Innovate:

Issue 16 2021

A REIMAGINED FUTURE

Hydropower for rural communities

Digital neural networks for rail safety

The Hatfield Digital Twin CIty

Humanising technology

Relieving digital fatigue

XR Technology

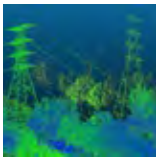
UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotsi ya Tshedimošo

Inside

THE FACULTY'S RESEARCHERS ARE RISING TO THE CHALLENGE OF MAKING A SIGNIFICANT CONTRIBUTION TO SOCIETY AT LARGE. THE FACULTY IS ALSO ENCOURAGING STUDENTS TO EMBRACE THE DISRUPTIVE TECHNOLOGIES BROUGHT ABOUT BY A RAPIDLY CHANGING WORLD IN ORDER TO PREPARE THEMSELVES FOR THE WORLD BEYOND UNIVERSITY ON AN UNPRECEDENTED SCALE.






Innovate:

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Innovate is an annual publication of the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology.

ON THE COVER

A REIMAGINED FUTURE

The Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria is bracing itself for a dynamic digital future. Through its thought leadership, the Faculty is preparing to tackle the challenges of the future with a generation of problem-solvers and innovators who are ready to change the world.

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Science fiction or tomorrow's reality?

A few years ago, I co-presented a research paper at an international conference. The paper was titled "Future thinking: The scarcest management skill". The main finding of the research was, perhaps not surprisingly, that many executives and senior managers in public and private organisations were not really focusing on thinking about and/or preparing for the longer-term future. Nor were some of them, understandably, adequately skilled to develop and manage the longer-term roadmaps of their respective organisations.

During the follow-up discussion at the conference, it became clear that these findings were true further afield than just in South Africa, where the research had been done. The question in our minds was obviously if this was a sustainable situation.

Looking back over the last few years, the pace of innovation is continuing to accelerate. The emergence of new technologies as part of the Fourth Industrial Revolution has created many new opportunities to improve productivity and achieve higher levels of competitiveness. If there were still any doubts in the minds of leaders that they should pay more attention to the longer-term future of their organisations, the sudden, unexpected emergence of the COVID-19 pandemic, and its impact on the lives of people and their organisations, has certainly changed thought paradigms about the future dramatically.

It became clear that the future is no longer "science fiction", but rather the reality that approaches much sooner than we ever thought it would. The pace of technological advances in the major industries is breathtaking and often mind-boggling. A closer look at innovation in industries such as healthcare, automation, telecommunications, banking, aerospace, food and many others provides evidence of how quickly the future is approaching. There is no doubt that these changes will have an impact on all of us.

These technological changes come with numerous challenges, but also opportunities for organisations. People are concerned about the future of their jobs, as well as what would be expected of them in the future and how they should reskill themselves. Young people carefully assess the changing world in order to plan for a future career. Organisations restructure themselves to become lean, but also to prepare themselves for the new skills and technological capabilities they have to invest in.

Changes to existing business models and the adoption of new business models are the order of the day in industry. These are clear indications that people at all levels of organisations and society are looking at the future with new perspectives.

Researchers are looking at the next Industrial Revolution as one of "intelligent automation". Several researchers are already talking about the Fifth Industrial Revolution as one where cyber-physical systems will integrate with human-centered systems.

A slogan from a well-known German industry group says it all: "We make the future, the future does not make us!" Brave words, but they tell a story!

The Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria is working hard to fulfil its mission of contributing to the growth of our industry and economy through relevant research and educational endeavours. Our knowledge networks not only span many other departments at the University, but include many South African, African and other institutions across the globe.

The theme of this edition of *Innovate* was appropriately chosen to focus on "reimagining the future". We give you an interesting glimpse into some of the research and educational activities of the Faculty, but also describe how they cross over into other disciplines in the form of interdisciplinary and transdisciplinary solutions – all focused on making the future better for our people and organisations.

Enjoy the selection of articles we have included in this edition of ***Innovate***.

Prof Tinus Pretorius
Editor

MESSAGE FROM THE DEAN

Prof Sunil Maharaj
Dean: Engineering, Built Environment and Information Technology

As we take our place on the front-line of innovation, the Faculty of Engineering, Built Environment and Information Technology (EBIT) at the University of Pretoria (UP) is repositioning itself to tackle the challenges of the Future World of Work with a generation of problem-solvers and innovators who are ready to change the world to create a peaceful and more sustainable planet.

WE ARE LED BY OUR SLOGAN, *INNOVATING OUR TOMORROW*, IN OUR QUEST TO REMAIN RELEVANT, TO BE GLOBALLY COMPETITIVE, TO REINVENT OURSELVES AND TO DELIVER GRADUATES WHO WILL BE READY TO EMBRACE THE DISRUPTIVE UNKNOWN WITH AN AWAKENED MIND.

To ensure that we remain globally competitive in the Fourth Industrial Revolution (4IR), our focus continues to be on producing high-quality research to make UP a leading research-intensive university. In this way, we are situated in the ideal position to maintain our place as an innovation leader.

Our Faculty is one of the few in Africa to feature among the top 500 in the world in six subject areas in the 2021 QS World University Rankings by Subject. These are engineering and technology, electrical and electronic engineering, mechanical and aeronautical engineering, chemical engineering, computer science and information systems, and minerals and mining engineering. The School of Engineering is ranked 356th out of more than 10 000 engineering schools in the field of engineering and technology. In addition, our programmes in electrical and electronic engineering continue to feature at the top of all South African universities. We are also particularly proud of the recognition received by our programmes in minerals and mining engineering, which have been ranked among the top 50 worldwide for the first time.

Through our close ties with industry partners, we are constantly searching for collaboration opportunities to enhance the relevance of our research and academic programmes. We also continuously improve our teaching and learning activities to ensure that our students acquire scarce and highly specialised skills.

It is through the thought leadership of the Faculty and its researchers that EBIT manages to remain relevant in a world shaped by the principles of a post-pandemic way of life, work and education. Fuelled by dynamic new technologies, EBIT is ready to embrace a reimagined future.

QS World University Rankings by Subject

Engineering & Technology	Electrical & Electronic Engineering	Mechanical & Aeronautical Engineering	Chemical Engineering	Computer Science & Information Systems	Minerals & Mining Engineering
356	251–300	301–350	301–350	451–500	48

Exceptional features of the Faculty

100
NRF-rated researchers

30
Externally funded research chairs

17
International agreements

28%
Estimated supply of South African engineers

70%
Academic staff members with a doctorate

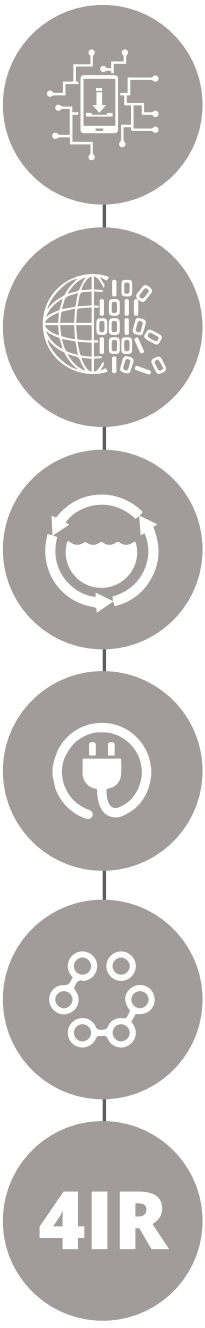
Message from the Deputy-Dean:

Research and Postgraduate Education

Prof Jan Eloff

The research strategy of the Faculty of Engineering, Built Environment and Information Technology is aligned with the University's overall vision to be a leading research-intensive university in Africa. It also aims to make a significant contribution to society at large. The Faculty encourages research and innovation through transdisciplinary integration. Given its unique position to facilitate research opportunities to advance the Fourth Industrial Revolution (4IR) through future technologies, it is poised to increase South Africa's competitiveness in this fast-evolving arena.

Since 2017, the focus in the Faculty has been to establish cross-cutting research focus areas, which are mostly interdisciplinary in nature. These research focus areas are based on existing strengths and expertise, which can each exploit pockets of excellence to embrace the 4IR. These focus areas cover the following themes:



Smart cities and transportation:
Healthy urban systems; smart urban and public spaces; new-age building technologies; smart transportation

Big Data science, information and communication technology (ICT), and technology and innovation management:
Novel technology implementations; Big Data and information systems; ICT and accountability; ICT and the 4IR

Water and environmental engineering:
Sustainable water processes; positive human-environment interactions, water management and optimisation

Energy:
Optimised energy supply; sustainable energy resources

Minerals and materials beneficiation:
Minerals and materials value chain; mining optimisation

The Fourth Industrial Revolution

Since 2018, the Faculty's research focus areas have been aligned with the Sustainable Development Goals (SDGs) of the United Nations. As such, they serve as a catalyst to promote multidisciplinary research.

For the period 2022 to 2026, the Faculty's main focus will be on transdisciplinary research. This will enable the Faculty to develop critical mass and synergies at the intersection of the Faculty's research focus areas, the University's institutional research themes, including energy, and the SDGs.

ADDITIVE MANUFACTURING FOR ELECTRONIC SYSTEMS

This is one of the Faculty's flagship transdisciplinary research projects, conducted in the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) in the Department of Electrical, Electronic and Computer Engineering. In terms of the Faculty's research focus areas, it supports the initiatives of Big Data science, ICT, and technology and innovation management, as well as the 4IR. It will establish new electronic system design techniques and reliable packaging strategies that best exploit modern additive manufacturing technologies, thereby creating a fair and sustainable economic environment for small and medium enterprises in the electronics sector.

These methodologies will contribute to the institutional research themes of science and technology innovation in general and the health of people and places by harnessing the transdisciplinary domains of health, water, wireless communication and climate sciences to realise novel solutions in optical, electrochemical, millimetre-wave and microfluidic sensor systems. Key processes will include planar printed electronics (inkjet, screen and aerosol jet printing) and 3D printing through the selective laser melting of metals.

The project aligns well with SDG 9 (industry, innovation and infrastructure) by considering low-cost and low-volume production technologies that will enhance scientific research and support domestic manufacturing infrastructure, extending to small-scale industrial enterprises. In addition, the use of materials and processes that facilitate sustainable and responsible production will be investigated and facilitated through transdisciplinary collaborations. Waste reduction is possible when opting for additive manufacturing processes and selecting environmentally friendly materials (e.g. paper). Both approaches will contribute considerably to the achievement of SDG 12 (responsible consumption and production).

THE FACULTY ENCOURAGES CROSS-CUTTING INTERDISCIPLINARY RESEARCH BASED ON ITS EXISTING STRENGTHS AND EXPERTISE.

Message from the Deputy-Dean:

Teaching and Learning

Prof Alta van der Merwe

The demands placed on the higher education sector, and contact tuition, in particular, continued in 2021 as the country entered its second year of restrictions in accordance with the President's COVID-19 Risk-adjusted Strategy. As it had already established a solid foundation of hybrid learning, the Faculty of Engineering, Built Environment and Information Technology could build forth on the successes it had achieved in the previous year.

Despite the turbulent times our lecturers and students have experienced since the start of the pandemic, I have the greatest appreciation for the efforts of the Faculty's teaching staff as they continued with their activities in an online environment. Staff members took the initiative by adopting creative approaches of transferring knowledge, thereby achieving improved academic performance. Many of these approaches are illustrated in this issue of *Innovate*.

While online teaching is not without its challenges, many lessons have been learnt over the past 18 months. What has been most heartening in a faculty characterised by innovation and technological advances are the exciting new teaching approaches that have come to the fore. Many staff members, who would never have imagined being called on to engage with their students in a virtual environment, have gone above and beyond what was expected of them.

Although many initiatives have been launched that make use of artificial intelligence, machine learning and Big Data applications, as well as augmented and virtual reality, we are seeing the evolution of technology to focus on the human element, where technology is placed in the service of humankind. This trend, known as Society 5.0, is set to enhance teaching and learning in the future, and will better prepare our students for the world of work in a technology-enhanced environment. This has led to the current discourse around humanising technology.

The benefits of online learning in extending the reach of universities and making education accessible to more people cannot be disputed. However, several challenges remain. These relate specifically to South Africa's unique problems of access to technology and overcoming the digital divide. Our objective will therefore always be one of optimising learning opportunities by utilising the advantages of contact tuition, while enhancing the benefits of technology.

The focus on digital forms of communication has, however, brought about a challenge of another kind. This relates to the emotional and psychological wellbeing of our students and staff. This is a nationwide dilemma brought about by the social isolation that resulted from the pandemic's various lockdown levels, and is something we aim to address in the future.

In conclusion, I wish to assure our staff and students of our continued support as we overcome teaching and learning challenges in this difficult time. I am confident that we will emerge stronger and better prepared to face any eventuality with the best practices that we have mastered.

DESPITE THE TURBULENT TIMES OUR LECTURERS AND STUDENTS HAVE EXPERIENCED SINCE THE START OF THE PANDEMIC, THEIR EFFORTS TO CONTINUE THEIR TEACHING AND LEARNING ACTIVITIES HAVE BEEN COMMENDABLE. STAFF MEMBERS TOOK THE INITIATIVE BY ADOPTING CREATIVE APPROACHES OF TRANSFERRING KNOWLEDGE, THEREBY ACHIEVING IMPROVED ACADEMIC PERFORMANCE.

How **COVID-19** has changed the face of academia

Prof Sunil Maharaj

As Dean of the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology, and Chair of the Global Engineering Deans' Council, Prof Sunil Maharaj has first-hand experience of how the COVID-19 pandemic has impacted on the teaching and learning of engineering and related disciplines. His view provides a perspective on the new game and new rules in a post-COVID-19 world.

THE PANDEMIC HAS CHANGED THE WAY WE LIVE, WORK, EDUCATE AND SOCIALISE. THIS UNPRECEDENTED SHIFT HAS THEREFORE OFFERED AN OPPORTUNITY TO EMBRACE BEST PRACTICES ASSOCIATED WITH THE FOURTH INDUSTRIAL REVOLUTION. IN TERMS OF THE FUTURE SUCCESS OF STUDENTS, IT IS VITAL THAT THEY ARE TAUGHT TO BE ENTREPRENEURS.

The COVID-19 pandemic has brought significant change to all sectors and spheres around the world. Engineering education at tertiary level has not been spared. As we approach the end of a second year in the midst of a global pandemic, we should pause to rethink how things are being done, as we cannot play the same game by the same old rules.

While there is no need for concern regarding the state of engineering education at universities in the developing world, there remains a need to innovate by constantly promoting disruptive approaches to higher education in an effort to stay relevant for the future world of work.

With the rapid spread of COVID-19, academics the world over were impelled to embrace remote teaching and learning. Taking classes online was a challenge. Lecturers had to prepare material for online purposes, be adept in engaging with students remotely, conduct assessment online, and prepare online-based tests and exams.

At many African universities, in particular, there were students who did not have laptops or access to the internet. In such cases, universities had to step in to ensure that these students could continue with their studies so that no student was left behind. Engineering studies also generally involve laboratory work, and with students unable to physically work in the labs, academic staff had to reimagine ways to do this sort of work online.

One of the various approaches the University of Pretoria (UP) undertook to achieve this was by asking students to make video recordings of simple experiments done at home, or in which they described the process. They would then engage online with their lecturers and peers.

Fortunately for UP, the transition to remote teaching and learning was less onerous than expected. In fact, UP has, since 1999, progressively implemented a system-wide hybrid approach to teaching and learning. The aim was for each undergraduate module to include up to a minimum of 30% of teaching and learning engagements online. When COVID-19 therefore reached South African shores, the University was able to take its classes fully online with relative ease, as faculty members did not need to be trained from ground zero.

DISRUPTIVE TECHNOLOGIES OFFER OPPORTUNITIES

When academics encourage students to embrace disruptive technologies such as online learning, they are preparing their students for a new world beyond university: one that has been shaped, among other factors, by forces such as COVID-19.

The pandemic has changed the way we live, work, educate and socialise. This unprecedented shift has therefore offered an opportunity to embrace best practices associated with the Fourth Industrial Revolution (4IR). Trends to look out for in this regard include data science, Big Data, the Internet of Things (IoT), machine learning and data analytics.

In terms of the future success of students, it is vital that they are taught to be entrepreneurs so that they can create jobs, as opposed to simply looking for jobs.

To this end, in 2017, TuksNovation – a non-profit company fully owned by the University – was established as an incubator and accelerator to support students to start their own businesses. This has already produced a few success stories in a short period.

Engineering students also need to understand the fundamentals of problem-solving, impact on the environment, and how to work as part of a multicultural and diverse team.

REMEMBER THE SOFT SKILLS

In Africa, the biggest challenge facing institutions is inequality among students. There are those from more privileged backgrounds who enter the engineering stream with good skills and knowledge, and others who have basically no knowledge of a computer. Lecturers do not have many years to bridge this gap. The challenge is therefore to fast-track students who enter university on the hind foot. Universities therefore need the appropriate infrastructure to train all students in Africa.

Whether we continue with online teaching and learning or go back to contact or hybrid education post-COVID-19 will depend on the way individual programmes are structured, and our appetite for innovation. However, human contact and interaction is important. People interacting and sharing knowledge, touching and sharing views (the possession of "soft skills") is an integral part of a well-rounded education.

Increasingly, everything we do demands multidisciplinary work. To get a certain task done, one needs different skills and – through collaborative work – this can largely be done via remote means. These ways of working have taken a huge forced leap forward over the course of the past year. However, there will always be certain types of collaboration that work best with what now seems like "old-fashioned" human-to-human interaction.

COVID-19 may have shaken up the way we teach in dramatic ways. As we start to move beyond the pandemic and to assess the changed world in which we live, there is much that is exciting and points us towards new horizons that demand exploration.

From a human and technological standpoint, engineering faculties around the world are perfectly placed to be at the forefront of expanding on the lessons learnt during the pandemic.

I look forward to being part of unleashing all the spectacular skills inherent in our colleagues and students globally as we continue to strive towards the peaceful and sustainable world we dream of.

The future is in our hands.

This article was first published on 4 March 2020 in *World University News: Africa Edition*.

FROM A HUMAN AND TECHNOLOGICAL STANDPOINT, ENGINEERING FACULTIES AROUND THE WORLD ARE PERFECTLY PLACED TO BE AT THE FOREFRONT OF EXPANDING ON THE LESSONS LEARNT DURING THE PANDEMIC.

Accelerating a new generation of UP tech start-up companies

In the Faculty of Engineering, Built Environment and Information Technology, students are not just prepared for a career that will take them to the top of their respective fields. They are also encouraged to be innovative thinkers who can identify gaps in the market and develop solutions and unique products that will improve the wellbeing of society. Entrepreneurship is therefore a skill that is nurtured. The University's technology business incubator, TuksNovation, plays a crucial role in this respect.

Established in 2017 as a non-profit company fully owned by the University of Pretoria (UP), TuksNovation provides specialised product and business development support to start-ups. It is firmly aligned with UP's 2025 vision of an entrepreneurial university, which aims to introduce entrepreneurship as a comprehensive offering across all its campuses, including all disciplines with potential linkages in the entrepreneurial process.

It has already produced several success stories in a relatively short period of time, supporting budding entrepreneurs throughout their growth journeys by assisting them to refine technologies and validate their business models for the relevant markets. It also assists start-ups to commercialise innovative technology into new sustainable enterprises with social and economic impact. The complexity and magnitude of this challenge motivated UP to conclude collaborative partnerships with industry and government to form a true triple helix partnership model that supports innovation and entrepreneurship to contribute to a better future for all. The anchor partnership is with the Department of Small Business Development through its Small Enterprise Development Agency (seda) and the Technology Innovation Agency (TIA), which supports the Tuknovation Seed Fund.

On 1 June 2021, TuksNovation welcomed its new permanent Centre Manager, Phindile Tshabangu, who is enthusiastic about taking TuksNovation to the next level to accelerate the new generation of UP tech start-up companies. Tshabangu is no stranger to technology venture funding and development, having spent much of the past two decades in the business incubation industry, both in the private sector and in the higher education environment. He has an engineering background and is also an alumnus of the University's Graduate School of Technology Management (GSTM).

Tshabangu has big plans for taking TuksNovation forward.

"We are consolidating existing partnerships and harnessing existing structures within the University. With seven UP campuses across Pretoria, Johannesburg and Mamelodi, TuksNovation has identified a unique opportunity to link both township and urban high-tech entrepreneurs to markets and resources through its incubation programme," he says. "We are also supporting start-ups to achieve a global footprint by partnering with the French Embassy in a cross-acceleration programme".

This programme, in partnership with the Institut Mines-Télécom (IMT), a public institution in France that is dedicated to higher education, research and innovation in engineering and digital technology, together with its business incubators, offers tech start-ups the opportunity to test and validate their business models and solutions in a foreign market. This entails a South African start-up spending two months in France, and a French start-up respectively spending two months in South Africa to facilitate access to international markets and build partnerships.

TuksNovation's good relationships with the City of Tshwane and the Innovation Hub led to participation in the first inter-university innovation challenge in 2020.

The objective of this challenge was to find innovative solutions that can solve some of the problems the metro is facing with regard to transport, revenue collection, waste management, electricity and energy. Ten student start-ups from UP, supported by TuksNovation, were identified as finalists in this competition, and two of the teams emerged as winners in their respective categories. TuksNovation will soon be launching a continent-wide Entrepreneurial Challenge. This will be an annual event led by UP and managed by TuksNovation, aimed at showcasing entrepreneurial opportunities in Africa.

In line with its focus on business launch and growth support, TuksNovation's incubation programme follows a three-stage approach. This entails technology and business model development, business launch and commercialisation, and business growth. However, it is fully aware that every business might be in a different stage in its life cycle, so it tailors its support to match each individual start-up's specific needs.

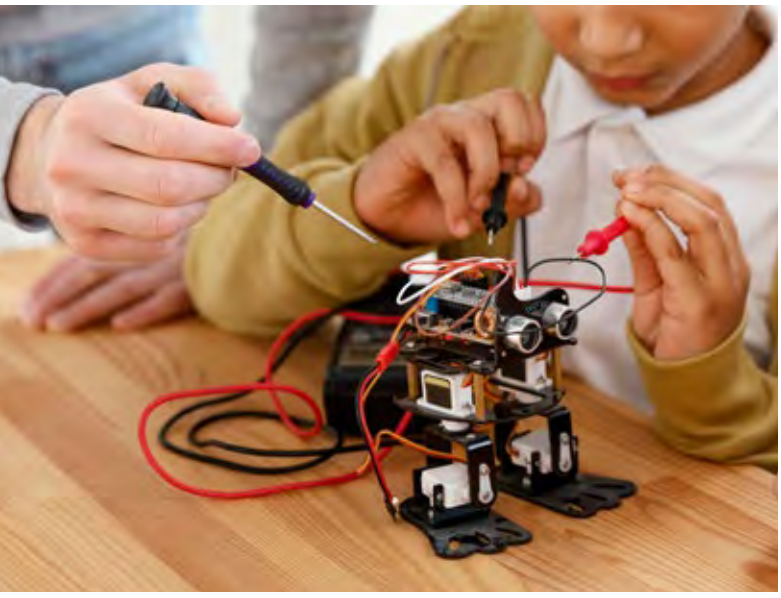
Phindile Tshabangu, TuksNovation's Centre Manager

CASE STUDIES

TuksNovation has already supported several start-ups in the engineering, built environment and information technology fields, who have successfully gone on to commercialise their innovations.

FUNDABOTIX

FundaBotix (Pty) Ltd is an education technology start-up company dedicated to equipping the young generation for the Fourth Industrial Revolution (4IR) and beyond. FundaBotix seeks to bridge the digital divide and bring affordable and innovative education technology solutions to underserved communities, such as townships and rural areas. The company was established in 2019 and is based in Pretoria. The FundaBotix product line consists of a low-cost robotics kit and an e-learning platform called the FundaBotix Online Academy.

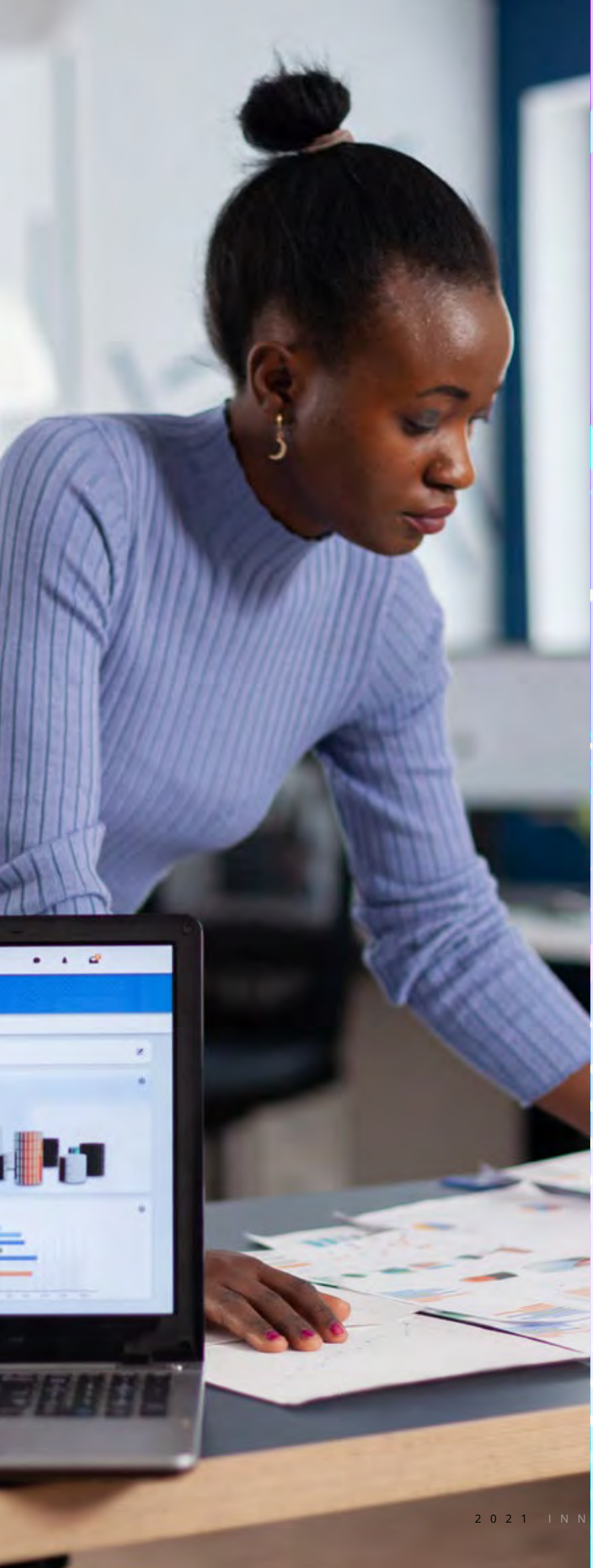


PROTEA MACHINE TOOLS

This company was formed to commercialise a patented hybrid five-axis machine tool invented by Dr Lukas du Plessis, a lecturer in the Department of Mechanical and Aeronautical Engineering. He was one of two South African entrepreneurs among 16 shortlisted candidates for the Royal Academy of Engineering Africa Prize for Engineering Innovation in 2018.

MULTIFRACTAL SEMICONDUCTORS

This company develops low-cost, fully integrated e-band radio frequency front-ends to enable 5G, massive multiple-input multiple-output (MIMO) and autonomous cars. The patented cutting-edge technology can enable the roll-out of 5G at a fraction of the cost, compared to existing technologies. It has already secured a R22 million in-kind investment from a Silicon Valley-based incubator and has raised substantial funding from the TIA.



IN LINE WITH ITS FOCUS ON BUSINESS LAUNCH AND GROWTH SUPPORT, TUKSNOVATION'S INCUBATION PROGRAMME FOLLOWS A THREE-STAGE APPROACH. THIS ENTAILS TECHNOLOGY AND BUSINESS MODEL DEVELOPMENT, BUSINESS LAUNCH AND COMMERCIALISATION, AND BUSINESS GROWTH. IT TAILORS ITS SUPPORT TO MATCH EACH INDIVIDUAL START-UP'S SPECIFIC NEEDS.

Controlling malaria with longer-lasting repellents

Dr Benjamin Mapossa

Malaria has been identified as one of the leading causes of illness and fatalities around the world. It is caused by the bite of an Anopheles mosquito infected with the *Plasmodium falciparum* parasite, which is endemic to Africa. This life-threatening disease results from the transfer of the parasite to humans through a bite from this mosquito. A preventative measure recommended by the World Health Organisation (WHO) is the spraying of insecticides indoors and the use of bed nets treated with long-lasting insecticides.

NEW METHODS OF CONTROLLING MOSQUITOES ARE URGENTLY NEEDED, ESPECIALLY IN LIGHT OF THE RESISTANCE TO INSECTICIDES (PARTICULARLY PYRETHROIDS), WHICH IS EMERGING IN SOME AFRICAN COUNTRIES.

Existing interventions have one major flaw. They focus on minimising malaria infections indoors, while infections can still occur outdoors. New methods of controlling mosquitoes are urgently needed, especially in light of the resistance to insecticides (particularly pyrethroids), which is emerging in some African countries.

The Institute of Applied Materials in the Faculty of Engineering, Built Environment and Information Technology, and the University of Pretoria's Institute for Sustainable Malaria Control, in collaboration with the Martin Luther University Halle-Wittenberg in Germany and the Eduardo Mondlane University in Mozambique are applying skills in chemical and polymer technology to design and develop products that may help reduce Africa's malaria burden.

In association with researchers at the Institute of Applied Materials, the recent research of postdoctoral fellow in the Department of Chemical Engineering, Dr Benjamin Mapossa, has focused on using polyolefin strands as controlled-release devices for mosquito repellents.

Findings from this study revealed that the main vectors of malaria in Africa are attracted by human foot odour, and tend to bite victims in the ankle area. Affordable mosquito-repellent polymer foot bracelets with long-lasting protection could therefore reduce infective bites on the lower limbs, and help reduce the overall malaria transmission rate.

According to Mapossa, researchers at the Institute of Applied Materials are making use of a technology that releases chemicals from plastic malaria bracelets in a controlled manner. The objective is for the active ingredients of the mosquito repellent to emerge gradually and at the same concentration over a prolonged period of time. The polymer product acts as a reservoir for suitable repellents by trapping the active ingredients inside a polymer matrix. The release rate is controlled by a membrane-like structure at the surface of the system. The study thus investigated the possibility of increasing the duration of repellent activity by incorporating repellents into inexpensive thermoplastic polymers, such as poly (ethylene-co-vinyl acetate) (PEVA) and linear low-density polyethylene (LLDPE).

Volatile repellents need to be released into the surrounding air to be effective.

This is because they are continuously lost to the atmosphere. The bracelet should therefore also act as a reservoir for relatively large quantities of the active compound. In an effort to achieve this goal, polymer strands containing mosquito repellent were prepared by twin-screw extrusion compounding. Furthermore, a co-continuous phase structure was achieved through the rapid quenching in an ice bath of the homogeneous polymer-repellent melt mixture leaving the extruder.

Phase separation occurred through spinodal decomposition that trapped the liquid repellent in the microporous polymer matrix. A skin-like membrane that covered the extruded polymer strands controlled the release rate.

The two mosquito repellents that were used to infuse the plastic bracelets were diethyltoluamide (DEET) and icaridin. DEET is the key active ingredient in many commercial mosquito-repellent formulations. It is also an environmentally friendly compound. Icaridin is also a safe and effective repellent that has been available for many years for mosquito-repellent application.

Polymer strands that were filled with 30% by weight of either of these two repellents were tested over a 12-week period under controlled conditions to determine whether they would still provide effective protection against mosquito bites even after 12 weeks of ageing at 50 °C. The strands were tested in an insectary to determine their activity against mosquitoes. Caged mosquitoes were offered the opportunity to feed on both treated and untreated body parts of human volunteers. Three hundred mosquitoes were placed in a large netting cage. The volunteers could put their legs into the cage through portals.

A test strand, 3 m in length, was wound around one leg of a volunteer, leaving the other leg fully exposed. Both legs were then inserted into the cage, one leg per entry hole, and the person had to stand still for five minutes. After five minutes, two other people used flashlights to count the number of mosquitoes on the lower leg of the test person. The number of mosquitoes on the treated and untreated legs were recorded separately.

The result showed that most of the mosquitoes chose to feed on the untreated legs. The lifespan of the novel repellent-based polymer product was found to be 12 weeks longer than any commercially available repellents. It had the added benefit of not only repelling mosquitoes, but killing them too if they made contact with it.

The polyolefins are widely available and cost effective, which makes the final product affordable. This is an important consideration in the eventual commercialisation of the product. However, more extensive and rigorous entomological and epidemiological testing would have to be done on products like this before they could become commercially acceptable.

COVID-19 vaccines:

South African case study sheds light on the development of vaccine manufacturing

Prof David Walwyn

The uneven availability of COVID-19 vaccines has become an increasingly urgent and vexatious issue. However, managing the problem of what has been labelled "vaccine nationalism" is proving to be quite a challenge.

The shortage of medication and vulnerable supply chains for critical medicines are issues for nearly all developing countries. In Africa, in particular, there is limited manufacturing capacity. Over 20 countries do not have any capacity at all, and many regions continue to import at least 95% of their pharmaceutical requirements. The situation for vaccines is even worse; about 99% of the vaccines used on the continent are imported.

Understanding why this is the case is key. After all, there is ample evidence that governments can be effective economic actors.

This includes being able to exercise a large influence on the manufacturing sector. They can, for example, build capacity through incentives, regulation and policy. Experiences from other countries show that public investment and public procurement in the domestic pharmaceutical sector can create capacity and markets. So why hasn't this happened on the continent?

LECTURE

https://www.up.ac.za/graduate-school-of-technology-management/news/post_2995685-public-seminar-held-on-23-june-vaccine-manufacture-in-south-africa-policy-failures-of-the-past-can-inform-our-options-for-a-better-future-prof-david-walwyn

BARRIERS TO PRODUCTION

Typically, vaccine production is technology and capital intensive. It requires highly skilled personnel and reliable supply chains for key raw materials and specialised equipment. The initial investment in people and infrastructure necessitates long-term stable markets with sufficient volume to justify the risk.

The absence of this security, even in the continent's larger markets, such as Egypt, Nigeria and South Africa, limits the expansion of this critical sector.

A study was conducted in the Graduate School of Technology Management (GSTM) to understand the extent to which gaps in the availability of financing are constraining the development of manufacturing capacity for vaccines and other health equipment. The findings show how governments, firms and donor agencies should align their efforts to support diagnostics, vaccines and therapies as a critical resource.

A number of approaches were identified that should be explored. These include joint plans for regional production hubs, pooled procurement, direct grants, periods of market exclusivity, international technology transfer and redirecting international development aid.

CASE STUDIES

As part of the study, the researchers looked at two case studies in South Africa: Ketlaphela Pharmaceuticals and the Biovac Institute.

Ketlaphela is a state-owned company, established to manufacture active pharmaceutical ingredients and medical products, mainly for communicable diseases such as HIV/AIDS, tuberculosis and malaria. It has yet to produce any pharmaceuticals.

Biovac is a public-private partnership between the South African government and a consortium of healthcare companies. Its capacity is small compared to the COVID-19 vaccine market. Nevertheless, it holds three important lessons on how a country like South Africa can go about building this kind of capacity.

Firstly, it provided long-term market security. This was done through an effective 15-year contract with the national Department of Health. Secondly, it allowed Biovac to receive a price premium as a means of funding the company's reinvestment in vaccine manufacturing. Lastly, it supported the establishment of a strong research and development (R&D) capability.

To understand how these experiences relate to the broader realities of pharmaceutical production across Africa, the researchers mapped funding flows for pharmaceutical projects on the continent. They also interviewed stakeholders, including civil society advocacy groups and industry experts, and talked to diagnostics, vaccine and therapy manufacturers across the continent to understand the realities on the ground.

THE FINDINGS OF THE STUDY OF THE GRADUATE SCHOOL OF TECHNOLOGY MANAGEMENT SHOW HOW GOVERNMENTS, FIRMS AND DONOR AGENCIES SHOULD ALIGN THEIR EFFORTS TO SUPPORT DIAGNOSTICS, VACCINES AND THERAPIES AS A CRITICAL RESOURCE.

FINDINGS

Conditions for the financing of diagnostics, vaccine and therapy manufacturing across Africa are clearly very diverse. Some countries have liquid financial markets, readily available foreign exchange and sophisticated financial systems. Others face real constraints in terms of access to capital and foreign exchange.

Similarly, smaller producers were found to face different challenges to those experienced by larger, established producers. Nevertheless, some commonalities were found.

Companies reported clear discrepancies between political aspirations to reduce import dependency in healthcare, and the day-to-day realities. In particular, businesses complained about factors that increased their cost of capital and made them less competitive. These were related to systemic or infrastructure failures over which they had little control, such as high electricity costs and unreliable supply, a lack of clean water, port delays, weak infrastructure and a limited availability of skilled personnel.

Interviews conducted as part of the research confirmed that these additional costs made it harder for local companies to break even and recover working capital in highly competitive markets. As a result, firms often retreated into narrower product categories, or closed, unable to compete with Indian and Chinese companies without greater government support.

The study highlighted two critical areas as being fundamental in reforming

THE ESSENTIAL FINDINGS FROM THE INTERVIEWS WERE THAT WHEN LOCAL FIRMS CAN PRODUCE GOOD-QUALITY PRODUCTS, THEY NEED TO BE ABLE TO ACCESS MARKETS WITHOUT BEING "CROWDED OUT" BY LARGER COMPANIES WITH ECONOMIES OF SCALE AND SCOPE. THIS COULD HELP CREATE A WIDER RANGE OF SUPPLIERS FROM DEVELOPING COUNTRIES IN THE LONG RUN. THE ROLE OF INTERNATIONAL FINANCING AGENCIES IS CRITICAL IN BUILDING LOCAL RESILIENCE TO GLOBAL HEALTH EMERGENCIES.

public support structures in favour of local companies.

1

In the first place, governments must use public procurement. They can do so by providing longer-term supply contracts with strong offtake guarantees (take-or-pay).

2

Secondly, donor agencies need to review their procurement strategies and reconsider them in favour of local manufacturers. These are presently based on accredited low-cost facilities, mainly in India and China.

This is more easily said than done. Nevertheless, the essential findings from the interviews were that when local firms can produce good-quality products, they need to be able to access markets without being "crowded out" by larger companies with economies of scale and scope. This could help create a wider range of suppliers from developing countries in the long run. The role of international financing agencies is critical in building local resilience to global health emergencies. For instance, the Global Fund is responsible for financing and procuring 21% of the drugs for the treatment of HIV. Similar figures are reported for tuberculosis and malaria.

Similarly, one of the objectives of Gavi's Strategy for 2021–2026[1] (Gavi 5.0) is to shape healthy markets for vaccine products. This could be reviewed against these realities, especially given the supply constraints faced by the COVID-19 vaccination facility. These agencies have the market power to diversify sources of supply without undermining the cost of public health services. The entities could work with national governments to build local capacity and increase resilience.

UNLOCKING FINANCIAL SUPPORT

Interestingly, the mapping of funding flows showed that investment capital is available in global financial markets. This includes capital for African diagnostics, vaccine and therapy investment. Constraints on financing for manufacturing are not because of a global shortage of available capital. Institutions such as the World Bank, the International Finance Corporation and the African Development Bank have made big commitments to support responses to COVID-19.

Unfortunately, this funding has not yet been allocated to projects for African pharmaceutical manufacturing.

Likewise, foundations are financing research and development, providing advance purchase commitments of vaccines and diagnostics, and undertaking other efforts to address COVID-19. Yet, they too have not materially funded vaccines to produce in Africa.

Given the devastating impact of the pandemic on the continent's economies, international institutions and governments must work together to bring pharmaceutical manufacturing to African countries.

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1 This is a five-year strategy developed by the Gavi Vaccine Alliance Board with the vision of leaving no-one behind with immunisation.

Run-of-river hydropower plant to supply Kwa-Madiba rural community

Dr Marco van Dijk

Due to the relative scarcity of surface water in the country, there is a prevailing perception in South Africa that the potential for hydropower development is rather low. However, the country's almost 4 500 registered dams and the infrastructure that exists to convey large quantities of water for the irrigation, mining and municipal sectors are potential locations for hydropower development.

There are opportunities to provide accessible and economical hydropower hidden within the existing water infrastructure. There are also a number of conventional opportunities, such as the completed installation at Thina Falls in the Eastern Cape, which supplies the Kwa-Madiba community with electricity.

The research on which this hydropower development is based was conducted by members of the Water Division in the Faculty's Department of Civil Engineering, and was funded by the Department of Science and Innovation, through the Water Research Commission.

To reach this final stage of the project's completion was not an easy task as there were numerous legislative and regulatory obstacles that had to be overcome, as well as the administrative restructuring of the municipality. Other factors that presented a challenge included the extreme remoteness of the site, and external factors such as the weather, peak flows in the river, and the availability of equipment and personnel.

A major achievement, not only for the project, but for all future small-scale run-of-river hydropower projects, was that

the project team was able to successfully participate in the public consultation process to review the General Authorisation in terms of the National Water Act. With the revised publication of the General Authorisation, small-scale run-of-river hydropower projects that adhere to specific requirements now only have to comply with the conditions of the General Authorisation, and do not need to undertake a costly and lengthy full water use licencing process.

The development of the hydropower plant scheme entailed the following:

- Identifying the sites (with the main aim of providing electricity to a rural area)
- Conducting hydraulic or hydrological assessments
- Facilitating the regulatory and permitting aspects of the project
- Designing the intake structure, penstock and turbine room
- Designing the electrical grid integration and control system
- Constructing the hydropower plants
- Providing training and conducting workshops

The 50 kW crossflow turbine is housed in a retrofitted shipping container at the bottom of the Thina Falls. The plant's intake and headrace are at the top of the waterfall. A penstock, 450 mm in diameter, was drilled through the mountain near the site, linking the headrace with the turbine room. This run-of-river, modular unit harnesses the potential energy of water flowing into clean electricity, providing enough electricity for approximately 50 rural households in the remote village of Kwa-Madiba in the Mhlontlo Local Municipality through a standalone mini-grid.
It utilises a portion of the total flow in the river, approximately 150 ℓ/s, and a head difference of 50 m to generate clean renewable electricity throughout the year.

The project provided the opportunity to construct a full-scale working hydropower plant, which was a wonderful opportunity to learn about and understand the intricacies of such a development. This project provided an opportunity to introduce new technology into South Africa with the potential for implementation in other water sectors.

Small hydropower schemes can play a critical role in providing energy access to remote areas in South Africa as stand-alone, isolated mini grids or to alleviate the burden on municipalities by making them more sustainable.

This research project outlined the possibility of using small hydropower systems in a rural setup for electrification in South Africa. This will enhance the uptake of micro-hydro technology by making local stakeholders (the private sector, the financial sector and government entities) aware of the opportunities that this technology brings and the coordinated efforts required to ensure the success of this technology.

Reimagining transportation networks for a digital future

André Broekman and Prof Hannes Gräbe

The development of digital technologies for the country's rail networks forms part of the University of Pretoria's endeavour to realise data-driven smart cities and transportation networks for the future. Under the helm of Prof Hannes Gräbe, the Transnet Freight Rail Chair in Railway Engineering and the Railway Safety Regulator Chair in Railway Safety, located at the Engineering 4.0 facility on the University's Innovation Africa @UP Campus, are advancing the digital railway with Fourth Industrial Revolution (4IR) technologies.

BY FUSING ARTIFICIAL INTELLIGENCE APPROACHES WITH TRADITIONAL RESEARCH METHODS, A NEW TYPE OF CONDITION MONITORING ALLOWS THE RAIL INDUSTRY TO IMPROVE THE SAFETY, EFFICIENCY AND COST-EFFECTIVENESS OF ITS RAIL AND TRAIN CONTROL SYSTEMS.

One of the initiatives that is already making an impact in the fast-developing world of the digital railway is that of condition monitoring. This is a technique that makes use of Big Data, Artificial Intelligence (AI) and the Internet of Railway Things (IoRT) to monitor the condition of railway assets. A test track that has been established at Engineering 4.0, together with a special road/rail vehicle that has been developed for sophisticated infrastructure condition monitoring, is utilised for the real-world testing of the data obtained via digital monitoring.

CONDITION MONITORING

Condition monitoring traditionally utilises a dedicated instrumentation vehicle that periodically measures the track geometry, quantifying parameters such as the gauge, profile, alignment, twist and cant. These vehicles are specialised and are frequently unavailable for the entire network of track that carries regular traffic.

This limitation gave rise to the development of an innovative system that makes use of 4IR technology to replace the relatively slow traditional methods of obtaining geometric measurements. These include techniques such as simultaneous localisation and mapping (SLAM) and photogrammetry, which produces high-resolution three-dimensional (3D) reconstructions that incorporate and combine state-of-the-art neural network architectures.

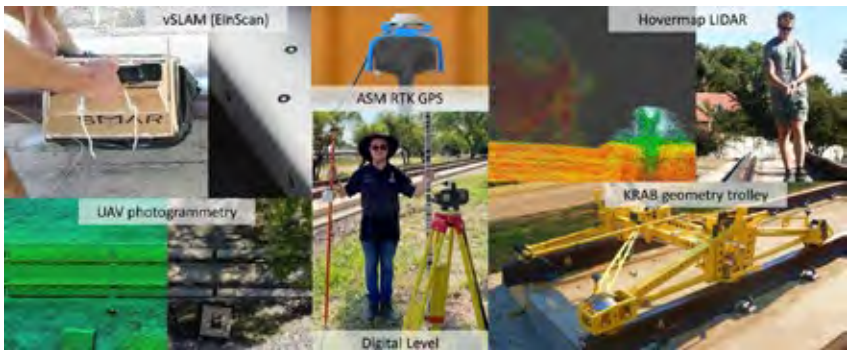
By fusing AI approaches with traditional research methods, a new type of condition monitoring allows the rail industry to improve the safety, efficiency and cost-effectiveness of its rail and train control systems.

INTERNATIONAL COLLABORATION

In 2019, the Chair in Railway Engineering partnered with 4Tel (Pty) Ltd, a software and hardware engineering firm headquartered in Newcastle, Australia, which specialises in rail technology and services in Australia and the international market. The primary objective of this collaboration was to address the disparity between state-of-the-art advancements in deep learning and the efficient condition monitoring of the digital railway.

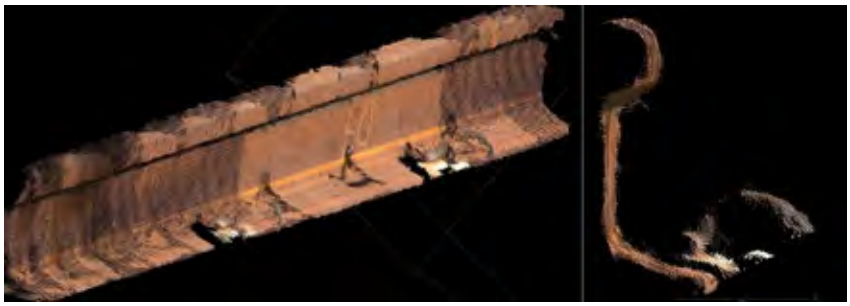
Intelligent solutions developed for this purpose consist of detection, localisation, awareness, dynamics and monitoring. Such solutions make it possible to identify hazards instead of acting on static and pre-programmed rules that are ineffective in complex and varied real environments. Information is gathered from a dedicated sensor platform that integrates data from a variety of sensors, such as colour and infrared-imaging cameras and radar, which are each suited to different environmental operating visibility conditions.

A doctoral project in the Department of Civil Engineering is contributing to the collaboration with 4Tel by making use of neural



Various measurement techniques and instrumentation are used to monitor the condition of railway infrastructure.

Comparison between samples of the synthetic dataset (top row) and real-life photographs (bottom row).



Point cloud reconstruction of the test track on the Hillcrest Campus.

Bloubank test site with the camera frame and RTK base station visible in the background (left) and a hovermap reconstruction of the Bloubank test site (right), measuring approximately 350 m in length.

networks and AI to address some of the shortcomings of traditional monitoring systems.

MACHINE LEARNING

This research project illustrates the use of an optical system to reconstruct the rail in 3D with the required accuracy to measure miniscule deviations, similar to that measured with sophisticated instruments. The anticipated accuracy of these deviations is anticipated to be in the region of 0.25 mm; the same level of accuracy typically obtained from commercial instrumentation.

In developing such a solution, the research was faced with the fact that the railway environment is difficult to monitor photographically because the railway lines often reflect light as the trains travel over them. This phenomenon has drawbacks for traditional reconstruction techniques and instrumentation.

As a result, this research investigated the use of powerful neural networks and machine learning techniques to "teach" the instruments to accommodate the reflective characteristics of the railway line. This is a challenging exercise, as neural networks require large datasets from which to "learn". While such datasets are readily available on the internet, they are not suitable for the reflective characteristics of the rail or the accuracy that is required for this purpose.

For this reason, a virtual railway was created to make photorealistic renderings of the rail environment, as well as depth maps of the camera's viewpoint (how far each pixel in the photograph is from the origin of the camera). This dataset, termed RailEnV-PASMVS, could then be used to optimise the system and "teach" the neural networks to design 3D reconstructions that

The Data House facility on the Engineering 4.0 Campus (left) with the RTK base station's static GPS antenna installed on the outside of the building.

could be used for digital condition monitoring.

An additional aspect of the project was to ensure the accurate positioning of the camaras, i.e. where the camera is situated on earth when the photographs are taken. Traditional GPS technology, which is accurate within 2 to 3 m, was not deemed sufficient, as the cameras were required to take photographs of the rails at intervals of 150 mm, as one moves along the rail, to measure the condition of the railway assets (track geometry).

An innovative feature of the system that was developed is the incorporation of a neural network-based multi-view stereopsis (MVS) reconstruction pipeline with a millimetre-accurate, real-time kinematics (RTK) geolocation service.

THE INTERNET OF RAILWAY THINGS

As a relatively new development in GPS technology, RTK is a low-cost mobile geolocation service deployed at UP. It entails a GPS sensor and a stationary antenna installed at the University's newly commissioned Data House facility at Engineering 4.0.

The Data House is a dedicated research facility for the deployment of state-of-the-art computer vision systems and the provision of RTK services. It has been constructed adjacent to the N4 freeway and is ideally situated to study the distribution and composition of vehicles, in addition to providing a clear line-of-sight RTK geolocation service. It serves as a centralised data acquisition and transmission platform for transdisciplinary research projects, including those carried out by final-year students.

The RTK GNSS relies on a permanent, stationary receiver, with accurately defined coordinates to transmit correction data. This data, which compensates for atmospheric delays, space weather, variations in temperature, relative humidity and gravimetric variations, enables the corresponding field unit to achieve accuracies (relative to the antenna) of 14 mm up to 15 km away from the base station. The correction data is transmitted over the internet using free and open-source software solutions. The small footprint of the RTK base station and the field unit provides versatile applications, even in remote locations. The corresponding RTK rover, moving together with the cameras, receives correction data from an Android smartphone using a bluetooth connection.

The mobility provided by the hardware enables diverse applications, ranging from multi-view stereopsis (MVS) techniques, which require an absolute reference frame for successful reconstruction, to direct antenna surface mapping (RTK-ASM) techniques for more intricate applications, such as the preservation of historical structures.

The data obtained from a recent field expedition near Bloubank in KwaZulu-Natal is currently being analysed. The preliminary results indicate that the small-scale measurements that are envisaged are indeed realisable. This will be followed by real-world testing on the road/rail infrastructure monitoring system and test track at Engineering 4.0.

An added advantage of the advancements in sensory capabilities and alternative geolocation services that form part of this system is its potential to act as a catalyst for digital twinning, where a computer-aided model, which is similar to a real-life structure, can be used to solve complex problems using 4IR technologies. This not only improves railway safety and the sustained good upkeep of railway assets, but opens the way for an automated, digital system that will play an important role in the transportation of products of economic importance.

Engineered solutions enhance agricultural exports

Prof Wynand Steyn

Ensuring that agricultural products intended for the export market arrive at their destination unblemished and suitable for further distribution and sale is a challenge experienced by producers in South Africa. Due to its reputation in smart transportation, the Department of Civil Engineering, located in the state-of-the-art Engineering 4.0 facility, was approached to devise a possible solution.

THIS FLAGSHIP PROJECT INVOLVES MONITORING THE TRANSPORTATION BY CARGO SHIP OF A CONSIGNMENT OF AVOCADOS DESTINED FOR ROTTERDAM IN THE NETHERLANDS, FROM WHERE IT WOULD BE FURTHER DISTRIBUTED THROUGHOUT THE EUROPEAN UNION. TO OPTIMISE THE DATA RECORDED DURING THE TRANSPORTATION OF THE AVOCADOS, THE TEAM DEVELOPED A MEASURING INSTRUMENT WITH MICROSENSORS EMBEDDED IN A NUMBER OF 3D-PRINTED AVOCADOS WITH A SOFT WATER-RESISTANT OUTER COVERING THAT WOULD BE EXPOSED TO THE SAME CONDITIONS AS THE REAL PRODUCE SURROUNDING THEM.

Based on its previous experience in determining the impact of transportation conditions on agricultural products, and optimising these conditions to ensure that products such as tomatoes and avocados arrive at the consumer in the best condition, the Department's researchers accepted the challenge. Its development of a concept known as "civiltronics" played an important role in finding an innovative solution. This entails the combination of traditional civil engineering with electronics, the Internet of Things (IoT), programming, computer science and additive manufacturing (3D printing).

The flagship project involves monitoring the transportation by cargo ship of a consignment of avocados destined for Rotterdam in The Netherlands, from where it would be further distributed throughout the European Union. In the words of researcher André Broekman, "If you can't measure it, you can't manage it." Therefore, the team made use of the Department's unique smAvo and smaTo sensor platforms, which are used to monitor the entire value chain, from farm to fork.

To optimise the data recorded during the transportation of the avocados, the team developed a measuring instrument with microsensors embedded in a number of 3D-printed avocados with a soft water-resistant outer covering that would be exposed to the same conditions as the real produce surrounding them. This instrument was developed from "off-the-shelf" components and microcontrollers. It was programmed and customised for the objectives of this particular project so that live, real-time data could be collected and stored for analysis. Real-time data on the ship's location in the Atlantic Ocean, as well as weather conditions throughout the trip, was sent to the University's researchers at Engineering 4.0 in Pretoria, where all the data will be captured on the Department's central platform for analysis, interpretation and the recommendation of future action.

The microsensors with which the "smart avos" were fitted measured variables such as accelerations in speed, rotational movements of the ship and temperature, as well as other elements of the ship's behaviour, to determine whether this impacted on the produce itself and the condition in which it arrived at its destination. It also determined whether the cold chain was preserved along the route.

This data will later be linked to maritime data.

This includes data such as the height of the waves, wind speed and the direction in which the ship is travelling, which were obtained from satellite data. This information is not just of value to producers to ensure that they can obtain top prices for South Africa's best products, but also to avoid additional costs related to transporting products that have been damaged or are no longer suitable for trade in the export market back to South Africa.

The University's world-class research footprint entails focusing on digital information across a transdisciplinary platform. The success of this project will therefore not be restricted to a single product or engineering discipline. Inherent in this innovative technology is the potential to apply it to other fields, as well to promote the transdisciplinary research for which the University of Pretoria is so highly regarded.

The upside of disruptive 4IR technology and innovation

Prof Wynand Steyn

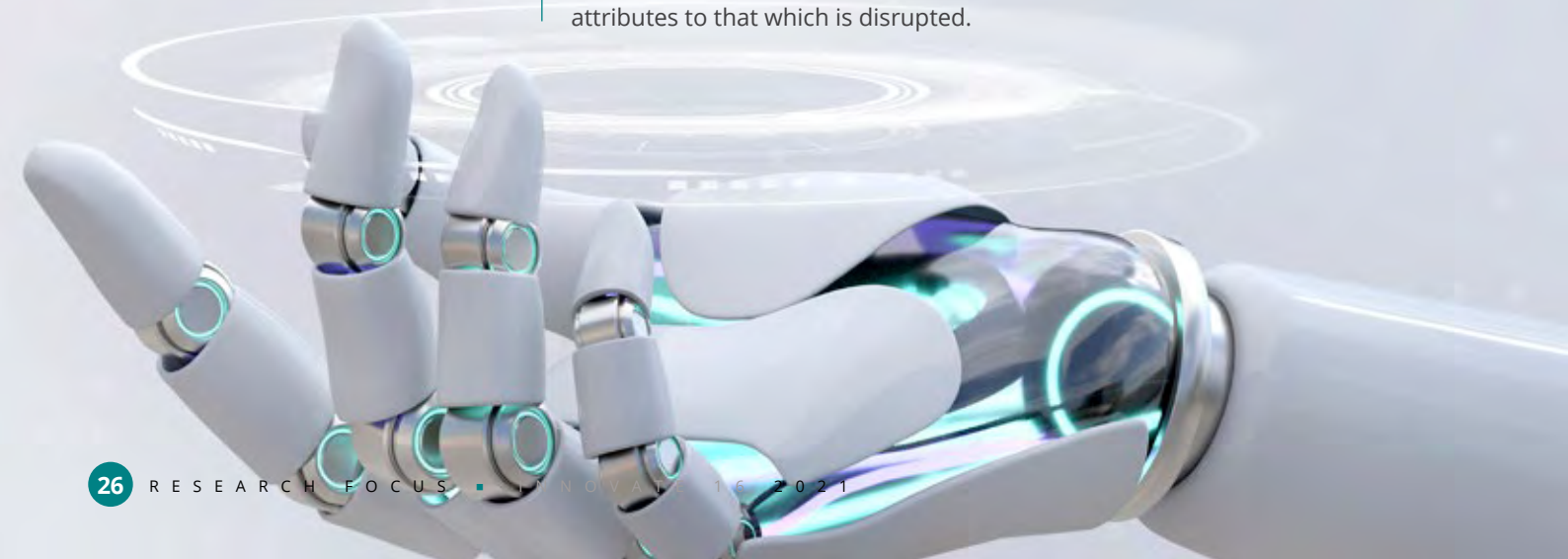
This commentary by Prof Wynand Steyn, Head of the Department of Civil Engineering, was published in* World University News: Africa Edition *on 19 April 2021, leading up to a panel discussion moderated by Prof Steyn on 21 April 2021 titled "4IR: Bracing for (and thriving in the midst of) disruption and innovation". This formed part of the University of Pretoria's LeadUP dialogue with the Vice-Chancellor and Principal.

Innovations and evolutionary developments have been part of humanity since the dawn of time. In most cases, these developments occurred over many years. In a typically evolutionary manner, those affected by change gradually adapted to the new normal and mostly did not realise the implications of the developments on their lives on a daily scale, except when they reflected on history.

Most changes of this kind have been beneficial to the development of humankind and, in the long run, have been welcomed and celebrated. These include developments such as how to control fire and the beneficial use of the wheel.

Over the past few decades, innovative developments have often been termed "disruptive". The term was coined in 1995 by American economist Clayton M Christensen and was first seen in a *Harvard Business Review* article titled "Disruptive technologies: Catching the wave".

Disruptions are generally defined as developments that significantly alter the way consumers, markets or industry operate, with mostly superior attributes to that which is disrupted.



EVOLUTION VS DISRUPTION

It appears that the major difference between traditional, innovative and evolutionary developments, and disruptive developments is mostly related to the timescale in which they occur.

Ride-hailing, for instance, started in around 2009 and, within a decade, became the norm for public transportation for a small number of passengers; digital photography took hold in 1988 with the Fujix DS-1P, moving from 400 kilopixels to 50 million pixels within a mere three decades. Compared to ride-hailing and digital photography, the wheel has been used by humans for about 550 decades and fire for around 150 000 decades. When one considers the implications of disruptive, innovative and evolutionary engineering developments on one's daily life, it is important to appreciate the process and reasons for these changes.

Engineers typically aim to serve the general population by improving living conditions, processes and experiences, such as through infrastructure provision, transportation, education and entertainment. The outcome of these developments affects how we do our jobs, conduct business, learn and teach, travel, eat and relax.

Many discussions around the world about the potential effects of disruptive and evolutionary events focus on how our lives will be negatively affected, centering mainly on the loss of jobs and work opportunities, privacy and freedom. These feelings of loss affect most people on a personal level, as that which they view as an emotional investment (the way things work) is lost, which could lead to different types of psychological responses.

Disruptive and evolutionary developments, therefore, affect people on both a physical level (the type of transportation options available and the type of available jobs) and an emotional level (not the way things were).

BALANCE AND STABILITY

To maintain balance and stability around our experiences of these disruptions, it is important to recognise that the core of most activities remains the same. People take photographs to capture a memory and, depending on the technology at the time, store it on film or digitally. They might also enjoy music that was created by an artist that could be human or a form of artificial intelligence; this music might also be live, virtual, on cassette, CD, vinyl or MP3.

Furthermore, people may travel between destinations on foot, by animal or using alternative-powered vehicles or ride-hailing; or they could gain new knowledge through stories told by ancestors or exposure to augmented reality experiences. In all these instances, the core of these activities – be it capturing a memory, enjoying music or travelling – remains the same. Therefore, in an attempt to continuously reflect on the implications of disruptive, innovative and evolutionary engineering developments on one's daily life, we need to question our behaviour as disruptors or innovators or "disruptees" (those affected by disruption).

These include (sometimes rhetorical) questions. What is the core activity of the disruptive technology? Does the disruption improve quality of life and life experiences? Is the disruption exploitative? Which opportunities have been lost? How should activities be adapted to recognise and benefit from the disruption?

In the same way that fire and wheels have destroyed lives in history, they also brought about major gains in the development of humankind. Similarly, the automation of mundane processes and datafication (the transformation of data into a digital format) can lead to job and privacy losses, but they also have benefits, such as an increased focus on more meaningful employment and the early detection of potentially deadly diseases and conditions. One possible appropriate reaction to the disruptive nature of our 21st-century existence is to engage in and focus on those human capacities that cannot be (easily) disrupted, such as equilibrium in our work or life experiences, emotional and physical wellbeing, and the continued search for an enhanced future for all humanity.

In a world with 7.9 billion humans where, for every 100 people, almost nine are going to bed hungry at night, eight are unemployed, about 10 adults are illiterate and 26 are affected by fragility, conflict or violence, we need targeted disruption from our current existence and way of living to ensure meaningful lives for all people.

DISRUPTIVE AND EVOLUTIONARY DEVELOPMENTS AFFECT PEOPLE ON BOTH A PHYSICAL LEVEL AND AN EMOTIONAL LEVEL. HOWEVER, TO MAINTAIN BALANCE AND STABILITY AROUND OUR EXPERIENCES OF THESE DISRUPTIONS, IT IS IMPORTANT TO RECOGNISE THAT THE CORE OF MOST ACTIVITIES REMAINS THE SAME.

Smart transportation platforms support interdisciplinary research

Prof Wynand Steyn

Initially installed to monitor environmental and road-related conditions for research associated with smart cities and transportation, the Department of Civil Engineering's long-range wide area network (LoRaWAN), with its associated antennae and sensors, is providing support to a multitude of interdisciplinary research projects.

This technology is in the process of completely reinventing the collection, processing and analysis of data in alignment with the research objectives of the University of Pretoria's transdisciplinary research platforms.

With base stations installed on the roofs of both the Engineering 4.0 Building on the Innovation Africa @UP Campus and the Natural and Agricultural Sciences Building on the Hatfield Campus, it provides signal coverage spanning the University's entire Hillcrest and Hatfield precincts. This is enabling the adoption of Internet of Things (IoT) devices across multiple research disciplines.

Realising the potential of sharing this technology with other research facilities at the University, especially the Future Africa Research Institute, the Innovation Africa @UP Campus and the Javett Art Centre, a Digitising Innovation Africa @UP Campus Committee was constituted under the guidance of Prof Bernard Slippers, Director of the University's Innovation Africa @UP Campus. Through interdisciplinary collaboration, research can now be supported across all the University's faculties and research institutes without unnecessary duplication.

Prof Slippers is also Director of the Forestry and Agricultural Biotechnology Institute (FABI), and was one of the first researchers outside the Faculty of Engineering, Built Environment and Information Technology to make use of the network's wireless sensor data to monitor environmental parameters such as air quality, temperature, humidity, soil moisture and concentrations of carbon dioxide for research related to plant health biotechnology.

Although originally designed to be used on the road to measure environmental and other conditions that affect transportation, the University's LoRaWAN system now comprises more than 150 sensors across the University's Hillcrest and Hatfield campuses, which can be programmed to measure a variety of environmental characteristics to support research across various disciplines. The wireless sensor data is then transmitted to a central platform, where it is collected at the Innovation Africa Information Hub. From there, it can be accessed via a digital link by researchers who interpret the data to support various research objectives.

While most of the sensors that support multiple research projects are industrial-grade sensors, the expertise of the Faculty's microelectronics specialists at the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) in the Department of Electrical, Electronic and Computer Engineering are at hand to support researchers who require specialised sensors for highly technical measurements. This is further evidence of the interdisciplinary collaboration that is at the centre of this initiative.

An institution-wide project that has made use of the live data of the LoRaWAN system is the Hatfield Digital Twin City initiative, which relies on data simulations to mirror the real-life conditions of a city precinct in order to test hypothetical scenarios that can improve the services, environments, infrastructure, performance, and social and health objectives of cities.

The rapid advancements in technology related to smart infrastructure networks, IoT architectures and Big Data analysis systems suggest that wireless sensors such as those used in this initiative can be expanded even further in the future as novel systems that make use of robotics, artificial intelligence and machine learning enter the market. And the University of Pretoria is poised to take advantage of them to find sustainable solutions to the complex challenges faced by society.

Dr Calayde Davey, Department of Architecture

Thriving African future cities:
The Hatfield Digital Twin City initiative

Dr Calayde Davey

The University of Pretoria (UP) is leading the charge in the future of African cities, particularly the exciting world of "digital twinning" – where reality and simulation meet in real time – by developing its own comprehensive digital twin city: the Hatfield Digital Twin City. This long-term initiative will be a living laboratory that provides a fully simulated, mirrored image of Hatfield and its surroundings. By establishing thousands of real-time feedback loops between nature, environments, cities, people and processes, researchers can ask new kinds of curious and innovative questions.

What can a living laboratory of our African city teach us? How can we imagine the future differently? What new areas of innovation should we cross-appropriate and what new ideas can we try out? Where are we taking our African cities, and how do we lead with innovation and creativity to create the future we want in Africa?

The Hatfield Digital Twin City, which originated in the Department of Architecture, is leading a large-scale transdisciplinary initiative that includes themes in city simulation modelling, artificial intelligence, machine learning, scenario and prediction design, urban systems, city-making, Society 5.0 and many other exciting topics. It aspires to mature both technological development and education opportunities for all participants, from

any discourse, and at all levels at University and beyond.

FUTURE CITIES – OUR GREATEST AND SHARED WICKED PROBLEM[1]

The problem of urbanisation, city-making and our concerns for sustainable development places our planetary system under extreme pressure. The great majority of the world's population lives in cities, which consume two-thirds of the world's energy, while being responsible for over 75% of global CO_2 emissions.

Cities drive the forces of the world economy, and are directly responsible for our nested resource feedback loops, as well as national and global economic performance. Since 2007, the world has moved far beyond the global urbanisation tipping point. According to the United Nations Human Settlement Programme (UN-Habitat), mankind will continue to add three million inhabitants to cities every week for the next 40 years. By 2030, the world's largest cities will be in Asia and Africa, which is where 90% of global urbanisation will occur. Vast, interconnected and complex megacities become increasingly harder to manage or maintain. Meanwhile, most cities are not resilient to system shocks such as climate events or public health threats. Despite disruptive phenomena, such as COVID-19, urbanisation will continue to accelerate at a rapid rate.

Both the ecological and economic prosperity of cities will continue to shape countries' contributions to long-term planetary sustainability. According to the World Economic Forum, city systems, the climate crisis and climate action failure pose the greatest, most likely and highest risk to humanity's future. Thriving cities are imperative to ensure planetary ecological survival. In the future of cities, we have our greatest and most shared wicked problem at hand. What tools do we have at our disposal to get to work on this?

FUTURE-READY AFRICAN CITIES

In fighting the climate crisis, complex megacity concerns and technological disruption, new ideas are emerging in city-making tools: the Smart City, and its big brother, the Digital Twin City.

A Smart City utilises digital sensors and communication technologies to improve the services, environments, infrastructure, performance, and social and health objectives of cities. Proponents offer "smart solutions" as the means to achieve resilient, socially equitable and climate-smart cities. System shocks (such as COVID-19 or climate events) expose the vulnerabilities of cities, which further accelerates the application of smart or digital solutions (Allam & Jones, 2021).

A common starting block to make cities "smarter" is to create instruments that improvise city performance efficiency. One such instrument is the digital twin – a smart 3D or digital mirror of an object, process or complex system. In city applications, a digital twin provides a real-time virtual model of the urban fabric (streets, buildings and infrastructure), along with real-time resource flows or feedback loops of the physical city.

A digital twin creates a data-driven platform for use and application by a wide range of stakeholders, serving as an armature into which other digital data can be plugged. These environments lead to rich, virtual, interactive models, simulations and visualisations.

Digital twin city environments allow for a multitude of real-time research and experimentation opportunities to occur, such as real-time urban service monitoring tools and processes, scenario and prediction design, risk and performance management, maintenance planning and operations, or design simulations of development interventions.

1 A "wicked problem" is a social or cultural problem that is often difficult or impossible to solve. It is a systems problem that is complex and interconnected in nature.

The Hatfield Digital Twin City area.

THE POWER OF DATA AND TRANSDISCIPLINARY PRACTITIONERS

To address the greater urgency at hand, the United Nations calls for a Decade of Action, requiring rapid results and experimentation on city issues, regardless of fiscal challenges. However, satisfying global and local sustainable development objectives (such as the United Nations' Sustainable Development Goals (SDGs), the New Urban Agenda, and the Build Back Better initiatives) or recovering from severe system shocks (such as a COVID-19-induced global recession and public health crisis) can be difficult and expensive, especially at subnational levels.

Many cities are using the United Nations' SDGs to drive their local sustainability objectives, mobilising all kinds of data to achieve specific and diverse goals. Emergent technology, open GIS (mapping) and open data approaches create new opportunities for collaboration and alignment within and across cities. Cities have troves of useful and underutilised data at their disposal, collected from a multitude of different sources, including monitors, sensors, smartphones, apps, maps, city data dashboards, information screens in public spaces, intelligent operations centres and public-facing websites. Combined, these sources generate so much data that traditional techniques and software cannot analyse it at all.

Big data analysis, real-time monitoring and the automation of urban services (from streetlights to community complaints systems) are extremely useful for city planning, operations and service delivery, which are key motivators in the Smart City discourse. Effective responses to harness or steward environmental value have also revealed increasing interest in data mining (or mobilising data) in cities. Digitalisation and data-driven technologies are among the promising possibilities to measure progress on and responses to important higher-order objectives.

THE HATFIELD DIGITAL TWIN CITY INITIATIVE

The University of Pretoria is spearheading world-class technological advancement in Africa across several domains (including engineering, the Internet of Things (IoT), artificial intelligence (AI), machine learning (ML), physical and digital infrastructure, the built environment discourse and spatial design, public health, environmental science and agricultural sciences). The University also aims to become the continental thought and experimental leader in the discourse of African digital twin cities and environments. One of these initiatives is to establish and grow the long-term maturity of the Hatfield Digital Twin City.

The Hatfield Digital Twin City is the 10 km^2 urban area surrounding the University's main campus. It includes a multitude of university-owned residential assets, natural systems, the UP Experimental Farm, the University's Sports Campus, the Innovation Africa @UP Campus

and other unique asset and environmental classes. The University is the dominant permanent asset and infrastructure owner in this territory, managing and owning approximately 65% of the land, communities, systems or stakeholder relations in this space. This puts the territory at a unique advantage to develop a world-leading comprehensive digital twin city: a living laboratory that can generate value in education, research, innovation and development trajectories in Africa.

The ultimate goal of the Hatfield Digital Twin City is to create the path for unlocking thriving African smart cities, while positioning the University of Pretoria, the City of Tshwane and our industry partners as global innovators in city futures. The value of this is clear to many supporters and prospective partners, and the project is gaining national support from entities such as the National Treasury City Support Programme and the Department of Trade, Industry and Competition.

THE WORLD HAS MOVED FAR BEYOND THE GLOBAL URBANISATION TIPPING POINT. A SMART CITY MUST UTILISE DIGITAL SENSORS AND COMMUNICATION TECHNOLOGIES TO IMPROVE ITS SERVICES, ENVIRONMENTS, INFRASTRUCTURE, PERFORMANCE, AND SOCIAL AND HEALTH OBJECTIVES. A DIGITAL TWIN CITY PROVIDES A REAL-TIME VIRTUAL MODEL OF THE URBAN FABRIC, ALONG WITH REAL-TIME RESOURCE FLOWS OR FEEDBACK LOOPS OF THE PHYSICAL CITY.

WE BUILT THIS CITY – OUR OWN DIGITAL TWIN CITY LABORATORY

The Hatfield Digital Twin City is transdisciplinary and non-exclusionary, allowing for direct vertical and horizontal collaboration between all the academic disciplines at the University, while inviting direct engagement with the public sector, industries and markets. It is already aligned with several key local city stakeholders' objectives, including the Hatfield City Improvement District (CID), the City of Tshwane and the Council for Scientific and Industrial Research (CSIR).

Through the Hatfield Digital Twin City, new transdisciplinary working relationships are being unlocked. As a transdisciplinary cohort, the building blocks for the laboratory are being constructed from the inside out. The data science teams of the University's Forestry and Agricultural Biotechnology Institute (FABI) are currently expanding the Digital Twin Cities Data Warehouse, while specialists in the Department of Geography, Geoinformatics and Meteorology are tackling the Digital Maps and Geonode interfaces.

The Hatfield Digital Twin City is also currently exploring topics in grassroots data generation for projects, education and research activities for the Faculty of Engineering, Built Environment and Information Technology. It is running various trials on type, use, methodology, engagement style and appropriate applications for digital twin technology in education at institutional, public and private sector levels. These trials will be further experimented with, formalised and expanded in 2022 and beyond.

The Hatfield Digital Twin City is also unlocking new transdisciplinary research funding, proposals and novel working relationships. This includes multidisciplinary funding proposals in public health and digital twin environments for African cities (with colleagues from Cambridge University, UK). For example, it is actively opening up new working relationships between the Department of Information Technology, Planning and Architecture on thriving future African cities as researchers explore questions on socio-cultural sentiment, perception and community safety concerns in African cities.

However, the real value of the Hatfield Digital Twin City is not just in the research and innovation outcomes it represents, but the distributed education, teaching and learning opportunities for the future of work. Through the establishment of comprehensive, complex virtual laboratories, the University hopes to lead and develop a new generation of future-ready candidates in any field.

THE PRODUCTION OF THE HATFIELD DIGITAL TWIN CITY PRESENTS A TREMENDOUS OPPORTUNITY FOR THE UNIVERSITY OF PRETORIA TO TAKE LEADERSHIP IN THE FUTURE OF WORK AND EDUCATION CONTINENTALLY.

BEYOND THE DIGITAL CITY – THE FUTURE OF LEARNING AND WORK

According to the World Economic Forum, automation, in tandem with the COVID-19 recession, is creating a "double disruption" scenario for current and future workers and educators in all sectors. As of 2020, 84% of employers are rapidly digitalising their processes, including a significant expansion of remote work. The World Economic Forum furthermore states that, by 2025, 43% of employers expect to reduce their workforces fundamentally due to technological integration; 41% plan to expand their use of contractors for task-specialised and remote work or bespoke skills; and there will be a 50% work split between humans and automation, via the design and maintenance of automation processes.

With the Hatfield Digital Twin City, the University is exploring the meaning of digital twin cities in Africa. Along with the broad-spectrum disruption in the work and education spheres, the production of digital twin cities presents a tremendous opportunity for UP to take leadership in the future of work and education continentally. By digitalising the University's practices and learning experiences, the Hatfield Digital Twin City could leapfrog beyond simply owning a virtual city. It could have its own complex virtual classroom.

Beyond field data and application learning, the Hatfield Digital Twin City environment and development processes provide students and staff with direct opportunities at all levels to participate in real-time work. The Department of Civil Engineering is investing in communication infrastructure in Hatfield to deploy a vast range of sensor networks to allow students to engage with Fourth Industrial Revolution (4IR) technologies at various cost scales, while also enabling training on data sets.

With the Hatfield Digital Twin City, we find ourselves in a complex virtual laboratory, where learning and training can happen at any level and at any location (from first-year to postgraduate level and beyond). The emphasis is on equitability and access, where the aim is to service the full tech-maturity spectrum (low-tech and high-tech education) through an emphasis on low-data, low-bandwidth and open-data (freeware) applications and practices.

The Hatfield Digital Twin City provides direct value to our community of educators in several ways. Firstly, the University could provide real-time work experience, supporting student career development and practical training through a shared virtual environment. It is currently cross-training architectural students in geoinformatics and GIS technologies from first-year to master's level. It is also using Hatfield Digital Twin City data for practical training for AI and ML in third- and fourth-year Chemical Engineering students.

Secondly, the Hatfield Digital Twin City could become an instrument to aid the University's curricula development objectives. Such a virtual city laboratory opens up new questions in future-ready education and allows non-exclusionary participation. Transdisciplinary collaboration is continuously being piloted in various disciplines. Approximately 115 students from architecture, construction economics, real estate, quantity surveying, chemical engineering and civil engineering, as well as from FABI, have already participated in Digital Twin City experimental or educational activities.

The Hatfield Digital Twin City aligns with other digital twin work being developed by the Department of Civil Engineering and FABI on the University's Innovation Africa @UP Campus. Here, the current focus is on distributed sensor networks, and the collection and management of, as well as the response to performance or behaviour data from infrastructure and environments. There is potential for broader applications in ecosystem and agricultural management.

Lastly, with the Hatfield Digital Twin City, the University has the opportunity to improve its own internal operations through business automation practices. It is currently experimenting with aligning background university operations (such as facilities management practices) directly with foreground learning to students and educators.

This helps the University service many other higher-order objectives (such as implementing and reporting on SDG 6, 7 and 8) or improving fiscal or programme operations. For example, during the conceptualisation of the Hatfield Digital Twin City, significant potential was discovered to reduce University operations and utility costs. Rough estimates range from around R8 million to R12 million per annum in savings alone if identified changes are implemented. With maturity, the Hatfield Digital Twin City concept and development process promises real value generation in many areas of internal and external concern.

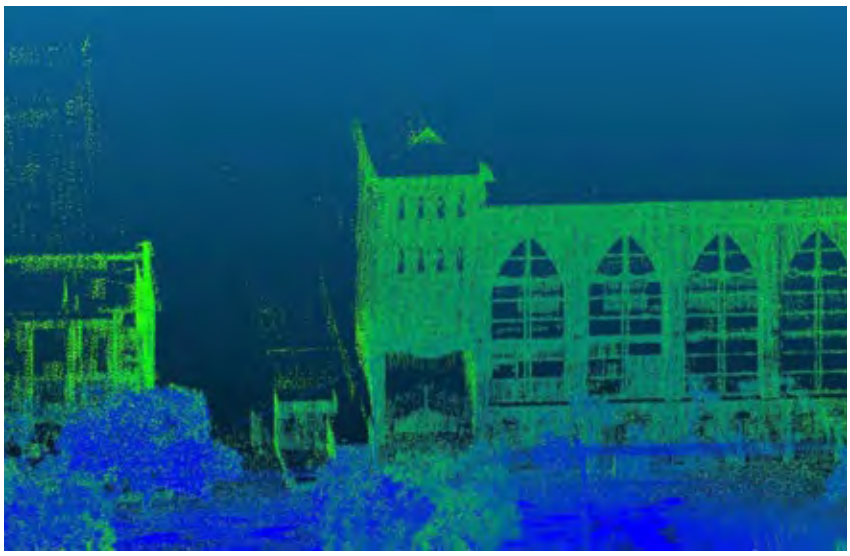
THE HATFIELD DIGITAL TWIN CITY INITIATIVE RELIED ON THE INSTITUTION-WIDE LONG-RANGE WIDE AREA NETWORK, WITH ITS ASSOCIATED ANTENNAE AND SENSORS, LOCATED ON THE ROOF OF THE STATE-OF-THE-ART ENGINEERING 4.0 BUILDING. THIS ENABLED THE INITIATIVE TO MIRROR THE REAL-LIFE CONDITIONS OF A CITY PRECINCT IN ORDER TO TEST HYPOTHETICAL SCENARIOS THAT CAN IMPROVE THE SERVICES, ENVIRONMENTS, INFRASTRUCTURE, PERFORMANCE, AND SOCIAL AND HEALTH OBJECTIVES OF CITIES. THIS PROJECT REPRESENTS AN EXCEPTIONAL OPPORTUNITY FOR TRANSDISCIPLINARY RESEARCH AT THE UNIVERSITY OF PRETORIA.

FUTURE AFRICAN CITY-MAKERS – SOLVING WICKED PROBLEMS TOGETHER

The contemporary and future uncertainties are growing exponentially and are shifting more rapidly than the prevailing regulations, standards, guidelines and best practices in African city-making can accommodate.

Our historic and customary urban practices usually take a deterministic approach. This approach was useful in helping to reduce degrees of uncertainty. However, uncertainties are very high today and are increasing at alarming rates. Along with impacts of current and future scenarios, a deterministic approach simply cannot deliver the results we need. The urgency of action necessary to improve complex systems, like cities, requires us to produce practitioners who are really good at operating in complexity and uncertainty. If we want to solve the wicked problems of the future of cities, we need complex critical thinkers who can think on their feet, work well with others, and leverage technology quickly to achieve their goals.

With the Hatfield Digital Twin City, we aim to create both high-end and low-data, and low-cost and real-time virtual labs for research, innovation, education and training. We hope to maximise our laboratory to greatly expand our remote and distributed learning capabilities, allowing anyone from anywhere to participate. The Hatfield Digital Twin City not only expands the University's student market to an unlimited number of participants at a variety of educational engagement levels, but also serves its teaching and learning aspirations.



A rendition of district 3D point cloud scanning

The digital twin city can integrate much of the baseline learning in our current education practices. Much of the baseline data necessary to construct such twins includes the production of maps, 3D buildings, engineering instruments, measurements, community engagement, interviews or observations. These are all standard practices and discipline agnostic. Furthermore, the upkeep of datasets, experiments and learning within comprehensive virtual cities is vital to the health of virtual laboratories. Teaching healthy data maintenance practices could also be directly integrated into the digital twin city, while we educate our students as usual. All we have to do is commit to digitalising the ongoing and current work in our respective disciplines and ensure that we share our learning and data sets with each other.

To solve the great wicked problem of cities and the crisis of our climate future, we need novel practices that produce vertical and horizontal integration among built environment practitioners. The future is indeed in city-making, but we urgently need another playbook and better tools. We need a place to learn, to unlearn and to relearn together. We need a place to experiment, make new things, and fix broken things together. To rapidly mobilise our cities towards sustainability and beyond, we need to become critically creative as a team. To develop these skills, we need a laboratory: a comprehensive complex system that imitates the real world.

Led by the Department of Architecture in the University's Faculty of Engineering, Built Environment and Information Technology, we have set out to build exactly that.

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Large-scale point cloud data enables the automated creation of realistic VR imaging

Hans Grobler

The industry support of AECI Mining was instrumental in the establishment of the AECI Mining Explosives Chair for Innovative Rock-breaking Technology in 2018. This is a joint research chair in the Department of Electrical, Electronic and Computer Engineering (EECE) and the Department of Mining Engineering, utilising the capabilities of the University's Kumba Virtual Reality (VR) Centre for Mine Design.

The Department of EECE's Virtual Reality Project forms an important part of the activities of this Research Chair. The overall goal of this project, under the management of Hans Grobler, senior lecturer and leader of the Department's Intelligent Systems Research Group, is to develop techniques that will allow the visualisation of real-world mining environments using VR technology. As such, it contributes to the University's mining footprint. The University of Pretoria is ranked globally in the top 50 universities for minerals and mining engineering according to the 2020/21 QS World University Subject Rankings.

Advances in sensor technology enable real-world environments to be digitalised in the form of a collection of 3D points called point clouds. At the same time, VR technology has advanced to the point where affordable platforms for the visualisation of 3D environments are available. Although sensors may also capture colour information, point clouds can typically only be visually interpreted at a distance and lose meaning when viewed at close proximity.

This effect is particularly problematic when point clouds are visualised directly in a VR environment. In order to produce realistic VR visualisations, a number of transformations must be applied to the point cloud. Among other things, surfaces must be generated, and these surfaces must be colourised and ideally texturised.

Another factor to consider is the constraints of the commercially available VR platforms, which typically limit the size of the point clouds that can be visualised.

These aspects were addressed during the early stages of the Virtual Reality Project, and a system was developed to allow the VR visualisation of static real-world environments. However, the surfaces produced by the approach described above do not have a geometric and/or semantic meaning attached to them. The generated VR visualisations are therefore static in nature and do not generally allow manipulation.

During the final stage of the project, methods are being researched to extract domain-specific geometric and semantic meaning from point clouds using techniques from the field of Artificial Intelligence. Researchers involved in the project are also investigating the automated extraction of 3D models, as well as motion analysis performed for sequences of point clouds and other data sources such as image sequences. They are also planning to investigate techniques to utilise both the 3D models and the extracted motion information in order to produce dynamic 3D visualisations of real-world environments.

As the current industry approach to the generation of VR simulations typically entails the laborious hand crafting of models and their motions, the primary objective of this research is to significantly enhance the viability of using VR for the realistic visualisation and analysis of real-world dynamic environments.

ADVANCES IN SENSOR TECHNOLOGY ENABLE REAL-WORLD ENVIRONMENTS TO BE DIGITALISED IN THE FORM OF A COLLECTION OF 3D POINTS CALLED POINT CLOUDS. AT THE SAME TIME, VR TECHNOLOGY HAS ADVANCED TO THE POINT WHERE AFFORDABLE PLATFORMS FOR THE VISUALISATION OF 3D ENVIRONMENTS ARE AVAILABLE.

Developing design formulae for reinforced concrete structures through AI algorithms and modelling

Prof George Markou and Dr Nikolaos P Bakas

Civil engineers around the world strive to construct a sustainable and safe built environment by engaging numerous design and numerical tools. The design and assessment of structures is performed through the use of national and international design codes that usually suggest the use of semi-empirical design formulae.

Numerical modelling has helped engineers to analyse and design larger and more complicated structures (in terms of geometry). Nevertheless, the limitations that derive from the nature of the design codes and time-consuming non-linear numerical analysis are still present. Furthermore, the investigation of full-scale structures and their numerical assessment through the use of non-linear advanced modeling remains a complicated procedure that most professional civil engineers find challenging to implement, given that it requires advanced knowledge and know-how.

In an attempt to solve these problems through innovation and the use of an approach that uses out-of-the-box thinking, a research project was initiated in 2018 to marry state-of-the-art 3D, detailed modelling with Artificial Intelligence (AI) and Machine Learning (ML) algorithms for the development of design formulae that can predict the mechanical characteristics of reinforced concrete structures.

This approach foresees the construction of datasets through the use of Reconan FEA (2020) software that can realistically model reinforced concrete structures, including their foundation system and the soil on which the structures are founded. The numerically derived datasets are then used to train AI and ML algorithms that can develop models with advanced predictive capabilities.

After the algorithmic training is done, the extracted predictive models are validated through the use of numerical and experimental out-of-sample data. The main advantage of this approach is the development of models that provide results to civil engineering problems in a fraction of a second in an objective and accurate manner, where more conventional methods would require days and would not be as accurate as the models developed through AI or ML.

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

The use of AI and ML algorithms in solving problems, such as those required for self-driving cars, face recognition and bot engines, has attracted the attention of scientists in different fields of study that seek to solve various complex problems.

To explain how these algorithms work in a simplistic manner, one has to imagine a set of input data that describes a specific problem, where this input data corresponds to a specific output.

For example, if the input is a set of numbers equal to 1, 2, 3,..., 10, while the corresponding output for each of these numbers is 1, 4, 9,... 100, respectively, then it is easy to conclude that the relationship that connects the input with the output is the expression $y = x^2$, where y is the output value and x is the input value.

Now, let us imagine a more complicated dataset that has 10 input values for each output, where the dataset has 100 000 of these input-output data, each consisting of 10 input values and one output value. By using AI and ML algorithms, a relationship can be developed that can predict the output data with acceptable accuracy. This is done through the use of numerical methods that follow different approaches. Some of the most well-known AI and ML algorithms are artificial neural networks (ANN), random forests and XGBoost. The ANN are usually used for AI applications, while the other two methods are ML algorithms.

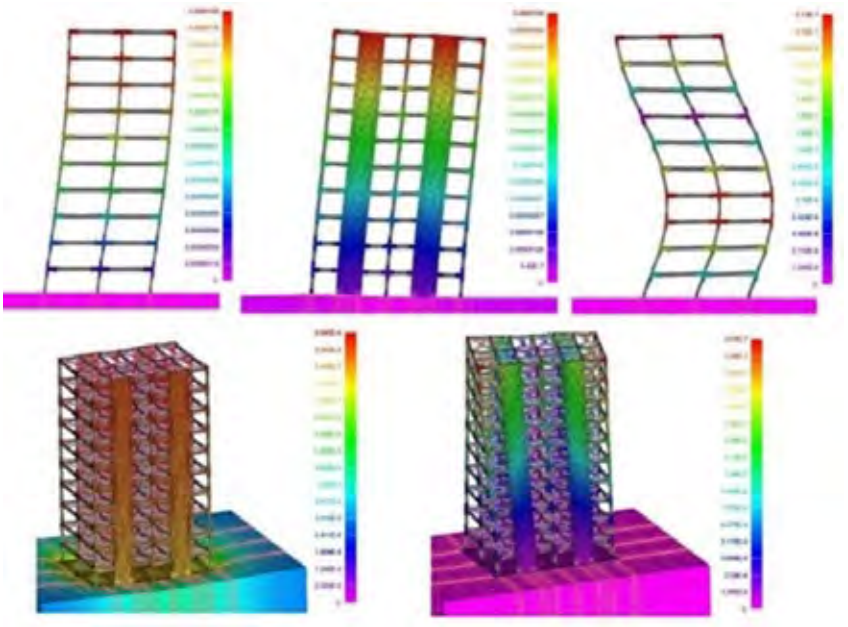
It is well known that there is not yet a one-size-fits-all solution when it comes to AI and ML algorithms. Multiple methods are usually engaged to discover the optimal one that will allow the development of the most accurate and objective predictive model. Therefore, both AI and ML algorithms are engaged to solve civil engineering-related problems.

PREDICTING THE FUNDAMENTAL PERIOD OF REINFORCED CONCRETE STRUCTURES

According to a research article published in *Soil Dynamics and Earthquake Engineering* (Gravett et al., 2021), tools that would help to accurately predict the dynamic properties of buildings is undoubtedly a crucial objective. In this research, a fundamental period formula is given for reinforced concrete structures with and without accounting for the soil structure interaction effect.

Models were developed and analysed under modal analysis. The dataset was then used to develop a closed form relationship, which was able to provide accurate predictions that had a 5.68% error. While conventional modal analysis requires several hours for it to be analysed by the finite element analysis software, the proposed fundamental period formula was able to provide the required results in a fraction of a second.

Recently, the development of an even more accurate formula was successfully attempted, where the training was performed through the use of a larger dataset developed by a research student at the University of Pretoria. In addition to that, Reconan FEA was updated to be able to run on high-performance computers, where large-scale models are being analysed on a Cyclone super-computer to broaden the spectrum of building geometries within the current dataset.



Modal analysis results of a 10-storey building with shear walls.
Eigenmode shapes of the first five computed periods (Gravett et al., 2021)

MODELS WERE DEVELOPED AND ANALYSED UNDER MODAL ANALYSIS. THE DATASET WAS THEN USED TO DEVELOP A CLOSED FORM RELATIONSHIP, WHICH WAS ABLE TO PROVIDE ACCURATE PREDICTIONS THAT HAD A 5.68% ERROR. WHILE CONVENTIONAL MODAL ANALYSIS REQUIRES SEVERAL HOURS FOR IT TO BE ANALYSED BY THE FINITE ELEMENT ANALYSIS SOFTWARE, THE PROPOSED FUNDAMENTAL PERIOD FORMULA WAS ABLE TO PROVIDE THE REQUIRED RESULTS IN A FRACTION OF A SECOND.

CURRENT AND FUTURE RESEARCH WORK ON OTHER DESIGN FORMULAE

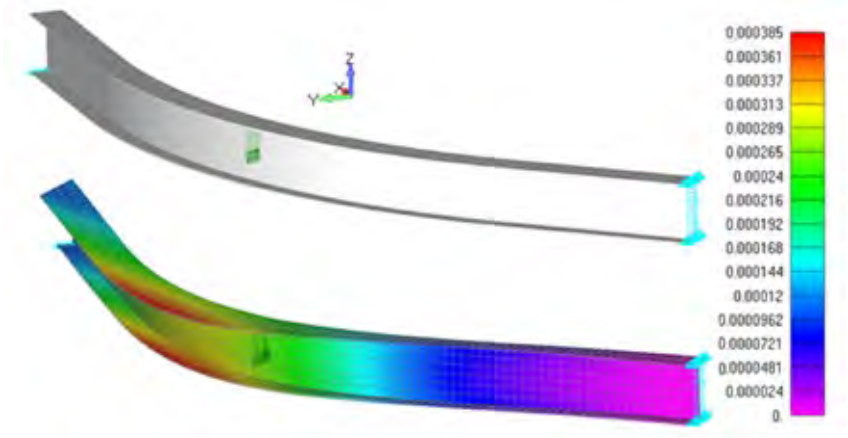
A predictive formula has been developed for the calculation of the shear capacity of slender reinforced concrete beams without stirrups. This research was presented at the 8th International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering in June 2021 (Spijkerman et al., 2021).

The entire training procedure was performed using digitally generated data, where the validation of the developed formula was performed using actual physical experiments. Based on the findings, the proposed formula outperformed conventional Eurocode 2 and ACI-318 design formulae. The extended dataset that was initially developed by researchers in the Department of Civil Engineering is now under review, where more than 35 000 items of data were used to train a predictive model through the use of an innovative distributed deep learning ANN algorithm.

Similar research work has been submitted for publication, which foresaw the development of a formula that predicts the shear capacity of reinforced concrete deep beams without stirrups, where the longitudinal reinforcement foresees the use of aramid, glass and carbon-fibre reinforced polymer (FRP) bars. Real FRP-reinforced beam specimens were used to validate the developed formula that was found to have phenomenal accuracy compared to any international design code. This is the first design formula of its kind.

A research project is currently being finalised, where a postgraduate student was able to generate more than a thousand data results for the case of steel structures with and without soil structure interaction considerations. Similar to the reinforced concrete structures discussed earlier, the research team managed to develop an objective and accurate fundamental period formula for steel structures that is also the first of its kind in the world.

Finally, a research project on curved steel I-beams is being performed. The objective of this research is to develop formulae that will be able to estimate the deformation and stress development of curved steel I-beams given a specific load level. This type of problem has never been solved in the past due to the extreme torsional behaviour of these beams and the lack of experimental data. Therefore, providing a solution to this eternal problem will be extremely rewarding to both the research team and the international civil engineering community.



Steel I-beam model. Undeformed and deformed shape with displacement contour after loading.

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Dr Schalk Grobbelaar,
Graduate School of Technology Management

Research supports timber-based construction

Dr Schalk Grobbelaar

Mass timber construction using advanced engineered wood products is emerging as a sustainable alternative to concrete and steel globally. The South African construction industry mainly makes use of locally produced timber products, but very little mass timber is manufactured or used in local building projects.

Mass timber comprises products such as cross-laminated timber (CLT), laminated veneer lumber (LVL) and glue-laminated timber (glulam), which have been used to construct multi-storey buildings in Europe, such as the Mjøsa Tower in Norway.

The production of similar products in South Africa will increase local demand, manufacturing capacity and competitiveness, and, in turn, contribute to the growth of the local sawmilling industry.

South Africa currently produces approximately 2 million cubic metres of softwood lumber per annum. This constitutes less than 0.6% of the world's production.

South Africa also has very limited glue-laminated timber production capacity, only one very small CLT manufacturer and no LVL manufacturing capacity.

Mass timber products are therefore rarely used in construction in South Africa as they would need to be imported from Europe or North America, which makes them very expensive.

INTERDISCIPLINARY RESEARCH

The University of Pretoria identified a gap in the knowledge of and standards for mass timber produced locally.

It therefore took the decision to advance research in this area in its Department of Civil Engineering, with the potential for interdisciplinary projects with other disciplines related to the wood-based bio-economy.

The construction of various specialised laboratories in its Engineering 4.0 Complex on the Innovation Africa @UP Campus subsequently provided the opportunity to develop a research laboratory for wood engineering. The collaboration and financial support of York Timbers (Pty) Ltd, the biggest sawmill and solid wood manufacturer in South Africa, therefore gave rise to the York Wood Engineering Laboratory in September 2020.

The development of such a research facility was furthermore necessitated by South Africa's lack of data on appropriate engineering, safety and best utility (building codes) of its locally produced timber. This is essential if we are to manufacture advanced wood structural products of similar or superior quality to that found in the Northern Hemisphere.

The idea advanced with the development of this research facility was to test mass timber in order to provide proof of the reliability of locally produced engineered wood products.

Once it has been established that locally produced mass timber is comparable to that produced in Europe and North America in terms of quality and strength, local manufacturers will have the confidence to invest in the required technology to develop advanced engineered wood products for mass timber construction. At the same time, research will be undertaken to incorporate mass timber construction in local building standards.

ENVIRONMENTALLY SUSTAINABLE

The popularity of timber as a construction material globally is based on its environmental sustainability, as opposed to the impact of concrete and steel production on the environment. Timber is the only construction material that actually absorbs carbon dioxide, as opposed to the production of concrete, for example, which has a very large carbon footprint, releasing an excess amount of carbon dioxide into the atmosphere in the manufacturing process. Timber construction therefore plays an important role in the alleviation of climate change.

A sustainable, mass engineered timber construction industry in South Africa and the African continent will be stimulated by the development of advanced engineered wood products from locally grown forest plantations. South Africa's climatic conditions are ideally suited for the cultivation of timber plantations. The country can thus only benefit from an integrative approach to the training of wood structural and chemical engineers, architects, data scientists, geneticists, breeders and forest scientists who can take a holistic approach to the development of a new, sustainable wood-based bio-economy.

INDUSTRY COLLABORATION

York Timbers' interest in collaborating with the University of Pretoria in this important initiative is based on the solid reputation of the University's Forestry and Agricultural Biotechnology Institute (FABI), which has established itself as a leader in forestry research both locally and internationally. The company also recognises the Department of Civil Engineering's involvement in timber research in South Africa, which focuses on standard applications and national standard developments, as well as the timber-related research conducted in the Department of Chemical Engineering.

The collaboration between the University's Faculty of Engineering, Built Environment and Information Technology and its Faculty of Natural and Agricultural Sciences forms an important part of the interdisciplinary research programme supported by York Timbers.

THIS RESEARCH ADDRESSES A GAP IN THE KNOWLEDGE OF AND STANDARDS FOR MASS TIMBER PRODUCED LOCALLY.

RESEARCH CHAIR

In addition to its support of the York Wood Engineering Laboratory in the Engineering 4.0 Complex, York Timbers is funding a multi-disciplinary Chair in data-driven wood structural engineering for a sustainable built environment and African bio-economy over a period of five years. This financial support will grow from R3.5 million in the first year to R6 million in the final year.

The funding will be applied to the salary of a full professor as Chairholder, the operational costs of the Chair, as well as running costs and bursaries for postdoctoral and postgraduate student projects linked to the Chair. The University will also contribute to postdoctoral and postgraduate student bursaries. This will involve researchers and experts from civil and chemical engineering, architecture, materials science, data science, biochemistry, genetics, microbiology and other related bio-economy disciplines at the University.

Research proposals have already been accepted for projects related to the wood-based bio-economy in the following departments:

- Department of Computer Science: One BSc Honours in Computer Science and three MIT (Data Science) students
- Department of Chemical Engineering: One MSc in Chemical Engineering student
- Department of Genetics/ FABI: One BSc Honours in Bioinformatics, one BSc Honours in Genetics student, as well as a postdoctoral student, and one MIT (Data Science) student
- Department of Civil Engineering: Two MEng in Civil Engineering students
- Department of Architecture: Two BSc (Architecture) students

EXPANDING THE TIMBER CONSTRUCTION FOOTPRINT

An important outcome of the interdisciplinary collaboration will be the cultivation, growth and expansion of South Africa's mass timber construction footprint. In addition to the research-based development of advanced wood products, it is recognised that disciplines such as architecture, construction management, quantity surveying and civil engineering play an integral role in the construction industry. In one way or another, they are the biggest specifiers of sawn timber in South Africa. They are therefore ideally positioned to promote the use of engineered wood products for construction as they can respond to the queries of practicing professionals about alternative and sustainable building materials that will benefit both the economy and the environment.

Green construction:
Evidence of a maturing industry

Danie Hoffman

Since 2014 the University of Pretoria, supported by the Green Building Council of South Africa (GBCSA) and the Association of South African Quantity Surveyors (ASAQS), investigated the cost trends of South African green buildings. This ongoing study aims to quantify the green building cost premium (GBCP) to refute the argument that green building is an unaffordable proposition. The latest evidence also strongly indicates a maturing green building industry.

THE PERFORMANCE OF THE GREEN BUILDING INDUSTRY IN RECENT YEARS HAS BEEN MORE CONSISTENT AND MORE CLOSELY ALIGNED TO THE EXPECTED PERFORMANCE LEVELS, WHICH POINTED TOWARDS A MATURING GREEN BUILDING INDUSTRY WITH INCREASING PERFORMANCE LEVELS TOWARDS ESTABLISHED BEST PRACTICE STANDARDS.

The GBCSA was established in 2007, and the first Green Star SA certification of a South African building was issued in 2009. By August 2021, the GBCSA had awarded more than 500 Green Star certifications. A main hurdle towards advancing green building internationally and in South Africa was the argument of the unaffordable cost premium of green building. Perceptions of cost premiums of 25% and more hampered the progress of green building.

A doctoral study conducted in the University's Department of Quantity Surveying on the cost premium of green buildings included all new South African office buildings with a Green Star certification issued up to December 2018. A total of 146 buildings qualified for inclusion in the study.

The study found that new South African office buildings achieve Green Star certification for a modest GBCP of 3.96% (median value).

For the period 2015–2018, the median GBCP was only 3.49%. This finding supported the GBCSA's claim that green building is an affordable proposition with a strong business case.

The study benefitted from gaining deeper insight into the often complex nature of the GBCP. Eight different building features with strong linkages to green building cost were used to explore the GBCP in more detail. In doing so, the growing maturity of the local green building industry came to the fore.

THE BASE BUILDING COST OF BUILDINGS

Buildings with a higher base building cost budget should accommodate additional green building cost items without increasing the project cost, resulting in a small GBCP. In contrast, buildings with a more limited base building cost will be unable to absorb the additional cost of green building, leading to a substantial GBCP.

The data obtained in the study categorised green buildings as certified in the early green building period (2009–2014) and certified in the subsequent years (2015–2018). All base building costs were escalated to one common date of December 2018 to allow for the time value of money. Escalated base building costs varied from R9 048/m^2 to R28 983/m^2 (a median value of R14 598/m^2).

For projects certified during the later years (2015–2018), the GBCP was, as expected, negatively correlated to the escalated base building cost. However, projects from the early years of 2009 to 2014 had a positive correlation between GBCP and the escalated base building cost, although with significant variability around the regression line.

The performance of the green building industry in recent years was, therefore, more consistent and more closely aligned to the expected performance levels, which pointed towards a maturing green building industry with increasing performance levels towards established best practice standards.

THE FAÇADE RATIO OF BUILDINGS

Many previous studies confirmed the link between a smaller façade-to-construction area of buildings and more affordable energy-efficient building designs. The façade-to-construction area ratios varied between 0.19 m^2/m^2 and 0.84 m^2/m^2 A positive correlation was found between the façade-to-construction area ratio and the GBCP of the buildings.

The buildings from 2015 to 2018 were much more closely aligned to the regression line than the buildings from 2009 to 2014, which varied significantly around the regression line. The findings of the research confirmed a better and more consistent green building performance in recent years, indicating a maturing industry.

THE CERTIFICATION DATES OF BUILDINGS

The research study confirmed a negative correlation between the certification date and the GBCP, with a diminishing GBCP over time. A green building from 2009 with a GBCP of, say, 6.0%, would have declined to 3.58% in 2018 or by 40.33%. This is a significant industry achievement in such a short space of time.

The Pearson's correlation coefficient for buildings from 2015 to 2018 obtained in the study was much higher than the overall correlation coefficient. The study also confirmed that, during the later years, the GBCP of buildings was much more consistent, with a decreasing separating margin between the annual median and minimum values of the GBCP.

The increased consistency and narrowing margins found in the study confirmed a maturing South African green building industry, which is able to deliver best practice performance more consistently over time.

THE RESEARCH STUDY CONFIRMED A NEGATIVE CORRELATION BETWEEN THE CERTIFICATION DATE AND THE GREEN BUILDING COST PREMIUM, WITH A DIMINISHING COST PREMIUM OVER TIME. A GREEN BUILDING FROM 2009 WITH A COST PREMIUM OF, SAY, 6.0%, WOULD HAVE DECLINED TO 3.58% IN 2018 OR BY 40.33%. THIS IS A SIGNIFICANT INDUSTRY ACHIEVEMENT IN SUCH A SHORT SPACE OF TIME.

Regenerative cities: Co-evolving with our planet

Prof Chrisna du Plessis

Sustainability should be more than just finding ways that allow us to continue our current lifestyle. Regenerative design strives for a future where human civilization evolves as one part of nature that is following its own laws of circularity.

The way we frame sustainability, and why it is necessary, has a huge impact on our perceived possibilities for action. Currently, there are two main sustainability narratives. The first talks about how bad things are getting, and that we are essentially doomed to civilizational, if not planetary ecosystem collapse. It is a narrative of guilt, fear, scarcity, austerity and control that keeps us trapped in the current degenerative spiral because we simply cannot imagine a different way.

There is no denying that so many of our ecological systems are on the brink of collapse, or that some of our social and economic systems maybe need collapse. Humans, perhaps rightly so, have a deep-seated fear of collapse, of endings, of death; forgetting that in nature collapse is merely the precursor of new growth. It releases nutrients, or potential, that can be the feedstock for new life and new ways of being. The second sustainability narrative tells a story of how we can use this pivotal point in human development, and the potential it releases, to create a better world in which humans can be a force for good. This is the calling of regenerative design and development – a story of hope made active.

This article was first published in Urbanet on 9 February 2021.

FROM SUSTAINABILITY TO REGENERATIVE DEVELOPMENT

The shift to regenerative thinking is not only about the how, but also, and perhaps more importantly, about the why. Regenerative development has been defined as an approach that is about enhancing the ability of living beings (and systems) to co-evolve, so that our planet continues to express its potential for diversity, complexity and creativity.

You will note it says nothing about reducing carbon emissions, or monitoring resource use, or shifting to renewable energy and public transport – all the hows of sustainability. Regenerative cities are not the same as sustainable, or even resilient cities. Their why is not to find ways that would allow us to continue living our current lifestyles. Their why is to find ways that would allow all of human civilization to evolve. They are the gateways to the transformation of our world from its current disconnected and dysfunctional state to a world that is healing its relationships, that nurtures life and creativity. Just as a caterpillar let go of its caterpillar reality to become a butterfly, regenerative cities let go of their current notions of cities to become places where living systems can co-evolve and express their full potential. What would this entail?

IT STARTS WITH PLACE

The first ambition of regenerative design is to heal the fractured relationship between humans and nature, so that we can fully participate in the web of life and its evolution. This starts with connecting humans to the place where they are: sensitising them to the way the wind blows and the rain flows and the path of the sun through the seasons; introducing them to the communities of life whose existence weaves through their own so that they can again find their place in this edifice, their role in the dance. The way we design buildings and urban spaces can help to build these connections to place.

Much has been written about the biophilia hypothesis of EO Wilson, which maintains that the need to affiliate with nature and other living beings is genetically hardwired in humans, and that, without such contact, various pathologies can develop. There is growing evidence of how introducing more nature into our designed spaces contributes to human health and wellbeing, increases productivity, and, in cities, cleanses the air, reduces the urban heat island effect and assists with stormwater management and biodiversity restoration.

Cities like Singapore pride themselves on the amount of nature they are reintroducing into the city. However, it is not enough to plant trees and introduce rain gardens if this does not lead to a reciprocal relationship where humans are also improving the lives of the organisms in these new ecosystems. The Khoo Teck Puat Hospital is an example of where the building and its occupants actively work towards building biodiversity.

This transformation of cities requires us to see the city itself as a nested set of ecosystems within which our infrastructure, buildings, gardens and humans themselves become functioning parts of nature, learning from nature to work with nature and, eventually, become like nature, following its laws of circularity and cooperation.

RECIPROCITY AND CONTRIBUTION AS THE ETHOS

Regenerative cities are like old-growth food forests, where all organisms cooperate in an endless cycle of support and exchange. Transactions, be they economic or social, are not driven by the imperative to maximise individual profit, but rather by how much they contribute to the common good and whether they will have a net-positive impact on the wellbeing of the system in which they take place.

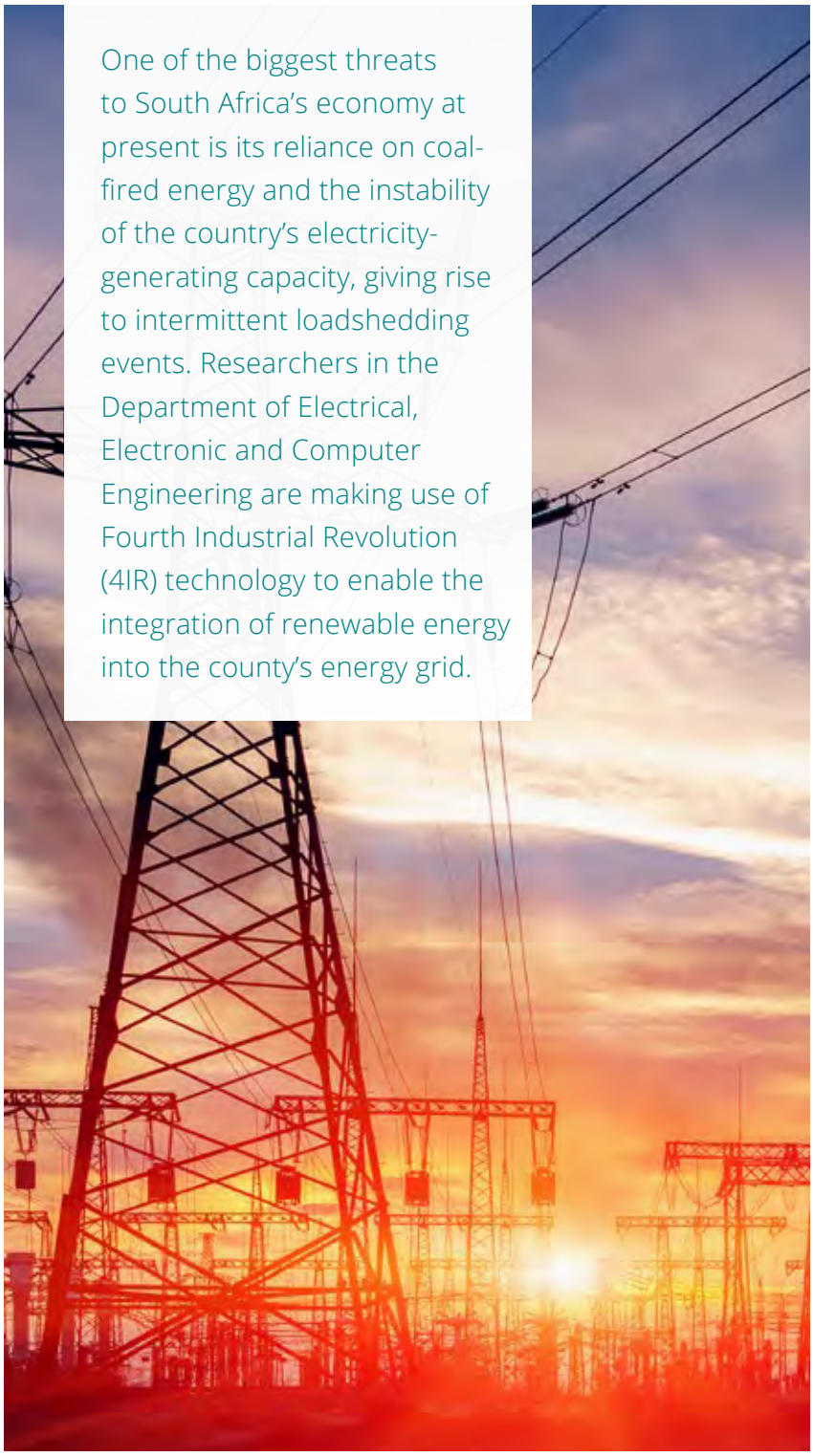
This spirit of contribution forms the basis of the models of regenerative economies being developed, but can also be simple design decisions like designing building edges so that they provide cover from the elements, or providing public drinking fountains.

BEGIN WHERE THE SYSTEM IS ALREADY FRAYING

The biggest question, though, is where to begin. The answer is: In those liminal places where the hold of the old system is losing its power, where things are no longer working and the call for something new and radically different cannot be ignored, where things are falling apart or were destroyed in the storms. A great example is Moja Gabedi in South Africa, an unofficial landfill that has been transformed into a meaningful food garden. Those are the places where the smallest seed can take root in the cracks of the old world, opening up the way.

Smart grids spark the modernisation of South Africa's energy grid

Prof Raj Naidoo



One of the biggest threats to South Africa's economy at present is its reliance on coal-fired energy and the instability of the country's electricity-generating capacity, giving rise to intermittent loadshedding events. Researchers in the Department of Electrical, Electronic and Computer Engineering are making use of Fourth Industrial Revolution (4IR) technology to enable the integration of renewable energy into the county's energy grid.

The application of communication and data collection technologies to provide more information on the state of the country's energy grid is a particular focus area of the Department's Smart Grid Labs.

This facility has established itself as a leader in smart grid research, where the power grid meets the Internet of Things (IoT). Its high-quality research, products, services and capabilities fill the widening gap between end-users and electricity suppliers across African markets.

Among other things, projects aim to determine how best to integrate renewable energy sources into conventional power systems using smart grids. This entails the application of smart distribution systems, smart metering and system diagnostics, and renewable energy integration, as well as smart prepaid metering (with time of use), advanced metering infrastructure (AMI) security and active network management.

The integration of smart technology such as sensors and smart devices for sharing information not only affects the national electricity system, but can also improve efficiency in residential, commercial and industrial sectors through connectivity. It does this by collecting important information from sensors in electrical systems that can reduce wastage and help investigate alternative sources of energy for specific tasks and times.

By deploying sensor technology, engineers working on an electrical grid can obtain additional information about the status of the grid, which will ultimately improve the efficiency of the system. This can help reduce wear and tear, extend the lifetime of the grid, and improve future grid design.

This fresh approach to smart grid research has benefits that will be realised across all sectors, empowering end-users, and delivering savings across the board, which will benefit utilities and municipalities as well.

For the household, the smart grid provides information on energy use in the house, which can advise homeowners on cost-saving activities, such as incorporating systems like solar water heaters or double glazing on windows. Municipal managers can also use this data to properly shape pricing for electricity and forecast future power demands to better service the community. For the commercial sector, smart grids can maintain productivity for a company by integrating secondary power sources and prioritising them accordingly, while for industry, this technology can vastly improve the efficiency of various electronic components. Ultimately, smart grid technology is focused on collecting more information on how electricity and power is being used to make better management decisions.

Capacity building and training forms an important element of the Smart Grid Labs' strategic planning. It currently has 15 master's degree and 13 PhD students, who are engaged in research related to the power grid. Research topics range from the protection of distribution systems and cost-effective ways of implementing the distributed energy resources into the current grid to optimal renewable energy.

It also presents short courses in partnership with the Department of Mineral Resources and Energy (DMRE) and the South African National Energy Development Institute (Sanedi) on smart metering for beginners, practical smart metering, with a focus on audits and installation practices, a systems approach to smart metering implementation at municipalities, cybersecurity essentials with a focus on AMI security in smart grids, and smart grid power distribution.

Towards the end of 2020, the Department trained graduates from technical and vocational education and training (TVET) colleges on hydrogen fuel cell systems in partnership with Bambili Energy, the Ministry of Higher Education, Science and Innovation, and the Energy and Water Sector Education and Training Authority (EWSeta). The purpose of this training was to develop competent, capable and work-ready technicians for the deployment, installation and maintenance of hydrogen fuel cell systems in South Africa and beyond. This is of particular significance for the future of renewable energy, as fuel cells are expected to play a significant role in providing energy to buildings and in off-grid electrification, particularly in areas where grid extension is not economically viable.

In addition, the Department's smart grid researchers offer consultation services to industry. In this capacity, they provide advice on aspects such as smart cities and smart grids, the green economy, product design and development, remote diagnostics, and the design and optimisation of renewable energy systems, including microgrids.

The Smart Grid Labs has a close relationship with Sanedi, Rand Water and the DMRE, and is working with these entities to understand and prevent the potential data security threats that might compromise smart grids. Located within the City of Tshwane, it has also established strong ties with the metropolitan municipality. Together, with these stakeholders in local and national government, as well as the private sector, it is paving the way for a new approach to solving Africa's energy crisis.

FOR THE HOUSEHOLD, THE SMART GRID PROVIDES INFORMATION ON ENERGY USE IN THE HOUSE, WHICH CAN ADVISE HOMEOWNERS ON COST-SAVING ACTIVITIES, SUCH AS INCORPORATING SYSTEMS LIKE SOLAR WATER HEATERS OR DOUBLE GLAZING ON WINDOWS. MUNICIPAL MANAGERS CAN ALSO USE THIS DATA TO PROPERLY SHAPE PRICING FOR ELECTRICITY AND FORECAST FUTURE POWER DEMANDS TO SERVICE THE COMMUNITY BETTER. FOR THE COMMERCIAL SECTOR, SMART GRIDS CAN MAINTAIN PRODUCTIVITY FOR A COMPANY BY INTEGRATING SECONDARY POWER SOURCES AND PRIORITISING THEM ACCORDINGLY, WHILE FOR INDUSTRY, THIS TECHNOLOGY CAN VASTLY IMPROVE THE EFFICIENCY OF VARIOUS ELECTRONIC COMPONENTS.

The viability of government support for rooftop solar

Prof David Walwyn, in collaboration with Warren Gertzen,
Paleesha Naidoo and Natasha Ramkirpal

The South African government is reported to be considering the introduction of a Universal Basic Income Grant (UBIG). Although still controversial, with the new Minister of Finance, Enoch Godongwana, arguing that the grant will only keep young people in a cycle of dependency, the grant is being proposed as a key instrument to address the extreme levels of unemployment, the decimation of the economy as a consequence of the pandemic and rising levels of poverty and food insecurity in South Africa.

There is growing recognition of the importance of energy access for development and, more generally, an acceptable quality of life. Access to sufficient energy, referred to as energy justice (González-Eguino, 2015), is as important as other basic needs, and is already incorporated within the Sustainable Development Goals (SDGs) as Goal 7: Affordable and clean energy.

Recent work on the necessary energy threshold to ensure that SDG 7 is achieved indicates that a modern energy minimum of at least 1 000 kWh per person per year should be provided (Energy for Growth Hub, 2021). Assuming a household of five persons, this value is equivalent to about 400 kWh per month, which is double the present average consumption of 200 kWh per month in low-income areas.

Although the two options are not equivalent, a Basic Energy Grant (BEG), which allows low-income households to become prosumers within an energy economy, could cover both income and energy needs. Moreover, distributed energy systems that use rooftop solar as the generation technology would simultaneously achieve other national goals, such as the decarbonisation of the energy sector. The potential of small-scale rooftop solar as a means of uplifting low-income areas has already been proposed and, indeed, adopted in other countries. South Africa could be a global role model in the implementation of the UBIG/BEG system.

The objective of a study conducted by researchers in the University of Pretoria's Graduate School of Technology Management (GSTM) was to determine the viability of rooftop solar as a means of delivering a portion of the UBIG in certain key geographic areas. The analysis used the standardised approach of the levelised cost of energy (LCOE)[1] to determine the cost of grid-connected rooftop solar and hence its value in supporting poor households.

INPUT ASSUMPTIONS

The study's model used, as its basis, a single household of five persons, all of whom fall below the poverty datum line and would qualify for a proposed R585 per month. It was assumed that each home would be equipped with a grid-tied rooftop solar system of 5 kWp capacity, at a cost of R103 000, paid by a special-purpose vehicle financed through National Treasury or municipal bonds, and generating a power output of 8 595 kWh per year. In terms of present energy usage, it was also assumed that each household presently purchases power at a cost of R2.17 per kWh (based on the prepaid tariff in urban areas).

Three scenarios were considered:

PRESENT
The existing situation with no social grants and 200 kWh per month using a prepaid meter

OPTION A
The UBIG with electricity consumption at the modern energy minimum supplied by the municipality based on prepaid meter rates

OPTION B
The UBIG/BEG with rooftop solar and energy consumption at the modern energy minimum with the charge rate being the LCOE value for rooftop solar

The lifetime of the solar panels was assumed to be 25 years with a degradation rate of 0.7% per annum. The cost of capital was set at 8.2%. The maintenance cost was calculated at 0.5% of the per-capita cost. A capacity factor of 20% was used. Given that local authorities rely on a profit margin on the sale of electricity as a means of ensuring financial viability, the impact of the scheme was considered from the perspective of both the municipality and the household. In this regard, it was assumed that the profit margin for municipalities is 20% (in other words, the cost of delivered energy, including the cost of bulk purchase from Eskom, its distribution and its supply, is R1.74 per kWh).

ECONOMIC RESULTS

The LCOE for the rooftop solar system is calculated to be R1.37 per kWh, which is less than the unit cost of electricity to the local authority, including the distribution charges (the actual Eskom price is somewhat lower). Using the LCOE value, it is now possible to calculate the net impact on income for the three scenarios. The results are shown in Table 1.

TABLE 1
Results for the three scenarios

	Units	Present	Option A (UBIG)	Option B (UBIG/BEG)
Household cash flow				
Grant income	R/month	0	2 925	2 925
Energy generated	kWh/month	0	0	715
Energy usage	kWh/month	200	417	417
Energy cost	R/month	434	904	674
Surplus energy	kWh/month	-200	-417	299
Net disposable income	R/month	-434	2,021	2,251
Municipality cash flow				
Net revenue to municipality	R/month	434	904	1 157
Monthly cost of rooftop system (capital)	R/month	0	0	819
Cost of power purchase and distribution	R/month	347	723	121
Net profit to municipality	R/month	87	181	216

Under the present arrangement, low-income households must find R434 per month to access the average consumption level of about 500 kWh per person per year. Under Option A, a doubling of this consumption to the modern energy minimum would be covered by the UBIG, leaving a disposable income of R2 021 per month per household. Under Option B, the disposable income for the household and the net profit to the municipality are both increased due to the lower generation cost of the rooftop solar system and the sale of excess power from the solar panels to the municipality's wider market; the latter reflecting as additional revenue to the local authority.

1 LCOE is defined as the lifetime costs divided by energy produced; the value allows different technologies to be compared regardless of parameters such as life spans, cost of capital, project size and capacity utilisation (https://www.energy.gov/sites/prod/files/2015/08/f25/LCOE.pdf).

This study delivered three important results. Firstly, the cost of energy supply at household level is reduced by the adoption of rooftop solar relative to the cost of purchases from Eskom, making the attainment of the modern energy minimum more realistic and affordable. Secondly, the use of a portion of the UBIG to finance the initial capital cost (on an annualised basis) has a minimal impact on the value of the grant, and increases income at both household and municipal level relative to the present situation. Thirdly, the system allows individual households to become energy prosumers should a portion of the excess energy be repurchased at a marginal feed-in tariff. In summary, shifting energy generation, at least in part, from a centralised system to distributed units allows cost savings at the household level, while retaining municipal viability.

Apart from the important benefits of grid-connected rooftop solar, this scheme offers many other intangible benefits and opportunities for low-income communities. These include access to power during load shedding and the removal of a liability on the Eskom income statement due to non-payment. It also offers multiple opportunities for the growth of local economies and employment through the servicing of the systems. The use of the additional energy and the decarbonisation of the energy sector due to a decline in electricity requirements from coal-generated power also become options.

Finally, the development of markets in energy wheeling can improve the resilience and reliability of energy systems.

While replacing the BIG with rooftop solar does not yield a cash-for-cash equivalent trade-off, addressing energy poverty and fostering a more equitable society have long-term benefits to sustain South Africa's future. The recommendation is that government should restructure the BIG to have both a cash portion and a portion focused on subsidising the cost of electricity from rooftop panels, thus ensuring that Eskom's LCOE is equal to the LCOE of the rooftop solar panel.

ACKNOWLEDGEMENTS

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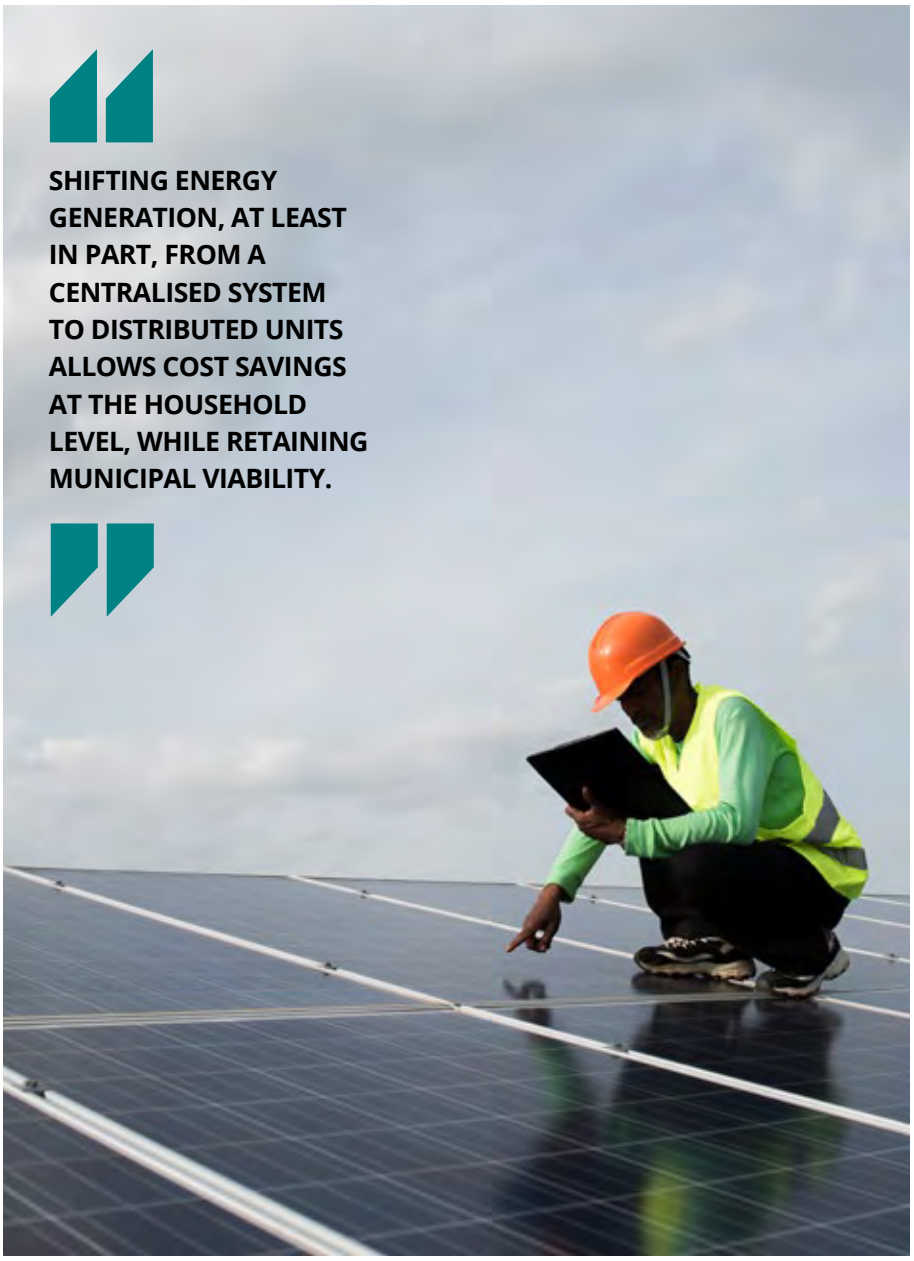


Reducing refrigeration systems' global warming impact through nanotechnology

Dr Bradley Bock

As the pace to reduce carbon emissions accelerates, and South Africa seeks to become a leader in clean energy, researchers at the University of Pretoria have teamed up with researchers from the Massachusetts Institute of Technology (MIT) and the Imperial College London to investigate whether nanostructures could be used to reduce the refrigeration sector's global warming impact.

Refrigeration (including air conditioning and similar devices) is estimated to contribute about 10% of the world's carbon dioxide (CO_2) emissions (based on data obtained prior to the COVID-19 pandemic), which is more than the contribution of all passenger road transport (approximately 5%), and only slightly less than the 15% that the entire transportation sector contributes to total global carbon emissions.

The CO_2 emissions of the refrigeration sector come from two primary sources: the electricity used to run the various refrigeration and air-conditioning units, and the speciality chemicals used in refrigeration.

The actual amount of CO_2 emitted as a result of the electricity used to cool our rooms and food depends largely on where one is in the world. In South Africa, most of the electricity is generated by fossil fuels. This means that the energy bill associated with the refrigeration sector is accompanied by a steep CO_2 bill.

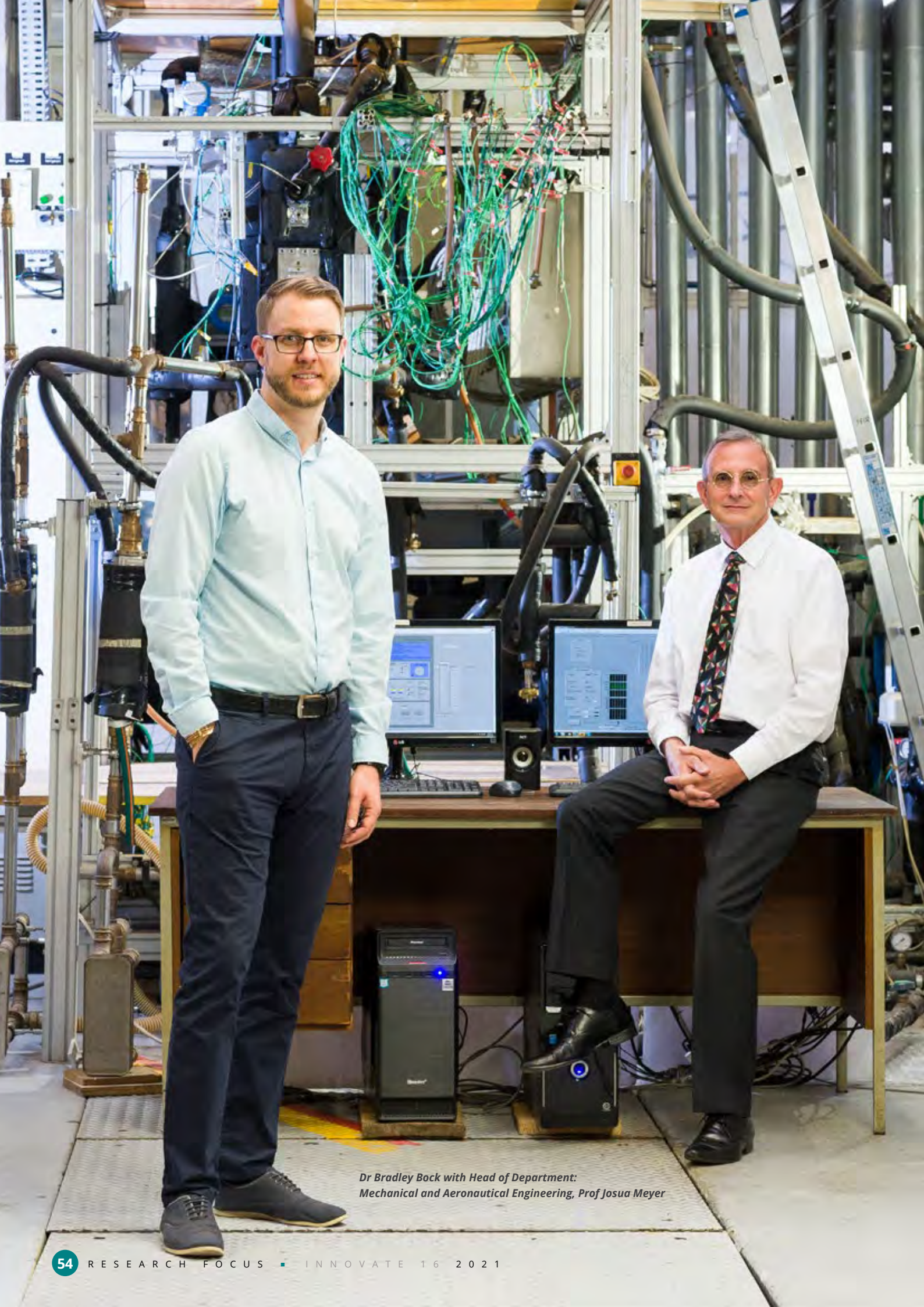
The speciality chemicals used in refrigerators and air-conditioning units, on the other hand, while not being CO_2 themselves, can also contribute to global warming. They often do a better job than CO_2 at heating our planet. For example, a single kilogram of the common refrigerant R-134a has, by some calculations, the same impact on global warming as 1 300 kg of CO_2. These refrigerants leak into the atmosphere over the life of the refrigerators or air-conditioning units. Once these machines break down or reach the end of their life, the refrigerant can simply be dumped into the atmosphere if correct disposal methods are not followed.

This has led to a drive by researchers at the University of Pretoria to improve the efficiency and reduce the size of refrigeration units. Smaller, more efficient refrigerators and air-conditioning units will mean that these machines will use less electricity and will need less refrigerant to fill them.

This research was conducted at a new testing facility located in the Clean Energy Research Group within the Department of Mechanical and Aeronautical Engineering. It allowed researchers to not only measure the heat transfer characteristics of tubes under conditions similar to those seen in the industrial machines it mimics, but also to watch the heat transfer process through viewing ports and record high-speed camera footage to better understand these often-complex processes. This experimental facility, which is two storeys high and has over 100 temperature, pressure and flow sensors, is an exciting addition to the Department's capabilities in heat transfer and refrigeration research.

Under the guidance of Prof Josua Meyer of the University of Pretoria and Prof John Thome of the University of Edinburgh, Dr Bradley Bock made use of this experimental facility in a recent study to investigate how nanostructures can improve the efficiency of refrigeration units by improving their heat transfer capabilities.

Nanostructures are any structures in the nanoscale and fall within the realm of nanotechnology. They have already been used in a range of industries such as electronics and medicine, and can change surface characteristics dramatically. Nanostructures are able to make



Dr Bradley Bock with Head of Department: Mechanical and Aeronautical Engineering, Prof Josua Meyer

surfaces wick liquids, much like paper towels, or can prevent surfaces becoming wet when exposed to liquids, much like the so-called "lotus effect" seen on the leaves of the lotus plant, where water droplets simply roll off its surface.

The research team at the University to Pretoria collaborated with Prof Matteo Bucci at MIT and Prof Christos Markides at the Imperial College London to coat copper tubes with nanostructures to see whether they could improve heat transfer in refrigeration units. This would allow for smaller, more efficient units. These specific nanostructures had previously been developed for the nuclear industry for use in water. This was the first study to see if this technology could be used to improve heat transfer on the surfaces of refrigerant heat exchangers.

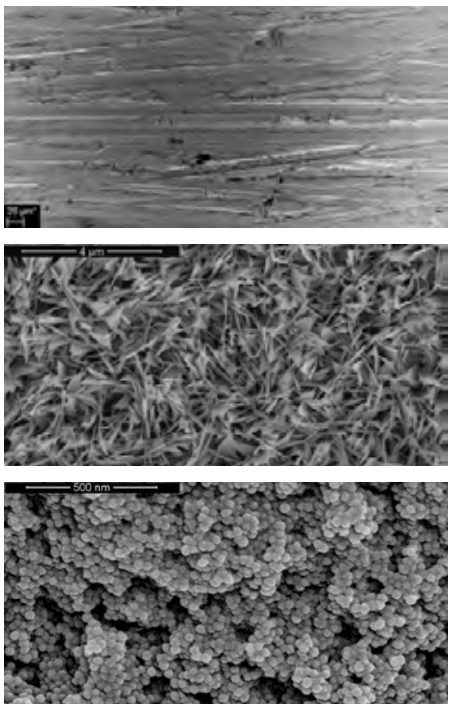
The nanostructures were created in two ways. The first method involved coating the outer surface of copper tubes with silica nanoparticles (specially manufactured balls that are only 20 nanometres wide and made from the same material as beach sand) one layer at a time. This process hoped to create a rough structure filled with voids and pockets to help with heat transfer. The second coating method involved dipping the copper tubes into a chemical bath, which created a fine matt of fibrous nanostructures on the surface of the tube. Too small to be seen by the naked eye, these fibrous nanostructures allowed the surface to absorb some liquid, changing the surface properties dramatically.

The team's research unlocked several new findings. The use of the fibrous nanostructures was found to increase heat transfer up to three times compared to that of a plain copper tube. However, the silica-nanoparticle nanostructures reduced heat transfer, showing the team that the choice of nanostructure is important, and the best nanostructure depends on the application.

After analysis of the high-speed video images, the nanostructures were also found to increase the heat transfer in new ways that had not previously been seen. "It seems that the liquid is sucked into the nanostructures and flows through the tiny pores. This can really improve the heat transfer," suggests Dr Bock. "Because we were researching boiling, it appears that the liquid might creep in underneath the boiling bubbles." But the team admits that more work will be needed to determine the exact mechanics of this improved method of heat transfer.

The nanostructures have proved to be an interesting opportunity to improve heat transfer in traditional refrigeration equipment, but this technology may be even more exciting for consideration in the next generation of refrigeration equipment. "Because many nanostructures can be produced with liquid chemicals, they can be used to cover almost any shape that designers might want. Thus, as the next generation of heat exchangers are built with advanced manufacturing technologies such as 3D printers that can produce new and complex geometries not previously seen, they might be able to benefit the most from these nanostructures," Dr Bock pointed out.

The Clean Energy Research Group is already working on the next research project to extend investigations into the full possibilities of nanostructures, not only in the refrigeration industry, but also in other heat transfer fields, such as the solar industry.



A picture of a plain copper tube under a scanning electron microscope (top), compared to two nanostructured surfaces (middle and bottom).

A nanostructured coated copper tube boiling refrigerant R-134a

BOOK LAUNCH

Prof Josua Meyer, Head of the Department of Mechanical and Aeronautical Engineering, has co-authored the newly published textbook *The art of measuring in the thermal sciences* together with Prof Michel de Paepe, professor of Thermodynamics in the Faculty of Engineering and Architecture at Ghent University in Belgium.

The textbook is aimed at anyone conducting measurements and experiments in thermal sciences, which are typical in a wide array of fields, such as refrigeration, transport, energy generation, manufacturing and mining. It is aimed at both industrial and academic contexts, where thermal measurements are required. This book thus offers engineers, researchers and graduates a source of best practices in the thermal sciences.

Transport's actual impact on the environment

Prof Johan W Joubert and Ruan J Gräbe

When it comes to the environment, everyone will agree that it needs protecting. It is arguably only Aloysius O'Hare from Dr Suess's *The Lorax* that will sing about the trees: *"I say, let it die, let it die, let it die..."* Yet, when it comes to the emissions from our vehicles, we seem to be conveniently oblivious of the effect of our actions on the environment. A new car sold in South Africa must declare its fuel efficiency and CO_2 emissions. These are in the form of stickers placed on vehicles in the new vehicle sales showroom in South Africa. However, one is unlikely to experience such excellent reported fuel efficiency. Why is this the case?

Salespeople will say that the difference is due to driver behaviour (how heavy one's foot is on the pedal), the weather, road gradient and general driving conditions.

The reported fuel efficiency follows from chassis tests under strict and controlled conditions (SANS 20101: 2006). The same argument holds for emissions. These standardised tests are not wrong. They are, indeed, necessary, just not nearly sufficient.

THE SOUTH AFRICAN SITUATION

In South Africa, we experience the actual effect of transport emissions in our cities daily. We do not inhale lab-level emissions. We expose ourselves daily to the pollutants emitted by the vehicles driven by real people under natural South African conditions.

The White Paper on South Africa's New Passenger Vehicle CO_2 Emission Standards (Posada, 2018) indicates that even South Africa's published emissions are higher (22% on average) than our European counterparts. One reason is our affinity for sport utility vehicles (SUVs) with, typically, more powerful and less efficient engines. Unfortunately, our ageing vehicles emit much more than their reported emissions because real people drive them.

Again, why the difference?

Because our cars and trucks expose us to actual driving behaviour on actual local road conditions, and, yes, in beautiful South African weather!

The infamous international Volkswagen diesel scandal, among others, sparked a global movement to enhance vehicle certification to include real driving emissions (RDE) testing.

In line with this state-of-the-art development, the Centre for Transport Development in the Faculty of Engineering, Built Environment and Information Technology acquired a portable emissions measurement system (PEMS) in 2020.

This was made possible through the funding contributions of the University of Pretoria, the National Research Foundation (NRF) (through the National Equipment Programme) and the Department of Science and Innovation (through the Waste Research, Development and Innovation Roadmap, managed by the Council for Scientific and Industrial Research (CSIR)).

The PEMS unit connects to the exhaust of a light or heavy vehicle, allowing one to measure a variety of pollutants while driving under actual and regular conditions. The unit, together with the Centre's capability, is the first of its kind in Africa.

The Centre's team is building up a database of emissions and vehicle diagnostics on various road types and vehicle loads in Gauteng. The current cohort of test vehicles includes the University's fleet of light vehicles and the NRF's road rail vehicle (RRV), a heavy goods vehicle located at the Engineering 4.0 facility on the University's Innovation Africa @UP Campus.

Ruan Gräbe and Prof Johan Joubert, Department of Civil Engineering

The Centre for Transport Development's portable emissions measurement system fitted to a small light vehicle of the University's fleet.

THE CENTRE FOR TRANSPORT DEVELOPMENT'S PORTABLE EMISSIONS MEASUREMENT SYSTEM UNIT CONNECTS TO THE EXHAUST OF A LIGHT OR HEAVY VEHICLE, ALLOWING ONE TO MEASURE A VARIETY OF POLLUTANTS WHILE DRIVING UNDER ACTUAL AND REGULAR CONDITIONS. THE TEAM IS BUILDING UP A DATABASE OF EMISSIONS AND VEHICLE DIAGNOSTICS ON VARIOUS ROAD TYPES AND VEHICLE LOADS IN GAUTENG.

The RRV is a customised research vehicle based on an Isuzu FTR850 AMT truck. The 7.8-litre, six-cylinder turbocharged, intercooled, common-rail diesel engine has a Euro 3 emissions rating. A flexible stainless-steel hose of approximately 1 m connects the PEMS's 3-inch exhaust flow meter (EFM) tube to the truck's exhaust. The PEMS unit is a SEMTECH DS+ gaseous analyser.

Exhaust gasses pass through the EFM, which is responsible for measuring the raw exhaust mass flows. The EFM operates under Bernoulli's principle using averaging pitot tubes and employing five dual-stage, differential pressure transducers. The gas analyser unit houses the analytical devices for the gaseous measurements of CO, CO_2, NO and NO_2.

A weather probe measures ambient temperature and humidity, while a geospatial positioning system (GPS) measures location and speed, the latter derived from the GPS measurements. An in-vehicle control module receives vehicle data from the vehicle's onboard diagnostic (OBDII) system while driving. For the RRV, data is collected like the engine's revolutions per minute (rpm), the vehicle's speed, throttle position, fuel flow, the air-fuel mixture ratio, and exhaust flows and temperature, among others. All data sources are time-aligned, captured and reported via the sample conditioning system's web server.

Before starting a field test, the unit is heated and calibrated to ensure that the expected pollutant concentrations are correctly accounted for. A field test entails driving the vehicle along a predefined route of approximately 60 km around the City of Tshwane,

starting and ending at the Engineering buildings on the University of Pretoria's Hatfield Campus. Each of the predefined routes represents different road types: residential, urban and freeway sections.

The system records all sensor data for the entire duration of the journey at a rate of 1 Hz (one observation per second). It is expected that the same route will result in varying pollutant concentrations based on the driver's style, driving behaviour in changing traffic conditions, the weather and many other factors. The heavy vehicles' field tests are also performed with different cargo loads. Each trip configuration must therefore have multiple field tests to account for the variation.

Over time and numerous field tests, the researchers at the Centre for Transport Development aim to build up an ever-increasing data set of emissions under usual driving conditions. During the first eight field tests, the amount of CO_2 per trip varied between 47 kg and 52 kg. The CO_2 quantity translates to an average of 765 to 847 g/km over the 61.5 km route, without any additional load.

Carbon monoxide varied between 69 g and 140 g, nitric oxide between 386 g and 512 g, and nitrogen dioxide between 13 g and 19 g. These summary statistics aggregate the pollutants over the entire route. Understandably, the pollutant concentrations vary significantly along the route.

So, the question that arises is:

What are the pollutant levels where you live? Or where you walk? Or where you jog to take your mind off the day's work?

This research had two main goals. Firstly, to study and understand the uncertainty and variance in vehicle emissions in the local environment. How do our South African vehicles really perform? If we do not know (and we do not), then we poke blindly in the dark to try and improve the state of transport emissions. Secondly, to inform policy when it comes to setting realistic targets. While South Africa subscribes to reducing greenhouse gasses attributed to transport, the national Green Transport Strategy has not adopted any quantitative targets (Department of Transport, 2018).

The reality of carbon tax, as one intervention, is on the cards. Since 2019, the fuel levy contains a dedicated portion as part of the carbon tax on fuel. It aims to promote the "polluter pays" principle. If we get the pricing wrong, we send an incorrect message to vehicle owners. It will have many unintended consequences and unwanted behaviour that can hurt the economy and its citizens.

Urging everyone to buy electric or hybrid vehicles sounds utopian, but it may only be achievable for the financial elite, adversely affecting economic equality. If freight vehicles are taxed disproportionately, it will manifest in price increases for essential goods on the shelves, which will hurt us all; more so, the poor and economically vulnerable.

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THIS RESEARCH AIMS TO STUDY AND UNDERSTAND THE UNCERTAINTY AND VARIANCE IN VEHICLE EMISSIONS IN THE LOCAL ENVIRONMENT, AND TO INFORM POLICY WHEN IT COMES TO SETTING REALISTIC TARGETS.

The potential of green hydrogen:

Refuelling options for electric vehicles

Prof David Walwyn, in collaboration with Linda Malinga, Mohau Ramakhula, Livison Mashoko and Evah Phago

THE GSTM CONDUCTED A STUDY TO DETERMINE THE VIABILITY OF ESTABLISHING A HYDROGEN STATION AT VILLIERS BASED ON A NUMBER OF TECHNOLOGY OPTIONS.

Green hydrogen is being promoted as the most viable option for the decarbonisation of South Africa's transport and manufacturing systems. Although presently more expensive than fossil fuel, a number of positive factors suggest that hydrogen could be the basis for building a green economy, meeting carbon emission targets, building exports in liquid fuels and adding value to local precious metals.

The potential of green hydrogen has led to the formation of a partnership between Sasol and Toyota South Africa Motors to explore the development of a green hydrogen mobility ecosystem. The two companies have announced that they will initially focus on the development of a mobility corridor on the N3 between Johannesburg and Durban. This will consist of the necessary hydrogen refuelling infrastructure to support a new fleet of heavy-duty, long-haul trucks. Conveniently situated midway between Johannesburg and Durban, Villiers is a key refuelling point for long-haul trucks transporting goods between Durban and the interior.

ESTABLISHING A HYDROGEN STATION

Researchers in the University of Pretoria's Graduate School of Technology Management (GSTM) conducted a techno-economic study to determine the viability of establishing a hydrogen station at Villiers, based on a number of technology options.

Although hydrogen is a colourless gas, which cannot be green, grey or blue, the literature uses colour as a means of separating the various manufacturing routes, as shown in Table 1.

TABLE 1
Categories of hydrogen according to the manufacturing process

Category	Raw material	Technology
Black	Coal	Gasification without carbon capture
Grey	Oil or gas	Steam reforming without carbon capture
Blue	Fossil fuels	Steam reforming/ gasification with carbon capture
Turquoise	Oil or gas	Steam reforming with production of carbon black
Green	Water and renewable energy	Renewable energy technology with fuel cell

The purpose of the study was to compare the techno-economics of green hydrogen as a transport fuel based on two different renewable energy technologies (wind and solar) as opposed to the use of grey hydrogen.

FOUR OPTIONS WERE CONSIDERED:

OPTION A
Photovoltaic (PV) panels as the energy source, with proton exchange membrane fuel cells (PEMFC) as the hydrogen source

OPTION B
Wind energy as an energy source, with PEMFC as the hydrogen source

OPTION C
PV-wind hybrid as an energy source, with PEMFC as the hydrogen source

OPTION D
The procurement of grey hydrogen from Sasol in Secunda, with supply by road tanker

INPUT ASSUMPTIONS

It was assumed that the station would be required to produce 45.6 tonnes of hydrogen per year, equivalent to the refuelling of two trucks per day. Weather data for Villiers was obtained from the databases of the software suite HOMER, which is widely used to calculate the cost of mini-grid systems across the world. Operational and capital costs were also obtained. The cost of grey hydrogen from Sasol was estimated at ZAR33.6 per kg, according to the 2020 international price of about $2 per kg based on the gasification of coal. Other assumptions are shown in Table 2.

TABLE 2
Input values for the model

Parameter	Units	Value
Project lifespan	Years	20
Discount rate	Percentage	12.0
Exchange rate	ZAR/USD	15
Wind turbine	ZAR/kW	15 000
Photovoltaic system	ZAR/kW	17 070
Electrolyser	ZAR/kW	51 060
Dispenser	ZAR/unit	2 550 000
Compressor and storage vessels	ZAR/m^3	600 525

COST OF FUEL

A discounted cash flow (DCF) algorithm was used to calculate the levelised cost of hydrogen (LCOH) in ZAR/kg over the lifetime of the project (20 years). The algorithm requires the separate calculation of the net present value (NPV) of the cost of hydrogen production and the NPV of the total hydrogen output, and then follows the standard approach for the calculation of the levelised cost of energy. Additionally, a sensitivity analysis was carried out for each option to determine the dependency of the LCOH on key variables of the production and supply process, as illustrated in Table 3.

TABLE 3
Results of the analysis

Option	Capital cost (ZAR million)	Operating cost (ZAR/kg)	Levelised cost of hydrogen (ZAR/kg)	Carbon emissions (MT/annum)
A	62.5	54.8	219.4	0
B	86.4	75.8	288.0	0
C	74.5	65.3	253.7	0
D	4.7	75.8	85.25	913
Diesel equivalent			**82.0**	**730**

The results indicate that standalone systems for the production and dispensing of hydrogen will be uneconomic at the present capital costs for electrolysers and renewable energy technologies, relative to the cost of grey hydrogen or the cost of diesel. The latter price is calculated as a benchmark comparator by adjusting the diesel price for its lower energy content, the lower energy efficiency of internal combustion engines and the relative fuel usage of internal combustion engines vs fuel cell electric vehicles.

In summary, the fuel costs for grey hydrogen and diesel are almost equivalent, whereas the options using renewable energy are two to three times more expensive.

EMISSIONS AND CARBON TAX

Despite being higher in cost, the obvious advantage of hydrogen-based long-haul vehicles over diesel fleets is the zero emission of fuel cell engines, which suggests that the operational costs of diesel fleets will increase as carbon tax rises. However, this additional cost is minimal given that the carbon tax is presently only ZAR120 per tonne. The latter will need to increase at least tenfold to achieve cost neutrality between the three fuel sources of diesel, hydrogen from the reforming of natural gas and hydrogen from electrolysis using renewable energy.

Similar results for the relative costs of operating delivery trucks on diesel, electricity or hydrogen have been reported for a study by Hall and Lutsey (2019) in the USA, as shown in Figure 1.

When comparing the cost of refuelling long-haul trucks at Villiers based on four different technology options, the option with the lowest cost was observed to be to purchase the hydrogen from Sasol, transport it by tanker to Villiers, and dispense it locally from high pressure storage, giving an LCOH of ZAR85.25 per kg of hydrogen.

Equivalent values for PV, wind and hybrid systems, with the energy being used to generate hydrogen by electrolysis, are ZAR219, ZAR288 and ZAR254 per kg, respectively. Wind is the option with the highest cost due to the poor wind conditions at Villiers. The costs of refuelling using either diesel or hydrogen from Sasol are almost equivalent.

The results suggest that the proposed mobility corridor between Durban and Johannesburg may not be able to rely on distributed refuelling stations with a dedicated hydrogen generation infrastructure. Alternative configurations, including centralised systems with pipeline delivery, will need to be investigated.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the class of Project Economics (IBD 880) within the Master's programme in Technology and Innovation Management at the GSTM.

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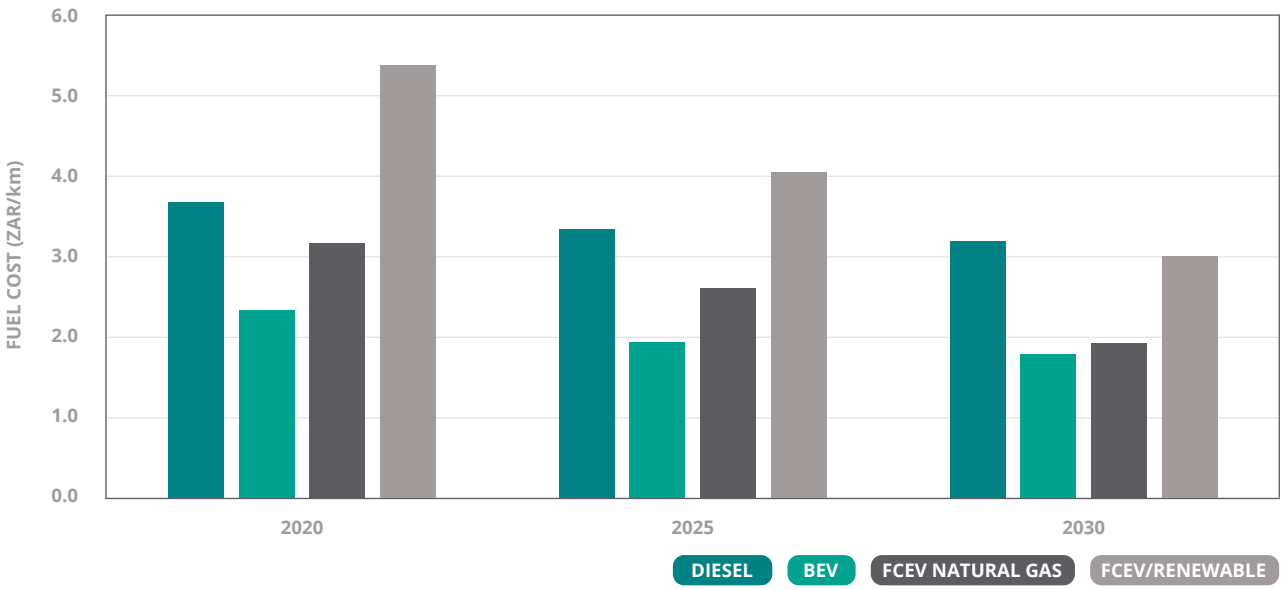
FIGURE 1
Relative cost of ownership for delivery trucks in the USA



BEV = Battery electric vehicle using energy from the grid. FCEV Natural Gas = Fuel cell electric vehicle using hydrogen from steam reforming of natural gas. FCEV/Renewable = Fuel cell electric vehicle using hydrogen from hydrolysis and renewable energy.

Source: Hall and Lutsey (2019)

MultiChoice Chair in Machine Learning addresses global skills shortage

Prof Pieter de Villiers

The ongoing global COVID-19 pandemic has highlighted the advantages of a digital society. Increased online activity has demonstrated how large volumes of data travel all over the world every second of the day. Machine Learning (ML) and Artificial Intelligence (AI) are two elements of the Fourth Industrial Revolution (4IR) that assist humans with tasks where underlying patterns in and insights into large volumes of data are not obvious.

Prof Nelishia Pillay

Prof Pieter de Villiers

MULTICHOICE HAS IDENTIFIED SEVERAL OPPORTUNITIES AND PROJECTS TO APPLY ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING AT VARIOUS POINTS THROUGHOUT ITS VALUE CHAIN. THIS INCLUDES CONTENT CREATION, UNDERSTANDING WHAT CONTENT TO OFFER CUSTOMERS (RECOMMENDER SYSTEMS), CUSTOMER SERVICE AND IMPROVING INTERACTIONS WITH CUSTOMERS.

In recognition of the key role that AI – and specifically machine and deep learning – will play in unlocking a truly digital future, MultiChoice South Africa partnered with the University of Pretoria (UP) to sponsor the MultiChoice Chair in Machine Learning. This research chair, which is located in the Faculty of Engineering, Built Environment and Information Technology, strives to address the global skills shortage in machine learning development skills. In this regard, Africa can excel, given its unique challenges and opportunities.

The Chair is jointly located in the School of Information Technology and the School of Engineering, with Prof Nelishia Pillay, Head of the Department of Computer Science, and Prof Pieter de Villiers, a lecturer in the Department of Electrical, Electronic and Computer Engineering and Head of the Department's Signal Processing and Telecommunications Research Group, as co-chairholders.

The agreement entered into between UP and MultiChoice South Africa in 2018 was aimed at the pursuit of joint collaboration and research for common and mutual benefit. The Chair subsequently undertakes academic and applied research, as well as human resource development, in the field of machine learning, which is applied to several advanced topics of interest to MultiChoice.

MultiChoice has identified several opportunities and projects to apply AI and ML at various points throughout its value chain. This includes content creation, understanding what content to offer customers (recommender systems), customer service and improving interactions with customers.

These challenges and opportunities are addressed through postgraduate master's and PhD projects that propose novel and creative ML approaches to solve real-world problems, while providing students access to pressing real-world industry research problems and realistic data. Several exciting ML-related research projects are currently underway or have been completed within the Chair in the application domain of satellite broadcasting and video streaming.

Topics include, but are not limited to, the automated genre labelling of motion picture (movie) trailers, the automated analysis of audio and video content to extract meaningful and descriptive metadata, the automated generation of closed captions through automated audio processing, automated audio and video segmentation for scene skipping, automated movie trailer creation, and even the forecasting of weather-related impacts on DSTV service delivery. Some of these projects address Big Data challenges, where the volume, velocity, variety, veracity and value (the 5 Vs of Big Data) of video and audio content have become so overwhelming that it is impossible for humans to process.

As Machine Learning is a very specialised field, the partnership between MultiChoice and UP is a forward-looking way to nurture and improve these skills in South Africa, while addressing problems of research and commercial interest through interesting collaborative projects. Benefits of this collaboration have already been realised by students who have performed vacation work at Multichoice, and a master's graduate of the Chair who has been offered employment at Multichoice.

Early in 2020, several MultiChoice staff members attended a course on Machine Learning that was presented under the umbrella of the Chair at UP, further demonstrating the benefits of this collaboration.

Cybersecurity:
Discovering botnet attacks

Prof Jan Eloff, Innocent Mbona and Prof Hein S Venter

There has been a significant increase in the number of interconnected devices over the past decade, mainly driven by the Internet of Things (IoT). IoT makes the world smarter by seamlessly connecting multiple devices. These range from small personal gadgets to autonomous vehicles. Current studies demonstrate that IoT applications will continue to grow around the world, and are expected to generate billions in revenue by 2025.

This technology permits multiple devices to connect and interact wirelessly, thus resulting in a large flow of data among interconnected devices. As exciting as IoT technology is, it comes with a multitude of cybersecurity challenges, such as data protection and network security. The most pertinent challenge facing IoT is network security.

IoT devices are vulnerable to cyber-attacks such as denial-of-service (DoS) and distributed-denial-of-service (DDoS) attacks, as they do not have physical boundaries to ensure security and privacy. Therefore, most of the current research in IoT focuses on countermeasures that can prevent and detect security threats such as DDoS and botnets. A botnet is a group of interconnected computers controlled by a botmaster to launch attacks. A botmaster can then execute large-scale coordinated attacks such as malware and DDoS attacks.

MITIGATING INTRUSIONS

Botnet attacks are very difficult to detect, as cybercriminals always explore new or unknown network vulnerabilities, referred to as zero-day vulnerabilities. The risks caused by botnet attacks can be mitigated by a network intrusion detection system (NIDS), which is a software system located strategically within a network. An NIDS often uses deep or machine learning algorithms to monitor and detect network attacks.

A machine learning NIDS can operate as a supervised, an unsupervised and a semi-supervised model. The performance of these machine learning models depends on input data, referred to as features. Examples of features that can play a role in describing the behaviour of network traffic are destination-to-source

byte count (dbytes), total count of packets in transaction (pkts), destination-to-source packet count (dpkts) and source-to-destination packet count (spkts). One of the challenges facing these machine learning models is that network traffic data, in environments such as IoT, is generated at high volumes and at high velocity.

Furthermore, network traffic data is often highly imbalanced in the sense that normal network traffic occurs more frequently, and network attacks are rare. A multitude of feature selection algorithms has been proposed in the past to address these challenges. However, current research demonstrates that botnet attacks remain problematic.

A BOTNET IS A GROUP OF INTERCONNECTED COMPUTERS CONTROLLED BY A BOTMASTER TO LAUNCH ATTACKS. A BOTMASTER CAN THEN EXECUTE LARGE-SCALE COORDINATED ATTACKS. BOTNET ATTACKS ARE VERY DIFFICULT TO DETECT, AS CYBERCRIMINALS ALWAYS EXPLORE NEW OR UNKNOWN NETWORK VULNERABILITIES. THE RISKS CAUSED BY BOTNET ATTACKS CAN BE MITIGATED BY A NETWORK INTRUSION DETECTION SYSTEM, WHICH IS A SOFTWARE SYSTEM THAT IS LOCATED STRATEGICALLY WITHIN A NETWORK. THIS SYSTEM OFTEN USES DEEP OR MACHINE LEARNING ALGORITHMS TO MONITOR AND DETECT NETWORK ATTACKS.

DETECTING CYBER ATTACKS

Researchers in the Department of Computer Science's Digital Forensic Science Research Group have been experimenting with a novel approach to simplify the detection of features that describe botnets.

Conducting a literature study, the researchers identified a novel method to discover features that can differentiate between normal and botnet attacks in an IoT environment. This method, known as Benford's Law, is very simple to implement. It could therefore be beneficial to an NIDS in analysing high-dimensional Big Data generated by IoT devices.

Benford's Law can detect malicious network attacks such as DDoS, given its unique frequency distribution of leading digit properties. Simply put, Benford's Law predicts that leading digits beginning with the digit "1" are expected to appear more often than digits beginning with the digit "9", such that a violation of this is deemed anomalous.

The Botnet IoT dataset, which was used for experimental purposes, was generated by researchers at the Cyber Range Lab of the University of New South Wales (UNSW) in Canberra, Australia, in 2018 (Koroniotis et al., 2018). It contains realistic simulated botnet IoT attacks that covered DoS, DDoS, information gathering and information theft attacks.

Research presented at the International Conference on Communication Systems Networks (COMSNETS) (Sethi et al., 2020) also described how Benford's Law could be applied to the NSL-KDD network intrusion dataset to demonstrate that the flow size difference of benign transmission control protocol (TCP) network traffic obeys Benford's Law, while malicious network traffic affecting the TCP violates it.

As significant features for differentiating between normal and botnet network traffic were discovered through the application of Benford's Law, the researchers set out to determine whether Benford's Law could be applied in other instances as well to discover features that can differentiate between normal and botnet IoT network traffic, and whether it can discover features that indicate anomalous behaviour between normal and botnet network traffic.

To effectively test this, the researchers divided the original botnet IoT dataset into two groups. The first group, referred to as the normal dataset, comprised normal network traffic. The second group, referred to as the botnet dataset, was a combination of all malicious network traffic DoS, DDoS, information gathering and information theft.

A feature, such as "source-to-destination packet count" (spkts) is deemed to be significant if it obeys one of Benford's Law's distributions on the normal network traffic, while simultaneously violating Benford's Law's distributions on the botnet dataset. The results obtained in this experiment therefore indicated that normal network traffic closely obeyed Benford's Law, while the same features violated Benford's Law's distributions on botnet network traffic. The features identified by a simple Benford's Law method proved to be consistent with significant features identified by other researchers on the same dataset using different feature selection methods.

Significant features that enabled the researchers to identify certain behavioural characteristics of normal and botnet network traffic included packets in transaction for botnet network traffic that had more congested small digits

compared to normal network traffic; botnet network traffic that displayed abnormally large sequence numbers compared to normal network traffic; a difference in the minimum and maximum duration in botnet network traffic as opposed to normal network traffic, which suggests that botnet network traffic sends a larger number of packets in an attempt to overwhelm the network; the total duration of aggregated records; and the source-to-destination packet count (spkts), destination-to-source packet count (dpkts) and destination-to-source byte count (dbytes), which indicate that botnet network traffic uses smaller packets compared to normal network traffic.

Benford's Law only works on numerical features. Therefore, non-numerical features, such as textual representation of transaction protocols present in network flow and flow state flags seen in transactions, could not be evaluated for their significance in differentiating between normal and botnet network traffic. Moreover, Benford's Law did not deem features such as source internet protocol (IP) and the destination IP address significant in differentiating between normal and botnet network traffic. These findings are intuitive as features of this type do not provide meaningful insights into the behaviour of network traffic.

RESEARCHERS IN THE DEPARTMENT OF COMPUTER SCIENCE'S DIGITAL FORENSIC SCIENCE RESEARCH GROUP HAVE BEEN EXPERIMENTING WITH A NOVEL APPROACH TO SIMPLIFY THE DETECTION OF FEATURES THAT DESCRIBE BOTNETS.

DIGITAL FORENSIC READINESS

Another way of enhancing an NIDS is to make use of digital forensic readiness. Digital forensics is the term given to encompass all forensics that are digital in nature. Digital forensics is conventionally a reactive process that involves the digital investigation of an incident. Roughly, the process followed during a digital forensics investigation involves the use of scientifically derived and proven methods for the preservation, collection, validation, identification, analysis, interpretation, documentation and presentation of digital evidence. Due to the reactive nature of digital forensics, concerns arose about volatile data stored temporarily on virtual machines running in a typical cloud environment that might be lost by the time an incident is reported. The term digital forensic readiness was therefore coined to enable an organisation to maximise its potential to use digital evidence, while minimising the costs of an investigation.

Compared to digital forensics, digital forensic readiness is proactive rather than reactive. By implementing digital forensic readiness, an organisation can gather volatile evidence of any network traffic, including network traffic generated by botnets. Due to the volatile nature of botnets, digital forensic readiness is an excellent technique to proactively gather digital evidence in a forensically sound manner. Digital forensic readiness would, therefore, enhance the capabilities of Benford's Law, and can be employed to produce more accurate results.

BY IMPLEMENTING DIGITAL FORENSIC READINESS, AN ORGANISATION CAN GATHER VOLATILE EVIDENCE OF ANY NETWORK TRAFFIC, INCLUDING NETWORK TRAFFIC GENERATED BY BOTNETS.

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Providing relief to **digital fatigue**

Rachel Fischer

The *en masse* migration to online platforms in the wake of COVID-19 is indicative of humanity's resilience and ability to respond quickly and effectively to a global pandemic. However, together with the multitude of online solutions, several challenges have arisen. These challenges may be technical or economic in nature, but impact on our digital wellness.

MORE THAN A YEAR INTO THE COVID-19 PANDEMIC, MORE PEOPLE ARE BECOMING INCREASINGLY FAMILIAR WITH DIGITAL FATIGUE; THE TIREDNESS AND BURNOUT CAUSED BY THE OVERUSE OF VIDEOCONFERENCING TOOLS AND OTHER DIGITAL PLATFORMS.

Digital fatigue results from constant exposure to digital media, such as Zoom, Microsoft Teams or Google Meet meetings, WhatsApp groups, mindfulness apps and email correspondence.

From an information science perspective, the following can serve as an antidote to digital fatigue:

- Elevating the roles and responsibilities of information professionals as social change agents
- Promoting the awareness of BRB; while this used to be an acronym for Be-Right-Back, it can now be used for the essential elements of boundaries, routine and breaks
- Regularly engaging with nature, green or other "offline" spaces to promote wellbeing

This seems to be a topical debate.

On 14 May 2021, the International Federation of Library Associations and Institutions (IFLA) Africa Section Standing Committee proudly hosted a panel discussion with the topic "Digital fatigue, infodemic and meta literacy". The panellists included Rachel Fischer and Collence Chisita from South Africa, and Sarah Kaddu from Uganda. Forty participants joined from across Africa and engaged in a discussion on digital wellness, digital hygiene, emotional diets, infobesity and the management of information consumption.

Questions to the panellists included how one can ensure the digital wellness of students, how to protect them from information overload, and who the caretakers of information specialists are themselves. Responses focused on self-management, organisations' support of their staff in terms of wellness and ethics programmes, as well as collaboration with other partners to break down silos.

Specific mention was made of the Information for All Programme (IFAP) of the United Nations Education, Scientific and Cultural Organisation (UNESCO) and UNESCO's newly launched resource: Media and Information Literate Citizens: Think Critically, Click Wisely (the second edition of UNESCO's Model Media and Information Literacy Curriculum for Educators and Learners)[1].

The participants welcomed the humour of the panellists (with regular references made to eating and exercise habits). They also commended the fact that no PowerPoint presentations were used, bringing welcome relief to attendees who could engage more spontaneously.

Nevertheless, the following question can be asked: Do information professionals have something to offer to address digital fatigue?

1 https://unesdoc.unesco.org/ark:/48223/pf0000377068

ELEVATING THE ROLES AND RESPONSIBILITIES OF THE INFORMATION PROFESSIONAL

Librarians used to be referred to as the custodians of knowledge: managing libraries and their content, and helping patrons navigate the shelves, index cards and other library material. Shifting to library and information science, these information and knowledge professionals became the gatekeepers of the world of online and offline material – helping students, learners, teachers, lecturers, researchers, professionals, the public and government officials navigate the numerous online platforms, e-journals and reference materials.

Perhaps it is now prudent to include promotors of social responsibility and wellbeing to the various roles of the information professional.

Social responsibility refers to the ethical, and media and information literacy (MIL) considerations pertaining to library and information science, such as avoiding plagiarism, integrating privacy, access, accuracy, intellectual property and security elements in all data, information and knowledge aspects. Improving basic, information, digital, media and other literacies in practice, ability and theory will bridge the responsibility and wellbeing dimensions in terms of promoting core competencies that include the requisite skills, knowledge and abilities inherent to MIL, according to UNESCO[2].

This leads to the role of promoting wellbeing. Having these MIL competencies will enable individuals to be more aware of and practice wellbeing in their daily online and offline habits. This is essentially what is meant by digital wellness: being well in a digital society, which is supported by the alignment of online and offline values and moral systems. So, perhaps the roles of library and information science professionals have evolved from knowledge custodians to online navigators, and now, to digital wellness champions.

THE CONTEXT OF DIGITAL FATIGUE

The *Wall Street Journal* has been writing quite a lot about "Zoom fatigue"[3]. This extends to other platforms as well, such as Microsoft Teams, Blackboard, Google Meet and WhatsApp calls.

More than a year into the COVID-19 pandemic, more people are becoming increasingly familiar with digital fatigue; the tiredness and burnout caused by the overuse

2 https://en.unesco.org/themes/media-and-information-literacy

3 https://www.wsj.com/articles/zoom-fatigue-is-real-11587652460

of videoconferencing tools and other digital platforms. Tiffany Pham, CEO of Mogul, reflects on the same condition, stating that the end of a workday can leave us feeling "physically and mentally exhausted"[4], which is ironic. We work in the comfort of our homes, dressed the way we feel most comfortable and display most professional (top upwards with comfortable pants or shorts); we can enjoy beverages while the camera and microphone are on mute (if we remember to mute it), and attend to emails or other activities when colleagues are rambling on. So, why do we feel so tired?

Based on personal experience, most activities – professional and personal – are captured on one's electronic calendar. If someone does not send a calendar invite, the event is forgotten and not attended to. But this leads to endless task-switching between online calls, electronic work (research, emails and writing) and real-life activities that need attention, such as eating, shopping, attending to family, friends, pets and other tasks that are not necessarily captured in an electronic calendar.

This daily feedback loop of information overload contributes to us risking the effects of digital mental fatigue. This digital fatigue can lead to a lack of energy, mental clarity and burnout, and can cause negative psychological and physical effects to our overall wellbeing and work output.

Tiffany Pham[5] argues that the impact on mental health does not only extend to ourselves, but is also impacting on our non-verbal communication and ability to convey non-verbal cues. Another consequence is our inability to interpret the non-verbal cues of friends and colleagues who may be struggling emotionally or psychologically. Conversely, this also impacts on our energy levels. Considering the fact that we are more than a year into lockdown (in some way or another), many are complaining of being tired of constantly engaging via an electronic medium. Even when we are not meeting online, we are still visiting social media platforms, watching television and using other mobile devices, which are not giving us a break from "digital life".

There are two major considerations: the psychological and the physical. A symptom of digital fatigue includes the fragmentation of our minds. Too much bouncing back and forth between tasks can lead to one feeling mentally disjointed and can cause anxiety. Too much anxiety in the emotional diet can lead to stretched tempers, hasty decision making, depression, loneliness, social isolation and feelings of being overwhelmed. Compounded by the lack of variety in one's "diet", one should also consider the lack of variety in one's environment. Therefore, physical implications include poor posture due to non-ergonomic office setups.

Being physically uncomfortable can lead to mental and emotional distress. This is evidenced by sore eyes due to copious screen time, knotted shoulders due to slumping, headaches due to limited visual variety, sore necks, backs and feet; the list goes on.

Discomfort can quickly lead to emotional pain. Since the pandemic began, people around the world of all ages are spending a lot more time looking at screens. Zhong-Lin Lu[6] reports that a survey conducted by Ipsos and the Global Myopia Awareness Coalition found that 44% of US children are using electronic devices for over four hours a day; more than double the rate prior to the pandemic . We need to be mindful of taking breaks from the constant screen time, bringing diversity to our routines, and ensuring that our work and study spaces are set up ergonomically.

RECOMMENDATIONS

Information professionals can make the following recommendations:

BOUNDARIES:

Due to the shifts from offline to online engagements, the boundaries have become blurred between our personal and professional spaces. This shift has shown how porous these spaces and engagements have become once everything can be handled from home. The porosity also comes with consequences. Some people sleep late and then work late into the night. Others continue to work over weekends to get ahead, keep busy or catch up with outstanding work. Or perhaps, now that home has become an office, one feels guilty being at home and not working. Our boundaries are therefore extremely permeable, and like any fortress, weakened walls lead to susceptibility for attacks (fatigue, illness, information overload, etc.). How do we address this?

ROUTINES:

Establishing routines is a functional and effective way to strengthen our boundaries. Routines do not need to be defined in a similar way as before the advent of COVID-19. In truth, some people function

4 https://www.entrepreneur.com/article/358112

5 https://www.entrepreneur.com/article/358112

6 https://knowablemagazine.org/article/health-disease/2021/can-screen-time-hurt-eyes?fbclid=IwAR0LER8x8Xcvqq4K1_RywrUnRf53_Y9e7pfygjDYaJArXS-vM52PdAbsBqE&

better at night and others earlier in the morning. COVID-19 has given us the opportunity to adjust and accommodate. Methods that suit us the most lead us to be more attentive. Some people benefit by taking a quick afternoon nap, which they would not normally have done during official working hours. We all know that dreaded slump at 15:00, where no one was really productive, but one was forced to be in the office. Now a quick nap, a walk in the neighbourhood or doing some stretches bring relief to the monotony of working from home or being online for the majority of the time. However, it is essential to set and stick to a routine that works for you and attends to the tasks set and expected by your managers or employer. This leads to the next recommendation, which is complementary to setting boundaries and creating routines.

BREAKS:

In terms of screen fatigue, it is essential to have regular breaks. Some recommend that for every 20 minutes staring at the screen, you should take a 10-minute eye-break. Breaks include walking around at home, not working "after your hours", and keeping your weekends "sacred" for family, friends or whatever is important to you. It is essential that we differentiate between screen-time and me-time. I have found value in taking breaks by applying mindfulness and greenfulness. But there is another stark irony to mindfulness.

A personal reflection on promoting "greenfulness" as an alternative to pure "mindfulness"

In the past decade, technology has transformed our personal and professional lives in many dramatic ways, states Jeff Gelinas[7]:

"The apps and technologies we have access to have generally made our lives much more comfortable and productive. This includes, but is not limited to how we communicate, and consume and process information, and how we innovate. Technology has also transformed how to learn new skills, buy and sell, work – and stay healthy."

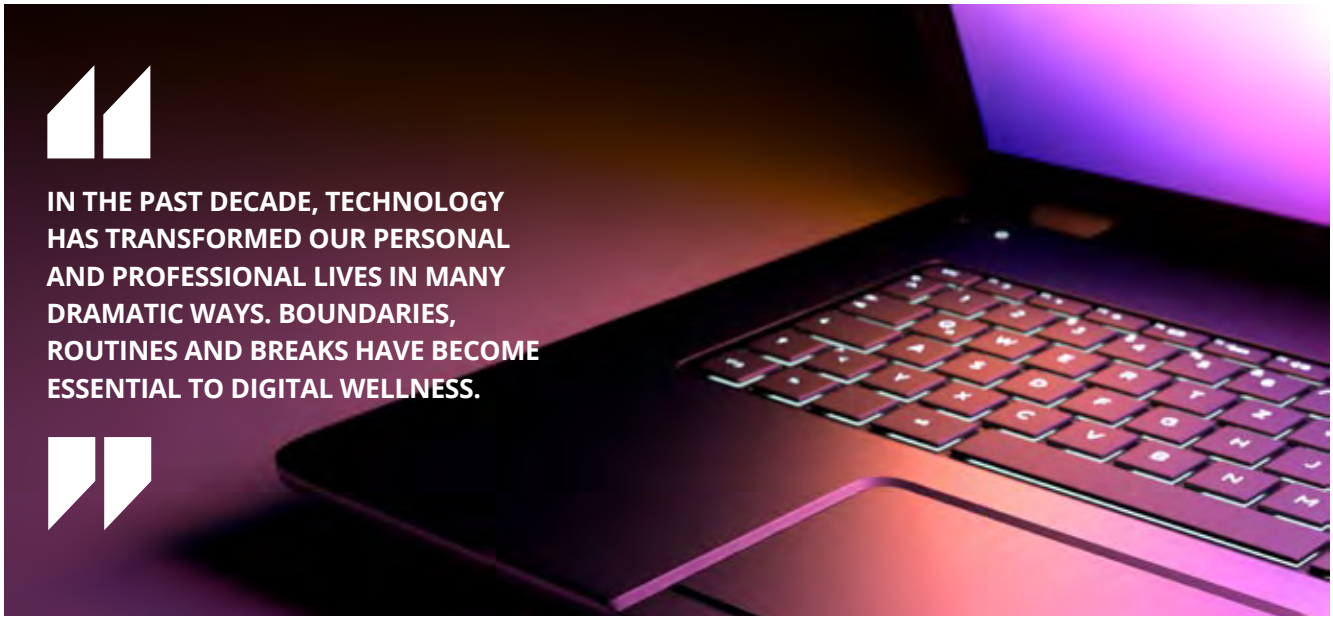
Reflecting on digital fatigue while writing this article, I noticed I had three different mindfulness apps on my phone. By taking a break from my computer, I would turn to my phone, put in the earphones, log into the app and enjoy the 10- to 20-minute breathing exercise, or visualisation exercise, all while some person guides me in my ears with soothing music.

I would also use the app at night to help me fall asleep, for although I was desperately tired, I anxiously struggled to fall asleep. And my ears got really sore. It then struck me how my work, socialising, relaxation, reading and sleeping habits were all tied to technology.

This led me to shift from digital mindfulness to being mindful in green spaces. In short: just get outside and take a walk in nature; with no music, no phone or earphones, just me and my dog. The simplicity of addressing digital fatigue was really astonishing. By no means can I declare myself to be free of this fatigue. In my personal experience, I can attest to bearing the brunt socially, physically, emotionally, intellectually and especially psychologically.

Therefore, I wish us to advocate for wellness and have open and honest discourses on how the pandemic and digital fatigue are impacting on us.

Mental health is essential wealth.



7 https://talentculture.com/digital-fatigue-how-to-make-technology-work-for-you-not-against-you/

Society 5.0 and humanising technology: From user experience (UX) to impactful human experience (HX)

Prof Hanlie Smuts

We live in a ubiquitous computing society, where digitalisation and technology are integrated into everyday activities. These include functions such as banking, shopping, consuming news, engaging with friends and family, and utilising chatbot service agents and smart home applications.

TECHNOLOGIES WILL EVOLVE, BUT THE HUMAN BEING IN THIS CONTEXT IS THE CONSTANT, WHO USES TECHNOLOGY AS A MEANS TO ENABLE HIS NEEDS.

Technology is used in healthcare procedures and nanobot treatments; human operational and repetitive tasks are automated through Artificial Intelligence (AI) and robotic process automation; and Big Data applications collect information about us that is used by retailers to create unique consumer profiles and value propositions.

Furthermore, even our interface with technology has evolved, with features such as conversational interfaces (chatbots), natural language processing and voice recognition. Augmented reality (AR) and virtual reality (VR) allow us to immerse ourselves in a computer-simulated reality – supporting commercial and learning experiences. Such experiences include product and service design and promotion, immersive computer games, digital twins used for teaching (such as in the case of medical students) and real-time representations of machine production and sensor networks, which collect real-time data – all changing our paradigms and how we experience society, culture, engagement and behaviour.

Society 5.0 is a human-centred society, which represents a vision where humans, nature, economic advancement and technology create a sustainable balance for social good through a system that optimally integrates cyberspace and physical space. This cyber-physical system is based on the premise that significant quantities of data from the physical space accumulate in cyberspace, where the data is analysed by super-smart AI systems, which exceed human capabilities. The results of such analysis are fed back to humans in various forms in the physical space. However, such a cyber-physical system, with its associated technological developments, raises significant issues around ethics, morals and regulations, and questions what is known as the "social good": what we believe to be "good for humans". It almost seems as if there are opposing objectives. With great technology comes great responsibility!

The discourse around humanising technology is guided – or perhaps mis-guided – by the term "humanise". According to the dictionary[1], humanise means "to make something more humane" or "to give something a human character". As it relates to Society 5.0 and its human-centred focus, these definitions provide an interesting dilemma. Does it mean we want technology to behave like humans, to understand, to decide, to sound and even look like humans? With all the power that we have, as evangelists of technology, it is our responsibility not to banish the human being in this race to make everything technically advanced. Our foremost responsibility should

1 https://www.lexico.com/definition/humanize

be to design technology so that it is better for humans, and better at interacting with humans. Humanising technology should be about designing, commercialising and using technology responsibly; making it as useful, meaningful, accessible, distributed and transparent as possible. From a human experience rather than a user experience perspective, technology should not be the point of friction between the product and the user.

Advancing technology needs to become more human-oriented. This will help us to streamline, simplify, evaluate and filter, and to better understand human needs, emotions and behaviour. Technologies will evolve, but the human being in this context is the constant, who uses technology as a means to enable his needs.

IN THIS CONTEXT, SEVEN HUMAN EXPERIENCE CONSIDERATIONS HUMANISE TECHNOLOGY DESIGN:

1 Consider human-like factors

Unlike machines, we experience the world through our five senses, which enable us to better understand our surroundings. Humanising technology in this context means that technology – both applications and devices – should attempt to communicate with us in a way that we recognise. Advances in conversational interfaces, voice recognition and natural language processing technologies enable personable and delightful interfaces, without trying to convince us that the technology is human (a chattier chatbot). By considering ergonomics or softer aesthetics and by moving the focus away from pure technological functionality (such as the algorithm, the code and the application) to the quality of the experience and user engagement, we can achieve a big step towards human experience. Furthermore, by using technology for intelligent automation and repetitive work, humans are unconstrained to engage in creative work, which is a unique human capability.

2 Assemble a team of diverse thinkers

The main aim of accessibility and inclusivity is that technology should not only be useful to a handful of people. Furthermore, the rate at which technology is evolving will always carry the risk of excluding less tech-savvy users. Therefore, in order to emphasise and achieve a human-centred focus, aspects such as co-creation, co-design, collaboration and corporation among different stakeholders, such as local leaders, entrepreneurs, academia and industry, must be facilitated.

Furthermore, organisations and technology developers have access to a diverse team of experts as far as conversational commerce technologies are concerned. Key inputs into the appropriateness of responses, quality of interaction, how machines make users feel, and how technology could impact on society may be provided by experts such as scriptwriters, human development specialists, sociologists, linguists, scientists, physicians and psychologists – all roles not traditionally associated with technology development. Such diverse thinking will ensure that the user experience is more accessible and humane.

3 Use the learning and education opportunities

Digital trust enables users to carry out transactions in a reliable manner. Humanising technology in this context will require educating users by explaining complex systems and software that has been reverse-engineered from the human experience it delivers, rather than its technical functionality or sophistication. Distinctly human attributes such as social intelligence and emotional intelligence must be balanced with technologies' logical reasoning and processing. Humans learn more comprehensively and engage far better through story-telling and human-to-human interactions than they do from non-human interfaces.

4 Build ethics into the algorithm

Ethical considerations cannot be an afterthought and the impact of technology should not only be addressed after the technology has been developed or even in the case of public backlash. Concerns of intended and unintended impacts need to be addressed during the system design process and embedded in the technology's development.

Organisations need to take ethical and legal responsibility for the impact of their technology on society and provide realistic assurances that they have considered the impact of their technology products and interfaces on their users. We therefore also need to understand our responsibility related to this great power of technology by anticipating challenges and asking critical human-centred questions before making user interface decisions such as whether the outcome of the technology will result in overall good for all people or whether there could be any unintended consequences of the technology. Technology empowers users, and how that "power" should be used is not a technological question, but an ethical and social one.

ADVANCING TECHNOLOGY NEEDS TO BECOME MORE HUMAN-ORIENTED.

5 Reduce the complexity

Humans use technology according to their requirements and application, and technology providers "push" technology to users. Technology should reduce the complexity of our daily lives, rather than cause us more complications. Humanising technology in this context should become more human-oriented to help us to simplify, assess and filter.

6 Make privacy paramount

Privacy by designing and proactively embedding privacy into the operation of technology products is a key aspect of humanising technology. Furthermore, it is important that users are able to access information about any technology they use. Two aspects are important in creating a humanised experience. Firstly, directly obtaining explicit permission from users before sharing their data. Secondly, explaining how their data will be treated and applied upon receiving approval, or immediately deleted upon request.

With one click, users should be able to leave a product or system when they choose to do so (this is now, in many instances, guided by legislation). In this context, organisations should provide frequent impact disclosures on all developing technology, including answers to questions about their impact.

7 Use the learning and education opportunities

The ultimate factor that should decide whether a technology will be adopted is not technical at all. The most essential aspect is how well a technology understands and can support our human cognitive capabilities. It needs to be easy to understand, convenient and optimised around people and their behaviour.

From a technology development perspective, anticipate technology adoption challenges. Therefore, focus on conducting experiments and tests with user groups and release the results to the public. Use the empirical evidence to establish how users may react to new technology or changes to existing technology.

In order to enable an excellent human experience in Society 5.0, less focus is required on technology, and investment in learning about human needs, emotions and behaviour is essential. Technology is not an end; it is a means to an end – to enable human requirements and enhance how we do things naturally. It is an enabler of a better community.

The main focus is therefore on a new approach to understand, create, design and implement humanised technology. Technologies will come and go, but the human aspects remain, and technology needs to be easy to use and understand, well engineered, and optimised around people and their habits.

It should advance humanity.

Utilising the tools of **Society 5.0** for affordable, accessible education for all

Prof Alta van der Merwe

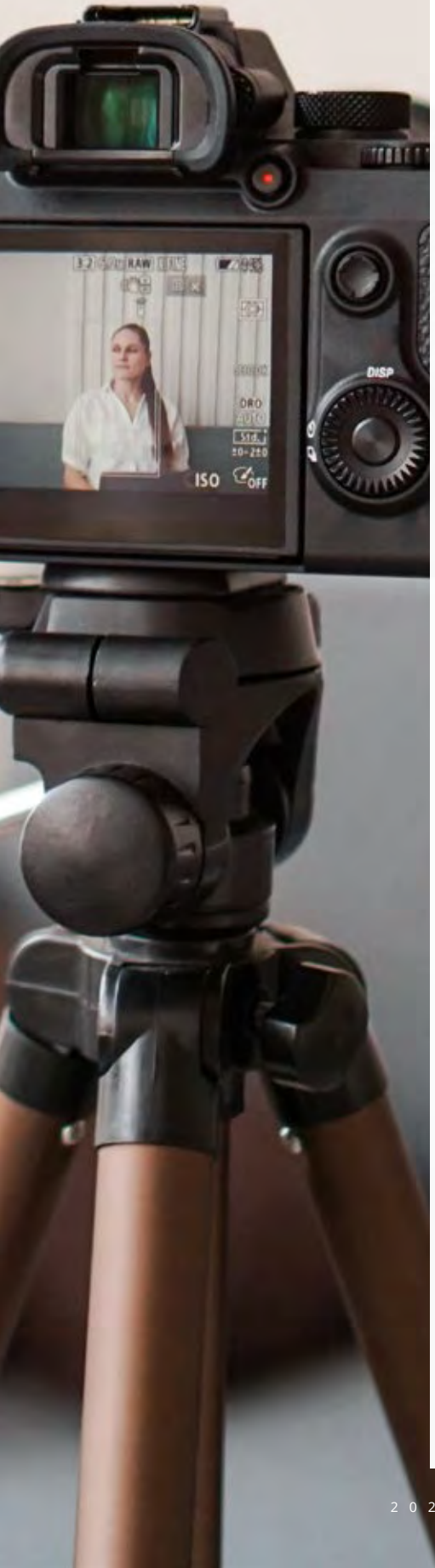
SOCIETY 5.0 AIMS TO ANSWER BOTH THE FUTURE ECONOMIC AND SOCIETAL CHALLENGES FACED BY HUMANITY AT ITS PRESENT AND FUTURE STAGE BY USING ALL THE ADVANCES OF INDUSTRY 4.0

We live in exciting times that present us with numerous innovations and opportunities. However, as a society, we also face many challenges, such as global warming and unequal resource distribution. In this era of challenges and opportunities, a new concept is emerging: Society 5.0. This refers to a society that will not only be able to bring about economic advancement, but will also be able to resolve society's problems by merging cyberspace with the physical space, eliminating both the challenges related to location and the inequalities brought about by age, gender and language.

Society 5.0 follows on the hunting society (Society 1.0), agricultural society (Society 2.0), industrial society (Society 3.0) and information society (Society 4.0). Confusion often arises regarding the question whether Industry 4.0 actually preceded Society 5.0, and how the two interlink. In 2019, the World Economic Forum acknowledged Society 5.0, stating that "As for the problems to solve, Society 5.0 aims to answer both the future economic and societal challenges faced by humanity at its present and future stage by using all the advances of Industry 4.0".

The question that arises is: What will be different in Society 5.0? Currently, we live in a society in which knowledge and information are used without sharing, whereas, in Society 5.0, the Internet of Things will connect all people; data, information and knowledge will be shared; and new value contributions will be possible. Society 5.0 will overcome social disparities with regard to access to goods, for example, by using drones for distribution in rural areas. People will not be overwhelmed by information, as technology will be used to analyse large datasets and other information, and recommendations will be made based on the findings.

In 2019, Nakamura Michiharu, senior advisor to the Japan Science and Technology Agency, linked the vision of Society 5.0 with the United Nations' Sustainable Development Goals (SDGs). SDG 4 focuses on education, with an emphasis on using technologies such as e-learning systems to make education affordable and available to everyone. In 2020, the use of e-learning systems became highly pertinent during the worldwide lockdown periods when teachers and students had to adapt to remote teaching and learning. The question that arises now is: How can technology be used to further assist education? What will the future of education be in Society 5.0?



In line with SDG 4, which states that no one should be left behind, and education should be affordable and freely accessible to everyone, Society 5.0 potentially offers education for all. There is a close relationship between the skills that need to be acquired, the use of technology in acquiring those skills, and the use of technology in the teaching model used by lecturers when teaching students.

Education in Society 5.0 faces many challenges, the most pertinent being that, although the underpinning foundation is to do things for the greater good, care should be taken to ensure that solutions do not create new problems. For example, access for everyone via online systems might provide access to the majority of students, but for those who do not have access to fast internet, it might be a challenge to access the content needed for education.

Focusing on the potential of technology in the domain of education, there are certainly numerous opportunities. Online education offers even students in remote locations access to education and enables them to interact with lecturers and fellow students. By using simulations and models, students gain access to scenarios where practical experience might be gained to prepare themselves to cope with real-life scenarios. In a simulation or modelling environment, mistakes cost nothing, and skills can be practised several times before they are finally applied. One example is the medical field, where surgery can be practised in a simulated environment prior to exposure to actual surgery.

South Africa faces unique problems related to the use of technology in our education system. One of these is how universities can overcome the digital divide. In our opinion, a potential solution is a low-synchronisation model that allows students who really cannot work online to attend classes, while those who prefer online teaching will be allowed to study online.

Different teaching models will need to be considered. Programming, data science and artificial intelligence should be included in skills training and should be combined with traditional disciplines such as mathematics, philosophy and languages. In preparing students for the world of work in a technology-enhanced environment, they will have to acquire digital literacy. Student success will continue to play a role and higher education will have to rethink the teaching model: In the first year, the focus should be on skills, and once real talent has been identified, students will advance to more focused educational programmes.

Society 5.0 has the potential to enable many students. The use of technology could facilitate training and assist students, especially those enrolled in training programmes where skills training through repetition is needed. It is imperative that lecturers remain informed about new technologies and understand how they can be effectively used in their different programmes.

We are aware of the challenges, but believe that it is more important to spend our energy on researching the potential of the use of technology made available in Industry 4.0 to establish how it can be used to the benefit of a South African society in which education is affordable and freely available.

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On 3 September 2021, the University of Pretoria hosted a panel discussion on "Society 5:0: Humanising Technology", featuring Prof Miguel Goede, a visiting professor at the Anton de Kom University of Suriname, Prof Norman Duncan, Deputy-Vice-Chancellor: Academic at the University of Pretoria, Prof Alta van der Merwe, Deputy-Dean: Teaching and Learning in the Faculty of Engineering, Built Environment and Information Technology, and Prof Hanlie Smuts, an Associate Professor in the Department of Informatics, with a research interest in Society 5.0 and related issues. The purpose of the discussion was to debate the role of Society 5.0 in teaching and learning. *https://www.youtube.com/atch?v=Fe8blyG8sBI&ab_channel=UniversityofPretoria*

Collaboration of human and machine for knowledge work

Prof Hanlie Smuts

To create business value from data-driven decision-making, organisations must apply insight from both knowledge workers and intelligent machines. The world is seeing revolutionary advances in science and technology, and with the evolution of digital technologies, there is a growing recognition that most workplaces are experiencing change.

The predominant tendency of this change is toward understanding and managing greater complexity, known from a collective perspective as knowledge work. Consequently, the evolution of digital technologies has also changed the landscape and nature of knowledge work as the growing use of digital technologies has created entirely new business models and ways to create value.

Some of these include control and monitoring through computer-based algorithms (cyber-physical systems such as autonomous vehicles), the proliferation of a connected world (the creation of enabling smart cities through the Internet of Things), the on-demand availability of computing power and data storage (cloud computing) and cognitive computing by making use of Artificial Intelligence (AI).

Maintaining an emphasis on knowledge work in this context is important, as intelligent machines are altering knowledge-creation and knowledge-sharing methods in organisations. A key contributor to the viability of intelligent machines (AI technologies and machine learning (ML) models) is the availability of data that may be applied in computer learning processes.

Both structured and unstructured Big Data structures are used to extract value from data. Consequently, data-driven organisations base their decision-making evidence on data, rather than on intuition.

Most organisations have more data than they know how to exploit effectively, and to a large extent, there is still a gap between impact and Big Data. According to a survey conducted among senior executives from 57 large corporations in the USA, organisations are slow to make the shift to a data-driven culture. Of the 99% of respondents who aimed to achieve it, only a third succeeded.

A key opportunity to achieving this impact is to create valuable knowledge from Big Data, and consequently enable winning strategies in a competitive world. This becomes apparent in the different and new ways of engaging customers and harmonising activities, as well as by the fact that some of the world's largest enterprises conduct business based on new technologies, challenging the conventional divisions of labour between man and machine. This consists of inter-related initiatives such as automation to diminish repetitive jobs, the digitalisation of work to improve worker efficiency, and AI to provide more reliable, useful and productive professional work.

Although the application of AI and ML proliferates perceptions that humans are obsolete to some extent, the ML delivery pipeline still requires human interaction. In addition, when models need to learn from human preferences, such as recommender systems, and when security concerns require the interpretability of the learning process and outputs, or adapt to users, human input is fundamental.

Recent research has therefore concentrated on interactive forms of learning and machine teaching

as they actively utilise human input and, in this way, learn from human intelligence (robotic process automation).

This enables machines to learn tasks they cannot yet achieve alone, adapt to environmental dynamics, and deal with unknown situations.

In light of deep technological changes brought about in every organisational facet by the emergence of intelligent machines and Big Data structures, it becomes highly relevant to revisit assumptions about the nature of knowledge work. Researchers found that, to create valuable knowledge from Big Data, at least four enablers must be considered: data analytics, data management, the data platform and the data-driven organisational ethos.

From an organisational perspective, decision-makers are now empowered to derive actionable insight based on the analysis of Big Data datasets through advanced analytics.

From a knowledge worker perspective, actionable insight and data-driven decision making are associated with transforming data to knowledge and ultimately to wisdom, which requires organisations to better understand fundamental constructs.

Prof Smuts is an Associate Professor in the Department of Informatics. She has been appointed as Deputy Chair of the Knowledge Management South Africa (KMSA) Board. The objective of KMSA is to look after the interests of knowledge management practitioners and the professionalisation, promotion, study and standardisation of knowledge management in South Africa.

ALTHOUGH THE APPLICATION OF ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING PROLIFERATES PERCEPTIONS THAT HUMANS ARE OBSOLETE TO SOME EXTENT, THE MACHINE LEARNING DELIVERY PIPELINE STILL REQUIRES HUMAN INTERACTION. IN ADDITION, WHEN MODELS NEED TO LEARN FROM HUMAN PREFERENCES, SUCH AS RECOMMENDER SYSTEMS, AND WHEN SECURITY CONCERNS REQUIRE THE INTERPRETABILITY OF THE LEARNING PROCESS AND OUTPUTS, OR ADAPT TO USERS, HUMAN INPUT IS FUNDAMENTAL.

Engineering 4.0 Training Laboratory transfers critical skills

The University's state-of-the-art Engineering 4.0 Complex, which was launched in 2020, includes a Training Laboratory with 20 work stations that will be used to train and certify civil engineering materials testers employed by various testing laboratories across the country.

The Training Laboratory forms part of Engineering 4.0's Integrated Laboratory Facility (ILF), which includes the National Roads Reference Laboratory of the South African Roads Agency Limited (SANRAL), as well as a concrete research laboratory and an accelerated pavement testing facility, combined with a live traffic research facility.

The Training Laboratory is linked to the SANRAL National Reference Laboratory, and its focus on the training of civil engineering materials testers is in alignment with the recommendations of the Presidential Commission on the Fourth Industrial Revolution (PC4IR). Abdul Razak Esakjee, the Facility Manager of the ILF, who also served as a Commissioner on the PC4IR, observes that the particular recommendation that the Training Laboratory hopes to address is investment in people (human capital). "This will leapfrog our youth into productive work and reskill current workers for job retention and ongoing productive work in the economy," he says.

According to Esakjee, this recommendation requires learners to obtain stackable competencies, which are micro-credentialed, industry-aligned and allow people to enter and exit the system at multiple points as part of a lifelong learning process.

In response to the recommendations of the PC4IR to develop human capacity in skills for the Fourth Industrial Revolution (4IR), SANRAL is collaborating with the University of Pretoria and the Southern African Bitumen Association (SABITA) to offer short courses for the training of civil engineering materials testers. Material types include aggregates, asphalt, bitumen and granular. An introductory course in the sampling of materials will also form part of the suite. The courses will be delivered through Enterprises University of Pretoria, making use of the facilities at Engineering 4.0, and presented by specialists from industry, in collaboration with academics from the University of Pretoria's Department of Civil Engineering.

In accordance with the recommendations of the PC4IR, once they have completed the courses, candidates can be integrated into meaningful, productive work that will benefit the economy, while developing the necessary experience towards certification against the ISO 17024 standard.

Upon certification, materials testers can be employed by testing laboratories, which can, in turn, provide accurate test data to engineers. From this point, the career progression would lead to registration by the Engineering Council of South Africa (ECSA) as a civil laboratory technical controller.

The University of Pretoria will play an active role in bridging the current knowledge gap in the transportation engineering sector, while addressing the shortage of training and testing facilities in the country. The principal objective of the short courses is to ensure that civil engineering materials testing in the field is unified and standardised, and that testers are capable and certified to do such tests with a high degree of accuracy.

It is envisaged that the first short course will be launched before the end of 2021.

THE FOCUS OF THE TRAINING LABORATORY ON THE TRAINING OF MATERIALS TESTERS IS IN ALIGNMENT WITH THE RECOMMENDATIONS OF THE PRESIDENTIAL COMMISSION ON THE FOURTH INDUSTRIAL REVOLUTION. ONCE CANDIDATES HAVE COMPLETED THE COURSE AND QUALIFIED AS MATERIALS TESTERS, THEY CAN BE INTEGRATED INTO MEANINGFUL, PRODUCTIVE WORK THAT WILL BENEFIT THE ECONOMY.

Innovative approaches to teaching and learning

The University of Pretoria is not immune to the demands placed on the higher education sector and contact tuition, in particular, during the current worldwide pandemic. The Faculty of Engineering, Built Environment and Information Technology is privileged to have staff members who think innovatively and experiment with new technologies and ways to incorporate better methods of teaching and learning. Its lecturers therefore rose to the challenge by adopting innovative approaches of transferring knowledge and ensuring improved academic performance by developing novel teaching innovations during the second year of restrictions in accordance with the President's COVID-19 Risk-adjusted Strategy.

IMPROVING STUDENTS' GRASP OF THREE-DIMENSIONAL GEOMETRY

Three lecturers in the Department of Civil Engineering, **Prof Billy Boshoff**, **Dr Anneke Roux** and **Dr Phia Smit**, approached the challenge presented by the first-year Mechanics module (SWK 122) by making use of a new innovation in the Faculty.

Mechanics 122 is a high-impact module, which is presented to almost 1 800 first-year students in the Faculty, as well as some students in the Faculty of Natural and Agricultural Sciences. It is a conceptually difficult module due to the three-dimensional geometry that has to be mastered, and poses a challenge to a large number of students.

In an attempt to increase the student pass rate and free up consultation time, the team implemented a system of optical character recognition (OCR) to grade their evaluations. This is the electronic conversion of images of typed, handwritten or printed text into machine-encoded text and is one of the functionalities of the Judicator Assessment Management System (JAMS), which was developed by Hans Grobler of the Department of Electrical, Electronic and Computer Engineering.

By converting the students' answers to machine-encoded text, it was possible for the students' answers to be graded by a computer, thus reducing the time it took the lecturers to complete this task. This made the reinstatement of weekly formative tutorial tests possible, whereby the students could receive weekly feedback. Due to the large number of students, this would not have been possible if these tests had to be marked by hand.

In preparation for the new computer-enabled grading system, the lecturers had to carefully set these tests to ensure that they could be automatically marked. There were some growing pains, as with any new system, but it proved to be a learning experience for both the lecturers and the students.

The greatest benefit lay in the fact that the students were able to receive weekly feedback on their progress.

LEARNING BY DOING PROMOTES PROBLEM-SOLVING IN PRACTICAL APPLICATIONS

Dr Wilna Bean, a senior lecturer in the Department of Industrial and Systems Engineering, was recognised for the overall impact of her teaching and learning practices in the Department, particularly in the third-year Operational Research (BOZ 312) module.

She approaches the presentation of Operational Research in the first semester from the perspective of developing advanced analytical models to solve actual problems. Through continuous assessment, students can learn by doing. After explaining a concept, students apply it practically by means of assignments and group projects. She attributes the students' success to placing a greater emphasis on practical exercises as part of their assignments, determining why a problem is formulated in a particular manner and how the information that has been obtained can be applied. Students are encouraged to identify an actual problem experienced by a company (preferably the company at which they are gaining their practical experience), and to work on the project and solve the problem during the semester.

Dr Bean has observed how students grow and develop through this problem-solving process. Where they had initially struggled, the extra practice that this approach gives them delivers good results.

TEACHING ENGINEERS TO THINK BEYOND THE MATH

Prof Schalk Kok, Professor in the Department of Mechanical and Aeronautical Engineering, drives the notion among his students that application far surpasses calculations in the real world of engineering. He teaches Structural Design (MOW 227) to second-year students, which introduces them to the principles of design.

To promote active learning in this module, experiments become an essential teaching tool. Prof Kok believes that the engineers of tomorrow need to be pushed further than ever before to come up with innovative solutions to industry problems. When a student is admitted to study engineering, it can be accepted that they are already capable of performing complex calculations with the help of mathematical formulae. However, the important distinction relates to whether the student can use the answer to make decisions. In industry, graduate engineers will be required to think beyond the math to design structures with integrity and which are fit for purpose.

To prepare students for the challenges they will face in their careers, Prof Kok requires them to design and build their own experiments to master the textbook material, rather than giving them "plug-and-play" activities. This gives students the space to make mistakes in an environment that is free from real-world consequences.

MODULE REVISIONS LEAD TO IMPROVED STUDENT PERFORMANCE

Dr Nils Timm, a lecturer in the Department of Computer Science, was recognised for restructuring the first-year Operating Systems module (COS 122), a high-risk module that had been moved into the first-year syllabus from the second-year syllabus with the necessary adaptations. A task team determined the reasons for the low pass rates and investigated possible changes that could be made to the module. Students who had repeated the module were involved in the evaluation.

Based on the evaluation outcomes, Dr Timm adapted the course content by reducing the number of textbook chapters presented in the lectures. This allowed the lecturer to discuss fewer topics in greater detail. He also changed the form of assessment by replacing the programming practicals with homework assignments. This was necessary as first-year students have not typically acquired the necessary programming skills yet. Finally, he introduced additional student support sessions, and ensured that the examination questions were better aligned to the exercises the students had already completed.

The overall measures resulted in a significantly improved pass rate and in high student satisfaction. These interventions will be continued in the future presentation of this module to ensure ongoing success.

INTEGRATING BA BOT AS A KNOWLEDGE CONVERSION STRATEGY

Dr Marié Hattingh, a senior lecturer in the Department of Informatics, spearheaded the development of a knowledge conversion platform in the form of a BA BOT in the second-year Informatics (INF 271) module.

In the Information System Design (ISD) stream, in which she lectures second- and third-year students, she applied her teaching philosophy of continuous learning (for both lecturers and students) to create an environment in which students are not just acquiring content knowledge, but are also developing graduate attributes and a professional skill set.

The idea was born from Dr Hattingh's own need to note information that was not captured in any textbook, but was required to complete the third-year (INF 370) capstone project.

The knowledge conversion model ensured that the BA BOT was populated with content to support scaffolded learning, starting at the data level, where key concepts and definitions were explained, and working up to integrated examples. This platform enabled the teaching team to provide students with various learning activities that cater for the different types of learning required by the context so that students can learn at their own pace. It also has the functionality to provide feedback, which is essential for effective learning.

LEARNING COMMUNITIES FACILITATE ACADEMIC SUCCESS THROUGH EMOTIONAL SUPPORT

Prof Marlene Holmner is an Associate Professor in the Department of Information Science. She lectures in the compulsory first-year Information Science module (INL 110). During her years of teaching this module, Prof Holmner has come to learn that the emotional wellbeing of first-year students can have a significant impact on their academic performance.

To support first-year students in the process of adjusting to university life and the academic demands that come with it, Prof Holmner has spearheaded the establishment of departmental learning communities. These are facilitated using the group chat feature on WhatsApp. Some 30 to 35 students are placed on a group chat, along with a module tutor. The instant interactive platform has proven itself to be ideal for communicating with students in a more personal manner.

The purpose of these learning communities is multi-faceted, addressing both the students' academic and emotional needs. During exceptionally stressful times, the learning communities enable the Department's support structures to intervene with relevant measures to promote the emotional welfare of the students. The learning communities have been embraced by both staff and students in the Department.

INTERNATIONAL COLLABORATION PAVES THE WAY TO ENHANCE POSTGRADUATE TEACHING

Prof Elma van der Lingen is Head of the Department of Engineering and Technology Management in the Graduate School of Technology Management (GSTM). She plays an important role in supporting teaching and learning at postgraduate level, particularly in entrepreneurship studies.

The importance of entrepreneurship studies has increased significantly with the realisation of their importance for economic growth. As a result, entrepreneurship courses should increasingly be incorporated into programmes in natural sciences and engineering faculties. This realisation led to research to determine the enterprising tendency of science, engineering and technology (SET) students with the General Enterprising Tendency (GET) test developed by Dr Sally Caird. It was found that SET students have an above-average enterprising tendency and that their first undergraduate degree does not appear to have any influence on this.

The study aimed to determine whether entrepreneurial experience has an influence on the preferred learning styles of students. The outcomes of this research will contribute to the way in which technopreneurship courses are structured to provide more effective training for science, engineering and technology students.

The use of gamification in higher education

Annique Smith

Gamification is increasingly being used in educational contexts to increase student motivation and engagement. Many studies have shown success in improving educational outcomes, but there are also pitfalls to be aware of when considering the addition of game elements to a course. Lecturers in the Department of Information Science used a gamification intervention in a first-year BIS Multimedia course and learnt some lessons in the process.

Gamification is often described as the addition of elements from games, digital or otherwise, to any non-game context. In educational contexts, well-designed gamified interventions have resulted in improved motivation in students towards learning the course content. This success is usually attributed to the ability of certain game elements, when used correctly, to satisfy the three basic psychological needs of competence, autonomy and relatedness. This, in turn, results in improved motivation. This is the core proposition of a well-established theory of human motivation called self-determination theory.

Within self-determination theory, the need for competence is the desire of a person to feel effective in their interaction within an environment. Games provide opportunities for competence satisfaction through adaptive difficulty levels, combined with instantaneous feedback to allow the player to adjust their course towards success. Autonomy describes the need for freedom of choice. Games usually offer multiple routes to the end, as well as the freedom for players to express themselves in a variety of ways. This leads to autonomy satisfaction. Lastly, relatedness refers to the human need to be connected to others. Multiplayer games are most effective at satisfying this need.

The theoretical link between games and psychological need satisfaction has been successfully proven through careful research. The question remains how best to transfer these game elements into an educational context to improve student motivation.

A gamified website was developed for this purpose and implemented in a first-year module in the BIS Multimedia programme. The module teaches students the basics of website development using HTML and CSS. This website was used instead of the Blackboard learning management system so that students did not have to use two different websites for the course. The website therefore performed all the usual learning management functions, such as access to learning materials, grades and announcements.

Self-determination theory has shown that a controlling environment harms motivation. The gamified component of the website was thus optional for the students to use.

This portion of the website included a map along which students could move their avatar to encounter various elements – course quizzes, points and quests. Course quizzes took the form of battles with monsters in which students needed to answer questions correctly to beat the monster. The prize for winning was points that enabled movement along the map and the ability to customise one's avatar. Quests were more in-depth web development tasks, which could be done in the browser and then submitted for assessment. A correct quest earned the student additional points. Students also had the opportunity to engage with each other through challenges to

see who could perform faster on a quest. Lastly, a narrative was developed to contextualise all the students' actions on the website and to bring additional meaning to the activities.

Two important design decisions were made in the creation of the website. Firstly, allowing the students the freedom to fail in all gamified activities. This meant that there were no negative consequences for failing a quiz or a quest. The student could simply try again. This would reduce anxiety and satisfy autonomy. Secondly, the system was designed so that any interaction with a game element meant that the student was directly engaging with the learning content of the module. This meant that the gamification was directly tied to the learning content.

The students used the website throughout the semester and data was gathered through website interaction, questionnaires and focus groups. The students reported enjoying certain game elements more than others. The freedom to fail at quizzes and quests allowed students to use these elements to prepare for course assessments without anxiety. This also served to satisfy the need for competence in an enjoyable way. The freedom to engage with the gamified elements without pressure was the primary means of satisfying autonomy for the students. They reported engaging with the website out of enjoyment rather than external pressure. On the other hand, it was difficult to satisfy relatedness using the website. The students reported feeling intimidated by the idea of challenging their classmates. Although the website was designed with the intent of creating a community within the module, this was not as successful as intended. Overall, the students reported feeling more motivated towards the module content because of the website.

Several lessons were learnt during this intervention. Firstly, good gamification is difficult to do properly. It requires an understanding of psychological processes, game design, as well as user experience design. It also requires iteration and improvement as data emerges to shed light on student interactions. It is much more than simply adding points and a leader board to a course hoping to improve long-term student motivation. Secondly, good gamification does not always need to be complex.

While this website included many game elements aimed at satisfying each of the three needs in various ways, a simple and well-designed approach can be just as effective and less time-consuming to implement. Adding a single element aimed at one psychological need can have a large impact on a course. Consider what it might look like if students had an optional activity to do to earn a deadline extension, which they could "cash in" at a later stage. Finally, relatedness is the most difficult need to satisfy. This has also been shown in previous research. However, if we continue to move forward with online teaching and learning, this will become the most important need to address as we start to see the negative effects of students learning in isolation at home.

Gamification is a tool with the potential to have a positive impact on education. However, using this tool without a clear understanding of the underlying theoretical foundations can result in damage to student motivation and disengagement from the course. Good versions of gamification require time and iteration, but when it is effective, the cost is outweighed by the positive educational outcomes.

Online short courses become the **"new normal"**

Vita Wilkens

Short courses not only provide a way for academics to share their expertise with industry, but contribute to employment, development and economic growth in South Africa. The Department of Construction Economics recently joined hands with Enterprises University of Pretoria (Enterprises UP) to address the challenges posed by the COVID-19 pandemic by making use of alternative modes of delivery in the presentation of a new online short course for the continuing development of the owners, trustees and occupiers of sectional title units.

This course, titled "Sectional Title Living – the nuts and the bolts", was developed in collaboration with the National Association of Managing Agents (NAMA), who identified the need for a course of this nature due to the exponential growth of this alternative form of ownership of immovable property. It is estimated that sectional title units make up approximately two-thirds of all residential units financed by the major banks, and that approximately 77 000 schemes have been established since the introduction of this concept in South Africa in 1971.

In preparation for the presentation of the new online short course, the course material was divided into 23 short lectures, which were filmed in the boardroom of Enterprises UP. This resulted in the boardroom being transformed into a fully equipped recording studio. The short course was developed by Vita Wilkens, programme leader for the BSc and BSc Hons in Real Estate and lecturer in the Department of Construction Economics.

The short course is specifically aimed at the owners, trustees and occupiers of sectional title units in sectional title schemes. It is a fully online, self-paced programme, which includes a comprehensive printable manual, with the content illustrated by means of the 23 filmed lectures. Course material also includes the relevant legislation, as well as other applicable examples. The purpose of the course is to give delegates a clear understanding of what a sectional title is, what it means to own a unit in a sectional title scheme and what their responsibilities are to ensure that they own and occupy property in a well-functioning sectional title scheme. The relationship between the body corporate and the managing agent is also discussed, as well as how this partnership is crucial for the success of the scheme.

Members of the production team (from left): David Brink (video director), Vita Wilkens (course leader and presenter), Donovan Matthews (cinematographer), and Elna Venter and Marinda Prinsloo from Enterprises UP.

Other important issues dealt with are the meaning of sectional title ownership compared to full-title ownership, the formation of a sectional title scheme, how a scheme is managed, the rights and obligations of sectional title owners, the Community Scheme Ombud Service (CSOS), as well as other matters relevant to sectional title schemes.

The programme was rolled out in July 2021, with NAMA purchasing 400 tokens for its members. Seventy-three of those members have already enrolled. According to NAMA, it has only received positive feedback from those who have completed the course.

The team is planning additional online short courses aimed at estate living and retirement villages. As with the sectional title course, these short courses will focus on owners and occupiers of property within residential estates and retirement villages.

Collaborative learning at postgraduate level creates responsive industry professionals

Prof Chrisna du Plessis

The Department of Architecture in the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology offers two one-year programmes to graduates in the Department's disciplines of architecture, interior architecture and landscape architecture. The one-year professional honours degree, combined with the one-year professional master's degrees, are the equivalent of the two-year professional master's degree programmes offered by some institutions.

The Department's approach to these degree programmes prepares graduates for advanced and specialised professional employment. The programmes also serve as a gateway to further post-professional design or research specialisations, both locally and internationally.

As a research-intensive Department, the professional postgraduate programmes in Architecture are premised on a research-led approach to design and construction. Students are encouraged to investigate real-world design problems that are situated in a local socio-cultural and environmental context. Directions for research themes emerge from the Department's research focus areas (urban citizenship, regenerative and resilient cities, designed ecologies, smart cities and neighbourhoods, memory, legacy and identity, inhabitation of place and architectural education). At the same time, the Department endeavours to produce responsive, future-ready industry professionals.

To this end, the curriculum emphasises community engagement, wellbeing and environmental responsibility, which instills an ethos of ecosystemic thinking in students, and prepares them for the responsibilities they have as professionals responding to the challenges of the 21st century.

The studio-based honours programme exposes students to a multidisciplinary learning environment, where the Department's three distinct disciplines are treated as one integrated spatial design continuum. This offers students an experience that is embedded in real-life research and practice, with outcomes that promote knowledge exchange within the academic environment, as well as in the professional context. They are exposed to complex social, cultural and environmental problems on multiple scales, and are encouraged to follow a holistic and regenerative design approach.

The studios are designed to result in a rich variety of experiences through integration with ongoing research projects, and collaboration with communities and practitioners. The pedagogical sequence of the studios ensures that students are exposed to a variety of research and design generation methods, eventually synthesising this knowledge in a critically reflective process of iteration towards detailed design resolution.

Students are encouraged to participate in studios other than their own discipline for two quarters of the year, where this possibility exists.

In addition, the honours programme considers the practical, technological, legal and practice-related aspect of professions in the built environment to establish an ecosystemic understanding of the scientific, natural and cultural settings within which designers work, together with the impacts of construction on individuals and society.

The master's programme comprises a personal, yet critical, design-led, research-based investigation. Students then produce designs that respond to their research findings. Projects also consider the inhabitants of the design and surrounding communities to ensure local relevance.

This process produces graduates with the ability to engage with theory and case studies to develop a responsive approach to the making of space and form, incorporating systems and technology. A rigorous, iterative and creative process of design postulation and enquiry, testing, evaluation and refinement seeks to push the boundaries of architectural convention.

Shaping young professionals in the design of urban green infrastructure

Dr Ida Breed and Helge Mehrtens

In the Global South, where high biodiversity, alongside rapid urbanisation and a lack of basic infrastructure, dominates, the inclusion of green spaces as part of the infrastructural services of urban development is not prioritised. Extensive informal settlements with poor service levels, and the exposure of cities to environmental disasters, such as floods, put pressure on and erode environmental assets. Most of these challenges will worsen as the effects of climate change progressively manifest. Design skills for developing innovative solutions to these complex problems are ever more critical.

This project has been funded by the University of Pretoria's Scholarship of Teaching and Learning (SoTL) Grant for 2019.

In an effort to expose students to the reality of the challenges to which they will be exposed in the workplace, the University of Pretoria's Landscape Architecture programme embarked on a collaboration with the Architecture Department of the eThekwini Municipality. The aim was to sharpen the ability of local municipalities and future professionals (students) to improve urban green infrastructure planning and design. This initiative took the form of a "learning by doing" approach, where the students were involved in the design of one of eThekwini's urban regeneration projects, the KwaMashu Urban Hub Project.

The participation of built environment designers in live projects in the public sector during their education is beneficial to their ability to remain relevant in practice. This particular project prepared students professionally to utilise urban green infrastructure guidelines for open space planning focused on implementation. These green guidelines do not currently influence land use decisions on the ground as they should.

Although postgraduate design students have less practical implementation knowledge, they are trained to test value standards and explore creative solutions. Universities' design faculties are becoming increasingly interested in community service and collaboration in an effort to broaden design relevance beyond aesthetic self-expression and to prepare students to deal with 21st-century global, systemic and contextual challenges. This project serves as an example of this trend.

A "learning-by-doing" approach requires a willingness to take risks, and to adapt to change, uncertainty and ambiguity. Participants are exposed to diverse values and insights, and environments are established where learning is directed at relevant and meaningful problems. The collaboration exploited the potential of live projects for the transformative learning of landscape architecture and architecture students in urban green infrastructure planning and design.

THE PARTICIPATION OF BUILT ENVIRONMENT DESIGNERS IN LIVE PROJECTS IN THE PUBLIC SECTOR DURING THEIR EDUCATION IS BENEFICIAL TO THEIR ABILITY TO REMAIN RELEVANT IN PRACTICE. ALTHOUGH POSTGRADUATE DESIGN STUDENTS HAVE LESS PRACTICAL IMPLEMENTATION KNOWLEDGE, THEY ARE TRAINED TO TEST VALUE STANDARDS AND EXPLORE CREATIVE SOLUTIONS.

Landscape architecture design students inspecting the flood plain of the Piesangs River in KwaMashu during the field trip to eThekwini.

LOCAL CONTEXTUAL CHALLENGES

The task of professionals and local government to manage trade-offs between social livelihoods and ecological infrastructure is complex. South Africa's urban population is projected to reach 79.8% by 2050. Most of the urbanisation is taking place in the form of informal settlements where people are living in poverty and where basic facilities and services are missing. Added to these are projected climate change, extremes in temperature and flooding patterns, biodiversity loss and challenges with local governance.

The legacy of former apartheid planning still dominates urban areas, manifesting as an unjust distribution of green assets across race and income. Township areas under apartheid had few developed green spaces, while vacant spaces operated as barriers to planned racial and economic opportunity. Today, development funding for urban green infra-structure is scant, competing with more desperate needs.

The eThekwini Municipality in KwaZulu-Natal, which encompasses the city of Durban, has a long history of urban open space planning and was the first city in South Africa to apply a Metropolitan Open Space System (MOSS) in city planning. It also has a good reputation based on a community and ecosystem-based adaptation (CEBA) approach. A number of CEBA-focused projects have been initiated, which have followed a "learning-by-doing" model of development and implementation.

The Bridge City KwaMashu Open Space Project follows this approach and stresses the importance of urban green infrastructure for sustainable township regeneration. This project focuses on a river catchment to bring about social and environmental sustainability and resilience. It furthermore addresses the importance of urban green infrastructure, particularly in the KwaMashu Urban Hub Project.

One of the challenges for the Bridge City development has been crossing the Piesang's River flood plain, which forms an insurmountable barrier. There is no pathway or pedestrian bridge over a length of nearly 2 km across the Piesang's River to allow the population of old-town KwaMashu to safely cross the river and steep slopes to reach the new facilities of Bridge City. In addition, part of the protected biodiversity of the Durban MOSS green space is in a state of neglect and is perceived to be a dangerous, no-go area.

The valley is one of the largest of a few remaining patches of

open space in KwaMashu with the potential to provide a range of economic, social and ecosystem services, if properly designed. Nearly the entire valley falls within the 100-year floodline, which needs to be free of grey infrastructure in any design solution. The flood plain's potential is mainly its flood storage capacity, as well as enhanced downstream water quality, but this needs intervention. The wetland system is in a critically modified and poor environmental state.

The concept on which the students would be working with the municipality was to develop the Piesang's River Valley into a major park. Additional and sometimes conflicting uses required around the wetland and floodline area are safe spaces for sports, rest and recreation for the surrounding communities, infrastructure for pedestrians and cyclists, and pathways and pedestrian bridges to reach Bridge City and to encourage non-motorised transport as a sustainable and affordable option. A Spatial Framework Plan and subsequent spatial designs were developed based on this concept.

To steer the planning process, the eThekwini Municipality set up an interdisciplinary team with members from various departments, assisted by private consultants. The opportunity for collaboration between the University's Landscape Architecture programme and the eThekwini Municipality was a way of bringing a fresh perspective to the project's design. The collaboration would benefit the municipality in terms of design brainstorming, while the University's students' exposure to a real-life project would benefit their professional formation.

Each of the students developed a proposal for one of the earmarked areas within the Piesang's River Park framework. Their briefs were based on the Municipal Spatial Framework. The municipal leaders for the project and the University's design studio staff provided guidance and managed the students' brief and design stimulus activities.

During the field trip, the students' initial design development was guided through a technical workshop with the eThekwini Municipality. Site visits were also conducted to Piesang's River and KwaMashu. The students then spent time working on conceptual ideas, which they presented to the municipal staff for feedback. Upon their return to Pretoria, the students received weekly feedback on their design progress. Midway through the process, a consultant and a municipal staff member from eThekwini came to Pretoria to provide input on the students' design developments. Municipal staff members were also present during the project's final examination. The final projects were made available to the municipality digitally for its use and further development.

ADVANTAGE OF THE COLLABORATION

As part of the collaboration, qualitative research was conducted to establish the degree to which the exposure to real-life projects stimulates postgraduate design students' experiential and transformative learning. The participating students completed questionnaires, in which their reflections were monitored and recorded. The educational benefits include adapting to a fast-changing world, bridging the science-implementation gap, and improving learners' understanding of themselves and their professional aspirations. The study also inquired about the design benefits to the municipality rendered through engagement.

The findings of the research show that the collaboration resulted in critical evaluation of the municipal planning and design process. The students delivered several inspired macro-level design proposals. Overall, the eThekwini team's expectations were met and exceeded by the standard of the students' design work and dedication to the project.

The real-life and interdisciplinary focus of the studio were important influences for students' transformative learning. The students had renewed insight on the basis of the design decisions, the role of the profession, the design process, confirmation of prior learning aspects and interdisciplinary importance.

The collaboration also allowed the practitioners to engage with academia and future professionals in the field of urban green infrastructure. The experts from different departments in the eThekwini Municipality, together with the consultants, showed an eagerness to share their "on-the-ground experience", while being challenged by students' honest, critical questions. By sharing, they helped the students understand the various challenges experienced in the real-life eThekwini environment.

The engagement resulted in some outstanding work, which will be considered and refined by professional design consultants in future projects. Overall, the project team was impressed with the students' well-reasoned design solutions. Creative and innovative thinking resulted in fresh ideas, which is a key component of a successful experimental CEBA-focused approach.

A "learning-by-doing" approach that combines real-life projects in challenging contexts can advance design proposals and professional formation. However, cost, time constraints and different expectations of role players call for a balance between live projects and other types of learning.

Taking teaching and learning to the **next level**

The University of Pretoria's commitment to ensuring that its teaching and learning initiatives enable students to excel and graduate in the minimum time set out for a degree, and to continue to pursue postgraduate studies, is entrenched in a culture of excellence. With the assistance of the Department of Higher Education and Training (DHET) in the form of the Scholarship of Teaching and Learning (SoTL) Grant, its academics have the opportunity to develop projects that will enhance their teaching and learning outcomes.

THE DEPARTMENT OF HIGHER EDUCATION AND TRAINING'S SCHOLARSHIP OF TEACHING AND LEARNING GRANTS ARE AWARDED TO ACADEMICS TO UNDERTAKE RESEARCH INTO THE TEACHING OF THEIR DISCIPLINE WITH THE AIM OF DEVELOPING THEIR TEACHING AND RESEARCH CAPACITY AND IMPROVING STUDENT LEARNING. THE PURPOSE OF THIS GRANT IS TO PROMOTE INSTITUTIONAL RESEARCH TO IMPROVE TEACHING AND STUDENT LEARNING AND SUCCESS.

In 2020, the Faculty of Engineering, Built Environment and Information Technology was fortunate to receive ten such grants across its four schools, which enabled the related research to be conducted in 2021.

Ms Dayle Shand
Department of Architecture
Promoting co-creation of teaching and learning in landscape architecture education through online teaching practice.

Prof Hanlie Smuts
Department of Informatics
The role of experiential learning as a creative, transdisciplinary and project-based approach for optimal, collaborative learning.

Mr Jannie Maritz
Department of Mining Engineering
Visualising and tracking of graduate attribute performance: A Mining Engineering case study.

Ms Karen Botes
Department of Architecture
African food crops in living wall systems: Virtual experiential learning through interactive videos.

Dr Helen Inglis
Department of Mechanical and Aeronautical Engineering
First-year student success in the School of Engineering: Identifying associated factors and devising interventions.

Dr Funmi Adebesin
Department of Informatics
Improving students' engagement and performance on learning outcomes through the use of new technologies in a fundamental module.

Prof David Walwyn
Graduate School of Technology Management
Transforming pedagogy to enhance the epistemic contribution capability of postgraduate students.

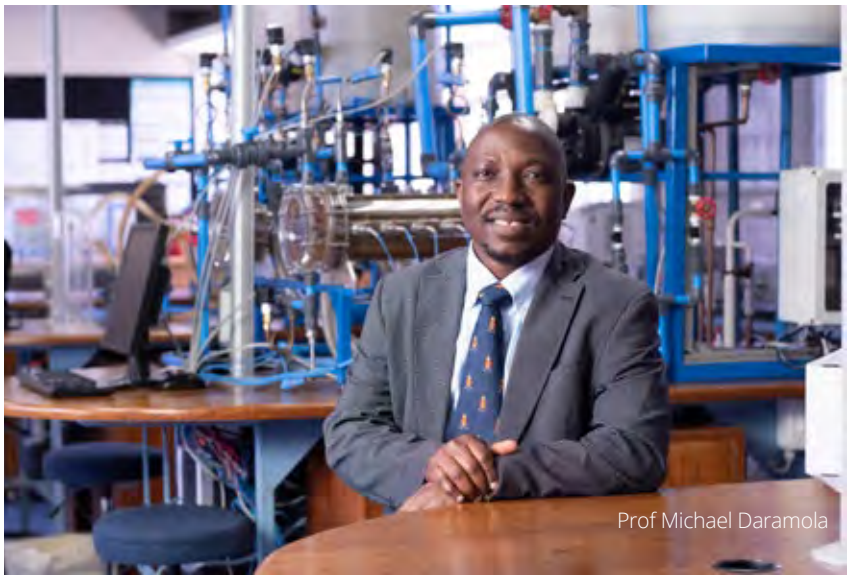
Dr Riana Steyn
Department of Informatics
Interactive infographics to introduce first-year students to systems analysis and design: Moving content from semi-offline to online.

Dr Suzanne Smith
Department of Electrical, Electronic and Computer Engineering
Reformulation of first-year engineering practicals for improved learning and strengthened links between theory and practice, with flexibility in online implementation.

Ms Nita Mennega
Department of Informatics
Community partners' experiences of service learning and community engagement: An evaluation of the relevance and value of student projects for community partners

Effective postgraduate supervision for transformative teaching and learning

Prof Michael Daramola


Prof Michael Daramola

As Head of Department of Chemical Engineering and active researcher at the University of Pretoria, I strongly believe that teaching and learning should promote transformation through the application of acquired knowledge. It should have the ability to transform the mind and rebuild character in society. At the same time, teaching and learning should be enjoyable, and should be engaged in with great passion and commitment.

Every teacher adopts one philosophy or another to achieve this goal. In addition, the objective of teaching and learning should be to create knowledge that will be beneficial to society. For instance, teaching and learning in any profession or field of study should develop knowledge and understanding that will stimulate curiosity to solve problems, such as the high mortality rate, high rate of unemployment, climate change, water and energy shortages and environmental pollution, to mention a few issues that are ravaging society.

In engineering, teachers transfer fundamental knowledge to learners to help them cultivate or build critical thinking skills through the understanding and application of various engineering concepts. This is also true for the postgraduate supervision of engineering students.

I share the opinion of the authors of research on sustainable assessment published in *Assessment and Evaluation in Higher Education* (Boud and Soler, 2015), who state that education should not be judged on what it delivers now, but on what it produces in the world beyond the present. In fact, what education produces in the world beyond the future defines its sustainability.

The effective postgraduate supervision of graduate engineers is imperative to ensure the sustainability of the engineering profession.

Apart from the foundation provided for graduate engineers at undergraduate level, the training of these scholars, who will eventually take over the batons from the older generation, at postgraduate level, is essential for the sustainability of the profession. Therefore, producing high-quality postgraduate engineers (at master's and doctoral levels) will depend, among other factors, on the effectiveness and efficiency of the supervision system.

To make postgraduate supervision efficient and effective for its purpose, one needs to know that learning through engineering education is expected to transform the mind. This transformation is expected to be noticed by learners and society because transformative learning should shape learners and reorientate their minds. In addition, postgraduate supervision in engineering education and training should not only be seen as a means to produce a good research outcome, but is rather a transformative process whereby special skills are developed.

An engineer is expected to have good analytical skills for deeper reflection on ongoing activities. For instance, engineering students should be guided to develop reflection-in-action skills that will shape their analytical skills and transform their judgment ability. An engineer is expected to be swift in making a decisive judgment about a situation and to take responsibility for the decision to prevent a calamity. In addition, postgraduate supervision in engineering education and training should be well organised and interdisciplinary in nature to enhance the effective transformation of knowledge and the development of new skills in order to apply holistic and creative approaches to engineering problems in society.

Research efforts in this area have revealed that the combination of several postgraduate supervision strategies will be effective in producing the high-quality doctoral engineering graduates that are desired. For instance, time and resource management, coupled with effective and constant communication in engineering research, are essential to achieve success. Coaching or mentoring is considered a postgraduate supervision strategy. Although this is essential in postgraduate supervision, the need to mentor or coach a supervisee depends on the interest and mutual understanding and agreement between the supervisor and the supervisee. In addition, a supervisor who wishes to take on a mentorship role in the supervision process should possess the quality and be able to undertake multiple roles, while setting boundaries in the process.

Despite the robust framework developed for postgraduate supervision in engineering to produce all-round sound and knowledgeable postgraduates, the existing supervision framework is faced with challenges such as completion rates, the modes and context of knowledge production, and the original contribution of postgraduate research, to mention a few. These problems influence the process, the supervisor-supervisee relationship and the quality of the research outputs during postgraduate supervision.

In addition, factors that mitigate the production of the high-quality research and training of future researchers, such as the heavy workload of the supervisors, and the degree and extent of intimacy with the supervisee, have been identified and discussed. Therefore, the hands of all stakeholders involved must be on deck to ensure that effective supervision occurs at our universities. For instance, a doctoral thesis in engineering is expected to provide scholarship that contributes to knowledge and is also useful in providing solutions to societal problems. Thus, it is the responsibility of supervisors to guide doctoral candidates to produce a high-quality thesis that will satisfy the assessment criteria of the degree-awarding institution or similar assessment criteria.

In spite of the enormous discourse around this subject, some key questions remain. These include the following:

- What constitutes good scholarship?
- What qualifies as doctoral work?
- Is there any way to improve on the postgraduate supervision framework to produce doctoral graduates that will be employers of labour rather than employees of labour?

THE EFFECTIVE POSTGRADUATE SUPERVISION OF GRADUATE ENGINEERS IS IMPERATIVE TO ENSURE THE SUSTAINABILITY OF THE ENGINEERING PROFESSION. TO MAKE POSTGRADUATE SUPERVISION EFFICIENT AND EFFECTIVE FOR ITS PURPOSE, ONE NEEDS TO KNOW THAT LEARNING THROUGH ENGINEERING EDUCATION IS EXPECTED TO TRANSFORM THE MIND. THIS TRANSFORMATION IS EXPECTED TO BE NOTICED BY LEARNERS AND SOCIETY BECAUSE TRANSFORMATIVE LEARNING SHOULD SHAPE LEARNERS AND REORIENTATE THEIR MINDS.

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Benefitting from a new generation of academics

The innovation generation – the new cohort of students graduating from the Faculty of Engineering, Built Environment and Information Technology – is benefitting from the talents of a new generation of academics. This is due to funding provided by the Department of Higher Education and Training (DHET) in the form of the New Generation of Academics Programme (nGAP), which recruits highly capable scholars as new academics, against carefully designed and balanced equity considerations and in light of the disciplinary areas of greatest need.


Dineo Ramatlo

One such academic in the Department of Mechanical and Aeronautical Engineering is Dineo Ramatlo, who joined the Department as a lecturer in January 2020.

The DHET's nGAP is a prestigious development programme to build future generations of academics with a vision to increase the number of black South African academics. Lecturers in this programme are appointed into permanent positions and their conditions are customised to ensure their successful induction into the ranks of established academics. The programme spans a six-year period and focuses on research and teaching development.

The nGAP candidate is expected to complete their doctoral degree within the first three years of appointment. Upon completion of this qualification, the lecturer's teaching commitments steadily increase with a spread of responsibilities and levels until they carry a full teaching load.

Ramatlo is currently completing her PhD in the field of guided wave ultrasound and structural health monitoring. Her research focuses on using ultrasonic waves to detect damage in structures, with a specific application to heavy haul railway lines. She is currently involved in a project on the upgrading of an ultrasonic broken rail detection system, which was developed by the Council for Scientific and Industrial Research (CSIR) and the Institute for Maritime Technology. The system is a permanent monitoring system that uses pitch-catch piezoelectric transducers attached to the rail to excite and receive ultrasonic guided wave signals. The recent version of the system can detect complete breaks. Current research efforts aim to upgrade the system to detect small damages such as cracks before complete breaks occur.

Ramatlo has published her research in peer-reviewed journals and has presented her work at local and international conferences. She won the third prize in the student poster competition of the Quantitative Non-Destructive Evaluation Conference in 2015, which represented the work she was doing for her master's degree. This work also earned her a Best Master's Student Award from the CSIR. She is currently a recipient of the Thuthuka Grant of the National Research Foundation (NRF).

The Faculty wishes her well in her future as a researcher and academic in the Department of Mechanical and Aeronautical Engineering.

Department of Mining Engineering celebrates its **diamond jubilee**

The Department of Mining Engineering is proud to celebrate its diamond anniversary in 2021. With its history of 60 years of excellence in mining engineering education, the Department plays a significant role in mining teaching, learning and research at the University of Pretoria (UP), and contributes new ways of innovating for the future.

Established in 1961 following the successful institution of the Faculty of Engineering at UP in 1956, the Mining Engineering programme had been hosted in the erstwhile Faculty of Mathematics and Natural Science since 1956.

The institution of an independent department 60 years ago was necessitated by the recognition of mining engineering as an important discipline in South Africa.

The Department's first student to enrol for the degree in Mining Engineering graduated in 1964. By 1968, 26 students had graduated from the Department.

It has since contributed greatly to the mining industry by providing world-class mining engineering leaders, with many alumni serving the mining industry with distinction.

Over the years, the Department has faced many challenges, with its strategic intent following the ebb and flow of the fortunes of the industry.

However, it has proved to be resilient and ready to turn challenges into opportunities.

This was demonstrated most recently in 2020 when the challenges posed by the COVID-19 pandemic caused it to embrace disruptive approaches to teaching and learning, and to emerge more agile and flexible than ever before.

The change of its language of tuition to English in 2001 to facilitate access, the present strong emphasis on leadership skills grounded in sound technical skills, and contributions to inculcating a safety culture in mining operations serve as further examples through which it ensures the delivery of work-ready graduates.

Through its Mining Resilience Research Centre (MRRC), the Department strives to enable the mining industry to transition from being reactive and compliant to becoming resilient in issues related to safety, health, environmental sustainability, social responsibility and community management through well-structured and committed undergraduate and postgraduate education and research. It is therefore dedicated to visibly aligning its educational and research objectives with industry needs.

EDUCATING AND LEADING MINING ENGINEERS TO BECOME IMAGINEERS BY EMPOWERING THEM WITH TECHNICAL AND NON-TECHNICAL SKILLS THROUGH THE USE OF WORLD-CLASS EDUCATION, RESEARCH, LEADERSHIP AND RELATED TECHNOLOGY INTERVENTIONS.

INDUSTRY FOOTPRINT

As an important role-player in the South African economy, the country's mining industry is optimally positioned to embrace the disruptive technologies that characterise the Fourth Industrial Revolution (4IR). In this regard, the Department partners with industry by supplying it with between 15 and 20% of its mining engineering graduates. The Department's innovative teaching practices and relevant research are highly regarded by industry.

The Department collaborates with various stakeholders, such as the Minerals Council South Africa (MCSA), the Mandela Mining Precinct (MMP) as part of the South African Mining Extraction Research Development and Innovation (SAMERDI) strategy and the Mine Health and Safety Council (MHSC), which makes it a key participant in future innovations in the mining industry.

Through the generous financial support of its industry partners, the Department has been able to develop world-class teaching and research facilities, such as the Kumba Virtual Reality Centre for Mine Design, as well as industry-supported research chairs.

It is able to support students financially through the provision of industry-sponsored bursaries, which have also been rolled over to full-time postgraduate students in the Department over the last 10 years to build capacity and capability in terms of future researchers and potential academic lecturers.

Industry support has also contributed to the development of a robust continuing education programme. The presentation of short courses in conjunction with Enterprises University of Pretoria (Enterprises UP) forms an important part of the Department's third-stream funding strategy. The Department furthermore benefits from the expertise of leaders from industry and academia, who serve on the Mining Engineering Advisory Board.

ALUMNI FOOTPRINT

The Department's alumni are among the country's leaders in mining and other industries, such as oil and gas, as well as water purification, locally and abroad, and include a significant number of individuals who serve in the leadership ranks of prominent organisations and on their boards of directors, and are recognised for the role they play in the development of the country's economy.

The Department's many alumni who are employed at senior executive level in the mining industry are a true testament to the quality of graduates that the Department has produced over the last 60 years, and will continue to produce. These individuals are champions for the University of Pretoria, and enhance its image through their exceptional achievements as the chief executive officers, chief operating officers, managing directors and executive heads of various mining companies.

The Department also enjoys the active support of its alumni through the Mining Alumni Society of the University of Pretoria (MASUP), the University's largest alumni society. Through this platform, alumni support the Department by raising sponsorships, and ensuring that a high level of skills and educational standards are maintained. This society also serves as a social network for mining engineers in industry.

INTERNATIONAL RECOGNITION

The University of Pretoria is recognised as one of the top 50 universities in the world in minerals and mining engineering according to the QS World University Subject Rankings of 2021. It is one of only two departments in South Africa to educate professional graduate mining engineers. Its graduates are well accepted in the market, and its racial and gender profiles are representative of the country's landscape.

The Department's prime resource is its teaching staff, which has about 150 years of combined industry experience. The active participation of industry experts as part-time lecturers forms an important part of its teaching strategy. The financial contribution of the Minerals Education Trust Fund (METF), in the form of a staff salary subvention, has enabled the Department to attract high-quality lecturers from industry. The additional involvement of guest lecturers keeps its staff and students up to date with the latest industry trends. Its postgraduate research programme has benefitted from the involvement of Prof Con Fauconnier as honorary professor and Prof Bharath Belle, Prof Jan du Plessis, Prof John Napier and Prof William Spiteri as extraordinary professors.

One of the Department's key strategic initiatives is to ensure that its research is recognised internationally for its high standards. The intention is to increase the collaboration potential among international researchers with similar technical subject knowledge and skills, and to foster international co-publication.

The Department is also a member of the global academic community through the representation of the University of Pretoria on the international Society of Mining Professors (SOMP). This body represents mining academics all over the world, and is committed to making a significant contribution to the future of the minerals discipline internationally. All the Department's lecturers are members of this organisation, and the Head of Department, Prof Ronny Webber-Youngman, serves on its Council.

AS AN IMPORTANT ROLE-PLAYER IN THE SOUTH AFRICAN ECONOMY, THE COUNTRY'S MINING INDUSTRY IS OPTIMALLY POSITIONED TO EMBRACE THE DISRUPTIVE TECHNOLOGIES THAT CHARACTERISE THE FOURTH INDUSTRIAL REVOLUTION.

FACILITIES

The Department's excellent relationships with its industry partners led to the establishment of the Kumba Virtual Reality Centre for Mine Design (VR Centre), which was made possible through an R18.8 million investment over three years by Kumba Iron Ore in 2013. This was the first centre of its kind in Africa to be housed at a university, and enables the Department to realistically simulate a range of mining functions in a low-risk, high-impact learning environment.

The facilities comprise a wall-to-wall 3D theatre, as well as an immersive mine simulation theatre, which casts 360⁰ images against dark surrounding panels with cinematic clarity and highly realistic sound effects. The infra-structure development, which was completed in 2015, included new offices for the Department on the fifth floor of the Mineral Sciences Building, while African Rainbow Minerals provided funding for a new mining laboratory and exhibition centre.

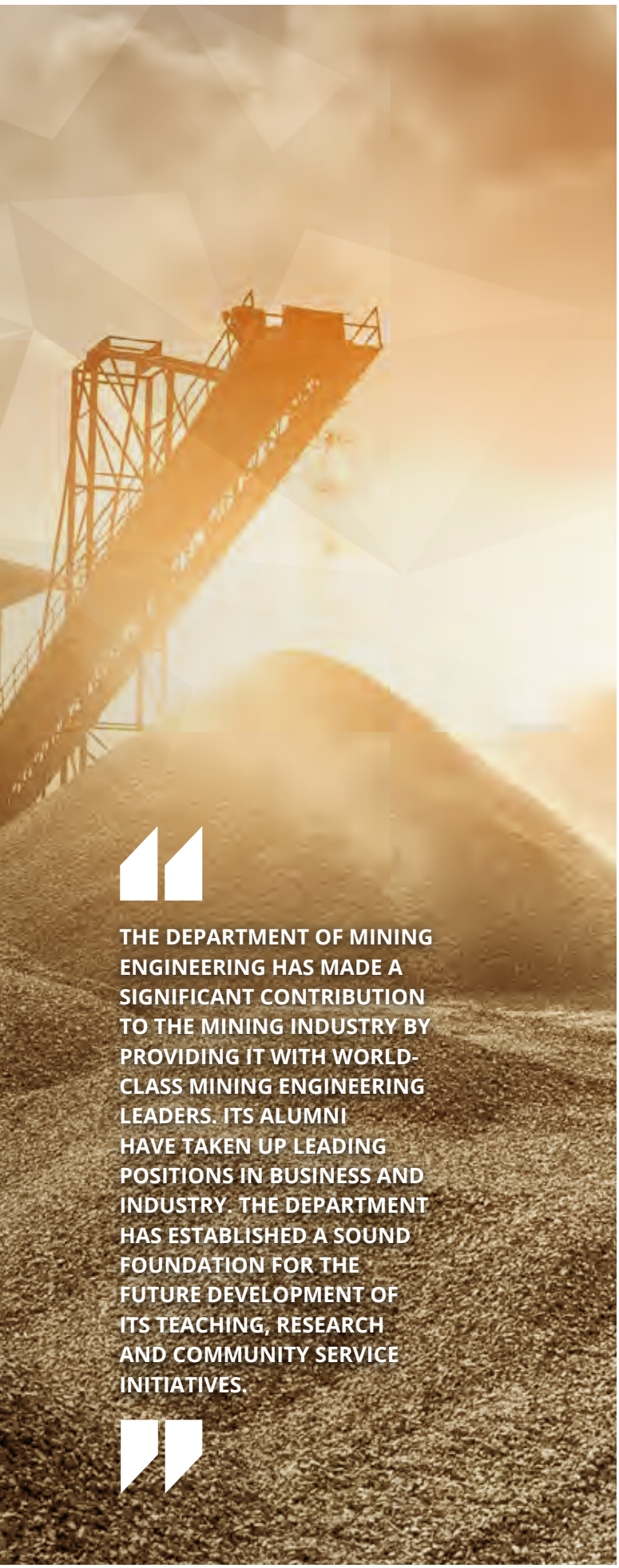
In 2019, the METF made a substantial sum available to the Department to acquire new laboratory equipment for mining modules. This new equipment has added to the Department's virtual reality theatre and 360° cylinder, and will ensure that it can cater for new needs in terms of technology transfer to enhance students' learning experience and understanding. The support of the METF is graciously acknowledged and appreciated.

RESEARCH EXCELLENCE

The Department is concentrating its efforts on growing research capacity in five key research areas, which will have an impact on the future of mining and the sustainability of the industry: mechanisation and automation, rock-breaking and explosives engineering, management and leadership, rock engineering and extended reality (XR) technology.

The strategic intent of the Department to increase its postgraduate student numbers has a direct impact on its research output. It is increasing its publications in national peer-reviewed journals and at conferences, and has a healthy research pipeline. The challenge that it is embracing is to increase publications in accredited international journals and cement its relationships with international mining schools. The appointment of extraordinary lecturers with PhDs in future to fill the gap in research areas that the Department wants to explore will become more important and, in this way, increase its research capacity and capabilities.

Prof Francois Malan, the Department's Research Function Head, has a B2 rating as a researcher from the National Research Foundation (NRF). This signifies an internationally acclaimed researcher.



THE DEPARTMENT OF MINING ENGINEERING HAS MADE A SIGNIFICANT CONTRIBUTION TO THE MINING INDUSTRY BY PROVIDING IT WITH WORLD-CLASS MINING ENGINEERING LEADERS. ITS ALUMNI HAVE TAKEN UP LEADING POSITIONS IN BUSINESS AND INDUSTRY. THE DEPARTMENT HAS ESTABLISHED A SOUND FOUNDATION FOR THE FUTURE DEVELOPMENT OF ITS TEACHING, RESEARCH AND COMMUNITY SERVICE INITIATIVES.

The Department's postgraduate teaching and research is supported by its industry chairs, as well as the Mining Resilience Research Centre. These chairs are the AEL Intelligent Blasting Chair for Innovative Rock-breaking Technology, the Harmony Gold Chair in Rock Engineering and Numerical Modelling, and the Murray & Roberts Chair in Industry Leadership 4.0. It also collaborates with the Department of Information Science on the Exxaro Chair in XR Technology. In addition, the Mandela Mining Precinct, an initiative of the Department of Science and Innovation, approved the establishment of the SAMERDI Research Centre for Mechanised Mining Systems (MMS) at the University of Pretoria, to be officially launched in November 2021. This centre is a joint initiative with the Department of Mechanical and Aeronautical Engineering. Its research activities relate to continuous rock drill condition assessment; an estimation of rock strength properties using selected mechanical parameters obtained during drilling; and the predictive maintenance management of mechanised mining equipment.

The establishment of the Mining Resilience Research Centre in 2017 came about due to recognition of the fact that a resilient mining industry is of particular relevance to Africa. This multidisciplinary research centre draws on the resources within the University's nine faculties, matching the right skills sets to any mining problem.

It contributes to finding practical solutions to complex mining problems related to productivity, safety, health, environment, social responsibility and community management challenges. It does this through well-structured and committed postgraduate education and rigorous, integrated, scientific research initiatives. It pursues practically implementable solutions, educates graduates who are equipped with relevant skills and conducts collaborative contract research for industry. In the process, it contributes to strengthening the University's mining footprint, as well as its national and international minerals research profile.

This forms part of the Department's long-term strategy to become a world leader in mining research for practical implementation, and is well supported by Enterprises UP with regard to the contractual and administrative arrangements associated with applied research in particular.

The activities of the MRRC have enhanced the Department's capabilities by utilising research capacity from other departments in various faculties at the University to actively participate in mining research. It also supports the MHSC with research projects.

TEACHING AND LEARNING

The Department has developed innovative teaching and learning initiatives. These are aimed at supporting undergraduate students and enhancing the Department's throughput and success rates, while ensuring that it delivers well-rounded mining engineers to the workforce.

Leadership development
The development of its students as future managers and technical specialists remains a priority and the development of life skills and responsible leadership through participation in student activities is continuously encouraged.
As a result, graduates from the Department are employed in a wide range of companies both locally and internationally. According to the latest available statistics, approximately 95% of the Department's graduates from 2018 and 2019 are employed in various fields in the minerals sector, as well as in consultancies and financial institutions.

Prospective mining engineers need to be able to deal with up to five different generations of workers in the workforce, and this requires special skills. To address this challenge, the Department is grooming its students for the modern workplace by equipping them with various non-technical skills that promote creative and innovative thinking to enable them to deal with the complexities of the mining industry.

This initiative, known as the Murray & Roberts Mining Engineering Leadership Academy (M&R MELA), forms part of the Murray & Roberts Chair in Industry Leadership 4.0. It focuses on the development of leadership and communication skills, as well as conflict resolution, problem-solving and stress management skills. It also plays an important role in addressing the challenges pertaining to the next generation of mining. These need to be dealt with differently than in the past.

English literacy support drive
Another initiative to support students to succeed academically is the English literacy support drive, which was launched in the Department in 2013. This was developed following the identification of students' mastery of the English language as one of the challenges that affects their academic performance, since only 7% of the Department's students have English as their first language. The fact that English is the language in which they have to study can become a hurdle to adequately understand and communicate their understanding of complex concepts. The Department's dedicated English support staff give presentations, conduct testing, present writing workshops and offer private consultations that are aimed at providing students with individualised solutions for their language skills improvement.

Industry visits
Industry visits form part of the Department's curricula. Each year, the Department's third-year class visits mining operations in industry. During these visits, students are exposed to real-life mining activities before completing their studies.

Industry capacity-building
The Department presents in-house leadership development short courses to the staff of leading mining companies on their own premises.

STUDENT WELLBEING

An important focus of the Department is the wellbeing of its students. Its interaction with its students takes place according to a value-driven framework, in which the principle of heartfelt leadership features prominently. The values it entrenches in its students are those of respect, care, honesty, integrity and trust. In accordance with these values, it has established a Student Wellbeing Committee, which offers emotional and other support to students. Where possible, the Department also lends support to avert any anxiety students may experience during their studies, especially students who are in need. Confidentiality is guaranteed and all cases are handled on merit.

In the extraordinary circumstances brought about by the nationwide lockdown and related COVID-19 regulations in 2020, several challenges had to be overcome. These included the availability of data for students, access to laptops and the narrated recording of lectures. In addition, it was found that a real level of uncertainty and anxiety was prevalent among students regarding the resources available to support their online needs.

In this regard, both the Faculty and the University as a whole were instrumental in their efforts to make free data available, supply laptops to students on a loan basis, accommodate students in the University's residences and issue travel permits. Without these support initiatives, an effective roll-out of the online approach to teaching, learning and assessment would not have been possible.

Under normal circumstances, students are assisted in other ways as well, including the provision of prescription glasses, daily meals, accommodation and registration fees. The Department also receives financial assistance from industry for student support, including annual donations from MASUP and other industry partners. The Southern African Institute of Mining and Metallurgy also supports students in their early years of tertiary education on a year-by-year basis through its Scholarship Trust Fund.

NETWORKING AND MENTORSHIP

Mining engineering students are given the opportunity to network and socialise with other students and staff of the Department outside lecture halls through the Tuks Mining Society, a student organisation that supports the Department's students on a holistic level. A mentorship programme is in place where junior students are assigned senior students to assist them with academic issues and provide guidance based on personal experience.

THE WAY FORWARD

With commodity prices picking up, and the fact that nothing that is happening in the 4IR would be possible without mining, it is clear that mining will remain a major contributor to the country's GDP for many years to come. The many challenges associated with Mining 4.0 (next-generation mining) form an integral part of the Department's teaching, learning and research activities.

Although not many new mines are being opened in South Africa, it is becoming increasingly important to enhance the productivity of the country's existing mines. By adopting new technology interventions and mining methods, as well as focusing on the health and safety of our workforce, mine management is realising that it is no longer a question of whether one should embrace technology, but when one should do so. An essential element in our quest for increased productivity is mine management's awareness of its social responsibility.

According to Dr Gordon Smith, a member of the Department's Advisory Board, "mining engineers who are strongly grounded in Industry 4.0-enabling technologies and systems engineering, as well as in change management and innovation, will be integral to the success of mining operations in the future".

In a recent report by Swan Global Investments on addressing the mining skills gap, the authors mention that, for the next 25 years, there will be a high demand for metals in the world to meet the requirements pertaining to the 4IR. The report amplifies the pressing skills shortage that needs to be addressed as students' interest in mining declines, and the industry becomes increasingly characterised by an ageing workforce that needs to be replenished. It furthermore highlights five key areas for the lack of interest in mining: a lack of information pertaining to mining, climate change, resistance to coal-fired power stations, which are detrimental to a healthy lifestyle, uncertainty in job opportunities due to the cyclical nature of mining, and politics.

From this, it is evident that mining schools across the world are looking at different ways of attracting students. What the mining engineer of the future should look like is a very important topic that is being debated worldwide. Different ways can be explored to increase the attractiveness of mining as a career option, including collaboration with other engineering disciplines. In this way, mining engineers can be equipped with new skills that are not only appropriate for the present, but also for the future beyond the 4IR.

We are standing on the threshold of the Fifth Industrial Revolution. This new era is set to highlight the significance of humanity in the workplace. This future era will build on the 4IR and it is foreseen that it will be an artificial intelligence (AI) revolution, with the potential of quantum computing, which will draw humans and machines together in the workplace.

It will be about harnessing the unique attributes of AI by recruiters and employers who, in effect, will be equipped to make even better and more informed decisions. The importance placed on human intelligence will be greater than ever before.

The Department of Mining Engineering is already starting to think beyond the 4IR, and to prepare its students for the Fifth Industrial Revolution. This future era may need an entirely new set of skills to cope, but in many ways, should complement the skills identified to thrive in the 4IR.

It is clear that industries and related work have changed forever, and the mining industry is no exception. This further amplifies the need for a specific leadership approach that can accommodate the various complexities and deal with them accordingly.

OVER THE YEARS, THE DEPARTMENT HAS FACED MANY CHALLENGES, WITH ITS STRATEGIC INTENT FOLLOWING THE EBB AND FLOW OF THE FORTUNES OF THE INDUSTRY. HOWEVER, IT HAS PROVED TO BE RESILIENT AND READY TO TURN CHALLENGES INTO OPPORTUNITIES.


Prof John Napier

Sir John Napier:

A distinguished extraordinary professor in the Department of Mining Engineering

The Department of Mining Engineering's postgraduate research programme has benefitted from the expertise of several experienced and highly qualified academics as extraordinary professors. One of these is Prof John Napier – or Sir Napier if one were to use his hereditary title!

Although South African by birth, Prof Napier's English ancestry goes back centuries, and he has many illustrious forebears, the most notable of which is John Napier (1550–1617), a Scottish mathematician and philosopher who invented logarithms. Prof Napier holds the title of 14th Baronet of Merchiston (also known as Sir Napier). The baronetcy is a hereditary title passed to the eldest son. The Napiers' ancestral home was Merchiston Castle in Edinburgh, which today forms part of Napier University.

Prof Napier originally trained as a chemical engineer at the University of the Witwatersrand (Wits), graduating with a BSc degree in 1967. After working in the oil refinery industry for two years, he completed an MSc in Chemical Engineering at Wits. He then joined the Chamber of Mines Research Organisation (COMRO) and worked extensively on problems of operations research relating to coal mine production planning and gold mine planning.

He completed his PhD at Wits in 1980 with research focused on the development of an econometric model of gold mine capital expenditure and the analysis of optimal cut-off grade selection policies. While at COMRO (and later the CSIR Division of Mining Technology), he developed a computer code for the analysis of large-scale tabular mining excavations (MINSIM-D) that has been used extensively in the South African gold mining industry.

He is internationally renowned for his special expertise in rock engineering and numerical modelling. His recent research activity has concentrated on the development of a computer program to analyse tabular mines for countless layout designs. This program has been used extensively in South African gold and platinum mines.

Prof Napier is world-renowned for the development of a displacement discontinuity computational method to simulate three-dimensional fracture growth with application to hydraulic fracturing, mixed mode fracture propagation and dynamic rock fracture processes near mine excavations. His research interests have furthermore included the econometric modelling of deep mine capital expenditure and the application of optimal control methods for the selection of cut-off grade levels in tabular gold mining.

He supervised or co-supervised six PhD students in work related to rock mass behaviour research at the CSIR between 1990 and 2004; three of whom (including Prof Francois Malan, the Department's Research Function Head) received the prestigious Rocha medal of the International Society of Rock Mechanics for the best PhD thesis in rock mechanics in the world. This record is unmatched in any country. To add to this achievement, his legacy of expertise at the University of Pretoria led to a student supervised by Prof Malan, in turn, also receiving this prestigious award. Dr Michael du Plessis is currently employed as a Mining Engineering Manager at Gold Fields.

Prof Napier is a member of the American National Academy of Engineering. This is one of the highest professional distinctions that can be accorded an engineer. It is awarded to those who have made outstanding contributions to engineering research, practice or education, including significant contributions to engineering literature, pioneering new fields of technology, advancements in engineering practice and innovative approaches to engineering education.

Her was elected as an international member of the American National Academy of Engineering (NAE) in 2018 and is a Fellow of the Southern African Institute of Mining and Metallurgy (SAIMM). He has authored and co-authored 43 papers in peer-reviewed journals and approximately 47 national and international conference papers.

Interdisciplinary research in XR technology explores mining-related challenges

The University of Pretoria supports research to challenge the obstacles associated with the Fourth Industrial Revolution (4IR). With the support of Exxaro, one of the country's top five coal producers, a strategic intervention has been launched to deal with challenges related to mining by utilising extended reality (XR) technology.

XR TECHNOLOGY REFERS TO ALL REAL AND VIRTUALLY COMBINED ENVIRONMENTS, AS WELL AS HUMAN-MACHINE INTERACTIONS GENERATED BY COMPUTER TECHNOLOGY, INCLUDING AUGMENTED REALITY, MIXED REALITY AND VIRTUAL REALITY.

The establishment of the Exxaro Chair in XR Technology in the Department of Information Science is another milestone for the Faculty of Engineering, Built Environment and Information Technology. It recognises research in the field of multimedia, as well as the collaboration between the Faculty's departments of Information Science and Mining Engineering. University Vice-Chancellor and Principal, Prof Tawana Kupe, believes that this Chair will be a game-changer for training in mining operations, particularly mine safety.

This Chair is the outcome of negotiations originating in the Department of Mining Engineering, as well as the vision and initiative of Head of Department, Prof Ronny Webber-Youngman, together with Koos de Beer from the Department of Information Science and Jannie Maritz from the Department of Mining Engineering. While the all-pervasive nature of XR technology and its applications in many sectors is evident, the resources of a JSE-listed company like Exxaro will enable the University to optimise the relevance of this technology for mining-related challenges.

The generous funding of Exxaro over a three-year period will contribute to making the University a leader in digital transformation on the African continent, and prepare its graduates for the future of work. Among other things, developers will be appointed to work on applications in virtual reality (VR) and augmented reality (AR) in Exxaro's training facilities, and to improve production and technology selection. It will also build capacity and expertise among developers, and create opportunities for students in Multimedia and Mining Engineering to work on industry-related projects. This investment in technological advancement will furthermore allow ongoing research to be undertaken to establish a safer, more economic and more environmentally sensitive form of mining.

Exxaro's decision to invest in this technology was motivated by several factors within the context of digital transformation. The future needs innovative technology to cope with the challenges of the 4IR, and XR technology offers a strategic intervention to deal with these mining-related challenges.

From left: Prof Ina Fourie (Head of Department: Information Science), Prof Sunil Maharaj (Dean: Faculty of Engineering, Built Environment and Information Technology), Mxolisi Mgojo (CEO: Exxaro), Prof Tawana Kupe (Vice-Chancellor and Principal: University of Pretoria), and Prof Ronny Webber-Youngman (Head of Department: Mining Engineering) at the launch of the Exxaro Chair in XR Technology.

As mining and other industries are investing in XR technology solutions to optimise their resources, the ubiquitous nature of this technology and its applications need to be explored in terms of their relevance to the mining industry. Based on the fact that many companies lack the know-how to successfully implement XR technology, this investment will make Exxaro a leader in this field.

The Virtual Reality and Interaction (VRI) Laboratory in the Department of Information Science, in which the Chair will be located, is already actively involved in research and development, as well as the education of future developers, designers and researchers related to XR technology across a wide spectrum of contexts. With the support of the Department of Mining Engineering, it can thus extend its scope to working with mining applications as well.

The Exxaro Chair in XR Technology will offer a framework of how XR technology can be used to address challenges in the mining industry and identify which of the available technologies will provide the best solutions. Through its XR technology programme, the two collaborating departments will therefore be able to do the following:

- Select the most effective XR technology for specific applications, and design interactions that enable intuitive interaction with virtual environments.
- Perform extensive user testing of proposed solutions to ensure that the selected solutions best address the identified challenges.
- Expose users to XR technology through creative and interactive paradigms and experiences, making the application of XR technology as accessible as possible.
- Educate and train the next generation of developers and researchers with real-world projects unique to XR technology and immersive learning.

Speaking at the official launch of the Exxaro Chair in XR Technology on 1 September 2021, Prof Ina Fourie, Chairholder and Head of the Department of Information Science, expressed her enthusiasm at the support of the mining company in this initiative.

"Exxaro is opening new opportunities for us to excel in industry-related XR research. It is offering us an opportunity to become international leaders in the use of XR technology in the mining industry and mining safety. Many other applications and opportunities can follow."

The Chair will likewise give Exxaro access to the XR intervention expertise and facilities in the two collaborating departments. It will also provide a channel to contribute towards the social development of the people of South Africa by identifying suitable postgraduate students and providing them with financial support through bursaries as part of the objective to build XR technology capacity and capability.

Exxaro's support will furthermore enable UP to educate and train the next generation of developers and researchers with real-world projects unique to XR technology and immersive learning. According to Exxaro CEO, Mxolisi Mgojo, the company is keen to explore the potential benefits of XR technology as a strategic intervention across its operations.

"Together with the University of Pretoria, we are expanding on the practical capabilities of XR in the South African context, while supporting our need for industry to embrace the opportunities of the 4IR."

The XR technology programme will assist in selecting the most effective XR technology for specific applications, and then design interactions that can enable intuitive interaction with the virtual environment. It will also offer extensive user testing of proposed solutions to ensure that the solutions address and solve as many challenges as possible.

"We are extremely excited about this partnership as part of our drive to support research that overcomes the obstacles associated with the 4IR," Mgojo said. "We believe that XR technology has immense applications for dealing with mining-related challenges and can optimise the resources of companies like Exxaro."

According to Prof Ronny Webber-Youngman, Head of the Department of Mining Engineering, collaboration with the Department of Information Science will contribute to improving the safety, health and productivity of the mining industry, while enhancing sustainability and ensuring responsible mining through the use and implementation of XR technology.

The following research topics in the Department of Mining Engineering have already been identified, which will make use of the expertise of the XR Technology Chair:

- The current state of XR technology in South Africa's mining industry
- Application areas for XR technology in the South African mining industry
- The use of XR technology on all levels of the mining operation

The collaboration of the Department of Information Science and the Department of Mining Engineering in this initiative further enhances the University's objective of promoting interdisciplinary research to solve the challenges faced by society.

THE EXXARO CHAIR IN XR TECHNOLOGY WILL OFFER A FRAMEWORK OF HOW XR TECHNOLOGY CAN BE USED TO ADDRESS CHALLENGES IN THE MINING INDUSTRY AND IDENTIFY WHICH OF THE AVAILABLE TECHNOLOGIES WILL PROVIDE THE BEST SOLUTIONS. IT WILL ALSO GIVE EXXARO ACCESS TO THE XR INTERVENTION EXPERTISE AND FACILITIES IN THE TWO COLLABORATING DEPARTMENTS. THIS WILL PROVIDE A CHANNEL TO CONTRIBUTE TOWARDS THE SOCIAL DEVELOPMENT OF THE PEOPLE OF SOUTH AFRICA BY IDENTIFYING SUITABLE POSTGRADUATE STUDENTS AND PROVIDING THEM WITH FINANCIAL SUPPORT THROUGH BURSARIES AS PART OF THE OBJECTIVE TO BUILD XR TECHNOLOGY CAPACITY AND CAPABILITY.

Gen Z gamers are preparing themselves for a new way of learning and doing

Prof Ronny Webber-Youngman

Youngsters of school-going age who demand more screen time than the average adolescent are already acquiring the skills needed for exposure to new ways of learning and doing. This includes those related to technologies such as virtual reality (VR), augmented reality (AR) and extended reality (XR). These are essential skills when enrolling for university courses in science, technology, engineering and mathematics (STEM). Their predilection for gaming as a preferred way of spending their time therefore has unintended benefits.

Learning techniques such as gamification and gameful design are aligned to the requirements for the training of developers in the Exxaro Chair in XR Technology in the Department of Information Science. This programme not only creates opportunities for students in multimedia, but also in industry-related projects such as those in the mining sector.

Gamification is defined as the use of game design elements in a non-game context, while gameful design has the goal of affording the motivating, enjoyable experiences that are associated with game play in non-gaming contexts.

Interactive immersive technology (IIT) is a methodology used in the Department of Mining Engineering, building on the success of its Kumba Virtual Reality Centre for Mine Design, that presents real-world scenarios for immersive experiences by means of VR. Systems related to IIT in education and training, particularly in mine contexts, have several benefits. Face-to-face education and training are not always possible and take much longer than making use of technology, especially in the case of large groups.

In mines, different literacy levels make the visualisation of certain scenarios an important aspect to further enhance the learning and knowledge application experience. The implementation of IIT is already changing the way we learn and apply knowledge in education and training. It has also been proven to promote knowledge retention and application. Immersive education is furthermore designed to engage trainees, giving them the sense that they are involved on the ground. The mobility of AR that incorporates smart phones provides added value to the accessibility of the technology.

Extended reality takes the innovative technologies that are able to cope with the challenges of the Fourth Industrial Revolution (4IR) a step further by combining different virtual platforms. It can then be utilised in combination, in various practical applications, to cover the continuum that ranges from the real-world environment to the virtual world. In this regard, VR and AR function to merge the real world with the virtual world through interactive technologies that can function across various dimensions.

It is becoming increasingly important for the mining industry to embrace the opportunities posed by the 4IR. It is almost no longer possible for a mine or any other industry to operate without the benefits inherent in AR- and XR-based training, which encompass future-driven visualisation.

The world has entered a visual phase. The concept of gamification among the youth, and even older people, is no longer alien, and has become very advanced in terms of the visual and interactive dimensions in which the action takes place. Within the academic space, and by extension, industry training, game design elements are increasingly used in a non-gaming environment.

In the past, the mining industry mostly responded reactively to mine accidents and aspects related to mine safety and productivity. This was because information regarding such matters was only available after the fact, which meant that a great deal of time passed before problems could be addressed and preventative measures put in place.

In the digital environment in which we currently find ourselves, there is no reason not to be proactive in terms of mine health and safety, as well as productivity, in order to ensure a sustainable industry. The modelling of scenarios in a virtual environment makes this possible.

This reimagined environment provides an ideal setting for tech-savvy youths, and those with an interest in gaming and game design will find themselves priorly skilled. The future generation of students is, without a doubt, favourably inclined towards a more visual way of learning. Their creativity makes an added contribution to the solutions that can be developed through this interactive technology.

Online learning, which has become a characteristic of the way of life during the COVID-19 pandemic, has already illustrated the benefit of an interactive approach to retain learners' attention. XR technology will play an increasingly important role in the future. This will also contribute to the development of new career options that do not even exist in terms of the application of 4IR-related technology – also in the mining industry.

With the application of new skills, such as those provided by XR technology, the mining industry is becoming an attractive career option for the youth – including women – as it opens up the possibility of humanising technology to the benefit of society, the industry and the environment.

This new way of doing things will increase the viability of a career in the mining industry. This benefit will extend beyond the traditional mining careers to enhance operations and opportunities in other industries as well.

THE WORLD HAS ENTERED A VISUAL PHASE. THE CONCEPT OF GAMIFICATION AMONG THE YOUTH, AND EVEN OLDER PEOPLE, IS NO LONGER ALIEN, AND HAS BECOME VERY ADVANCED IN TERMS OF THE VISUAL AND INTERACTIVE DIMENSIONS IN WHICH THE ACTION TAKES PLACE.

SANRAL's National Reference Laboratory at **Engineering 4.0** prepares for accreditation

The University of Pretoria's state-of-the-art Engineering 4.0 Complex on its Innovation Africa @UP Campus in Hillcrest was made possible through a collaborative partnership between the University of Pretoria (UP), the South African National Roads Agency Limited (SANRAL) and the Council for Scientific and Industrial Research (CSIR).

The facilities that form part of this complex were initially established to address the challenge posed by a shortage of training facilities and independent testing laboratories in South Africa. This led to the development of the Integrated Laboratory Facility (ILF), comprising the SANRAL National Reference Laboratory, SANRAL Training and Certification Laboratory, Concrete Research Laboratory, Accelerated Pavement Testing (APT) track and Active Traffic Lane.

The SANRAL National Reference Laboratory is currently preparing for accreditation by the South African National Accreditation System (SANAS). This is necessary for the laboratory to be recognised as an independent reference testing facility, which will ensure that its results become the standard for the properties of road materials to which field data can be compared, and for it to be able to characterise materials for appropriate construction.

Once accredited, the SANRAL National Reference Laboratory will be the first independent transport reference testing facility for the road construction industry in Africa. While standard testing will mostly be conducted on road materials originating from SANRAL (for national roads projects), but also from the provinces and even neighbouring countries, the laboratory will also conduct reference testing for private customers.

Since the official launch of the complex on 30 November 2020, progress has been made in preparing the laboratory for accreditation. This has included the appointment of a Facility Manager, Abdul Razak Esakjee, in March 2021, who has been overseeing the progression of the facility towards accreditation.

The SANRAL National Reference Laboratory will be accredited in line with ISO 17025 requirements. This is the standard of the International Standards Organisation (ISO) for testing and calibration laboratories, and covers all the requirements a laboratory would need to comply with to be considered an independent laboratory, which is able to perform tests that will deliver trusted results.

The operation of the National Reference Laboratory will contribute to improved road infrastructure in South Africa and, by extension, the African continent.

ONCE ACCREDITED, THE SANRAL NATIONAL REFERENCE LABORATORY WILL BE THE FIRST INDEPENDENT TRANSPORT REFERENCE TESTING FACILITY FOR THE ROAD CONSTRUCTION INDUSTRY IN AFRICA.

Town and Regional Planning PhD graduate inspires young girls

Dr Kundani Makakavhule, a lecturer in the Department of Town and Regional Planning since 2018, received her PhD degree during the University's Spring Graduation Ceremony, and is inspiring young girls to follow in her footsteps. Her own inspiration to study in this field was derived from her desire to make meaningful change in society, coupled with her natural ability to make sense of space and objects in space.

She realised that she was interested in society and its relations with social institutions, such as the government and the economy; but more importantly, in societal relations with the built environment that structure our mobility, resources and sense of identity. For Dr Makakavhule, town and regional planning was a degree that brought harmony between all her interests and natural abilities.

The University of Pretoria (UP) was her first choice because of its national prestige, academic excellence and understanding of what constitutes a good university experience. When she first visited the Hatfield Campus with her parents at the beginning of 2011, she experienced the University as a community asset, and that was important to her. "It represented a place to study and excel, but also a space to make relationships and enjoy the experience," she says. "The focus at UP is not only on academics, but on culture, community and building lifelong relations."

After completing her master's degree in Town and Regional Planning in 2016, Dr Makakavhule went on to register for her PhD in 2017. "I wanted to pursue academia as a career, and knew that obtaining a PhD qualification was the licence I needed to do that. I knew I had to push myself for the career I wanted for myself."

Her PhD research was titled: "(An)other space is possible: An exploration of the conflicts and contestations in the realisation of "democratising" public spaces in the City of Tshwane".

Her study explored societal and municipal perceptions, meanings and engagement with urban public spaces of different typologies in the City of Tshwane. She found that the spaces under study are made and remade by societies' contentious processes of physical and psychological appropriation of space on the one hand, and municipal efforts of sanitisation and domination on the other, embedded in notions of belonging, resistance, citizenship, planning aspiration and societal need.

"As a significant contribution, my thesis proposes a conceptual framework, which shifts the perspective of democratic urban public spaces as a means to an end. Rather, the framework positions democratic urban public spaces as an ongoing process of democratising space through conflict and contest between evolving actors, interests, meanings and engagements with space."

She believes that her research answered a question of relevance to South African society. "The attainment of democracy in 1994 meant so many things to so many people. It influenced people's expectations of what the new South Africa would be, and in town and regional planning, it influenced ideas of what the democratic landscape of South Africa would be". The assumptions were that democracy would turn our landscapes into democratic spaces with democratic institutions.

However, her thesis suggests that democracy in our landscape, spatiality and public spaces could not be achieved merely by the attainment of democracy in 1994, rather it is a continuous process that will require society, the state and the private sector to (re)define and (re)construct democracy over time and space.

Dr Makakavhule's vision for African women is for them to take up their place in the built environment.

"I think women can play a significant role in (re)constructing a built environment that is functional, efficient, just and responds to societal needs. I think women have a role to play in ensuring that our cities, towns and rural areas are sensitive to the needs of the South African population.

They can be pioneers in ensuring that our cities are safe, equitable and accessible, not only for women, the elderly, the disabled and children, but for men as well."

She believes that female town and regional planning academics are key to achieving this. "They can inspire young girls in the lecture rooms; they can be role models; and they can be key representatives to show what is possible in the industry."

Reflecting on her PhD journey, she has the greatest appreciation for the Department of Town and Regional Planning. "It was amazing. I was paired with an excellent supervisor, who was experienced and very professional. Any challenges I experienced were not necessarily related to my studies, but rather to the lack of a PhD community. Many PhD scholars in my discipline are scattered all around South Africa and the continent. As such, one can easily feel alone. I think that was a challenge I had to overcome on my own."

Dr Makakavhule is positive about the prospects for women in the industry. "Town and regional planning touches on many aspects of the built environment, as well as the social sciences. As such, women can find themselves working for different organisations that deal with relations between society, the natural environment, law, the economy and the built environment. Town planning is a career that women can make and remake for themselves as technology and society evolve."

Her future plans are to continue the work she has begun in academia and the town and regional planning industry, and to make an impact through her industry work, publications and her presence in the lecture room. As a role model for young African women in the industry, her success story is certainly one that many young girls can relate to.

Dr Kundani Makakavhule

BRICS support for nationwide collaboration to strengthen the fight against COVID-19

As part of concerted efforts in Brazil, Russia, India, China and South Africa to control and mitigate the COVID-19 pandemic, the BRICS Science, Technology and Innovation (STI) Framework Programme has allocated more than R30 million for research to strengthen the fight against the disease. Prof Hanlie Smuts, a researcher in the University of Pretoria's Department of Informatics, is one of the awardees appointed to lead a multilateral innovation research project to facilitate collaboration among researchers and institutions across the member countries of the BRICS alliance.

The research project on which Prof Smuts is the principal investigator is titled "BRICS-ICT alliance for smart resource utilisation to combat global pandemic outbreaks", and will be known by the acronym BRICSmart. Each partner country is working on a particular focus area within the project:

- The team from Brazil will focus on the correlation between symptoms and regular test results, supporting more efficient contact tracing through machine learning.
- The team from the Russian Federation will focus on the consequences of management decisions and their impact on pandemic management through multi-agent modelling, multi-criteria decision analysis and Artificial Intelligence (AI).
- The South African team will focus on improving the healthcare supply chain to optimally match supply and demand through system-view modelling and simulation experiments. The objective of this team's research is to develop a simulation model to optimise supply and demand matching, and provide decision-making support to reroute health system supplies according to hotspot areas.

The South African team has already completed the preparatory activities of its project and is currently busy with the technical design phase. Specific activities include the acquisition of simulation software, the identification of South African healthcare data that will be required for the models and documenting the framework outlining important aspects required for a greenfield analysis.

As the project also includes a significant team learning and capacity-building aspect, focus is also on creating a project knowledge base and facilitating workshops where team members share and present learning.

The digital technology associated with the constructs of prediction, modelling and simulation points to the application of AI, machine learning, modelling both space and time, and visualising real-world scenarios. Such technologies may support and facilitate pandemic strategy, preparedness and response in multiple ways, including the identification and tracking – in real time – of pandemic activity, such as individuals who might have been in contact with an infected person. Digital technologies also support global supply chain scenario planning and focus on production scheduling capability and enhancing the visibility of inbound materials.

Viewing COVID-19 through the lens of systems thinking and representation ensures that policy makers do not merely maintain a linear view of a country. Seeing the pandemic as an inter-related system will inform preparedness and smart resource utilisation strategies, and support governments to pull the right levers to get the economy and society back on track after pandemic-related shocks and crises.

THE SOUTH AFRICAN TEAM'S ACTIVITIES INCLUDE THE ACQUISITION OF SIMULATION SOFTWARE, THE IDENTIFICATION OF SOUTH AFRICAN HEALTHCARE DATA THAT WILL BE REQUIRED FOR THE MODELS AND DOCUMENTING THE FRAMEWORK OUTLINING IMPORTANT ASPECTS REQUIRED FOR A GREENFIELD ANALYSIS. AS THE PROJECT ALSO INCLUDES A SIGNIFICANT TEAM LEARNING AND CAPACITY-BUILDING ASPECT, FOCUS IS ALSO ON CREATING A PROJECT KNOWLEDGE BASE AND FACILITATING WORKSHOPS WHERE TEAM MEMBERS SHARE AND PRESENT LEARNING.

Nicol Verheem

Oscar-winning Faculty alumnus

In February 2021, the Academy of Motion Picture Arts and Science honoured alumnus Nicol Verheem and his company at the Scientific and Technical Awards (SciTech) for their invention of a wireless radio transmitter that transmits uncompressed video without delay.

WHEN WORKING TOGETHER IN UNITY, ONE CAN COME UP WITH SOLUTIONS THAT ARE MUCH STRONGER THAN THE INDIVIDUAL ELEMENTS.

Verheem is an alumnus of the Faculty of Engineering, Built Environment and Information Technology. He obtained a degree in electrical and electronic engineering from the University of Pretoria.

The SciTech Awards, which form part of the immensely popular Oscar Awards, recognised the invention of the Teradek Bolt, a wireless radio transmitter, which transmits uncompressed video with no delay over 3 km away. His innovative project started in 2010, when digital cinematography had really just started and cinematographers were eager to use cameras in new and far more flexible ways. This revealed a big opportunity in untethering the monitor from the camera. Cameras were continuing to move to steadicams, dollies, jib arms and cranes; and drones were taking off, but coax cables were holding things back. Teradek decided that this was not good enough.

The team developed a miniature wireless transmitter, small enough to mount on even a digital single-lens reflex (DSLR) camera. It was capable and sturdy, yet still affordable. However, the cube had a small, but noticeable delay of about four frames. They then discovered Amimon's technology, which managed to send uncompressed video over a wireless signal without any delay, but the product was meant for living rooms rather than cinematic production.

Teradek and Amimon worked closely together to refine the technology and create the Teradek Bolt. Over 100 000 systems have been sold, and many more global productions have benefitted from cameras being freed from their cables.

Teradek will also be receiving an Emmy Award for its invention on 21 October 2021. It was nominated for an Engineering Emmy, which is presented for engineering developments that considerably improve existing methods or innovations that materially affect the transmission, recording or reception of television. It is one of eight companies to receive this award for 2021.

Top-down excellence:
Faculty Dean's industry footprint


Prof Sunil Maharaj

Dean of the Faculty of Engineering, Built Environment and Information Technology (EBIT), Prof Sunil Maharaj, not only leads the Faculty on the road to innovating our tomorrow, but also actively contributes to industry in his capacity as an accomplished electronic engineer. He serves the South African engineering community as President of the South African Institute of Electrical Engineers (SAIEE), as well as Chair-Elect of the Global Engineering Deans' Council (GEDC).

Prof Maharaj is the first Dean from an African university to be appointed as the Chair-Elect of the GEDC. He will work alongside Prof Sirin Tekinay of the American University of Sharjah until he assumes the position of Chair in November 2021. In this leadership role, Prof Maharaj will work closely with the International Federation of Engineering Education Societies, which links global organisations, professors, students, corporate entities, United Nations agencies and other multilateral global organisations, as well as leaders throughout the world.

The GEDC's vision is to enhance the capabilities of engineering deans to transform engineering schools in support of societies in a global economy. As a global network, it can leverage its collective strengths for the advancement of engineering education and research.

In 2020, Prof Maharaj chaired the GEDC and the World Engineering Education Forum's first virtual conference about disruptive engineering education amidst global challenges. He believes that there is a need for universities in the developing world to innovate by constantly promoting "disruptive engineering". South Africa is the only country in sub-Saharan Africa that is part of international accreditation bodies, including being a signatory to the Washington Accord. As such, the country's engineers are part of the global space, and are global players.

This notion was echoed in Prof Maharaj's SAIEE Presidential Inaugural Address, which focused on the disruptive trends that are emerging in the workplace and the impact of new technologies on society. In his view, digital transformation has triggered essential changes to the way we live, work, socialise and study, and has been exacerbated by COVID-19. In contemplating the nature of work and the workplace of the future, Prof Maharaj highlighted the fact that "technology is the catalyst to change in the workplace, but humans are the sustaining force behind the machines". Skills like leadership, deliberation and debate, conflict resolution and ethical considerations for decision making will be vital for companies to thrive in the future.

BOOK LAUNCH

Development in Cognitive Radio Networks

Authors:
BTJ Maharaj (EBIT Dean)
BS Awoyemi

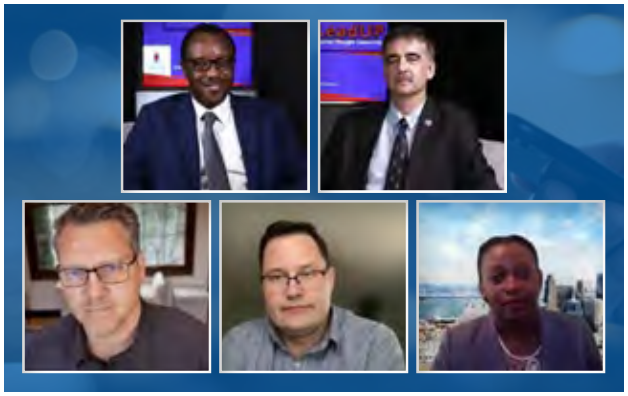
This book provides holistic yet concise information on what modern cognitive radio networks are, how they work, and the possible future directions for them. The authors first present the most generic models of modern cognitive radio networks, while taking their different architectural designs and classifications into consideration. The book then discusses, in-depth, the key tools and techniques that are being employed to formulate resource problems, investigate solutions, and interpret such solutions for the realisation of useful and practical modern cognitive radio networks. Furthermore, the book studies the impact of modern cognitive radio networks on other emerging technologies such as 5G, Internet of Things and advanced wireless sensor networks, and discusses the role that cognitive radio networks play in the evolution of smart cities and in the realisation of a highly interconnected world. In discussing the future of cognitive radio networks, the book emphasises the need to advance new or improved tools, techniques and solutions to address lingering problems, which can potentially limit the cognitive radio networks in their stride to becoming one of the most promising technologies for the immediate and near future.

Expanding EBIT's footprint through virtual panel discussions

With the restrictions imposed on international travel and social distancing, virtual panel discussions have taken on increased prominence as a means of sharing expert opinions and knowledge with a wider audience, thereby expanding the Faculty's international footprint.

LeadUP: ALUMNI THOUGHT LEADERSHIP

The University's Alumni Relations Office launched a series of virtual alumni events, hosted by the Vice-Chancellor and Principal, Prof Tawana Kupe, in April 2021. The initiative, called "LeadUP: Alumni Thought Leadership", brought leading alumni, academics and experts from the University of Pretoria into national, African and global conversations. As part of this series of events, prominent UP alumni were invited to speak on various topics, including those related to engineering, the built environment and information technology. Two of these online events provided the Faculty the opportunity to showcase its talented alumni and academic experts.



CIVIL ENGINEERING

The first event, which was also the launch event of the series, involved the Department of Civil Engineering, and provided the opportunity to reflect on the Fourth Industrial Revolution (4IR). It was titled "4IR: Bracing for (and thriving in the midst of) disruption and innovation". The facilitator was Prof Wynand Steyn, Head of the Department of Civil Engineering. It comprised a panel discussion featuring Nicol Verheem, Founder and CEO of Teradek in Los Angeles; Mr Justin Coetzee, Founder and CEO of GoMetro, Director at flx Mobility Ltd and Non-Executive Director at Greater Tygerberg Partnership: Cape Town; and Dr Bridget Ssamula, Senior Director: Major Pursuits, AECOM in Los Angeles. Panellists broached topics ranging from general business disruptors to groundbreaking innovations and how universities can play a role during the uncertain times created by the COVID-19 pandemic.

MINING ENGINEERING

The second event, held on 7 July 2021, involved the Department of Mining Engineering and coincided with the celebration of the Department's 60th anniversary. The topic was "The role of leadership in the context of the 4IR in mining and related industries". The facilitator was Prof Ronny Webber-Youngman, Head of the Department of Mining Engineering. The panel discussion featured Henry Laas, Chief Executive Officer of Murray & Roberts; Tarusha Moonsamy, Engagement and Project Manager at McKinsey and Company; Nozipho Dlamini, Technical Services Manager at Thungela Resources; André Joubert, Chief Executive of the Ferrous Division of African Rainbow Minerals; and Peter Steenkamp, Chief Executive Officer of Harmony Gold. The panellists concluded that quality leadership will be the driving force in eradicating poverty, unemployment and inequality, which are threatening the sustainability of the sector.

WOMEN EMBRACING THE WORLD OF ENGINEERING

In celebration of Global Women in Engineering Day on 23 June 2021, the Faculty of Engineering, Built Environment and Information Technology hosted a virtual panel discussion on the role of women in engineering. The host was Prof Elsabé Kearsley, a senior lecturer in the Department of Civil Engineering and President of the South African Academy of Engineering. The panellists included Nozipho Dlamini, Technical Service Manager: Thungela Resources; Malani Padayachee-Saman, CEO of MPAMOT Group and subsidiaries, the largest 100% black women-owned engineering and infrastructure consulting firm of its size, capacity and capability in South Africa; Dr Lelanie Smith, Head of the Community-based Project Module and Programme Director of UP's Vertically Integrated Project; and Marielle Hobson, a student in the Department of Electrical, Electronic and Computer Engineering, who is also Chairperson of the UP Student Chapter of Engineers Without Borders. They shared their experience and expertise as leaders in a traditionally male-dominated field.

POSTGRADUATE RECRUITMENT

Another virtual panel discussion that attracted much attention was the virtual postgraduate recruitment event that was held on 28 September 2021. It took the form of a virtual panel discussion, in which industry leaders answered the question: "Why do a postgraduate degree?" Prof Jan Eloff, Deputy-Dean: Teaching and Learning in the Faculty of Engineering, Built Environment and Information Technology facilitated the discussion on the merits of a postgraduate qualification. The panellists included Heidi Harper, Head of Skills Development at the South African National Roads Agency Limited (SANRAL); Zanele Mavuso Mbatha, CEO of the Bambili Group; Andries Mthethwa, Chairperson of the Board of ACTOM (Pty) Ltd; Hina Patel, Managing Director for Applied Intelligence Africa, Accenture; and Gerdus van Eeden, Group Chief Technical Officer of Multichoice Group Limited. In the process, the Faculty succeeded in supporting students to make the very important decision to pursue postgraduate study. It was viewed by more than 500 prospective postgraduate candidates.

VIRTUAL INAUGURAL ADDRESSES ATTRACT A WIDER AUDIENCE

A long-held tradition at the University of Pretoria to celebrate a seasoned academic's promotion to full-professor has been the delivery of an inaugural address. This year was no exception, despite the challenges posed by the prohibition of large gatherings. To overcome this obstacle, the Faculty of Engineering, Built Environment and Information Technology presented this illustrious event in an online format. In the process, members of the Faculty's newly promoted cohort of academics could share their views with an even wider audience than they would otherwise have done – even reaching colleagues in the international sphere. This cohort included Prof Michael Daramola, Head of Department: Chemical Engineering, Prof Ina Fourie, Head of Department: Information Science, Prof Francois Malan from the Department of Mining Engineering, Prof Johan Joubert from the Department of Industrial and Systems Engineering, Prof David Walwyn from the Graduate School of Technology Management and Prof Schalk Kok from the Department of Mechanical and Aeronautical Engineering.

This year's inaugural addresses considered the following topics:

Prof Michael Daramola
Head of Department: Chemical Engineering

Sustainable chemical engineering practices as a catalyst to realise the Sustainable Development Goals (SDGs)

Within the framework of the SDGs of the United Nations, responsible resource production and consumption, in a way that preserves the ecological footprint, coupled with challenges to meet the needs of the growing population, while minimising the pressure on the planet, will be the great challenge of engineers. Therefore, a circular economy stimulates the conservation of materials, energy and other resources by reducing, reusing and recycling them in various ways. Sustainable chemical engineering practices that consider the application of knowledge gained by study, experience and practice could be critically applied to develop economic ways of using materials and energy for the benefit of mankind, and to accelerate the realisation of the SDGs. Unfortunately, as a result of unsustainable chemical engineering practices, unintended by-products of these processes have caused significant damage to human lives and the ecosystem. However, recent research efforts have been directed at eliminating or minimising the negative ecological footprints of unsustainable chemical engineering activities by closing the material cycles and creating value-added commodities from the waste products of these processes.

Prof Ina Fourie
Head of Department: Information Science

Information behaviour as a research lens for life

As a subdiscipline of information science, information behaviour is both a field of study and an umbrella concept for all human information activities. People engage in these activities daily in contexts ranging from work, health and studies to everyday life decision making. In this way, they make sense of situations in which they experience knowledge gaps. Information behaviour is particularly complex in the contexts of, for example, life-threatening diseases, viral infections and palliative care, where there are prospects of pain, death and bereavement. Knowledge and understanding of information behaviour-in-context in such situations can help identify the methods for providing information design, effective information systems and addressing information literacy needs. Research in health communication and palliative care has already generated helpful guidelines. Information behaviour, however, offers another research lens. This can comprise a range of research methods, such as auto-ethnography and the eclectic use of other methods according to context, insightful theories and the importance of awareness of a diagnosis. Important considerations are the concept of space, as in physical, emotional and mental space, as well as the concept of time, in addition to awareness of a diagnosis and insightful theories that might deepen understanding.

Prof Francois Malan
Department of Mining Engineering

Rock engineering research as a prerequisite for sustainability and growth in the mining sector

As a consequence of the rising demand for metals, surface resources are being depleted, and the depth of mining is gradually increasing. At great depths, flat dipping tabular excavations present unique rock engineering challenges. This is typically encountered in many South African mines. There is limited knowledge on the rock mass behaviour at these depths, which affects the sustainability of the mining sector. Even shallow tabular mines are prone to instabilities. The requirement is to design and develop stable excavations in an anisotropic, inhomogeneous and extensively fractured rock mass. Recent advances in the rock engineering field address these challenges. Methods to simulate the fracture zone in pillars and stope faces have been developed. These techniques enable engineers to simulate the effect of pillar scaling, different mining rates and mining increment lengths. The models also accommodate energy dissipation computations, and the released energy can be used as a measure of seismic activity. This addresses a number of the weaknesses in the traditional usage of energy release rate as a criterion for layout design. Of further interest is the design of rockburst support, in which new methods to improve the areal characteristics of the support systems have emerged.

Prof Johan Joubert
Department of Industrial and Systems Engineering

Mobility inequality: Taking small but deliberate steps

Industrial and systems engineering deals with decision-making under uncertainty. While we tell ourselves that we aim for optimal decisions, the idea of optimality is, in fact, a mirage. Our choices have multiple, conflicting objectives; the information on which we base our choices is primarily vague and uncertain or often wholly absent. Should we challenge the assumption that people make rational choices? Is it realistic to think that we can predict and model the behaviour surrounding daily decisions? And why would we want to? Because a large portion of our budgets go towards our mobility infrastructure. Advances have been made in building decision-support models using agent-based simulation that better captures our mobility challenges. A different modelling approach that is both intuitive and crucial for accurately capturing the state of inequality and accessibility of South Africans is considered. We build models – imitations of reality – because we want to investigate both the intended and unintended consequences of infrastructure interventions before spending our precious, but ailing budgets on those interventions. If we do not get it right and cannot answer key mobility questions, how can we claim to be actively addressing the inequality gap?

Prof David Walwyn
Graduate School of Technology Management

The challenge of industrial development in South Africa – insights from research and practice

The industrial development of South Africa has embedded a set of institutions whose legacy continues to derail efforts to diversify the economy, develop high-technology industries and generate employment for millions of job seekers. Despite a plethora of carefully constructed policy documents, the country has only partially succeeded in disentangling itself from dependence on extractive industries, particularly in its exports. Insights have been gained from 30 years of research and practice on industry localisation based on four distinct approaches: the neo-classical framework of techno-economics, the supply-side/demand-side perspective of the industrial policy mix, the systems approach of innovation policy, and the socio-technical model of the multi-level perspective. The advantages and disadvantages of each approach have been presented through specific examples from local projects in the health and energy sectors, including vaccines, antiretrovirals and solar power. The development of a high-technology circular economy will be a truly transdisciplinary endeavour, requiring the integration of the techno-economic, socio-technical and political perspectives for a successful outcome. Most importantly, regime resistance from the existing incumbents must be recognised and actively challenged for future transitions to environmental sustainability and social wellbeing.

Prof Schalk Kok
Department of Mechanical and Aeronautical Engineering

Simple lessons to keep in mind when adding complexity to numerical models

Numerical modelling is increasingly used to predict the response of physical systems. Prof Kok focused on predicting material response (displacements, stresses and strains) due to external loading. A crucial ingredient for performing numerical prediction is a constitutive model, a mathematical formulation that predicts material stress due to any imposed strain. If the constitutive model does not adequately fit the experimental dataset, it may seem attractive to add complexity for the constitutive model to fit the dataset better. In his lecture, he illustrated the pitfalls in this approach if the experimental dataset does not contain sufficient information to identify all the constitutive model parameters. One strategy to determine which parameters can be identified from the experimental dataset is to solve a virtual inverse problem to control for combinations of constitutive parameters that produce simulated experimental data. If the constitutive model is understood well, additional experiments can be proposed to identify the elusive parameters. In his lecture, Prof Kok used numerous examples to demonstrate the concept, ranging from engineering materials (steel) to biomaterials (the human cornea).

André de Ruyter delivers the annual Hendrik van der Bijl Memorial Lecture

The annual Hendrik van der Bijl Memorial Lecture is a proud collaboration between the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria and the South African Academy of Engineering (SAAE).

This year, it was held in a virtual format on 17 August 2021. The featured guest speaker was André de Ruyter, Group Chief Executive of Eskom Holdings SOC Limited, who provided his vision for a restructured supply industry in South Africa.

Mr De Ruyter is a seasoned executive who has plied his trade both locally and internationally in various portfolios in the energy space. He has significant experience in managing coal, oil, chemical and gas businesses, including the marketing of export coal to international utilities and taking responsibility for the operations of very large coal and gas conversion plants, including electricity generation.

He was a member of the Sasol Group Executive Committee from 2009 to 2014, and spent some time in China as President of China Ventures and also in Germany in a business turnaround and management capacity. He was appointed as CEO of Nampak in 2014 – a position he left to accept the role of Group Chief Executive of Eskom in January 2020.

Mr De Ruyter holds a Master of Business Administration (MBA) from the Nyenrode Business University in the Netherlands, a Bachelor of Law (LLB), which he obtained from the University of South Africa, as well as a Bachelor of Civil Law and a Bachelor of Arts from the University of Pretoria.

CIVIL ENGINEERING STALWART APPOINTED PRESIDENT OF SAAE

Prof Elsabé Kearsley, an experienced lecturer and researcher in the Department of Civil Engineering, has been appointed President of the South African Academy of Engineering (SAAE).

Prof Kearsley holds a PhD from the University of Leeds in the United Kingdom (UK). After working as a structural engineer in both South Africa and the UK, she joined the University of Pretoria as a member of staff in 1990.

In 2009, she was President of the South African Institution of Civil Engineering (SAICE), and for the last 20 years, she has been involved with cement and concrete materials research.

The SAAE is a young, growing, non-profit, independent institution with 199 members. It functions as a voluntary association under its own constitution and follows the model of academies of engineering in many countries around the world. It comprises eminent engineers of all disciplines and related professionals with proven ability and achievement. It is able to harness their wealth of knowledge and experience, which, with the interdisciplinary character of its membership, provides a unique resource for independent, evidence-based advice.

Industry body recognises Faculty's Deputy Dean: Teaching and Learning

The Faculty of Engineering, Built Environment and Information Technology is honoured that its Deputy Dean: Teaching and Learning, Prof Alta van der Merwe, has been recognised by industry for her life's work.

She received the Lifelong Achievement Award of the Southern African Chapter of the Association for Information Systems (AISSAC) for her contribution to the field of information systems in South Africa. The Association for Information Systems (AIS) is the premier professional association for individuals and organisations, which leads the research, teaching, practice, and study of Information Systems worldwide.

Prof Van der Merwe is also a full professor in the Department of Informatics, where she provides supervision to postgraduate students. She focuses on the design of socio-technical solutions with research activities in enterprise architecture, Society 5.0 and different theories supporting the successful use of technology in the organisation. Her research related to her position as Deputy-Dean: Teaching and Learning focuses on student success and especially using technology to enhance throughput.

She is the past president of the South African Institute for Computer Scientists and Technologists (SAICSIT), a past Council member of AISSAC and, on international level, was involved in the proposal and acceptance of the Institute of Electrical and Electronics Engineers (IEEE) Systems, Man and Cybernetics (SMC) Enterprise Engineering and Enterprise Architecture Technical Committee.

In 2018, she was appointed as the International Federation for Information Processing Technical Committee 8 – Information Systems (IFIP TC8) Vice-chair. Until 2020, she was also the South African representative for the International IFIP TC8.

Leading global alumnus recognised for contribution to the metallurgical industry

Dr Willem van Niekerk, an alumnus from the Department of Materials Science and Metallurgical Engineering, is widely recognised for his contribution to the metallurgical industry internationally. He is a specialist in the titanium dioxide (mineral sands) industry and was recently honoured with the Honorary Life Fellow Award of the Southern African Institute of Mining and Metallurgy.

His PhD in Pyrometallurgy, prepared him for a lifelong career in the minerals and metals industry, culminating in his appointment as Senior Vice-President: Technology and Saudi Arabia for Tronox Holdings in April 2020.

He spent more than 33 years at Exxaro Resources until the integration of Exxaro Mineral Sands with Tronox Holdings in June 2012, when he was appointed Senior Vice-President: Strategy and Business Development in the USA. This was followed by his appointment to the position of Senior Vice-President: Business Transformation in June 2019. Between 2006 and 2008, he co-managed the Tronox-Exxaro Tiwest joint venture in Australia.

Chancellor's Medal for industry expert

Mr Andries Mthethwa was awarded the Chancellor's Medal at the University of Pretoria's Autumn Graduation Ceremony on 19 April 2021. Mr Mthethwa (previously known as Andries Tshabalala) has been a member of the Faculty of Engineering, Built Environment and Information Technology's Industrial Advisory Board since 2014 and helped to establish the DENI Bursary Fund at the University of Pretoria in 2015.

Mthethwa studied mathematics, applied mathematics, chemistry and physics for two years at the University of Zululand. In 1979, he received government permission to study electrical engineering at the University of Natal, where he graduated with a Bachelor of Engineering in 1983. In 1993, he completed the Management Development Programme at the University of South Africa (Unisa).

In 1976, he joined GEC South Africa – now ACTOM (Pty) Ltd – and, in 1977, he was awarded a GEC bursary. He returned to GEC in 1983 as a junior motor designer. During 1985, he worked for various GEC companies in the United Kingdom. He was the chief electrical designer for GEC's small machines for six years, after which he became Group Commercial Director and Divisional Managing Director for the Rail Transport Division. He currently serves as Board Chairman.

Mthethwa was the founding Chairman of City Power Johannesburg from 2001 to 2003 and Chairman of Johannesburg Water from 2003 to 2005. In 2008, he served as President of the Railroad Association of South Africa. He was also a member of the Board of Trustees of Sci-Bono from 2014 to 2018 and a trustee of the Ithemba Institute of Technology, Soweto.

He is a Fellow of the South African Institute of Electrical Engineers (SAIEE) and served as its President for 2011. He still serves on its Council. In 2017, he received the prestigious SAIEE President's Award. He is currently the Chairman of the Board of the South African Electro-Technical Export Council (SAEEC).

In 1985, Mthethwa co-authored a paper with Prof RG Harley titled "Induction motor behaviour in the presence of unbalanced supply voltages", which received the Eskom Award.

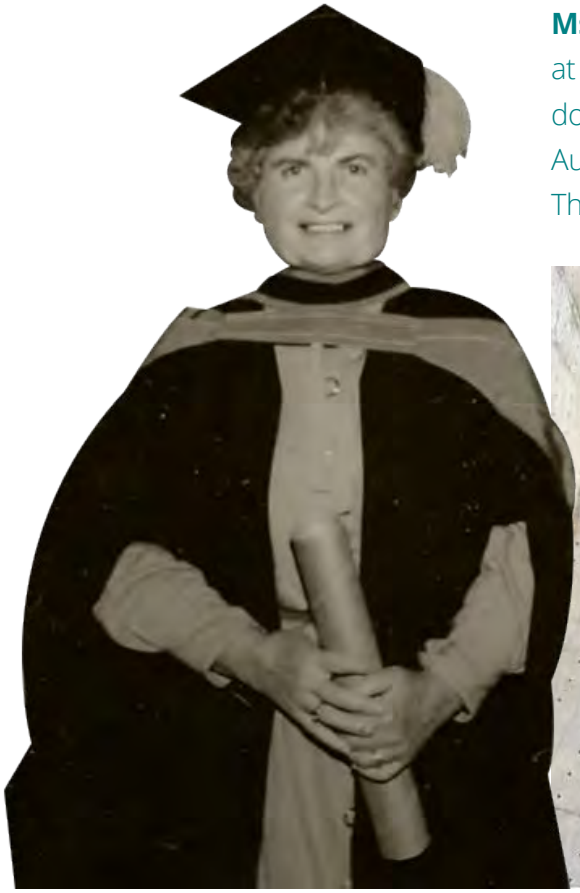
Accepting the Chancellor's Award, he noted that he considers the Faculty of Engineering, Built Environment and Information Technology to be "a world-class facility that prepares students to meet the challenges being ushered in by the rapidly evolving digital and information technology age."

Vice-Chancellor and Principal's Medal for EBIT graduate

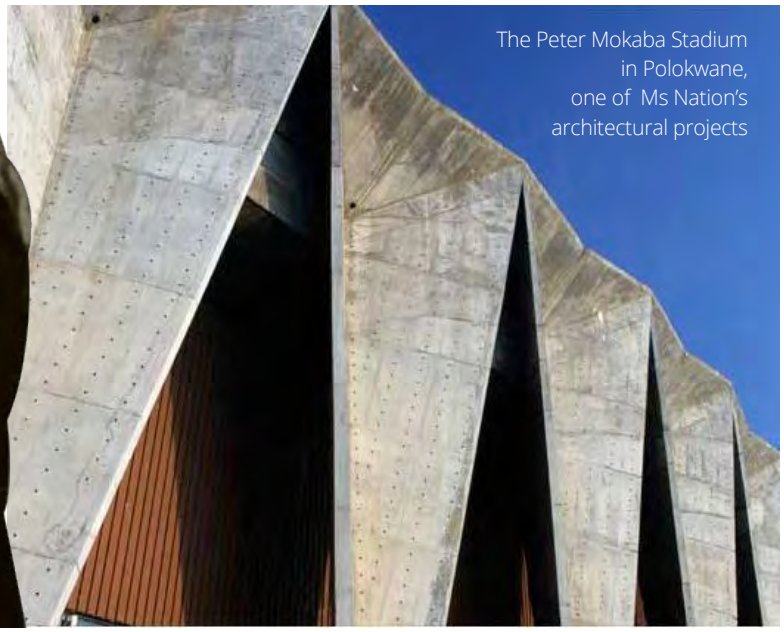
Jaco-Louis Venter, a graduate of the Department of Chemical Engineering, was one of nine students to be awarded the Vice-Chancellor and Principal's medal at the Autumn Graduation Ceremony for maintaining an excellent average throughout his undergraduate studies.

The medals were awarded by Vice-Chancellor and Principal, Prof Tawana Kupe, who hopes that these excellent students continue to fly the University's flag high and become great ambassadors of the institution. Jaco-Louis achieved a cumulative weighted average of 92.62% throughout his degree. He is enrolled for a BEng (Hons) degree in Electronic Engineering, specialising in process control and optimisation. "I see it as a great honour to receive this recognition, and feel it is my responsibility to use my skills to contribute to society," he said.

Posthumous honorary doctorate for established female architect



Ms Shelagh Nation, who passed away on 29 March 2021 at the age of 91, was awarded a posthumous honorary doctorate in Architecture during the University of Pretoria's Autumn Graduation Ceremony on 21 April 2021. This ceremony took place virtually.



The Peter Mokaba Stadium in Polokwane, one of Ms Nation's architectural projects

Ms Nation enrolled to study Architecture at the University's newly opened School of Architecture in 1947, and was one of the Department's first female graduates. After her graduation in 1957, she was actively engaged in private architectural practice and architectural research, first at the National Building Research Institute, and later at the Council for Scientific and Industrial Research (CSIR).

She made an indelible contribution to the practice of Architecture in South Africa, developing novel construction systems and brief development processes, which led to increased project efficiency, improving the design of affordable public sector educational facilities suitable for the local context, developing practices for community engagement, and recording the history of key figures in South African architecture.

As an alumna of the Department of Architecture, she continued her association with the Department by serving as an external examiner, giving occasional lectures and involving students in her research projects at the CSIR. In this she played an instrumental role in establishing a tradition of community engagement and participative design in the Department. In 2013, Ms Nation was declared a Friend of the Department.

Rejecting the pursuit of awards, Her legacy is distinguished by her uncompromising quest for an egalitarian architecture that provides dignity to all members of society and the processes that give communities a say in the creation of the built environment in which they live.

She was also a pioneer in opening up a very male-dominated profession and industry to women, and continues to be celebrated for her tireless contribution to empowering female architects.

Furthermore, she is one of the rarest of creatures – a South African architect with a distinguished career not just in the profession, but also as a researcher.

Speaking prior to her passing, she reflected on how times have changes, from designing using a pencil to drawing on computer. However, some things never change. "Hard work always lies ahead of anyone in this field of study, as does the need to explore, to investigate, and to learn constantly. It demands flexibility, with new materials, methods, systems – and legislation – changing constantly."

Award for African machine learning interface

The Masakhane natural language processing (NLP) research project, an African machine translation web interface, has won the inaugural 2021 Wikimedia Foundation Research Award of the Year. This system was developed by the Data Science for Social Impact (DSFSI) research group in the University of Pretoria's Department of Computer Science, in collaboration with researchers from the African Master's in Machine Intelligence programme of the African Institute for Mathematical Sciences in Ghana.

THE WIKIMEDIA FOUNDATION CALLS THIS RESEARCH AN INSPIRING EXAMPLE OF WORK TOWARDS KNOWLEDGE EQUITY.

Despite the fact that 2 000 of the world's languages are African, African languages are barely represented in technology. This is further exacerbated by the continent's colonialist past, which has been devastating for African languages in terms of their support, preservation and integration, and has resulted in technological space that does not understand African names, cultures, places or history.

The idea of a machine learning tool to assist in the translation of 50 of the regional languages on the continent was developed at the #SautiYetu African NLP Unconference 2020. This event is linked to the Deep Learning Indaba, an organisation focused on strengthening African Machine Learning (ML) and supporting Africans to be owners of technology advances and Artificial Intelligence (AI). An objective of the Indaba is to create leadership and recognise excellence in the development of ML and AI across Africa.

A two-year participatory research project spanning different countries in Africa was launched in 2019 with the assistance of funding received from the Mozilla Open Source Support (MOSS) Foundation.

Dr Vukosi Marivate, holder of the Faculty's Absa Chair of Data Science, is one of the chief investigators on this project. Research outputs included the publication of two journal articles, as well as an electronic application similar to Google Translate, but focusing specifically on the African languages for which accommodation is not made in existing machine translation tools.

The research that formed part of the development of the Masakhane machine translation tool attempted to fundamentally change how the challenge of "low-resourced languages" is approached in Africa. It describes a novel approach to machine translation for African languages, illustrating how the challenges these languages face to join the web can be overcome, and some of the technologies from which other languages benefit today. The Wikimedia Foundation calls this research an inspiring example of work towards knowledge equity, which is one of the two main pillars of the 2030 Wikimedia Movement Strategy.

Collaborating with Dr Marivate on this project are his colleague in the Department of Computer Science, Abiodun Modupe, and Catherine Gitau and Salomon Kabenamualu from the African Master's in Machine Intelligence programme of the African Institute for Mathematical Sciences in Ghana.

The project also gave rise to the establishment of the Masakhane community, a grassroots community that aims to develop NLP systems for Africa by Africans. Masakhane, which roughly translates as "we build together" in isiZulu, has as its goal for Africans to shape and own technological advances towards human dignity, wellbeing and equity through inclusive community building, open participatory research and multidisciplinarity.

Members of the Masakhane community provide data for the research project, and also assist in building models and testing sample translations to improve the accuracy of the machine translation tool. They represent the African countries and languages that form part of the research, and comprise individuals from a range of relevant professions, including data scientists, researchers, language practitioners, translators and software developers.

Architecture lecturer takes the top spot in global abstract-writing contest

Karen Botes, a lecturer in the Department of Architecture, has won the World Building Congress (WBC) 2022 abstract-writing competition.

The International Council of Research and Innovation in Building and Construction challenged applicants to write a 300-word abstract relating to building for the future.

Her abstract aligns with the literature review for her PhD study in Landscape Architecture, titled "An efficiency analysis of selected traditional African vegetable species and modular living wall systems for food security for Gauteng, South Africa".

The University's support for her research has already enabled the construction of two living wall prototypes with traditional African vegetable species on the Future Africa campus.

Engineering 4.0 Building recognised for innovative excellence

The University of Pretoria's state-of-the-art Engineering 4.0 Building, which was launched on the Innovation Africa @UP Campus in Hillcrest on 30 November 2020, has been recognised for its innovative excellence by the South African Property Owners' Association (SAPOA) in its property development awards for 2020. These awards recognise the efforts of architects, engineers, project managers, construction specialists and other property development professionals, whose work is an inspiration for reimagining a world where property development activity continues to inspire creativity and encourage productivity.

An indigenous forest and grassland form an integral part of the facility's design, and support the area's biodiversity. The main laboratory is flanked by corridors on either side for the movement of services and pedestrians. Ancillary reception and social interaction spaces, an auditorium and office areas connect with the main spine. Outwards from the public interface, the design allows for storage, manufacturing and sub-laboratories. Large concrete tilt-up panels were used in combination with a steel structure and full-height glazed façades to enhance the interaction with the natural environment and promote biophilia. The sustainability measures that were applied transcend to wellness principles, with the aim of creating the ideal interactive learning, research and testing facilities in an open-architecture, fully immersive, world-class institution.

ARC Architects, with Anton de Jongh at the helm and Marié Smit as lead architect on the project, was given the design brief to develop a facility that could operate as both a learning and a testing facility in an all-inclusive design. "The result was a facility that makes a significant impact," said Prof Wynand Steyn, Head of the Department of Civil Engineering.

The creativity of the design lies in its functionality, with an impressive external envelope and meticulously designed flow patterns, reminiscent of a machine.

Hydropower empowers communities

Dr Marco van Dijk, a researcher in the Department of Civil Engineering, was named the winner in the Empowering Communities category for the Knowledge Tree Awards of the Water Research Commission.

The awards are presented to recipients whose research and innovations have impacted and uplifted the water and sanitation sector in South Africa.

Days after receiving the award, Dr van Dijk's innovative small-scale hydropower plant, designed to generate 50 kW of electricity, was presented to the remote rural village of Kwa-Madiba in the Mhlontlo Local Municipality, north-east of Mthatha in the Eastern Cape. The Kwa-Madiba scheme borrows a small proportion of water flowing over the Thina River Falls by diverting it into a steep and narrow tunnel. The water is then returned to the main river after its power has been harnessed to spin a turbine. This renewable energy does not generate the fossil fuel carbon emissions that drive global climate change.

The University of Pretoria's Hydropower Research Group is also busy compiling a national hydropower atlas for the country. This atlas will help to identify areas where hydropower projects can potentially be implemented. The researchers hope their efforts will provide policy makers with a way to address the current slow pace of small-scale hydropower development.

Special award from the Water Institute of South Africa

Prof Evans Chirwa, incumbent of the Rand Water and Sedibeng Water Research Chairs in Water Utilisation Engineering in the Department of Chemical Engineering, has been elected by the Board of the Water Institute of South Africa as a Senior Fellow.

This honour is for the dedication and support that he has shown the Water Institute of South Africa and the water sector throughout his career. Through this award, Prof Chirwa joins the ranks of highly respected South African academics and professionals in the water sector. Through his research into various pertinent issues related to water quality and the concomitant impact on the environment, Prof Chirwa has made significant contributions to the water landscape both nationally and internationally.

Chemical engineers write best article

Three researchers in the Department of Chemical Engineering recently received the annual Douw Greef Prize for excellence in science writing from the Suid-Afrikaanse Akademie vir Wetenskap en Kuns (SAAWK/South African Academy for Science and the Arts).

The SAAWK is a multidisciplinary organisation that promotes science, technology and the arts in Afrikaans.

While the Faculty's chemical engineers were certainly not in the running for any of the literature prizes, they certainly caught the attention of the judges for an article published in the *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie,* for which they were awarded the Douw Greeff Prize for the best article in this publication. The prize was awarded to Marno Grobler, Gerard Puts and Philippus Crouse of the Department of Chemical Engineering, together with Hertzog Bissett of the Applied Chemistry Unit at the South African Nuclear Energy Corporation, for an article titled "Die effek van die skermgassamestelling in 'n induktiefgekoppelde plasma: 'n Eindige-elementanalise" (The effect of sheath gas composition in an inductively coupled plasma reactor: A finite-element analysis).

They were congratulated on this achievement by Prof Tawana Kupe, Vice-Chancellor and Principal of the University of Pretoria, who praised them for having exemplified UP's mission to pursue excellence in its core functions of research, teaching and learning, and utilising that research to constantly improve our society and communities.

The diversity of a flagship UP project earns international recognition

Dr Lelanie Smith, Head of the Faculty's Community-based Project module and Programme Director of UP's Vertically Integrated Project (VIP) programme, was one of two international finalists in the 2020 Diversity Award of the Global Engineering Deans' Council (GEDC), and the only one that did not come from North America.

This is a global award for innovative projects that inspire students of all profiles and backgrounds to study and succeed in engineering. It should therefore be a project that can make an impact in engineering education worldwide.

The project that Dr Smith entered for this competition was the Aircraft for Rhino and ENvironmental Defence (AREND) project, a multinational, multidisciplinary, vertically integrated engineering design project with a co-curricular framework, integrated into problem-based learning modules in the School of Engineering at the University of Pretoria.

The project includes students from second-year to master's level, across different cultures locally, and includes international interns from a variety of countries in the European Union, as well as the USA, allowing for a team of diverse backgrounds. The project is also supported by local industry, and aims to foster global awareness and civic responsiveness in engineering students at an early stage in their degree studies.

The project was recognised for addressing diversity, not only of race, gender and discipline, but also for a diverse design approach. In addition, the project uses existing project-based modules to structure vertical integration through the curriculum.

Dr Smith remarks that this award was quite an achievement, as entries were not just attracted from university teams across the world, but from industry partners as well.

Engineering students make their mark on international platforms

AREND CONTINUES TO MAKE AN INTERNATIONAL IMPACT

The Faculty of Engineering, Built Environment and Information Technology hosts the internationally renowned Aircraft for Rhino and ENvironmental Defence (AREND) project, which uses unmanned aerial vehicles to detect and track rhino poachers in South Africa's Kruger National Park. The project forms part of the Vertically Integrated Project (VIP) programme, and was recognised by the international VIP Consortium.

The team from the University of Pretoria tied for the honour of second place with the team from New York University. Ray Sokola, Executive Director of the VIP Consortium, complimented the ingenuity of VIP students as they tackle and develop real-world solutions to ambitious challenges. The outcomes of VIP programmes, such as those embraced by the Faculty, demonstrate how well prepared students will be when they transition into the workforce with experience in working on interdisciplinary teams.

MECHANICAL ENGINEERING STUDENTS' ONLINE HACKATHON

Kabelo Phiri, Tané Coetzer and Patrick Knight, students from the Faculty of Engineering, Built Environment and Information Technology, were part of a six-member team to participate in the Youth Innovators Design Bootcamp 2021, hosted by UNESCO.

The aim of the event was to explore how technology can be leveraged for sustainable living and economic development in Africa. The team submitted a project on a modular organic waste processor that produces electricity and water from biogas. "My dream is to be part of the innovators who shape renewable energy and high-level automation in Africa. I truly believe that these technologies will facilitate the future if we, as Africans, aim to be in the forefront of innovation," Kabelo explained.

Online **Robot Race Day**

This year, the Department of Electrical, Electronic and Computer Engineering hosted its ninth annual Robot Race Day on an online platform for the first time.

The event was initiated to create an engaging and enjoyable practical project for the third-year Microcontrollers module. Students compete against one another on a five-metre track for Microcontroller-based Autonomous Robotic Vehicles (MARVs).

Although it was not possible to present the event in 2020, it was reimagined and reinvented so that the third-year class of 2021 could participate in the race in cyberspace. Paper tracks were designed that could be printed out and glued together at home.

All the practical demonstrations that preceded the final event were done online. The qualifier, quarter-final and semi-final entries for the race were submitted as video entries, posted (and judged) on the event's Facebook page.

Judging was difficult due to the inevitable variations, as well as the high quality of the entries. The teams that came out on top during the online trials could participate in the in-person final event held on 28 August 2021.

Funding secured for EECE students

CONTROL TECHNIQUES

Two students in the Department of Electrical, Electronic and Computer Engineering (EECE), Tshepo Freddy Masike and Thembelihle Mnguni, received a full annual engineering tuition bursary from Control Techniques.

According to Vice-President: Middle East and Africa, Bruce Grobler, the company is excited to partner with the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology to serve the interests of these young students and make a contribution to broad-based black economic empowerment in the country. In addition to its sponsorship of these bursaries, Control Techniques has further strengthened the partnership through a donation of demonstration equipment to support the Department's curriculum, and by extension, the future of the South African engineering industry.

Prof Sunil Maharaj, Dean of the Faculty, said that the Faculty is particularly grateful to companies in the private sector who realise that an investment in the country's youth is an investment in the country's future.

MOTSENI HI-TECHSPACE

The postgraduate research capacity of the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) in the Department of Electrical, Electronic and Computer Engineering (EECE) received a boost with the signing of a Memorandum of Agreement (MoA) with Motseni-Hi-TechSpace.

The agreement relates to the enrolment, training and supervision of postgraduate students. The company will support this programme financially for a period of five years from 2022, with an emphasis on the development of previously disadvantaged candidates. The funding will take the form of a research support grant, which will primarily involve a student bursary, but also make provision for prototyping, minor equipment and upgrades (if required), provision for the candidate to attend an international conference to present their work, and a small contribution to shared laboratory expenses, including software licensing and laboratory maintenance.

Industry support such as this is crucial to address the gap in human capital development that currently exists in Africa and South Africa.

Industrial and Systems Engineering PhD candidate receives international scholarship

Ratidzo Yvonne Nyakudya was granted a full scholarship for her PhD research by UNESCO's Organization for Women in Science in the Developing World.

Her research, which focuses on environmental degradation modelling and sustainability evaluation, served as a driver for this award. The organisation considers environmental-related research as a priority research area that is strongly linked to human wellbeing.

Nyakudya's work is interested in the quantification of degradation per time/per activity via the development of a holistic generalised degradation model, premised on the life cycle analysis of functional and physical elements of systems, including their inherent processes and minutest of activities. She will be deploying her generalised model to an iron sponge manufacturing industry, noted for its high level of pollution and environmental degradation.

Sustainability engineering considers the benchmarking of identified components of the environment with initially defined international standards by the World Health Organization, among other global organisations. Nyakudya's research also seeks to patent the proposed concept through a designed and developed hand-held device, which could serve as a barometer for the measurement of environmental degradation and the wellness of environmental sustainability practice.

LAST WORD

Leonardo da Vinci:

The inventive genius of the Renaissance

Prof André Buys

Leonardo da Vinci was an Italian polymath of the High Renaissance. As a painter, scientist, sculptor, engineer, thinker, town planner, storyteller, architect, musician and philosopher, he was one of the greatest universal geniuses of Western civilisation.

Presumed self-portrait

THE TERM "RENAISSANCE MAN" INDICATES THE ABILITY OF ONE INDIVIDUAL TO EMBRACE MANY DIFFERENT DISCIPLINES. DA VINCI WAS RELENTLESS IN HIS OBSERVATION OF NATURE IN ALL ITS FORMS – A TRUE RENAISSANCE MAN.

EARLY LIFE AND EDUCATION

Leonardo da Vinci was born on 15 April 1452, in Vinci, just outside Florence in Italy. He was the illegitimate son of Ser Piero, a Florentine notary and landlord, and Caterina, a young peasant woman. He was raised by his father, but his education barely extended beyond the basics of reading and writing. However, at an early age, he showed remarkable artistic talent. At the age of 14, his father enrolled him as an apprentice with Andrea del Verrocchio, one of the most well-known artists in Florence. Leonardo worked with Verrocchio for nearly 10 years, where he was trained in all aspects of the artist's trade, including painting, technical drawing, sculpture, goldsmithing and metal casting. Leonardo helped Verrocchio with some of his most famous work, such as the painting *The Baptism of Christ*. In 1472, Leonardo received membership of the Florence Painters' Guild and began his professional career.

CAREER

He had just received his first substantial commissions in Florence, when Leonardo was employed by Duke Ludovico Sforza as *pictor et ingeniarius ducalis* ("painter and engineer of the Duke") and moved to Milan in 1482. In Milan, he worked as a painter, sculptor and designer of court festivals, but was also a technical advisor in the fields of architecture, fortifications and military affairs. During this period, Leonardo studied Latin seriously, as well as advanced geometry and mathematics. He also began practical work in anatomy on the dissection table in Milan. During this period, Leonardo recorded his first notebooks with the intention of writing treatises on painting, architecture, mechanics and anatomy.

From about 1483 to 1486, he worked on the altar painting *The Virgin of the Rocks*, a project that was never completed, and the mural *The Last Supper* (1495–1498). This mural began to disintegrate soon after it was completed as he used an experimental painting technique that did not work.

The main reason why Leonardo was invited to Milan was to sculpt the monumental equestrian statue that was to be erected in honour of Francesco Sforza, the founder of the Sforza dynasty. After many years, the clay model of the horse was eventually displayed in public in 1493. The bronze metal, ready to be cast, was however used to make cannons because of the imminent danger of war. After Ludovico's fall in 1499, the clay model was destroyed during the ensuing war.

At the end of 1499, Leonardo returned to Florence, where he concentrated more on mathematical studies than on painting. He left Florence in 1502 to enter the service of the notorious Cesare Borgia as "senior military architect and general engineer". He drew city plans and topographical maps and created early examples of aspects of modern cartography, but the next year, he returned to Florence where he worked on a plan to build a large canal to connect Florence to the sea, a project that was never carried out. During this period, Leonardo began three major works of art: *The Virgin and Child with Saint Anne* (c. 1503–1519), *Mona Lisa* (c. 1503–1519), and *Battle of Anghiari* (unfinished; beginning in 1503). It was also a period of intensive scientific study: anatomical work, flight of birds, hydrological studies, astronomy, botany, cartography and palaeontology.

After Gian Giacomo Trivulzio forced Ludovico Sforza to abandon Milan in 1499, Louis XII of France appointed Trivulzio governor of Milan. He contracted Leonardo to sculpt his tomb monument in the form of an equestrian statue in 1508, but after years of preparatory work, the commission was terminated. During his second period in Milan, Leonardo's studies in anatomy progressed so far that he planned to complete his anatomical treatise in the winter of 1510–1511.

The Virgin of the Rocks

Mona Lisa

The Last Supper

He conducted his research at hospitals in Florence, Rome and Pavia, where he worked with physician-anatomist Marcantonio della Torre. According to his own count, Leonardo dissected 30 corpses in his lifetime. At the same time, he also worked on manuscripts on his mathematical, optical, mechanical, geological and botanical studies.

In 1513, Leonardo went to Rome hoping to find work there, but no large commissions followed. He therefore accepted the invitation of the young French King Francis I to enter his service as *premier peintre, architect et méchanicien du roi* ("first painter, architect and engineer to the king"). In 1516, he left Italy and settled in Cloux (later Clos-Lucé), near the King's summer palace at Amboise on the Loire. He once again made sketches for court festivals. He also drew up plans for the palace and garden of Romorantin, but the project was stopped because the region was threatened with malaria. Leonardo spent most of his time in France arranging and editing his scientific studies and treatises. He died at Clos Lucé on 2 May 1519 at the age of 67. His student and companion, Melzi, inherited Leonardo's great artistic and scientific manuscript legacy, and sometime before 1542, Melzi compiled a *Trattato della pittura* ("treatise on painting"), which was only published almost 300 years later, in 1817. However, it is impossible to determine to what extent Melzi's presentation of the material reflected Leonardo's intentions.

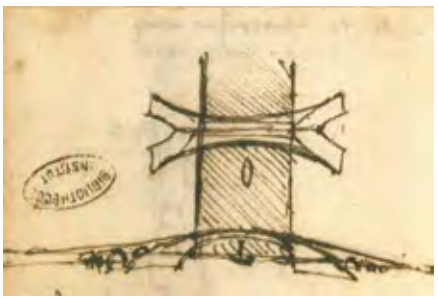
AT THE END OF 1499, LEONARDO RETURNED TO FLORENCE, WHERE HE CONCENTRATED MORE ON MATHEMATICAL STUDIES THAN ON PAINTING. HE DREW CITY PLANS AND TOPOGRAPHICAL MAPS AND CREATED EARLY EXAMPLES OF ASPECTS OF MODERN CARTOGRAPHY. NOTABLY, HE RETURNED TO FLORENCE WHERE HE WORKED ON A PLAN TO BUILD A LARGE CANAL TO CONNECT FLORENCE TO THE SEA, A PROJECT THAT WAS NEVER CARRIED OUT. IT WAS ALSO A PERIOD OF INTENSIVE SCIENTIFIC STUDY: ANATOMICAL WORK, FLIGHT OF BIRDS, HYDROLOGICAL STUDIES, ASTRONOMY, BOTANY, CARTOGRAPHY AND PALAEONTOLOGY.

LEGACY

Leonardo da Vinci is honoured as the artist who created arguably the most famous painting of all time, the *Mona Lisa*. He was undoubtedly the most creative and versatile genius the world has known. It is ironic that his interests were so diverse that he managed to complete only a few paintings, two of which are the *Mona Lisa* and *The Last Supper*. Most of his works remained unfinished or were abandoned.

Leonardo was one of the greatest inventors that ever lived. His notebooks are evidence of a scientific inquiry and mechanical ingenuity that were centuries ahead of their time. In 1502, he designed a single-arch bridge to span the Golden Horn in Istanbul. It was never built, but a bridge built to his design was erected 500 years later in the town of As, near Oslo in Norway. He invented the astronomical telescope and used it to observe the moon in 1513, almost 100 years before Lipperhey and Metius patented it in 1608 and Galileo built his first telescope in 1609 (Buys, 2011). Leonardo invented the armoured car in 1487, but the first armoured car built was the Simms motor war car, designed by FR Simms in 1899. Leonardo designed a flying machine to be lifted by a man-powered rotor in 1493. The first free flight of a rotary-wing aircraft built by Paul Cornu was on 13 November 1907.

Leonardo was the inventor of the parachute, the flying machine, the machine gun, the diving suit, airburst ammunition, the helicopter, the robot, the rotating bridge, concentrated solar power, the adding machine, the double-hulled ship and many more. He enjoyed the company of rulers and kings, but his contemporaries could not quite fathom who and what he was. As Sigmund Freud put it, "He was like a man who woke up too early in the dark while the others were all still asleep."



Leonardo's design of the Golden Horn Bridge, 1502

Leonardo Bridge near Oslo in Norway 2001 (Photo by Terje Johansen)

Leonardo's armoured car, 1487

The Simms motor war car, 1899

Leonardo's rotary-wing aircraft, 1493

Paul Cornu's rotary-wing aircraft, 1907

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IF YOU FIND FROM YOUR OWN EXPERIENCE THAT SOMETHING IS A FACT AND IT CONTRADICTS WHAT SOME AUTHORITY HAS WRITTEN DOWN, THEN YOU MUST ABANDON THE AUTHORITY AND BASE YOUR REASONING ON YOUR OWN FINDINGS.

Leonardo da Vinci

Leonardo was a possessive and secretive person. He was left-handed and wrote in mirror writing, which made it difficult for others to read. When he finished the *Mona Lisa*, a commissioned portrait of the Italian noble-woman, Lisa Gherardini, he would not part with it and kept it with him for the rest of his life. His notebooks were kept private and his only published work was the book he illustrated on mathematical proportion in art, written by his friend Luca Pacioli and called *De divina proportione*, published in 1509. The first extant Italian patent was already awarded in 1416, and patents were systematically granted in Venice by the 1450s. Leonardo could have patented most of his inventions, but chose not to do so.

Leonardo gave priority to the illustration – which he called *dimostrazione* ("demonstrations") – above the written word. In his notebooks, the drawings do not illustrate the text; the text serves rather as an explanation of the image. Leonardo's work was thus a forerunner of modern scientific illustration and technical drawings.

Perhaps the greatest tragedy of his life was that, although he made significant discoveries in anatomy, civil engineering, geology, optics, tribology and hydrodynamics, he did not publish his findings, and they therefore had little or no impact on subsequent science and technology. He was an inventor, but not an innovator. Invention can be defined as the creation of a new or improved product or process, and innovation as the implementation of an invention. It is true that few of his designs were practically feasible during his lifetime, as metallurgy and engineering were still in their infancy and there was not yet a sufficient power source available for the propulsion of many of his machines and vehicles.

Above all else, Leonardo was the personalisation of Renaissance humanism that emphasised the value of human beings and opposed dogma and scholasticism. He was the first great empiricist. Empiricism is the notion that true knowledge comes primarily from physical observation and experience. Leonardo said, "If you find from your own experience that something is a fact and it contradicts what some authority has written down, then you must abandon the authority and base your reasoning on your own findings."

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