplinary teaching and research, and interface science. This includes collaborative initiatives with other research entities and with industry, at the local, regional, national or international level. We produce professional graduates who are well positioned to address the needs of resource management organisations and business sectors in a sustainable manner.

School of Natural Resource Management http://snrm.nmmu.ac.za/
Sustainability Research Unit http://sru.mandela.ac.za/

AEON is a transdisciplinary Earth Stewardship Science department with the Executive Deans of all the faculties on its advisory board. AEON is leading the transdisciplinary arena for a new way of teaching and learning (about global change for example) from first year undergraduates to PhDs, and through its citizen science initiatives.

The Department of Botany

By Dr Phumelele Gama
Acting Head of the Botany Department
Researcher in Freshwater and Estuarine Microalgal Ecology & Ecophysiology

At the undergraduate level, students interested in the biological science programme are introduced to the fundamental aspects of plant life and the critical ecological role they play in the natural environment. At postgraduate level, these natural and anthropogenically induced characteristics can be explored through real life research that attempts to address some of the negative impacts human society is having on the environment.

Through our botany programme, with modules that offer terrestrial and marine plant ecology and conservation studies, we can present current scientific innovation and understanding, using the South African context which is relevant to our society's needs, particularly in the areas of study that deal with ecological and economic ways marine and terrestrial plants can be protected as well as used sustainably. Students who graduate with a degree in botany should be able to tackle some of the pressing environmental issues facing our communities.

Some of the research work recently carried out in the department investigated and documented for the first time important ephemeral wetlands that occur in different geological substrata across different rainfall zones of the Nelson Mandela Bay Metro. This research produced a landscape map that has been incorporated into the Nelson Mandela Bay municipal spatial planning programme, which is intended to protect these and other wetlands from unchecked urban development.

Recent exciting research has been the discovery of human settlements in the southern Cape that date back about 60 000 to 70 000 years. Such evidence is internationally relevant and attracts international interest and partnerships, as it explores our ancestral origins and the fundamental development of early human societies.
http://botany.mandela.ac.za/

Department of Zoology

By Professor Nadine Strydom
Marine biologist and Acting Head of Department

The Zoology Department is a centre of excellence in zoological and environmental research, appropriately situated within a nature reserve on our Summerstrand Campus. It serves to educate and promote the study of a wide range of both terrestrial and aquatic animals in mostly African ecosystems. Animal research is facilitated by close proximity to national parks with the Big 7 (lion, elephant, buffalo, leopard, rhino, white sharks and southern right whales) as well as many rivers, estuaries and ocean environments. Our students are provided with a range of practical experiences beyond the classroom. Undergraduate courses are offered in aspects of animal anatomy, biodiversity, terrestrial and aquatic ecology, evolutionary ecology, ichthyology, fisheries ecology, animal genetics, animal physiology, animal–people interactions, animal resource harvesting and management, aquaculture and toxicology.

Our staff are internationally recognised for their expertise in disciplines including fish ecology, planktology, marine top predators, cetaceans, sandy beach ecology, small mammal and bird physiology, megaherbivore and carnivore ecology, including studies on charismatic and endangered species. The undergraduate curriculum as well as postgraduate research are an important mix of both Africanised and internationally applicable content, which provides an educational environment that enables our graduates to be internationally competitive in job seeking and research. The department celebrates its 50th anniversary in 2019.
http://zoology.mandela.ac.za/

InnoVenton

By Gary Dugmore
Acting Director of InnoVenton and the Downstream Chemicals Technology Station

InnoVenton is an institute of Nelson Mandela University that has been operating in the Faculty of Science since 2006. Its purpose is to leverage its position and resources to develop, implement and support technology in the chemical and related sector for tangible socio-economic impact that supports local, regional and national priorities.

InnoVenton has built up impressive facilities and equipment over the past 12 years and has been successful in leveraging grant funding to generate additional income as commercial income and/or additional grant funding. For example, the Technology Station core grant (27% of income) was leveraged to bring in additional project-based income (36%), and the InnoVenton asset base leveraged to generate further commercial income from services (15% of total income).

The institute's primary function is research and development (R&D) for the purpose of commercialising the technologies it develops through Innovation Fund funding, technology transfer funding and co-investments. Over the past 12 years, InnoVenton has averaged 4.2 technology development projects completed per year.

InnoVenton provides:

- training in areas such as GLP (Good Laboratory Practice – regulatory compliance training for the pharmaceutical industry), GMP (Good Manufacturing Practice – both primary and secondary manufacturing), and corporate entrepreneurship and/or technopreneurship.
- technology support, specifically to SME industries lacking the infrastructure and capacity to undertake in-house product and/or technology development or improvement projects. And,
- contract R&D (nationally and internationally), specifically in the area of downstream chemical process development in the newly erected Kilo-lab facility.

In 2006, InnoVenton was awarded a grant contract to operate a Technology Stations Programme (TSP) focused on the downstream (value added) chemicals sector, as part of the Technology Innovation Agency (TIA). The TSP provides technology development services to small and medium enterprises (SMEs). The Technology Stations provide innovative science, engineering and technology solutions for complex engineering challenges within the relevant industrial sectors, aimed at supporting government's socio-economic priorities.

InnoVenton's major project is the Algae Project, initiated in 2008 and centred on the cultivation of microalgae, with the objective of recycling carbon dioxide and conversion of the biomass to produce renewable energy. The project is currently funded through the DST's Technology Innovation Programme: Hydrogen & Energy, under the Transport Fuels directorate.

A technical demonstration phase has been completed for the production of Coalgae®, an agglomerate of waste coal fines containing 10–15% microalgae as the renewable component of a solid fuel. The current phase of the project is focused on conversion of Coalgae® to liquid transport fuels through various technologies, and the development of higher value products from the biomass in order to strengthen the business case for Coalgae®. This is a significant sized project in relation to the size of InnoVenton and therefore poses both opportunities and threats that must be considered. The current economic situation means there will be a smaller pool (at least in real terms) of public and private funding for Research, Development & Demonstration (RD&D). Funders, especially government, will require demonstrable evidence that outcomes are aligned with the country's development agenda: the National Development Plan, transformation, entrepreneurial activity and job creation.
http://innoventondcts.mandela.ac.za/

AEON – Africa Earth Observatory Network and its Earth Stewardship Science Research Institute

Professor Maarten de Wit

aeon.org.za

AEON is a transdisciplinary Earth Stewardship Science department with the Executive Deans of all the faculties on its advisory board. AEON is leading the transdisciplinary arena for a new way of teaching and learning (about global change for example) from first year undergraduates to PhDs, and through its citizen science initiatives.

The AEONetwork provides a university-wide research and education environment to seek unity of knowledge through intertwined earth and life sciences, engineering, economics, human and cultural sciences, with Earth as a commons and Africans exploring and solving complex problems, particularly for Africa.

One of its flagship programmes is *Iphakade: Observe the present and consider the past to ponder the Future.* It reflects the essence of Earth Stewardship Science where science is used in the broadest sense of the word, covering all fields of scientific enquiry and testing.

A second flagship programme is *Africa Alive Corridors (AAC),* endorsed by Nelson Mandela, in which AEON is documenting and visualising a transdisciplinary autobiography of Africa, with everyone as a stakeholder in addressing stewardship for Africa. AAC is being script-written by leading academics across the world, and choreographed by African students, learning along 20 pan-African corridors designed to provide pathways and focal points along which learning about Africa's origins and cultural history is explored; and where Africa-wise management of its resources may be realistically achieved. For example, AEON collaborates with the Department of Business Management's research on the triple bottom line of businesses along the pan-African corridors.

Another flagship programme is linked to developing baseline data in anticipation of complex industrial development and urbanisation. The first baseline research project is linked to potential shale gas development in South Africa. In ensuring readiness for shale gas exploration and recovery in the Karoo, the Eastern Cape Government through its Department of Economic Development, Environmental Affairs and Tourism (DEDEAT), mandated AEON to undertake research into the natural baseline conditions, the quantum of shale gas underground and the socio-economic and health impacts. The first four-year research report has recently been completed (online: www.aeon.org.za)

All research, engagement and learning at AEON is entirely collaborative and cuts across many disciplinary boundaries with a deep Africa focus that touches on themes as varied as its human and natural history and resources, mining and ecological economics, geothermal energy, water, ocean health, shale gas baseline and related ecosystem services, resource extraction, mine tailings, drainage and linked hazards, and mimicry of nature through geobioengineering, humanities and culture, citizen science and politics, art, filmmaking and storytelling.

Management of AEON and the development and implementation of its operational and business activities are done through its Managing Director Professor Moctar Doucouré. The scientific stewardship of AEON is led by its Science Advisor Professor Maarten de Wit.

Sustainability Research Unit

By Dr Bianca Currie

Director of the Sustainability Research Unit (SRU), George Campus

We are a transdisciplinary hub for new thinking, where scholars, decision makers and practitioners gather to deliberate social-ecological problems and re-frame them as opportunities, which the SRU helps to address through proactive research. The Garden Route is our laboratory, and our work has national and international relevance in advancing a new understanding of sustainability through engaged science: connecting society to the biosphere. Our multidisciplinary team provides research supervision that spans the ecological, social and economic disciplines. The unit's inclusive, humanising culture provides the space for motivated students and academics to grow and thrive.

The SRU hosts an annual research associate symposium which brings together research associates, academics, students and practitioners to discuss the impact of ongoing and new research in the field of natural resource management and its allied disciplines. In 2018 the unit hosted the Western Cape Biosphere Reserve Research Workshop, a landmark event that brought together researchers and managers on the ground who are grappling with reconciling the human–nature needs in the UNESCO biosphere reserves of the Western Cape. The event was designed to inform a research agenda for academics working in and around biosphere reserves.

Also in 2018 the SRU co-hosted the Garden Route Interface Meeting (GRIM), a conference attracting academics and practitioners working within social-ecological systems. Academics from South Africa, Canada, Finland and France attended. A spring school on social-ecological systems was linked to the event, and aimed at developing the capacity for postgraduate research in these systems.

The current research projects undertaken by members and students in the SRU include: research into climate change adaptation in the Tsitsikamma dairy industry; research into human–wildlife conflict (focusing on the baboon–human relationship on the George Campus and surrounding areas); governance and ecosystems services related to protected areas; community engagement in the forestry sector to combat incidences of human-induced fires; and exploring the rural–urban interface, and land use in and around small towns.

sru.mandela.ac.za

5 Faculty of Science Top Researchers for 2017/18

NOTE: These research awards were presented in 2018 and reflect research conducted in the previous year and ongoing in this year.

Professor Janine Adams

Department of Botany

Director of the Institute for Coastal and Marine Research (ICMR)

SARChI Chair in Shallow Water Ecosystems from 2018

Nelson Mandela University Researcher of the Year Award

In acceptance of the award, Prof Adams wrote: It was an honour to receive this award acknowledging my research outputs and the success of my research group, which includes 20 people, including postgraduate students, postdocs and research assistants. We are a large group making a significant contribution to understanding South Africa's estuarine environments.

My passion for research lies in exploring our diverse estuarine ecosystems, while working with others in multidisciplinary teams and growing our next generation of scientists. During the 2016/17 year I published 20 articles in rated journals with researchers from 11 different national and international institutes, which indicates the multidisciplinary collaborative nature of my research.

The purpose of this research is to investigate the health of South Africa's estuaries and to help develop appropriate conservation and management responses. My current focus areas are 'blue carbon' ecosystems and response to climate change, mangrove and salt marsh ecology, and management of water quality in estuaries.

Estuaries are complex, dynamic and productive ecosystems, as they form the interface between marine and freshwater environments. They are threatened by development, changes in freshwater inflow, deterioration in water quality and resource utilisation.

Research on the role of microalgae and macrophytes as indicators of change has been used to assess the ecological health and importance of estuaries and is globally recognised. In 2016/17 my research provided a detailed understanding of estuary structure and function: important information to support conservation and management efforts.

My research is driven by my desire to bridge the science–policy–practice divide. I like to tackle problems and find solutions working collaboratively with local management authorities and a wide group of stakeholders. I also enjoy working with students and seeing their growth and development into excellent research scientists.

For the future, I would like to focus on restoration of estuaries and rebuilding our green infrastructure. Healthy estuaries and other coastal habitats are essential in order to ensure that they deliver the ecosystem services that we are dependent on. It would have a socio-ecological systems approach that would involve many collaborators.

Distinguished Professor Graham Kerley

Director of the Centre for African Conservation Ecology

Research Excellence Award and Faculty of Science Researcher of the Year Award

In acceptance of the award, Prof Kerley wrote: The awards reflect my work in the field of African ecology, and specifically the papers that my team and I produced in 2016. These 13 peer-reviewed papers cover topics as diverse as predator–prey interactions, and historical ecology; the perspectives of the papers are both highly applied (largely in the field of conservation biology, but also human–wildlife conflict) and strongly theoretical (in evolutionary ecology).

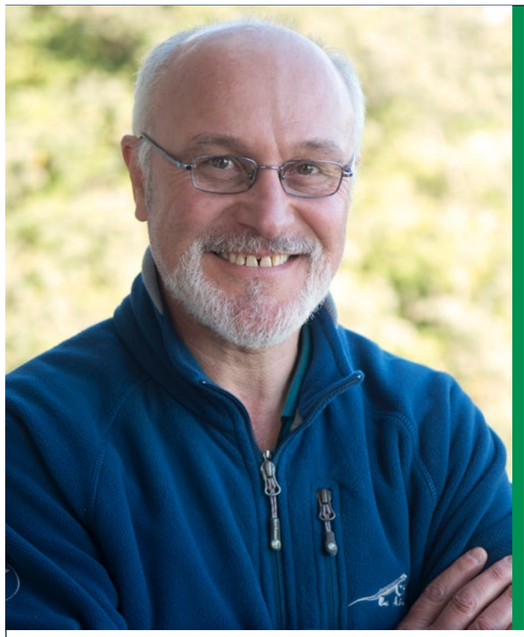
The study on jackal, for example, provides the first evidence that the killing of jackals by livestock farmers does not solve the livestock predation problem, as the jackal respond by breeding younger and faster. The paper on the historical distribution of mammals has been recognised as one of the 20 most influential environment studies published in the Transactions of the Royal Society of South Africa since 1877.

In the 2017/18 period I published several more papers on research of global significance, including research on Africa's unique megaherbivores – elephants, rhinos and hippos – which could potentially play a major role in mitigating climate change. I am one of six authors of "Trophic rewilding as a climate mitigation strategy?" a paper attracting global attention, which was published on 22 October 2018 in the world's oldest scientific journal, *Philosophical Transactions*.

We already have various strategies and goals for carbon emission reduction and carbon sequestration but what are the additional opportunities out there that can significantly contribute to the toolbox of climate change mitigation? This study looks at an area that has not been addressed previously: the role of large or megaherbivores in mitigating climate change.

The study emanates from speculative discussion between scientists at a global level and proposes a fascinating approach, with Africa as the living laboratory. Unlike the rest of the world, we have not lost our megaherbivores, and we are therefore perfectly placed to lead the world in understanding how these animals influence the landscape and climate.

The deeper value of my research is that these studies and papers feed directly into my teaching, and so, in addition to the sheer thrill of developing new ideas, it is hugely stimulating to be able to use this work to inform and hopefully inspire the next generation. Furthermore, this approach allows us to directly contribute to the process of bringing science ever more prominently into an African context. We need to encourage and empower bright young people to help society in overcoming future challenges and pressing problems. How we manage our environment and benefit from biodiversity is clearly one of the greatest issues facing humanity.



Professor Renzo Perissinotto

SARChI Chair in Shallow Water Ecosystems
until 2018

Research Excellence Award

In acceptance of the award, Prof Perissinotto wrote: The key areas of research undertaken during the period of the award can be summarised as follows:

- Biodiversity, ecological functioning and rehabilitation of Lake St Lucia, iSimangaliso Wetland Park (KwaZulu-Natal);
- Biogeochemistry of living stromatolites along the Eastern Cape coastline;
- Characterisation of micro-estuary systems along the eastern and southern Cape coast; and
- A baseline study of the biodiversity and ecology of wetlands in the Karoo region earmarked for shale gas exploration.

Among these, the most novel advancements were achieved in the research we undertook on the extant stromatolites recently discovered along the Eastern Cape coast. These are essentially living fossils that date back at least 2.7–3.5 billion years in the Earth's history. In the Archean aeon, the cyanobacteria involved in the formation of hard deposits and reefs that formed stromatolites comprised the first photosynthetic algal organisms responsible for transitioning the Earth's atmosphere into its current, productive, oxygen-rich state. Modern stromatolites are scarce globally for two primary reasons: firstly, ocean chemistry has shifted from conditions which were once rich in calcium carbonate; and secondly, animals and higher-level algae have now evolved that can outcompete or graze upon and disrupt the stromatolite matrix.

More than 500 living marine stromatolite systems have been discovered along a 200 km stretch of South African coastline, between Cape Morgan in the east and the Storms River mouth in the west, which has allowed us to understand the reasons for their continual survival and the threats posed by anthropogenic activities and climatic change along this coastline. We were also able to make a very significant contribution to our understanding of the pressures and dynamics that these partial analogues of ancient stromatolites may have been exposed to in the distant past, especially with regard to how these may have shaped evolutionary processes in modern metazoans.

Our research team's plan for the future is to undertake a comparison of the trace element composition and rare earth element fractionation patterns of ancient and extant South African stromatolites. This could clarify the validity of the interpretations of the biogenic origin of ancient stromatolites and the suggestion that modern stromatolites are counterparts to the Archean structures. These investigations will, therefore, prove important to addressing problems regarding the origin of life, paleo-environmental conditions, and the search for extraterrestrial life.

Chemistry Excellence Awards 2018

In 2017 Professor Zenixole Tshentu, Head of the Department of Chemistry, instituted annual excellence awards for students in the department.

In attendance at the awards ceremony on 19 April 2018 were staff members from the Department of Chemistry, students nominated for the excellence awards and their guests. Opening the event, the Master of Ceremonies, Mr Nehemiah Latolla, a second year PhD Chemistry student, said:

"To contextualise this prestigious event, I would like to share a quotation by our namesake, President Nelson Mandela, who said, 'Education is the great engine of personal development. It is through education that the daughter of a peasant can become a doctor, that the son of a mineworker can become the head of the mine, that a child of farm workers can become the president of a great nation. It is what we make out of what we have, not what we are given, that separates one person from another.'"

The Director of the School of Biomolecular and Chemical Science, Professor Gill Dealtry emphasised the importance of these awards in recognition of excellence, as well as the teamwork displayed by colleagues in the Department of Chemistry and InnoVenton.

Prof Tshentu congratulated the award recipients for their commitment to excellence, and elaborated on this by quoting American football star Vince Lombardi who once said, "Perfection is not attainable, but if we chase perfection, we can catch excellence." Prof Tshentu also quoted Aristotle, who observed that "Excellence is a habit".

"In addition," said Prof Tshentu, "excellence is made continuous by the need to continue a process such that the experience is achieved all over again". He encouraged the award winners to continue to shine everywhere they go.

The Department of Chemistry awarded 139 students with diplomas and degrees in the graduation ceremony on 19 April 2018 for the following qualifications:

- BSc with Chemistry major (24 students),
- BSc Hons in Chemistry (8 students, graduated in December 2017),
- Diploma in Analytical Chemistry (39 students),
- Advanced Diploma in Analytical Chemistry (3 students),
- Diploma in Polymer Technology (9 students),
- Diploma in Chemical Process Technology (27 students),
- Bachelor of Technology in Chemistry (2 students),
- BSc Honours in Formulation Science (4 students),
- Master's degrees (2 MTech, 1 MSc Nanoscience and 8 MScs in Chemistry) and
- PhDs in Chemistry (4 students).

Prof Tshentu thanked both academic and support staff for their input to the academic project, as well as the coordinators of programmes for their sterling work. He noted that the Department of Chemistry is proud to be associated with the Centre for Rubber Science and Technology (Dr Percy Hlangothi as Director), InnoVenton (Dr Gary Dugmore as Director), uYilo (Prof Ernst Ferg as Director) and the DST/NRF SARChI Chair in Microfluidic Bio/Chemical Processing held by Prof Paul Watts. "These associations continue to make a significant contribution to the success of our department," he said.

The awards were presented to the students who obtained the highest marks, with distinction.

- Best student for Diploma in Analytical Chemistry (Ms Nicole Naidoo)
- Best student for Diploma in Chemical Process Technology (Ms Nosibusiso Jokani)
- Best student for BSc Honours in Chemistry (Mr Jordan Slabbert)
- Best student for BSc Honours in Formulation Science (Mr Siyabonga Shoba)
- Best student for MSc in Chemistry (Mr Tendai Dembaremba)

6 Engagement in the Faculty of Science

A Community Engaged Faculty of Science

Executive Dean, Professor Azwinndini Muronga talks about the faculty's approach to engagement:

From the time I assumed my role as Executive Dean, I have recognised the opportunity for placing engagement within the Faculty of Science at the same level as our teaching and learning, and research and innovation activities. I have written about this in the mainstream media where I have made commitments to public engagement with science.

In 2019 Senate approved the establishment of a Faculty of Science Engagement Committee. This is a one-year pilot initiative, and the first of its kind at a faculty level in our university. Other faculties and the university as a whole have Research and Engagement Committees, but the Faculty of Science saw fit to have separate Research and Engagement committees. The rationale is that the Faculty of Science is research intensive and therefore if Engagement is bundled with Research, Engagement will suffer. The faculty is also significantly expanding our engagement activities, which warrants a stand-alone committee. Engagement is also a core focus of the university, and our vision is to be an engaged, dynamic African faculty of science.

As an engaged faculty we should not treat public engagement as an 'add on' or fringe activity. We should:

- Embed public engagement into the way we approach our work;
- Have activities in place which incorporate public engagement into our research, knowledge exchange, teaching, and social responsibility;
- Embed a commitment to public engagement in our faculty mission and strategy, and champion that commitment at all levels; and
- Actively involve staff, students and representatives of the public, using their energy, expertise and feedback to shape the engagement strategy and its delivery.

There are several activities the faculty is undertaking in this regard, such as engaging with the Department of Science and Technology (DST) and the Eastern Cape Department of Education in an engagement strategy framework for science outreach and science education, to establish a culture of science and mathematics education. This very much includes the Eastern Cape's rural areas, such as our Cala, Mvezo and Cofimvaba projects, which combine maths, science and IT educational advancement programmes in the region's schools and communities.

As a faculty, at the same time as we introduce exciting new developments and systems, we need to significantly strengthen our multimedia science communication skills for the benefit of all our stakeholders

We are also engaging with the Eastern Cape Socio-Economic Consultative Council (ECSEC) as a potential partner in the maths and science challenges that our faculty is attempting to address in the Eastern Cape schooling system.

We are strategically partnering with the Department of Science and Technology and the South African Agency for Science and Technology Advancement (SAASTA) in science communication activities. Together with DST and SAASTA we are in the process of developing a science communication curriculum.

In 2017 we held the launch of the National Science Week, hosted by the Minister of Science and Technology. We were the first faculty to have a pre-launch programme of activities, which we ran successfully. About 6000 learners from schools in the Eastern Cape, mainly in the greater Nelson Mandela Bay Metro, attended the pre-launch, launch and National Science Week programme.

In 2017 we hosted two maths and science teacher development workshops at Nelson Mandela University. Our primary strategic faculty partner in addressing basic education challenges is the Faculty of Education, with whom we have developed a healthy working relationship. With the Faculty of Education we hope to address the educational challenges through programmes from Grade R in the Foundation Phase all the way through to undergraduate level at university.

There are fine examples of how these partnerships are working well, based on, for example, the Vhembe region in Limpopo, where I have coordinated and participated in science engagement projects in partnership with the educational and local authorities in different villages. A number of schools in the Vhembe region are excelling in maths and science because of the culture of maths and science in their communities and the commitment of the leadership there, while schools in other regions of the Limpopo province that do not have this culture, are dysfunctional.

We have also started engaging with other faculties in programmes such as "Art meets Science" with the Faculty of Arts. We need buy-in from each department for this, and for each to develop key performance indicators and achievements.

The Science Centre

Now that I am at Nelson Mandela University I believe that the Missionvale Campus would be an excellent location to house a Science Centre and related programmes. Since the Faculty of Education also has a base there we could pursue research coupled to this programme with postgraduate students and postdocs from the two faculties jointly collaborating.

The Faculty of Science will work towards an improved model of a Science Centre that will be suitable for learners and educators in Nelson Mandela Bay and surrounding areas. This model will also serve as a hub and example of good practice for the Eastern Cape and in the greater George area and other parts of the southern Cape.

Taking science communication to the centre stage

As a faculty, at the same time as we introduce exciting new developments and systems, we need to significantly strengthen our multimedia science communication skills for the benefit of all our stakeholders, notably our students, the academic and non-academic community within and outside of the faculty, government, business, funding organisations, communities and society.

Once we win on science communication engagement, our impact, outreach and reputation will take a giant stride forwards and we will be able to achieve so much more in many different ways, including attracting partners.

For example, it required strong science communication skills to be able to convince government and funding organisations that the Ocean Sciences Campus is imperative, which the university achieved. Now we need to take communication much further. Part of the reason for the significant failure rate in science is that many of our academics, as accomplished as they are, are unable to properly communicate their field to our students.

We want to embed science communication within our curriculum goals to be better teachers in the classroom and good communicators of our fields of study and research in our interactions with students, as well as with government, industry, communities, journalists and citizens. Showing a few graphs in a PowerPoint presentation is not good enough: we need to clearly explain what we are doing and why, in a way that people get what we are saying, are interested in hearing more, and understand the importance of it. Climate change is a good example. If we look at how climate change is generally explained, it is little wonder that few people really understand what it is.

In our faculty, if we do not develop strong science communication skills, our students are faced with the double challenge of not being able articulate their science and purpose themselves, and of not seeing how it fits in with what they want to pursue in their careers. Students who cannot articulate their science will not, for example, do well in interviews.

In our communities we need to spread the word about the excitement of science. We need to go into the rural areas and talk about science; we need to form bonds with the traditional leaders, royal families, leaders, principals and teachers in our rural communities who will influence learners to want to study maths and science. For example, the royal council of one community contacted me and asked about the requirements for their Grade 11 learners to qualify to study science at Nelson Mandela University. They see us a friend because they can contact the faculty and talk directly to people here.

Science communication is also a two-way engagement: there is so much that our faculty can learn from our villages and rural areas, opening doors for postgraduate research in a partnership of trust and mutual respect; the impact of this can be huge.

Faculty of Science Engagement Strategy

From our vision statement we want to be known as an engaged Faculty of Science.

We are in the process of discussing the Science Engagement Strategy. The strategy seeks to inspire, engage, and educate the future workforce, explorers and innovators while creating citizens who engage with science,

For the purposes of this strategy, the use of the overarching term 'science engagement' includes all aspects of public engagement with science, science communication, science literacy and science outreach and awareness. In addition the Science Engagement Strategy focuses on partnerships with other higher education institutions and research and training facilities, industry relations and partnerships, African and international relations and partnerships, and marketing.

The Science Engagement Strategy framework is intended to provide an overarching structure for advancing science promotion and engagement in the faculty, university, Eastern Cape and South Africa, Africa and internationally, in pursuit of a society that understands and values science and technology and their critical role in national prosperity and sustainable development, and that engages critically in their development.

In this context the Science Engagement Strategy embraces a broad understanding of 'science' and 'the sciences', encompassing systematic knowledge that spans natural and physical sciences, engineering sciences, medical sciences, agricultural sciences, mathematics, social sciences and humanities, technology, all aspects of the innovation chain, and indigenous knowledge. Public engagement requires awareness and the discussion not only of scientific and technical matters, but also of societal and attitudinal aspects.

From a citizen-centred approach, public engagement encourages people to join the public dialogue about a problem or issue, and provides them with the tools to do so productively. The two-way dialogue model emphasises the importance of listening and interaction as key characteristics of public engagement, and is inclusive of issues from a combination of scientific, social, political and technical perspectives. Upstream engagement that attempts to capture public involvement in setting the values and priorities that direct scientific research, is regularly conducted in applied research areas like nanotechnology.

The faculty's Science Engagement Strategy is inclusive of all knowledge fields insofar as it draws on a wider social scientific perspective to explore the value of public engagement in the context of a broad, progressive understanding of 'Science'. By integrating the natural sciences, engineering, and social sciences and humanities, it aims to foster better, more valuable science engagement.

At the core of the strategy are four major aims, under which several proposed or existing interventions or initiatives are outlined. To a great extent, the faculty's existing science engagement activities already overlap with many of those indicated in this document, but this strategy provides a systematisation and organisation of those initiatives, with the intention of enhancing their collective impact.

Strategic Aim 1: To popularise science, engineering, technology and innovation (STEMI) as attractive, relevant and accessible in order to enhance scientific literacy and awaken interest in relevant careers. To attract and retain students in STEMI disciplines along the full length of the educational pipeline.

Strategic Aim 2: To develop a critical public that actively engages and participates in the national discourse of science and technology to the benefit of society. To inform, engage, and inspire the public by sharing the faculty's mission, research, challenges and results.

Strategic Aim 3: To promote science communication that will enhance science engagement in South Africa.

Strategic Aim 4: To profile the Faculty of Science, its science and science achievements nationally and internationally, demonstrating our contribution to national development and global science, thereby enhancing our academic and public standing. To engage the public in the faculty's science activities by providing new pathways for participation.

Science Education, Communication and Outreach Programme (SECOP)

An initiative within the Science Engagement Strategy is the Science Education, Communication, and Outreach Programme (SECOP), which seeks to advance science, engineering and innovation, regionally and nationally, for the benefit of all people.

SECOP identifies the steps the faculty will take to enhance and increase public understanding and awareness of its education programmes and opportunities. We hope this information will motivate and inspire the faculty community to seek opportunities and to use the resources available to pursue more knowledge.

As we navigate through the 21st century, we must maintain our

As part of the 2018 National Science Week programme, the faculty visited the rural Eastern Cape community of Mvezo, birthplace of Nelson Mandela, and engaged with learners. A geosciences student is helping a learner to read maps here.

commitment to excellence in science, technology, engineering and mathematics (STEM) education to ensure that the next generation of South Africans can accept the full measure of their roles and responsibilities in shaping the future. The faculty will establish a tradition of investing in the nation's education programmes and supporting the country's educators, who play a key role in preparing, inspiring, exciting, encouraging, and nurturing the young minds of today. These are the thinkers, leaders, innovators, and workforce of tomorrow.

The faculty's education programme strives to inspire and motivate students to pursue careers in STEM subjects by supporting education in Eastern Cape and South African schools, and to engage the public in shaping and sharing the experience of exploration and discovery by supporting informal education and public outreach efforts. The faculty's commitment to education places special emphasis on these goals by increasing elementary and secondary education participation in faculty projects; enhancing the institution's capability in STEM disciplines; increasing participation by under-represented and underserved communities; expanding e-Education; and expanding the faculty's participation with the informal education community.

Access for Success

In the faculty's commitment to access for success, significant strides and contributions are being made by many notable academics in the faculty, including Prof Muronga.

"In my role as a physics researcher, maths and science educator, immediate past president and international liaison councillor of the South African Institute of Physics (SAIP), and Executive Dean of Science, I am extremely concerned about the state of maths and science education in South Africa," says Prof Muronga.

"As academics, we cannot sit back and watch our learners fail at school, fail to gain entrance to university or fail at university. We have therefore introduced several programmes to help change the state of maths and science education in the Eastern and southern Cape."

This includes the Faculty of Science's flagship Science Education, Communication and Outreach Programme (SECOP), which focuses on science education from Grade R learners to undergraduate university students, with outreach programmes for learners, teachers and communities across the Eastern Cape, starting with schools in the Nelson Mandela Bay Metro and in the rural communities of Mvezo, Cala and Cofimvaba. This is part of the faculty's engagement strategy.

In its recurriculation and programme review, the Faculty of Science is focusing on ensuring that all students are able to access the diverse range of programmes offered, and to move into various career paths appropriate to the Fourth Industrial Revolution. An example of this recurriculation is the expansion of the current BSc extended studies programme (four-year BSc degree) to cover all the streams in the faculty, in line with the three-year BSc degree programme.

At the final-year BSc and postgraduate level, Prof Muronga, through the National Institute of Theoretical Physics Internship Programme (NITheP), runs workshops during the university holidays for final-year BSc students majoring in mathematical and physical sciences, and physics postgraduate students from throughout South Africa, many from rural areas. These students will join the global science community.

Prof Muronga at the 10th anniversary celebration of SA-CERN in Cape Town in November 2018. With him is Nkateko Baloyi whom he inspired to study physics in 2008 when he gave a presentation for schools in the Mopani District of Limpopo Province. She was a Grade 9 learner at Zivuko Senior Secondary School at the time.

Baloyi explains that after completing her BSc degree in chemistry and physics at the University of Limpopo, she was admitted to the National Astrophysics and Space Science Programme (NASSP) extended programme at the University of Cape Town. She completed her BSc Hons in Astrophysics and Space Science in 2018 and is now doing her MSc in Data Science at Wits University and working on the search for new bosons, using machine learning techniques, supervised by Professor Bruce Mellado from Wits' High Energy Physics Group.

2018 National Science Week

Theme: Deepening our democracy through science

During the 2018 National Science Week programme, the Faculty of Science hosted numerous schools from the Nelson Mandela Bay Metro, the broader Eastern Cape and George in the Southern Cape.

Grade 10 to 12 learners from these schools were invited to participate in a range of Science Week activities including a tour of InnoVenton's premises, rocket building and launching, an organic chemistry lab tour, a women in science event and a SA-CERN virtual tour. These events highlight science as a potential career path for these learners and what Nelson Mandela University and the faculty offers in the field of science.

As part of the National Science Week Programme, the faculty visited the rural Eastern Cape community of Mvezo, birthplace of Nelson Mandela, and engaged with learners from the Mandela School of Science and Technology and several rural Eastern Cape schools. The faculty also engaged with schools in George and the surrounding townships.

Faculty of Science: National Science Week Symposium Report 2018

Report prepared by PhD Chemistry student Mr Nehemiah Latolla, PhD Biochemistry student Ms Carri-Ann Bloom and the Head of the Department of Chemistry, Professor Zenixole Tshentu

On 18 July 2018, the Faculty of Science, through the Faculty Transformation Chair, hosted a symposium in line with the theme of the National Science Week 2018: *Deepening our democracy through science*. The event formed part of the pre-National Science Week activities leading up to Nelson Mandela University activities, titled *The Road to Mvezo*, at the Nelson Mandela School of Science and Technology in Mvezo. The symposium was held at the start of the university's institutional celebrations to mark 100 years since the birth of Madiba.

The symposium included the Executive Dean of Science, faculty staff, postgraduate and undergraduate speakers from the Science Faculty, and the keynote speaker Prof Amos Saurombe, professor of International Economic Law at the University of South Africa (Unisa). The event generated many thought-provoking contributions that presented a framework for how we can deepen our South African democracy using science as the lens.

Prof Zenixole Tshentu, the Faculty of Science Transformation Chair, raised the question of equity of access versus lack of equity of outcomes in higher education, and that timely interventions are required to deal with this challenge.

Prof Saurombe's keynote lecture was titled: *Using indigenous knowledge (IK) as a tool for curriculum transformation and Africanisation in deepening the science of democracy.* In highlighting the need for curriculum transformation and Africanisation, Prof Saurombe suggested the use of indigenous knowledge systems to achieve this, diverting the focus from the Africa that has been stripped away, to the emergence of the people's knowledge. In this regard, Saurombe called us all to action saying, "Each of us has to play a role in dismantling the colonial mindset." Furthermore, he stressed that the evolution of Africanisation is critical to fully realise this dismantling, including that of the philosophies. Saurombe went on to illustrate the importance of placing indigenous knowledge on the same footing as Western sciences.

The Executive Dean of Science, Prof Azwinndini Muronga, in his address titled *Speaking up for science – the value(s) of science and the scientific method,* engaged the audience on the simple question; "What is the value of science?" He proceeded to detail three core ideas: providing the quest for knowledge in science, which always makes space for doubt, "as nothing is beyond a shadow of a doubt"; providing the opportunity for innovation and the development of new technology; and inspiring us to work out who we are as people and as scientists. Drawing on a Buddhist proverb that he relates to science, he quoted: "To every man is given a key to heaven; the same key opens hell", sending the subtle message that with great power comes great responsibility. Thus, Prof Muronga called upon us to speak up for science in future, for example during movements that call for "#shutdown" of the institution, to prevent the negative after-effects such movements might have on the study of science.

One of the Faculty of Science staff speakers was Dr Gaathier Mahed from the Department of Geosciences, who presented under the title: *Free and Open Source Science*, in which he shared his inspiring story and tied it to the call for free and open sources of science to overcome the problem posed by inaccessibility.

The student voices at the symposium included Ms Sinegugu Mbense, Mr Lizalise Mngcele and Mr Masivuye Mahleba (Faculty of Science postgraduate students) and Ms Lindelwa Badi (Former SCISA Chairperson at Nelson Mandela University). Ms Mbense presented under the title: *To science or not to science? Is democratised science really the future for women?* In her presentation, Mbense presented her story as a young black woman in science, speaking to issues of sexism, discrimination and whiteness. She also touched on lack of progress in training black women scientists from rural backgrounds despite more than two decades of access to higher education for all in South Africa.

Mr Lizalise Mngcele presented under the title: *The Road to the Fourth Industrial Revolution*. He gave a detailed account of the Fourth Industrial Revolution and its effects in a democratic state. In closing he posed the question, "I wonder where the poorest of the poor will be when we no longer require manual labour?"

Mr Masivuye Mahleba presented under the title: *The position and situation of the previously disadvantaged with respect to science and technology, and capitalism and democracy*. He delivered a critique on the impact of capitalism, science and technology on the previously disadvantaged and interrogated whether democracy has had a real impact on real people, given the multiple challenges that they face today. He acknowledged the complexity of the situation and the diversity of beings.

Finally, Ms Lindelwa Badi presented under the title: *A Science that appeals to everyone*. She started her presentation by greeting the audience in the name of past, present and future great female scientists, displacing the notion of the absence of women in science, and, instead, placing them at its epicentre. She went on to deliver a presentation on how science can be effectively communicated and practised so that all who engage with it may find it appealing despite the stereotypes and cultural barriers encountered by people like herself: a young black woman in science.

Govan Mbeki Maths Development Centre (GMMDC)

Our South African youth must study mathematics and science in order for us to be a winning nation – Dr Govan Mbeki (LLD)

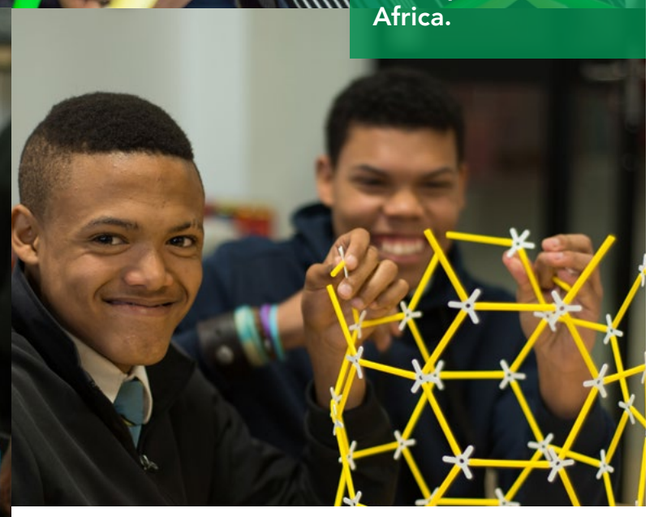
Launched in 2002, the Govan Mbeki Mathematics Development Centre's support programmes have played a significant role in improving the quality of mathematics and physical sciences teaching and learning at secondary schools and TVET Colleges in the Nelson Mandela Metro, Eastern Cape and other parts of South Africa.

An innovative offline techno-blended teaching and learning model (TBM) customised for South African conditions, has evolved over the past five years. Teacher and learner support programmes that incorporate customised ICT devices and digital resource materials developed by the centre, are used to address some of the key challenges in the basic education system.

Currently, over 1500 mathematics and science learners who show academic potential have been selected from six districts in the Eastern Cape. These learners have the 24/7 active use of tablet computers that contain a comprehensive offline suite of curriculum-aligned maths and science materials for the whole academic school year. Tablet-assisted support programmes in schools include a structured Saturday Incubator School Programme (ISP) that is offered to over 700 selected Grade 10 to 12 learners in the Eastern Cape each year. The aim of the ISP is to promote learner access to university programmes.

A structured SACE-accredited professional development and resource support programme that focuses on integrated skills development in technology, pedagogy and content knowledge (TPACK) has been offered by the GMMDC to hundreds of educators over the past five years, with great success.

The GMMDC has also established offline mathematics and science digital resource centres at project schools. Currently over 80 schools in the Eastern Cape have benefited in this way, including schools in the Nelson Mandela Bay Metro, Queenstown, Somerset East, Cookhouse, Adelaide, Bedford, Mthatha, Bisho and East London regions. In addition, since 2017 the centre has offered STEAM (science, technology, engineering, art and maths) experiential-learning workshops in a wide range of township schools in the Nelson Mandela Bay Metro and five other districts of the province.



Launched in 2002, the Govan Mbeki Mathematics Development Centre's support programmes have played a significant role in improving the quality of mathematics and physical sciences teaching and learning at secondary schools and TVET Colleges in the Nelson Mandela Metro, Eastern Cape and other parts of South Africa.

In 2018 the GMMDC expanded its programme beyond the Eastern Cape to a number of provinces, through stakeholder partnerships which include the National Department of Basic Education.

"A large part of our work is to get students enrolling at university who are proficient in maths of science, and to make maths and science more accessible to greater numbers of learners," says the Director of the GMMDC, Professor Werner Olivier, who was previously the Head of the Mathematics and Applied Mathematics department at the university.

"In 2008/9 we developed and introduced an animated PowerPoint and curriculum-aligned video lesson series for use by teachers and for our incubator school programme. For the latter we selected learners with potential from about 40 schools in the Nelson Mandela Metro who went through a two-year incubation programme. This proved extremely successful and was more widely introduced to the province in subsequent years.

"In about 2010, when tablet technology emerged, we developed offline tablet-based videos and interactive digital material to assist learners in schools and TVET Colleges. Called the TouchTutor® Maths and Science Package it is CAPS-aligned (Curriculum and Assessment Policy Statement) and it was registered by the university. The GMMDC is currently embarking on a new commercialisation project to increase access to the TouchTutor® Maths and Science Package through a techno-blended, curriculum-aligned offline teaching model for Grade 8 to 12 mathematics learners and Grade 10 to 12 physical sciences learners."

The latest TouchTutor® package for offline support includes video lessons covering the complete school curriculum, physical science experiments, dynamic demonstrations, interactive self-assessment feedback, exam revision support, interactive self-tests with scoring and feedback, an onscreen calculator (emulator) with lessons on how to use it, interactive multi-language support in eight indigenous languages, with explanations of mathematics terms, and a career guidance component. This digital package has been developed over eight years with the support of partnership agreements with a number of stakeholder organisations.

In 2017, the TouchTutor® package was redeveloped as a second, free, low-data Android application that runs on mobile phones. The TouchTutor® Quiz application can be downloaded from Google Play Store and used for mathematics support by any mathematics learner anywhere in the country.

The latest innovation to support education is the Gamma Tutor – a mini PC stick or screen-less Android device – which is plug and play and fits into the palm of your hand. The Gamma Tutor can run on any Android application, including any component of the TouchTutor® package. Such applications can be presented flexibly anywhere, any time via a digital screen, data projector or TV, so teachers can effortlessly use and manage it in classrooms, and learners can put it into their pocket or school bag, and continue studying at home.

Another exciting new development in 2018 was the MATH-ART competition project for secondary schools in the Eastern Cape. This project, which was successfully piloted in the first half of 2018, aims to promote links between maths and the arts to improve awareness of the power of creativity and design in problem solving. The MATH-ART project has attracted strong support from stakeholders, including the Eastern Cape Department of Education, local municipality and the Arts Faculty at the university. The winning artworks were also exhibited at an international conference in Stockholm, Sweden in July 2018. Plans are at an advanced stage to roll out this exciting school competition nationally in 2019.

George Campus Sustainability Research Unit

The Sustainability Research Unit (SRU) sees itself as a catalyst of change towards achieving more harmonious relationships between society and the biosphere. In 2018 the SRU hosted the Western Cape Biosphere Reserve Research Workshop, a landmark event bringing together researchers and managers on the ground who are grappling with reconciling human and environmental needs in the UNESCO biosphere reserves of the Western Cape. The event was designed to inform a research agenda for academics working in and around biosphere reserves.

The SRU also co-hosted the Garden Route Interface Meeting (GRIM), a conference attracting academics and practitioners working within social-ecological systems. Academics from South Africa, Canada, Finland and France attended the event. A spring school on social-ecological systems was linked to the conference, and aimed at developing the capacity for postgraduate research in social-ecological systems.

In November 2018 the SRU hosted a conflict management course for natural resource managers, using real world case study conflict scenarios and challenges in scenario-based role playing and group work sessions to build the capacity of managers to manage and resolve conflict in their contexts.

The profile and framework of the MATH-ART pilot competition (free for all learners) can be accessed via the link: https://www.youtube.com/watch?v=BSZLG5ebbrg

A short student video summary of the outcome can also be accessed via the link: https://www.youtube.com/watch?v=WmVop6C0SEo&t=18s

Bringing coding theory to disadvantaged schools across the Eastern Cape

By Nicky Willemse

Pupils from disadvantaged schools across the Eastern Cape are taking their first steps towards IT careers by getting a feel for coding theory. From October 2018 the Govan Mbeki Mathematics Development Centre (GMMDC) has included coding theory in its interactive STEAM (science, technology, engineering, art and maths) experiential-learning workshops, run in classrooms from East London to King William's Town, Queenstown, Bedford and Somerset East. The STEAM workshops are run in partnership with Capitec, Old Mutual, Cookhouse Windfarm Trust and BK Admin Services.

Pupils from Archie Velile Senior Secondary School get to grips with an innovative coding game called "Tanks", at a STEAM (science, technology, engineering, art and maths) workshop run by Nelson Mandela University's Govan Mbeki Mathematics Development Centre (GMMDC) in Dimbaza, near King William's Town.

"STEAM typically looks at various geometric structures including 2D or 3D tessellations (patterns) to help pupils see the links between mathematics and careers in science, engineering, design and architecture. Now we are adding a new dimension – in the form of two coding theory games called 'Tanks' and 'Boats' – to introduce them to the world of IT as well," says GMMDC Director Prof Werner Olivier.

"Coding theory is a precursor to programming and it's very important for setting oneself up for a career in IT," he continues. The introduction of coding theory is timeous, given that in September 2018 the national Department of Basic Education (DBE) proposed coding as a new school subject. The Boats game links to a second proposed new school subject, marine sciences.

Senior DBE officials recently travelled to rural Dimbaza near King William's Town, to observe GMMDC's STEAM activity sessions with pupils at Archie Velile Senior Secondary School, gaining a first-hand glimpse of Tanks and Boats.

Both games were developed by postgraduate students in the university's Department of Computing Sciences, under the supervision of Prof Jean Greyling. In Tanks, pupils, in teams competing against each other, must piece together puzzle-piece instructions to guide a tank through obstacles to a predetermined destination.

They then take a picture of their puzzle-piece pattern using a tablet or mobile phone with the free Tanks app installed (available at Google Play stores). The app uses photo-recognition to execute the path they have coded – and to determine whether their steps were correct. Once they have found the solution, they can proceed to the next level of difficulty.

"Tanks is very tricky because you have to know which pattern to put where. What I learnt was that no matter how challenging your situation, there is always a solution waiting to be discovered," said Esona Sipho Nombali from Alphandale Senior Secondary School at a STEAM workshop in Duncan Village, East London.

Boats takes the form of a board game, where pupils must navigate to pick up plastic pollution in the ocean and learn about critical environmental issues in the process.

Teachers from schools participating in the STEAM workshops received Tanks and Boats sets, along with tessellation sets and guides to engage with other groups of pupils at their schools.

Prof Olivier comments: "Our STEAM workshops are all about experiential learning linked with the integrated use of technology. We want pupils to learn through practical, hands-on experience in collaboration with their peers – and not just through textbooks – so they can make relevant mathematical connections for themselves. We want them to make discoveries linked to problem-solving in real life and to become aware of the important role mathematics plays in this regard."

Most of the pupils and teachers at the STEAM workshops are also participants in GMMDC's ongoing teaching and learning development projects, which use leading-edge technology to help pupils improve in maths and science.

Marine Science Camp with SAEON and the Department of Botany

Together with the South African Environmental Observation Network's (SAEON) eLwandle Coastal Node, the Department of Botany collaborated in a Marine Science Camp for Grade 11 learners – a hands-on experience during which they visited some of the marine habitats along the Port Elizabeth coastline. These activities expose learners first-hand to issues concerning the marine environment, including returning to the laboratories to look at the collected biological material under the microscopes. They also participate in collecting real environmental data using sophisticated multiparameter equipment; they then create a graphical representation of the environmental information and present it at a symposium to their peers.

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