Innovate:

Issue 17 2022

A HUMAN-CENTRED FACULTY

A future-focused faculty

Society 5.0

AI and machine learning

Silicon light emission

Smart transportation platforms

Green infrastructure planning

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

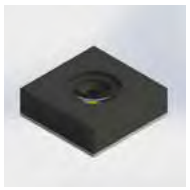
Faculty of Engineering, Built Environment and Information Technology

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

Make today matter

Inside

THE FACULTY'S RESEARCHERS ARE RISING TO THE CHALLENGE OF MAKING A SIGNIFICANT CONTRIBUTION TO SOCIETY AT LARGE. THE FACULTY ENCOURAGES ALL MEMBERS OF THE EBIT GENERATION TO EMBRACE INDEPENDENT THINKING AND A HUMAN-CENTRED PERSPECTIVE OF TECHNOLOGY TO CHANGE THE WORLD.





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FACULTY NEWS

Innovate:

Issue 17 2022

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

EDITORIAL TEAM

ON THE COVER

A HUMAN-CENTRED FACULTY

While technology is the catalyst for change, humans are the sustaining force. This means that we need to develop new mindsets and find new ways of working. The Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria encourages independent thinking and a desire to discover and create new knowledge that will make a difference in the world.

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Technology in the "new world"

It appeared suddenly, killed many people across the globe, and now it seems that COVID-19 is becoming part of our daily lives. Still in a state of shock and confusion, we try to understand what happened, and more importantly, what will happen in the future? While health researchers spend much time trying to find out exactly where and how it originated and spread across the globe, the rest of us are trying to make sense of the economic and social confusion that has been created over the past few years.

The impact of the COVID-19 epidemic was widespread, with no industry or government sector being spared. The airline industry was one of the first victims of COVID-19. The impact of the pandemic was disastrous, not only for the airline industry, but also for tourism and supply chain networks as it brought global trade to a standstill. Because of social distancing and isolation, people could not go to work, and schools and churches were forced to close their physical contact activities. These are just two examples that illustrate the ripple effect of COVID-19, and the enormous challenges governments and industries across the globe have had to cope with.

The role that technology has played in surviving the challenges brought about by COVID-19 has been immense. Communication between governments, companies, institutions and people relied totally on technology. Modern health technologies were immediately enacted to find appropriate vaccines; companies relied on technology to enable employees to work from home; the online purchasing business grew exponentially; schools and universities adopted online education technology; the list continues. Slowly but surely, a "new world" was created, which was built on technology.

Everybody started speculating what this "new world" would look like. Put another way, which of the new technologies and practices would remain part of our lives for the years to come? We started seeing new trends in online purchasing, working from home a few days a week, online conferences, more home schooling, Zoom towns and many other new practices. Property companies experienced a decline in office rentals; office workers saved on transport costs; people started moving to country living in higher numbers; governments provided more online services, thereby reducing unproductive lead times and queuing; and much more. Organisations need to assess their current practices and adapt their business strategies to accommodate the new technology-world practices – they do not have a choice!

The University of Pretoria, like many other organisations, also faced these COVID-19-related challenges and impacts. Thanks to the University's unique people skills, the different academic, research and administration departments, guided by skilled management teams, contributed to the successful implementation of the new technologies and processes that were required to minimise disturbances

in the education of our students. At the same time, the University of Pretoria updated its research agenda with the necessary research topics to prepare our university, industry and government for the new world of technology after COVID-19. It is, after all, a case of "adapt or die"!

In this edition of ***Innovate***, you will again find a selection of interesting contributions on the research and educational activities of the Faculty of Engineering, Built Environment and Information Technology.

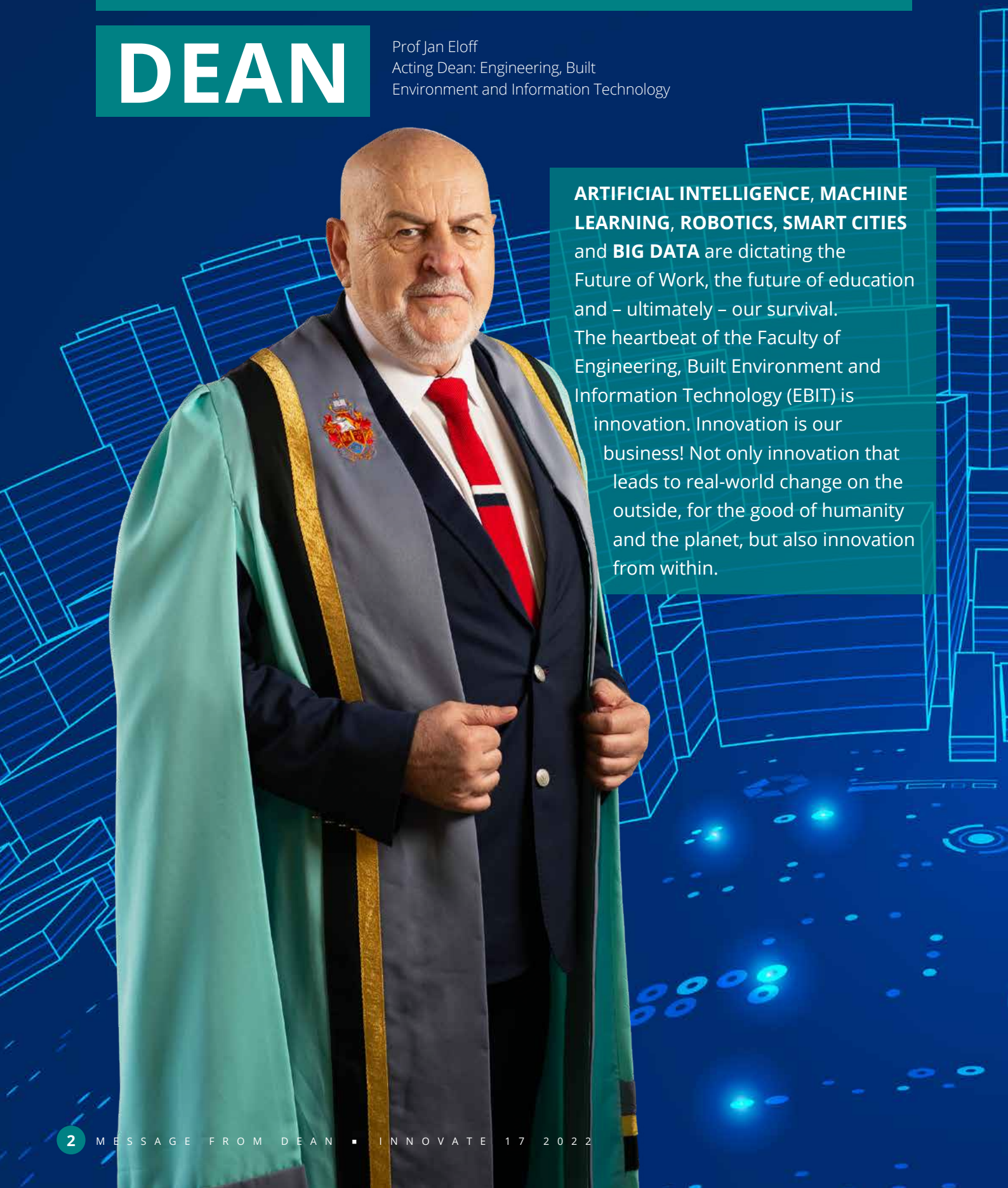
Enjoy reading!

Prof Tinus Pretorius
Editor

THE "NEW WORLD" CALLS FOR TECHNOLOGY PRACTITIONERS TO "ADAPT OR DIE"

MESSAGE FROM THE OFFICE OF THE DEAN

Prof Jan Eloff
Acting Dean: Engineering, Built Environment and Information Technology



ARTIFICIAL INTELLIGENCE, **MACHINE LEARNING**, **ROBOTICS**, **SMART CITIES** and **BIG DATA** are dictating the Future of Work, the future of education and – ultimately – our survival.

The heartbeat of the Faculty of Engineering, Built Environment and Information Technology (EBIT) is innovation. Innovation is our business! Not only innovation that leads to real-world change on the outside, for the good of humanity and the planet, but also innovation from within.

The ongoing COVID-19 pandemic has fast-tracked several technological innovations that have disrupted the world as we know it. It has propelled us into new and creative ways of navigating life. It has also reconceptualised the Future of Work. Our faculty has responded to these challenges by ensuring that we remain relevant and lead by example. We have become a human-centred faculty, characterised by digital transformation and engagement with the principles of Society 5.0.

The digital transformation process that has been launched by technology extends beyond tools and processes. It impacts on individuals and organisations, and results in the improved wellbeing of both people and the planet. It also enhances globalisation by removing physical barriers and making it possible to work anywhere, anytime, on any device.

Future-focused and transdisciplinary research is imperative to make sense of this new digitalised world. Our state-of-the-art Engineering 4.0 Complex is positioning the University of Pretoria as a centre of excellence in smart transportation. The research done here is testimony to our thought leadership and position on the forefront of the global stage. Other transdisciplinary projects include the Hatfield Digital Twin City, additive manufacturing for electronic systems, and the development of smart avos and smart alternative platforms. SmWoef is the latest smart alternative platform that is being used for research across various disciplines.

SmWoef is a robotic quadruped that can transport sensors into high-risk environments that are not safe or accessible for humans, where it can collect useful data. This is an excellent example of how robots and humans can co-exist and work together to innovate our tomorrow.

Over the next five years, the Faculty will focus on transdisciplinary research to develop critical mass and synergies at the intersection of the Faculty's research focus areas:

- **SMART CITIES AND TRANSPORTATION**
- **BIG DATA SCIENCE, INFORMATION AND COMMUNICATION TECHNOLOGY (ICT), AND TECHNOLOGY AND INNOVATION MANAGEMENT**
- **WATER AND ENVIRONMENTAL ENGINEERING**
- **ENERGY**
- **MINERALS AND MATERIALS BENEFICIATION**
- **THE FOURTH INDUSTRIAL REVOLUTION**

The Faculty currently has 100 National Research Foundation (NRF)-rated researchers, 30 externally funded research chairs and 17 international agreements, while 70% of our academics have doctoral degrees.

Our Faculty is one of the few institutions in Africa in the top 550 in the world in six subject areas related to engineering, built environment and information technology in the 2022 QS World University Rankings by Subject. The School of Engineering is ranked 352nd out of more than 10 000 engineering schools in the field of engineering and technology. Our programmes in both electrical and electronic engineering, and mechanical and aeronautical engineering are number one in South Africa, while minerals and mining engineering has been ranked in the top 33, improving on its ranking for 2021 by 15 places.

The pillars of digital transformation that can shape the future of academia include Artificial Intelligence, cloud computing, the Internet of Things and Big Data. It presents a unique opportunity to develop a human-centred and human-enhanced society. The evolution of ICT is at the core of Society 5.0. Organisations are building connections that can pave the way to improved planetary wellbeing instead of viewing man and machine as equals.

While technology is the catalyst for change in the workplace, humans are the sustaining force. This means that we need to develop new mindsets and find new ways of working. Companies need to embrace skills like leadership, deliberation and debate, conflict resolution and ethical considerations if they are to thrive in the future.

Our slogan, "Innovating our Tomorrow", keeps us on the path of pursuing innovation. We will remain relevant and address the challenges of the Future of Work with a generation of problem solvers and innovators who are ready to change the world and create a peaceful and more sustainable planet. We will achieve this, among other things, by embracing Society 5.0, leveraging the possibilities, prospects and challenges of digital transformation.

Message from the Deputy-Dean:

Research and Postgraduate Education

Prof Johan Joubert

Research in the Faculty of Engineering, Built Environment and Information Technology (EBIT) is aligned with the University of Pretoria's overall research strategy for 2025, in which it aims to be a research-intensive institution. The Faculty's research is focused on making a significant contribution to society at large, particularly with regard to the most pressing challenges of the developing world.

RESEARCH IN THE FACULTY IS FOCUSED ON SIX BROAD RESEARCH 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 (4IR)

The research conducted in each of these six broad research focus areas is interdisciplinary and includes contributions from a combination of the Faculty's 14 academic departments in its four representative schools: Engineering, the Built Environment, Information Technology and the Graduate School of Technology Management (GSTM).

THE FACULTY AIMS TO PROMOTE AND EXTEND TRANSDISCIPLINARY RESEARCH. SOME EXAMPLES OF TRANSDISCIPLINARY PROJECTS THAT HAVE BEEN IDENTIFIED FOR FUTURE RESEARCH INCLUDE THE FOLLOWING:

Pursuing a net-zero carbon construction industry

Net-zero carbon balances the amount of greenhouse gasses produced against the amount of greenhouse gasses removed from the atmosphere. The World Green Building Council defines net-zero carbon as a zero or negative amount of carbon emissions associated with the operational energy of a building on an annual basis. Transdisciplinary research initiatives on net-zero carbon will also support the 17 Sustainability Development Goals (SDGs) of the United Nations and the 2030 Agenda for Sustainable Development.

African future cities: the Hatfield Digital Twin City initiative

A digital twin city is a living virtual laboratory – a real-time digital mirror of city environments built on the 4IR, the Internet of Things (IoT), geoinformatics, virtual and augmented reality visualisation engines, urban informatics and econometrics, Artificial Intelligence (AI) and machine learning skills. Beyond developing the technical skills required to build a digital twin city, such a laboratory facilitates the management of many practical aspects for improving city systems, reveals real-time societal patterns that are emerging, drives real-time collaboration, and supports transdisciplinary education, leadership and change management skills.

Improving engineering student outcomes through transdisciplinary research

Engineering education is a transdisciplinary field of research and innovation, connecting the engineering disciplines with specialist knowledge from the fields of education, psychology and sociology. This project will consolidate the transdisciplinary field of engineering education at the University of Pretoria, and will allow us to work towards establishing a Centre of Engineering Education. This will increase the impact and contribution of the School of Engineering in the important conversations about the future of engineering education in a globalising and changing world.

Smart printed electronic micro-sensor systems (SPEMS)

Printed electronics is a key additive manufacturing technology that enables the integration of multiplexed sensor modalities, modern communication techniques and machine learning methods into small form-factor flexible electronic sensor systems. An important outcome is the improved availability of advanced electronics systems for low-cost transdisciplinary applications that leverage additive manufacturing to broadly contribute to the growth and inclusion of under-resourced (and especially rural) communities.

Future and smart transport in Africa

Smart city technologies and intelligent transportation systems can help cities absorb growing populations, overcome congestion and create a sustainable future. Incremental technological upgrades can support smart security video, monitor vehicle systems and deliver AI-powered predictive maintenance. Autonomous vehicles offer new possibilities for significantly improving safety and efficiency, and producing data that can be used intelligently and in real-time to optimise the whole transport system, including road infrastructure and maintenance.


Faculty of
Health Sciences

Message from the Deputy-Dean:

Teaching and Learning

Prof Alta van der Merwe

It was with great excitement that the University of Pretoria welcomed its students back on campus for face-to-face teaching and learning at the beginning of the second semester of 2022. Looking back at the challenges the entire higher education sector has faced over the past three years, in which it was compelled to develop measures to adhere to the President's COVID-19 Risk-adjusted Strategy, the Faculty certainly learnt some valuable lessons that it can take forward to benefit its students and academics.

Prior to the COVID-19 pandemic, the Faculty had already established a solid foundation of hybrid learning. It could thus continue to implement this mode of learning, and to establish new innovations in online learning to address the challenges experienced not only in the presentation of course content, but also in the implementation of tests and examinations, and the subsequent assessment of these evaluation opportunities.

Many of our academics adopted creative approaches of transferring knowledge, thereby achieving improved academic performance. The approaches lecturers utilised included the flipped classroom approach, where students completed pre-class activities at home and worked on live problem-solving tasks during class time, asynchronous and interactive videos, and synchronous lectures via Blackboard Collaborate.

While online teaching is not without its challenges, many lessons were learnt, which can extend the reach of universities and make education accessible to more people. The most prominent challenge relates specifically to South Africa's unique problems of access to technology and overcoming the digital divide.

The Faculty's future approach to teaching and learning may well incorporate elements of online learning. This will entail utilising the advantages of contact tuition, while enhancing the benefits of technology. For example, the recording of lectures, as an initiative instituted in online teaching, has proven to have additional benefits. Not only can these lectures be viewed later when students have access to the internet or a convenient location, but they give students the opportunity to revise the course content later. This approach received such positive feedback that the Faculty is considering its continued application.

Another initiative that succeeded in improving student performance was the institution of continuous assessment. Many lecturers made use of this approach to ensure that no student was left behind during online tuition. The enhanced results suggest that it might be beneficial to continue with this practice.

The focus on digital communication has brought about a challenge of another kind. This is the emotional and psychological wellbeing of our students and staff. Several lecturers focused specifically on this issue in the teaching approach they decided to adopt as part of online tuition. This will continue to form an important part of the Faculty's teaching and learning strategy.

In retrospect, it is clear that the challenges we have faced over the past three years have propelled us into a space where we can truly embrace teaching innovation.

The Faculty remains dedicated to reconceptualising the Future of Work to the benefit of our students, enabling them to make a meaningful impact on our world.

Smart alternative platforms enable innovative research

Research in the digital age has moved beyond the laboratory and traditional methods of data collection in the field. With the introduction of artificial intelligence, robotics and Big Data, the University of Pretoria's Department of Civil Engineering is making use of a smart alternative transportation platform in the form of a four-legged terrestrial robot. This Smart Woef – or "smWoef" – is used to facilitate data collection in high-risk environments that are difficult to access or require repetitive data collection that may lead to a lack of attention to detail.

A smart alternative research platform such as this serves as a vehicle to access infrastructure for data collection across various disciplines. It is a perfect example of how man and machine can work together for the betterment of humankind. By combining such an autonomous robotic platform with sensor networks, an infrastructure data collection methodology can be developed that provides for a safe, sustainable, continuous process of collecting current digital infrastructure data (including ambient environmental conditions and images at a range of wavelengths) that can form the basis of infrastructure maintenance, rehabilitation and risk management decisions.

The Department of Civil Engineering's Smart Woef was acquired from Unitree Robotics at the end of 2021. It is an agile quadrupedal robot that can navigate inaccessible terrain with unparalleled mobility. It can carry a payload of up to 5 kg at speeds of up to 12 km/h, depending on terrain conditions. Payloads can be self-sustained (linking with GPS and long-range wide area network (LoraWAN) stations) or integrated with the robot. Operational modes include a manual, follow-me and simultaneous localisation and mapping (SLAM) mode that allows for the selection of an option that is suitable to the specific application and terrain.

Prof Wynand Steyn, Head of the Department of Civil Engineering, together with a team that includes interns and postgraduate students, is currently training smWoef to assist with multiple research projects at the University's state-of-the-art Engineering 4.0 facility. Although it will be primarily utilised for transportation research, the digital repository that can be built based on the data that is gathered through this platform can be used for several transdisciplinary research projects, including those conducted by the University's Forestry and Agricultural Biotechnology Institute (FABI). Further potential interactions with departments in the schools of Medicine and the Built Environment are being pursued, where such access to unsafe, inaccessible and repetitive environments may aid in novel data collection and research support.

Smart technology such as this has not only propelled us into new and creative ways of navigating life, but has reconceptualised the Future of Work, enabling the Faculty of Engineering, Built Environment and Information Technology to develop a new generation of problem solvers and innovators who are changing the world.

WATCH
SmWoef – University of Pretoria's Robo-Dog


RPLIDAR

Innovative long-lasting insecticide treatment finds additional applications

An invention that originated in the University's Institute of Applied Materials (IAM) has developed into a product that is being marketed countrywide, while the technology behind its development is finding additional applications. The licensing of this invention also led to the development of a spin-off company of the University of Pretoria, a biotechnology company known as African Applied Chemical (AAC), with Dr Mthokozisi Sibanda as its founder.

This innovation, developed by Dr Sibanda, in collaboration with Prof Walter Focke, Director of the IAM, reduces the evaporation of expensive insect repellents, making them last longer. The company's flagship product is a hiking sock that has been treated with the long-lasting insect repellent. Following the licensing of the product to AAC in 2019, the company started shipping its first orders at the end of February 2020.

However, with the announcement of a nationwide lockdown in March 2020 following the COVID-19 pandemic, tourism experienced a downturn. As visitors to the Kruger National Park were the company's primary target market, this had a devastating effect on its sales. Although visitor numbers were limited when the park opened its gates to tourists again in September 2020, all the company's product lines were sold out by the end of December 2020. The company has also started exploring regional export markets, and will commence exports during 2022.

This invention will play an important role in the fight against malaria, one of the leading causes of illness and fatalities around the world.

Caused by the bite of a female 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. The World Health Organisation (WHO) recommends the spraying of insecticides indoors and the use of bed nets treated with long-lasting insecticides as a preventative measure.

Although the disease is mostly confined to tropical areas, it results in approximately 250 million clinical cases of malaria and nearly half a million deaths annually. Malaria is particularly prevalent in sub-Saharan Africa, where it affects mostly pregnant women, as well as children under five years of age. While the use of indoor residual spray has been found to be effective, long-lasting insecticide-treated nets are the most widely used mosquito control intervention, particularly in sub-Saharan Africa, because the mosquito net distribution programme is much cheaper and simpler to manage for resource-limited governments.

Until recently, the pyrethroid group of insecticides has been the only insecticide approved for use on

mosquito nets. Unfortunately, mosquitoes quickly developed a resistance to pyrethroids. This resistance has been reported in almost every country in sub-Saharan Africa.

Although the widespread use of long-lasting insecticide-treated nets showed initial success in reducing malaria transmission, malaria cases started to increase again in 2016, despite the obedient use of these nets. This trend seems to be sustained, and can be attributed to resistance to insecticides by the mosquitoes.

Insecticide resistance is now considered a major threat to malaria control in Africa. This observation is causing concern among malaria control stakeholders, and there is a desperate need for new innovative mosquito control products that can effectively deal with insecticide-resistant mosquitoes.

To solve this problem, manufacturers of mosquito nets have included the use of piperonyl butoxide (PBO) on the mosquito net fibres alongside pyrethroids. PBO is a non-toxic chemical that suppresses the mosquito's ability to resist pyrethroids. This effect is called synergism. The use of PBO as a synergist has been shown to have public health value in low- to medium-resistant mosquito strains.

The WHO suggests that new insecticides with a different mode of action to pyrethroids are the key to solving the problem of highly pyrethroid-resistant mosquito strains. The WHO has put out a call to innovators to develop vector control products containing novel actives that are safe and not used in agriculture, in addition to pyrethroids.

Research and development conducted by Dr Sibanda and his team have involved trialling a novel insecticide active for use in long-lasting insecticide-treated nets to tackle the problem of insecticide resistance. They are investigating the use of a new and promising natural insecticide, Nootkatone. Studies by the Centres for Disease Control and Prevention (CDC) have found Nootkatone to be a very effective natural insecticide against mosquitoes as it seems to make use of a different mode of action to pyrethroids.

This active has never been used in agriculture. It is currently used a food flavouring additive. Being edible, it is safe for human and animal consumption. "We can conclude that Nootkatone ticks all the boxes of what the WHO requires," remarks Dr Sibanda. "It is extracted in minute quantities from the skin of grapefruit, but is manufactured industrially by Evolva in the USA. Nootkatone is very expensive, with a kilogram selling for about US$3 000." Applied Protein Biotechnologies, a South African start-up, has developed an enzyme-based conversion technique that allows it to produce an impure form of Nootkatone, which may be cheaper to use in long-lasting insecticide-treated nets.

Using AAC's state-of-the-art proprietary Bi-Ko™ slow-release technology, originally developed at the University of Pretoria, the cost of using Nootkatone may be further reduced to a point where it can become cost-effective to infuse it into mosquito nets.

This technology will be used to deliver small quantities of PBO, mixed with Nootkatone. The aim is to have a dual-active mosquito net that incorporates a pyrethroid, PBO, and Nootkatone, as a novel natural insecticide, to maximise the insecticide properties of the mosquito net against high-intensity insecticide-resistant mosquito species.

According to Dr Sibanda, his team has concluded laboratory studies on pure Nootkatone, as well as Nootkatone incorporated into mosquito net fibres (Vikela™ 2.0). "Nootkatone has been found to be highly effective against pyrethroid-resistant and non-pyrethroid-resistant mosquito strains." The Nootkatone is also showing strong excito-repellent properties that are useful in preventing mosquitoes in blood feeding.

The WHO requires mosquito nets treated with insecticides to withstand 20 washes and still kill a minimum of 80% or knock down a minimum of 85% of susceptible (non-insecticide resistant) mosquitoes before the nets can be approved for mass distribution into the mosquito net market.

Initial laboratory efficacy tests conducted on the Vikela™ 2.0 mosquito net prototype containing betacyfluthrin, PBO and Nootkatone indicate that it passes the WHO's performance standard, and may be of public health value. "There is still a lot of work to be done to get a Nootkatone long-lasting insecticide-treated net on the market," says Dr Sibanda, "but current laboratory results paint a very encouraging picture of a product that can utilised on highly pyrethroid-resistant mosquitoes".

In dose-response studies of pure Nootkatone on *Anopheles funestus* mosquitoes with three levels of pyrethroid resistance, 25 mosquitoes were exposed to varying concentrations of Nootkatone dissolved in PBO, applied to an area of 12 cm by 15 cm for 30 minutes. Mortality was scored 24 hours after the initial exposure. Following exposure to 111.11 mg/m^2, a 100% mortality rate was achieved in insecticide-susceptible and -tolerant mosquitoes, while a 90% mortality rate was achieved in insecticide-resistant mosquitoes after 24 hours.

In tests of the performance of the Vikela™ 2.0 prototype mosquito net containing betacyfluthrin, PBO and Nootkatone as actives on susceptible *Anopheles funestus* mosquitoes, five mosquitoes were exposed to a sample mosquito net measuring 25 cm by 25 cm for three minutes and then removed. Knockdown was scored 30 minutes after exposure, while mortality was scored 24 hours after initial exposure.

The nets were also subjected to 20 washes. After five washes, a knockdown and mortality rate of 100% was achieved. After 10 washes, a knockdown and mortality rate of 99% was achieved. After 15 washes, a knockdown and mortality rate of 90% was achieved, while after 20 washes, a knockdown rate of 90% and a mortality rate of 85% was achieved. It therefore meets the WHO's requirements.

Additional future applications of the Bi-Ko™ slow-release technology are also being investigated. These include slow-release pheromone traps for sustainable agricultural pest control and the transdermal dosing of pharmaceutical actives. These projects have passed the proof of concept stage, and are currently under further development.

THE WHO REQUIRES MOSQUITO NETS TREATED WITH INSECTICIDES TO BE ABLE TO WITHSTAND 20 WASHES AND STILL BE ABLE TO KILL A MINIMUM OF 80% OR KNOCK DOWN A MINIMUM OF 85% OF SUSCEPTIBLE (NON-INSECTICIDE RESISTANT) MOSQUITOES BEFORE THE NETS CAN BE APPROVED FOR MASS DISTRIBUTION INTO THE MOSQUITO NET MARKET. INITIAL LABORATORY EFFICACY TESTS CONDUCTED ON THE VIKELA™ 2.0 MOSQUITO NET PROTOTYPE INDICATE THAT IT PASSES THE WHO'S PERFORMANCE STANDARD, AND MAY BE OF PUBLIC HEALTH VALUE.

Dr Mthokozisi Sibanda

Continuous electrowinning invention undertakes commercial benchmarking

A device to achieve the continuous production of metal in powder form by means of electrolysis has reached the commercial benchmarking stage with the relocation of the containerised continuous electrowinning plant to Impala Refineries' base metals refinery in Gauteng. The Rotowinner® is the brainchild of Ryno Pretorius, a PhD graduate from the Department of Chemical Engineering.

The first prototype of this invention was developed in 2016. It transformed the standard batch or semi-batch electrowinning process into a continuous process. This was shown to work well for the production of copper, but could also be used to produce metals from aqueous solutions of cobalt, nickel and zinc. The advantage of this technique, which could also be used for electrorefining with minor modifications, is its long-term continuous operation.

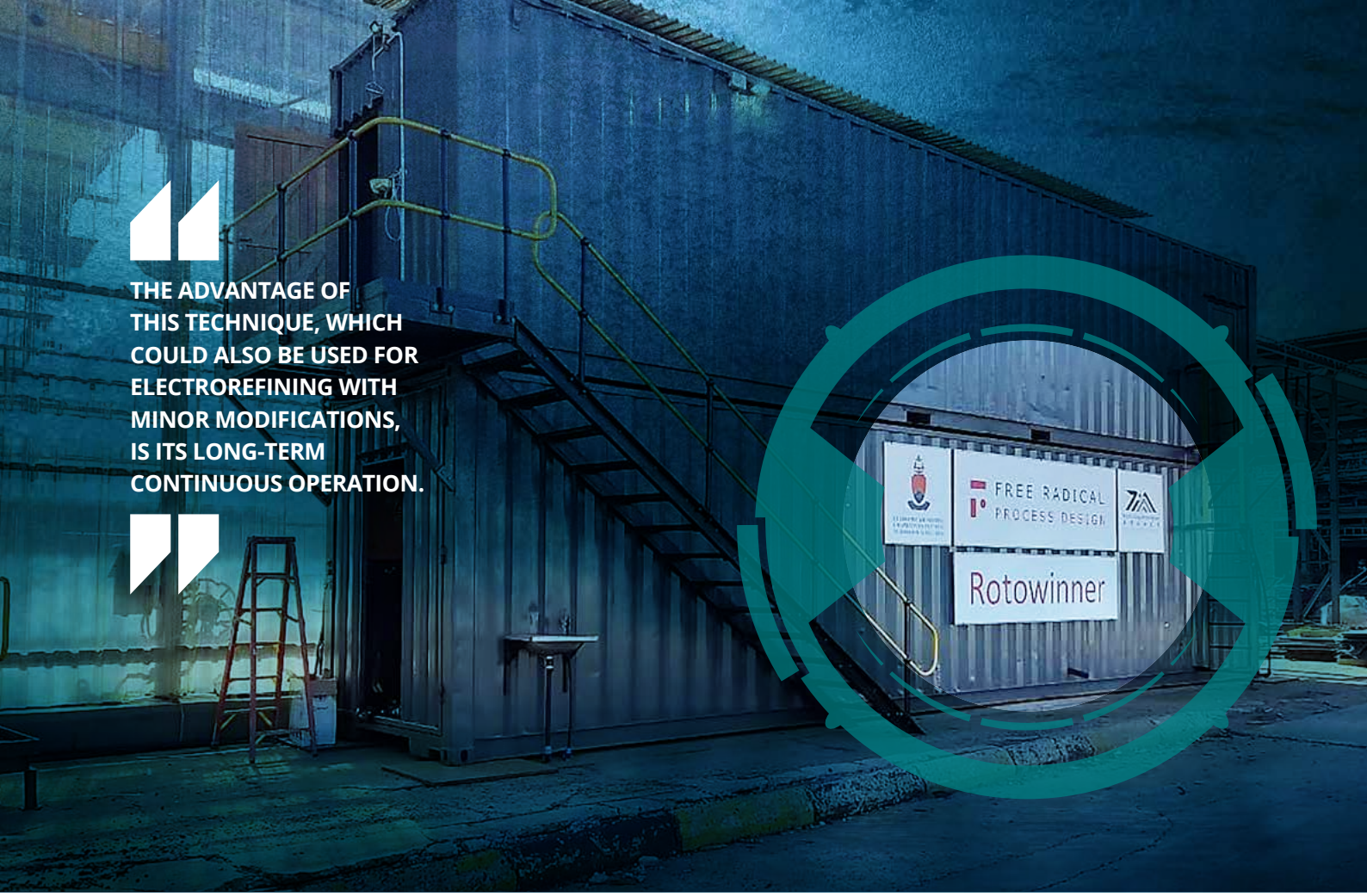
The invention is licensed to the process-engineering start-up, Free Radical Process Design, a process engineering start-up, which developed as a spin-off company of the University of Pretoria. Dr Pretorius, the founder of this company, recently completed an industrial benchmarking exercise on the Rotowinner® containerised demonstration plant, which was installed at Impala Refineries' base metals refinery.

This marks the first step towards commercialising this novel continuous electrowinning technology, which combines electrowinning and cathode stripping into a single continuous operation by reshaping existing parallel-plate electrodes into a rotating cylinder configuration. "The successful implementation of the Rotowinner® continuous metal electrolysis technology will increase the production rate of electrochemically extracted metals, decrease electrical costs, and improve plant safety," explains Dr Pretorius.

"The aim of this project was to produce a modular, transportable, demonstration plant capable of showcasing the commercial possibility of the in-house Rotowinner® technology."

The Rotowinner® technology emerged from a project managed by the University of Pretoria (UP) and seed-funded by the Technology Innovation Agency (TIA), the implementing agency of South Africa's Department of Science and Innovation. UP's Technology Transfer Office (TTO) evaluated the technology for intellectual property (IP) protection and filed a provisional patent application. Together with UP, Dr Pretorius has concluded a technology licence agreement for Free Radical Process Design to commercially exploit the technology.

The TIA awarded R10 million in technology development funds to the company to construct the plant and demonstrate the technology's economic feasibility to potential industry clients. "With the support of UP and the TIA, we were able to demonstrate the commercial and process possibilities of the technology to such an extent that we were invited to operate our demonstration plant at Impala Refineries, in parallel with its existing base metals refinery circuit. We hope to prove improved performance and safety in a commercial environment," says Dr Pretorius.



THE ADVANTAGE OF THIS TECHNIQUE, WHICH COULD ALSO BE USED FOR ELECTROREFINING WITH MINOR MODIFICATIONS, IS ITS LONG-TERM CONTINUOUS OPERATION.

Free Radical Process Design plans to supply Rotowinner® plants internationally as fit-for-purpose plants, designed to client specifications, or to offer toll-treatment options to clients who want to make use of a containerised plant for short-term beneficiation. The use of a mobile electrowinning plant disrupts the current standard practice requirement of limited financial deployment in the mining industry due to life-of-mine being too short to justify capital investment.

By using a mobile Rotowinner® plant, low life-of-mine reserves can be beneficiated until depletion. The electrowinning plant can then be moved to the next site for use on a new resource.

Free Radical Process Design plans to directly integrate the Rotowinner® plant with solar photovoltaics (PVs) to further enhance its remote operational possibilities and drive down the cost of production.

Future developments of the Rotowinner® include using it for continuous water softening and metals removal, thus removing metals and hardness from mine tailings or acid mine drainage, powered by solar energy and producing hydrogen and oxygen as by-products.

Once industrial trails have been completed, steps will be taken to commercially expand and implement the use of the Rotowinner®.

WATCH
Rotowinner™ – Electrowinning – Free Radical Process Design

Unlocking the potential of silicon light emission

Marius Goosen, Dr Jannes Venter, Dr Johan Schoeman and Prof Trudi-Heleen Joubert

Silicon is everywhere. The vast majority of electronic microchips are made using silicon as it is an excellent semiconductor with which to implement transistors and other electronic functions in a cost-effective manner. For this reason, silicon-based microchips have proliferated worldwide. Optical functions implemented in the same silicon manufacturing device have also gained traction through the commercial implementation of optical detectors and modulators. However, the key optical component still missing commercially from the silicon-based design toolbox is an efficient silicon light emitter.

An efficient optical light emitter in silicon has been called the "holy grail" of silicon photonics, underlining the potential impact it may have in the industry by unlocking applications ranging from communication links to microdisplays. Silicon is an indirect bandgap material, which makes any light emission fundamentally inefficient. INSiAVA (Pty) Ltd, a spin-out company of the University of Pretoria, was founded in 2005 with the main aim of commercialising its silicon light-emission technology. First and foremost, to get to a point of commercial feasibility, the efficiency of the silicon light emitters had to be improved dramatically.

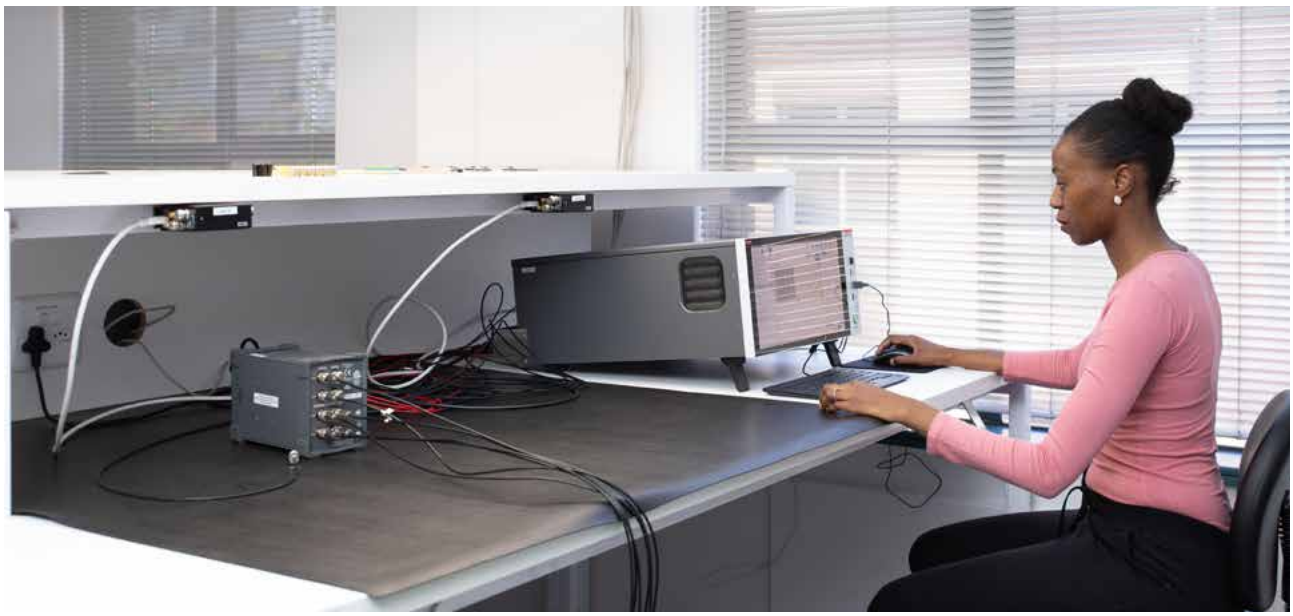
A research group was assembled in the Carl and Emily Fuchs Institute of Microelectronics (CEFIM), based in the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria, to improve the efficiency of silicon light emitters. After several years of research, more than 50 internationally granted patents, numerous international journal and conference publications, and more than 40 fabricated test chips to date, the technology and efficiency improvement has reached a plateau and a point of diminishing returns. Using the state-of-the-art hot carrier electroluminescent silicon emitters developed, the INSiAVA team explored two main applications areas: optical communication links and microdisplays.

Marius Goosen, an employee of INSiAVA (Pty) Ltd, is currently enrolled in doctoral studies at CEFIM to perform research on complementary metal oxide semiconductor (CMOS) polysilicon light emitters. The supervisors of his doctoral research project are Prof Trudi Joubert and Dr Johan Schoeman from CEFIM, as well as Dr Jannes Venter from INSiAVA. Goosen is also studying and modelling the effect that the larger number of defects inherent in the polysilicon material may have on the device's reliability, degradation and operating lifetime. As part of his research, he is designing, manufacturing and characterising two-chip opto-isolators and vertically integrated opto-isolators. These opto-isolators may find use in low-bandwidth/low data rate applications, such as switched-mode power supplies.

INSiAVA

EXEMPLIFICATION OF UNIVERSITY-INDUSTRY TECHNOLOGY TRANSFER

INSiAVA (Pty) Ltd is a spin-out company of the University of Pretoria. It was founded in 2005 with the main aim of commercialising its silicon light emission technology. Today, INSiAVA is a leading fabless semiconductor company that specialises in the design and development of the world's most advanced integrated circuits for digital passive infrared smart sensors.

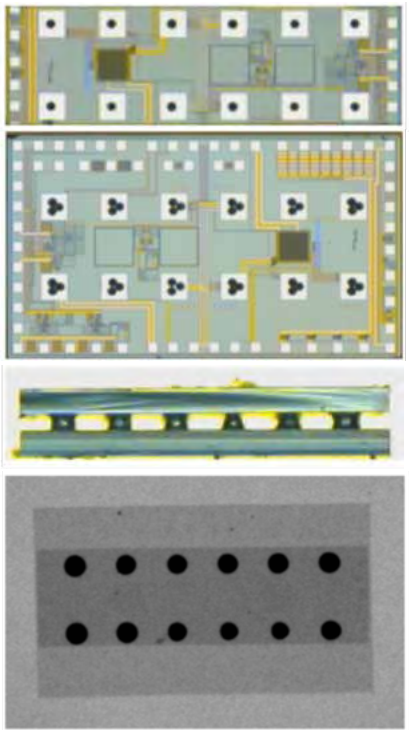


OPTICAL COMMUNICATION LINKS

Optical communication links were demonstrated up to data transfer speeds of 10 Mb/s and direct modulation speeds in excess of 1 GHz. Ultimately, the achievable data transfer rates are limited by the efficiency of the emitter. More complex detection techniques, such as avalanche photodiodes (APDs) and single-photon avalanche detectors (SPADs), may be implemented to alleviate the efficiency handicap. However, it comes at a cost of significant complexity, degrading the value proposition of using a cost-effective light emitter. The key takeaway from this applied research was that silicon light emitters have a good technology-application fit in low-bandwidth or low-data rate applications. One of the applications of interest in compliance with these requirements is that of an opto-isolator.

MICRODISPLAYS

INSiAVA's research and development (R&D) team has developed and manufactured several exciting microdisplays, from a 16 x 8-pixel, 128 x 96-pixel to a QVGA display. Pixel pitches ranging from 40 to 8 µm have also been successfully demonstrated. Utilising the integration potential of a CMOS, a 32 x 32-pixel microdisplay was developed, incorporating a full-frame buffer, easy-to-use serial peripheral interphase (SPI) and a built-in character set. This microdisplay is intended to be used to convey basic system information (e.g. on-board information displays, integrated near-to-eye displays, binoculars and toys). Unfortunately, the same efficiency handicap that limits the data rate in communication applications, also limits the achievable brightness of the microdisplays. This constrains the usability of CMOS microdisplays to low-light/night-vision applications where cost effectiveness is not the primary concern.



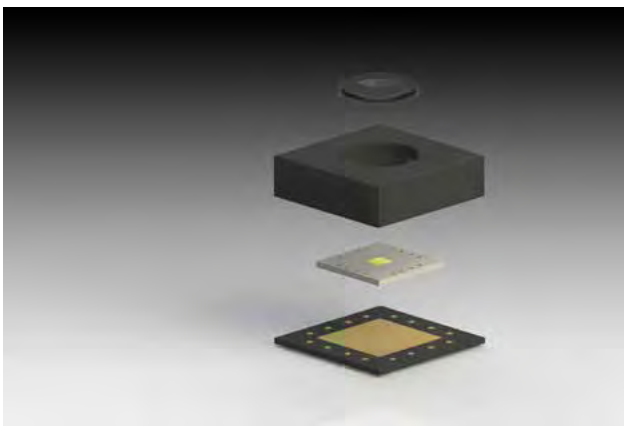
Top: Chip before assembly

Bottom: Chip before assembly

Side view: Chip after assembly

Top view: X-ray of chip after assembly

The construction of a two-chip opto-isolator



A proposed information display with built-in lens in a surface-mount land grid array package.

RECENT ADVANCES

INSiAVA recently developed a method with which the polysilicon layer/s inherent in all CMOS processes may be used to implement the silicon light emitter. Utilising the polysilicon layer as light-emitting material enables two key features: capitalising on crystallographic defects to enhance the light-emitting mechanisms and improve the efficiency; and decoupling the light emitter from the underlying bulk of the CMOS process.

Defects in the light-emitting material have long been identified and studied to play a significant role in the light-emission mechanisms. The polysilicon material has, by nature, many defects, due to the crystal boundaries and its interface with the surrounding field oxide. These defects are therefore intentionally utilised to enhance the device's efficiency.

Decoupling the light emitter from the bulk of the CMOS process allows more light to exit the top surface through back reflection from the silicon bulk itself. This amounts to a maximum possible light extraction efficiency increase of 20%. Additionally, decoupling the emitter from the underlying bulk allows the construction of a novel vertically integrated opto-isolator. Such an integrated opto-isolator promises superior coupling efficiency between the light emitter and detector, and may find use in low-voltage systems that require galvanic isolation.

The research to date shows a factor of 2–3 improvement in efficiency between the polysilicon emitters and bulk-based emitters implemented in the same CMOS process, while maintaining an operating voltage of below 5 V. The low operating voltage is a requirement for easy integration with surrounding circuits and systems, and forms an important part of the silicon light-emitter value proposition. Practically, this may result in more efficient communication systems (or higher data transfer rates), as well as brighter CMOS microdisplays.

Engineering, Built Environment and Information Technology: **A FUTURE-FOCUSED FACULTY**

The University of Pretoria's Faculty of Engineering, Built Environment and Information Technology (EBIT) is home to a generation of leaders and innovators who are dedicated to improving their lives, the lives of their families, their country and the world. It attracts high-quality students and staff, who actively contribute to their fields of specialisation.

Qualified professionals in engineering, built environment and information technology are assets to the economy of any country. They possess highly technical skills and process-thinking abilities. They are problem-solvers. As such, professionals in these fields make an important contribution, not only to their respective industries, but also to widespread social welfare. With its wide range of specialist fields, the Faculty develops a unique collection of critical skills through collaboration and a commitment to research excellence.

EBIT is a source of locally relevant and internationally competitive programmes, and is home to some of the University's exceptional researchers. It is organised into four schools:

THE SCHOOL OF ENGINEERING presents programmes in all the major engineering disciplines, with many specialisations offered at postgraduate level. It is ranked 352th out of more than 10 000 engineering schools in the field of engineering and technology.

THE SCHOOL FOR THE BUILT ENVIRONMENT offers the entire spectrum of programmes in this field, and prioritises close ties and alignment with the building industry. It places particular emphasis on the equitable and sustainable development of people.

THE SCHOOL OF INFORMATION TECHNOLOGY is a forerunner in the South African information technology (IT) environment. With its unique integration of the fields of computer science, informatics and information science, researchers benefit from an integrated approach, supported with modern laboratories.

THE GRADUATE SCHOOL OF TECHNOLOGY MANAGEMENT is the largest school of its kind in Africa, and offers the only Master in Project Management programme in Africa to be accredited by the Global Accreditation Centre for Project Management Education Programs of the Project Management Institute in the USA.

Innovation is the heartbeat of the Faculty. Its researchers are rising to the challenge of ensuring that they can make a significant contribution to society at large by focusing their research on topics that lead to real-world change.

EBIT is one of the few academic faculties in Africa to feature among the **top 550** in the world in five subject areas in the 2022 QS World University Rankings by Subject in the field of engineering and technology:

- **Chemical Engineering**
- **Computer Science and Information Systems**
- **Electrical and Electronic Engineering**
- **Mechanical and Aeronautical Engineering**
- **Mineral and Mining Engineering**

The Faculty's vision is to be a leading research-intensive faculty that contributes significantly to research and human capital development in the broad disciplines of engineering, the built environment and information technology. Strong links with industry and government are actively pursued, and have resulted in the establishment of 29 externally funded research chairs, which attract high-quality students and staff.

These include the following:

INDUSTRY CHAIRS

- Absa Chair in Data Science
- Anglo-American Chair in Pyrometallurgy
- Chair in Nuclear Safety and Security
- DRS Chair in Cybersecurity
- Eskom Chair in Plant Asset Management
- Exxaro Chair in Energy Efficiency
- Exxaro Chair in XR Technology
- Harmony Chair in Rock Engineering and Numerical Modelling
- Rand Water Chair in Business Management
- Rand Water Chair in Electrical Engineering
- Rand Water Chair in Water Utilisation
- SARChI Chair in Artificial Intelligence for Sustainable Development
- Sentech Chair in Broadband Wireless Multimedia Communication
- South African Council of Shopping Centres Chair
- MultiChoice Chair of Machine Learning
- Murray and Roberts Chair in Industry 4.0

CENTRES AND INSTITUTES

- African Centre of Excellence in Information Ethics
- Carl and Emily Fuchs Institute for Micro-electronics (CEFIM)
- Centre for Asset Integrity Management
- Centre for Connected Intelligence
- Centre for Electromagnetism
- Centre for New Energy Systems
- Centre for Pyrometallurgy
- Centre for Transport Development
- Industrial Metals and Minerals Research Institute (IMMRI)
- SAIW Centre for Welding Excellence
- Institute for Big Data and Data Science
- Institute for Technological Innovation
- Mining Resilience Research Centre

GET INSPIRED

WATCH
EBIT build up

Technology has launched a digital transformation process that extends beyond tools and processes. It impacts on individuals and organisations, resulting in the improved wellbeing of both people and the planet. It also enhances globalisation by removing physical barriers, and making it possible to work anywhere, anytime, on any device. Future-focused and transdisciplinary research is imperative to make sense of this new digitalised world.

WHILE TECHNOLOGY IS THE CATALYST FOR CHANGE, HUMANS ARE THE SUSTAINING FORCE. THIS MEANS THAT WE NEED TO DEVELOP NEW MINDSETS AND FIND NEW WAYS OF WORKING. EBIT IS A PLACE WHERE INDEPENDENT THINKERS AND THOSE EAGER TO DISCOVER AND CREATE NEW KNOWLEDGE THAT WILL MAKE A DIFFERENCE IN THE WORLD CAN EXCEL.

The Faculty has well-equipped teaching and research facilities, and superb laboratory facilities. Teaching is facilitated by a motivated team of committed and dedicated academics, supported by highly competent administrative staff members and student advisors, who work together to serve our students' best interests.

It furthermore has a progressive teaching and learning strategy in place to address several key priorities. This includes increasing overall module success rates, increasing minimum-time completion rates, transforming the curriculum, bringing about transformation through the curriculum, systematically monitoring the implementation of the hybrid model of teaching and learning, and improving the Faculty's international ranking through excellent teaching and learning practices.

The University's approach to teaching and learning embraces inquiry-based learning, hybrid learning and community-based learning. Key drivers to achieving the institutional teaching and learning goals include the centrality of the academic mission and the student-centredness of the University's offerings. Academics in the Faculty have started to implement award-winning projects to accelerate the transformation of teaching.

EBIT's research activities are on the forefront of innovation, and include topics such as disruptive technology, virtual and augmented reality, the Internet of Things, machine learning, additive manufacturing, green building, Artificial Intelligence, digitisation, Society 5.0, Big Data Science, smart grids, automation, smart cities and robotics. The research strategy is focused on the Faculty's research strengths, and encouraging research and innovation that is not restricted to finding solutions to challenges within a particular discipline only, but rather to developing initiatives that will have an impact locally, regionally and across the globe. Its six research focus areas[1] enable transdisciplinary research and have the potential to address challenges around the world.

The Faculty champions the University's work towards achieving the United Nations' Sustainable Development Goal (SDG) 9: Industry, Innovation and Infrastructure. In this regard, its state-of-the-art Engineering 4.0 Complex is positioning the University of Pretoria as a centre of excellence in smart transportation. It is the result of a partnership with the South African National Roads Agency Limited (SANRAL), the Council for Scientific and Industrial Research (CSIR) and York Timbers.

Engineering 4.0 shares its vast resources in technology and Data Science with all the University's facilities via Future Africa, the University's platform for developing transdisciplinary networks with the global research community.

The Engineering 4.0 Complex houses several laboratories, and research and training facilities, including a concrete laboratory, a timber laboratory and a training laboratory. It is also the site of SANRAL's National Roads Materials Reference Laboratory, where the independent reference testing of materials for the road construction industry will take place, as well as an accelerated pavement testing track, which entails a dedicated lane on the N4 into Pretoria that will be monitored to study data related to traffic, pavement design and road construction. This will support cost-effective and innovative pavement engineering for Africa's infrastructure development.

Through this initiative, the Faculty is well on its way to earning itself the reputation as the country's leading expert in smart transportation. Through its focus on the development of an integrated transportation system, its research is also concentrating on the reduction of energy consumption levels in transportation, maximising productivity in industry and creating a higher quality of life for the country's citizens.

1 Smart cities and transportation; energy; Big Data Science, ICT and technology, and innovation management; water and environmental engineering; minerals and materials beneficiation; the Fourth Industrial Revolution.

Enabling transdisciplinary research

The Faculty's unique combination of engineering, built environment and information technology makes it ideally positioned to perform transdisciplinary research.

Transdisciplinarity can be described as an integrative process, where scholars and practitioners from different disciplines work together to develop and use novel conceptual and methodological approaches. Participants bring the wealth of knowledge about their disciplines into a new arena, transcending disciplinary boundaries.

The focus of the Faculty over the past five years has been to establish cross-cutting research focus areas.

Its identification of six research focus areas was based on existing strengths and expertise. This research was mostly interdisciplinary in nature. However, the alignment of these research focus areas with the United Nations' Sustainable Development Goals (SDGs) has served as a catalyst to promote multidisciplinary research.

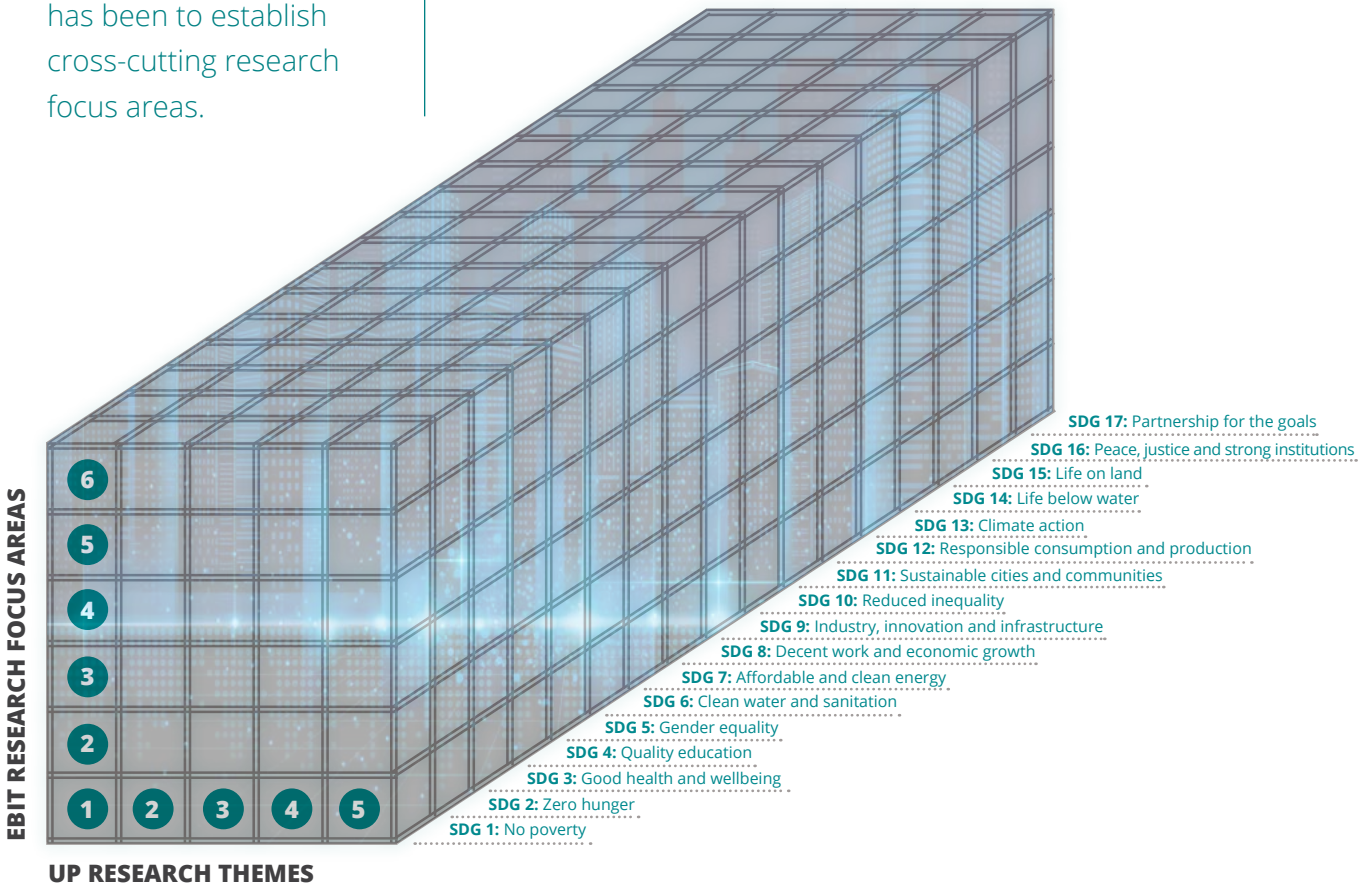
The Faculty's research agenda for the next five years is moving towards transdisciplinary research, which will enable it to develop critical mass and synergies at the intersection of the Faculty's research focus areas, the University's institutional research themes and the SDGs.

EBIT RESEARCH FOCUS AREAS

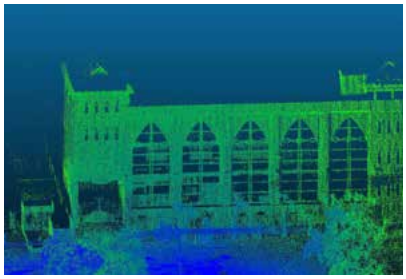
1. Smart cities and transportation
2. Big Data science, information and communication technology (ICT), and technology and innovation management
3. Water and environmental engineering
4. Energy
5. Minerals and materials beneficiation
6. The Fourth Industrial Revolution

UP RESEARCH THEMES

1. Connected Africa
2. Fair and sustainable economics
3. Natural resources and environment
4. Science, technology and innovation
5. Democracy, inequality, social justice and cultural diversity
6. Plant, animal, human life and well being



FLAGSHIP TRANSDISCIPLINARY PROJECTS



THE HATFIELD DIGITAL TWIN CITY INITIATIVE

The Hatfield Digital Twin City initiative has real-world application with multiple stakeholders. The Digital Twin environment is a collaborative data-driven platform that allows for a multitude of research and experimentation opportunities to occur.

This project focuses on the ten square-kilometre area that forms the Hatfield Metropolitan Development Node. This includes, among others, the University of Pretoria's Hatfield Campus, university-owned residential assets and the Future Africa Campus.

The Hatfield Digital Twin City provides opportunities for transdisciplinary work, and acts as a testbed for the development of smart applications that support improved service delivery, more efficient use of resources and building urban resilience.

For example, for facilities management and the civil infrastructure environment, the focus is on the development of continuous responsive networks, where real-time data informs maintenance and management decisions on both the local and national scale. The success and new possibilities from such collaboration could lead to a longer-term vision to establish a centre of excellence for African digital and smart cities, hosted and anchored in the University of Pretoria.

SMART TRANSPORTATION FOR THE FUTURE

Transportation research at the Engineering 4.0 Complex focuses on real-world problems through a so-called transportation hub. The goal is to directly contribute to the creation of a Connected Africa in the future.

Long-range sensor networks support data collection for a suite of environmental and infrastructure-related parameters, including air quality, temperature and humidity.

The project also supports research into smart alternative transportation issues, such as the use of unmanned aerial vehicles in support of data collection in areas where traditional transportation options are compromised.

This includes a focus on the use of sensors in the agricultural sector to evaluate the interlinks between transportation and agriculture produce quality. Through sensor networks and intelligent transportation, researchers are also able to investigate the monitoring of the health of people, places and animals.

This research focus area specifically integrates with the University of Pretoria's wider research theme for both a connected Africa and the health of people and places.

ADDITIVE MANUFACTURING FOR ELECTRONIC SYSTEMS

The Faculty promotes initiatives in ICT, and technology and innovation management, as well initiatives in the Fourth Industrial Revolution (4IR) through its research focus areas. In this regard, the Faculty's flagship project in additive manufacturing for electronic systems will establish new electronic system design techniques and reliable packaging strategies that best exploit modern additive manufacturing technologies to create a fair and sustainable economic environment for small enterprises in the electronics sector.

These methodologies will contribute to the University's institutional focus on science and technology innovation, as well as its focus on the health of people and places. Specifically, this will be done by harnessing the transdisciplinary domains of health, water, wireless communication and climate science to realise novel solutions in optical, electrochemical, mm-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 (SLM) of metals. Such research aligns well with SDG 9 of the United Nations (Industry, Innovation and Infrastructure) through consideration of 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, it is possible to investigate the use of materials and processes that facilitate sustainable and responsible production, in particular waste reduction, through transdisciplinary collaborations.

Future-focused academic departments

The Faculty of Engineering, Built Environment and Information Technology (EBIT) at the University of Pretoria is the only faculty at a higher education institution in South Africa that offers the unique combination of these three fields. This places the Faculty in a position to conduct exceptional multidisciplinary research to address relevant challenges in society. EBIT's 14 specialised academic departments focus on producing future-ready graduates and impactful research.

SCHOOL OF ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

Chemical engineering contributes to various aspects of human life, ranging from the production of food and energy to the provision of clean water and sanitation, the provision of shelter and health care, and other value-added commodities using chemical, biological and physico-chemical processes. Sadly, unintended by-products of these processes have caused significant damage to human lives and the ecosystem. The training provided in the Department of Chemical Engineering equips our graduates with the required skills that could be 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 using green and sustainable processes. Our researchers work in the following areas:

- Sustainable environment and water utilisation processes
- Sustainable and efficient energy processes
- Advanced and applied materials
- Process synthesis, modelling and optimisation

TOP 300 IN THE WORLD FOR CHEMICAL ENGINEERING
(2021/22 QS World University Subject Rankings)

DEPARTMENT OF CIVIL ENGINEERING

The current research of EBIT's Department of Civil Engineering impacts on the delivery of services to the public through the development of optimal road maintenance and water reticulation networks. This, combined with improved geotechnical analysis techniques, construction material improvements and structural analyses, impacts directly on the quality of life of the public. Our researchers work in the following areas:

- Smart cities and transportation
- Transportation development
- Railway engineering
- Railway safety
- Pipelines
- Hydropower
- Geotechnical centrifuge testing and geotechnical engineering
- Concrete materials and structures
- Civil infrastructure materials
- Structural testing
- Urban runoff
- Road pavements and materials

DEPARTMENT OF ELECTRICAL, ELECTRONIC AND COMPUTER ENGINEERING

The Department produces world-class engineers in electrical, electronic and computer engineering. Many of its graduates are leaders in engineering and also top inventors and entrepreneurs in the world, and many of its lecturers are world-class researchers. Close contact with industry, government and other institutions through contract research and consultation activities adds value to a postgraduate degree in any of our three disciplines. Our researchers work in the following areas:

- Advanced sensor networks
- Bioengineering
- Control systems
- Electromagnetism
- Electronics and microelectronics
- Energy systems
- Intelligent systems
- Power systems
- Telecommunications and signal processing

NO. 1 IN SOUTH AFRICA FOR ELECTRICAL AND ELECTRONIC ENGINEERING (THREE YEARS RUNNING) ***(2021/22 QS World University Subject Rankings)***

DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

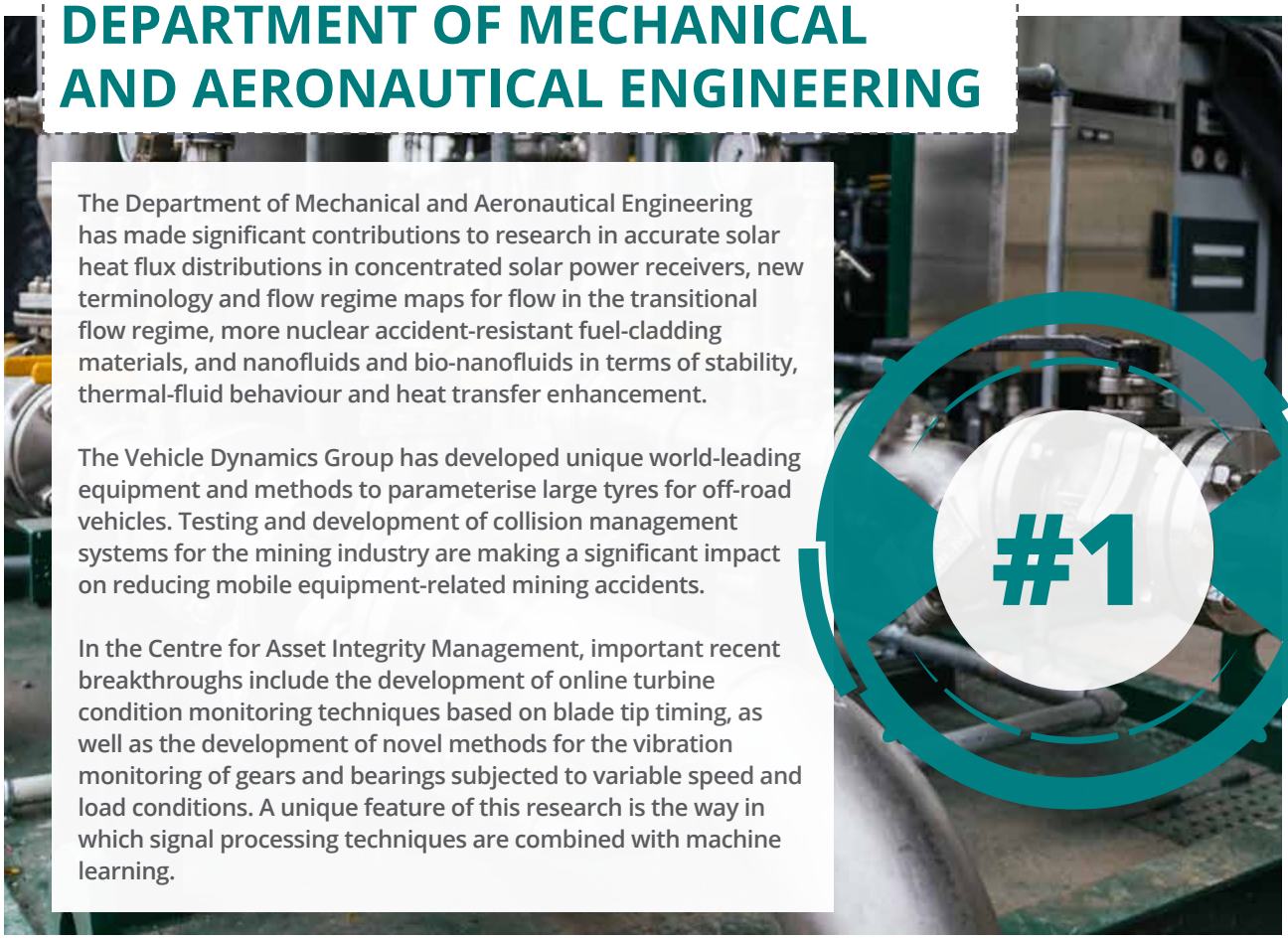
The Department of Industrial and Systems Engineering works towards the integration of contributions from all engineering disciplines into a functional and cost-effective product by using systems knowledge and understanding. It focuses on supply chain management, enterprise engineering and optimisation, and collaborates with the Centre for Transport Development.

Industrial engineering is an extensive field of study since it consists of many diverse scientific disciplines with interfaces to various fields of study, from the sciences to engineering and management. It is able to integrate the contributions of all the other engineering disciplines into a final, functional and marketable product, at the lowest possible cost.

Our researchers work in the following areas:

- Supply chain design methodologies
- Supply chain modelling and optimisation
- Intelligent logistics
- Humanitarian logistics
- Reverse supply chains
- Enterprise engineering
- Transportation development
- Large-scale, agent-based transportation modelling
- Commercial vehicle behaviour and risky driver behaviour
- Waste collection optimisation
- Data analytics
- Reliability engineering

DEPARTMENT OF MECHANICAL AND AERONAUTICAL ENGINEERING



The Department of Mechanical and Aeronautical Engineering has made significant contributions to research in accurate solar heat flux distributions in concentrated solar power receivers, new terminology and flow regime maps for flow in the transitional flow regime, more nuclear accident-resistant fuel-cladding materials, and nanofluids and bio-nanofluids in terms of stability, thermal-fluid behaviour and heat transfer enhancement.

The Vehicle Dynamics Group has developed unique world-leading equipment and methods to parameterise large tyres for off-road vehicles. Testing and development of collision management systems for the mining industry are making a significant impact on reducing mobile equipment-related mining accidents.

In the Centre for Asset Integrity Management, important recent breakthroughs include the development of online turbine condition monitoring techniques based on blade tip timing, as well as the development of novel methods for the vibration monitoring of gears and bearings subjected to variable speed and load conditions. A unique feature of this research is the way in which signal processing techniques are combined with machine learning.

#1

NO. 1 IN SOUTH AFRICA FOR MECHANICAL ENGINEERING
(2022 Shanghai Rankings)

DEPARTMENT OF MATERIALS SCIENCE AND METALLURGICAL ENGINEERING

The research of the Department of Materials Science and Metallurgical Engineering aims to achieve optimised industrial processes and products, be it in minerals processing, the extraction of valuable metals or the manufacture and fabrication of advanced alloys and products. Such process and product innovations are frequently aimed at the realities of South African plants and feedstocks, and result, among others, in the production of high-quality products through the innovative use of existing plant or available minerals. With regard to digital (4IR) manufacturing, research carried out in the Department aims to use laser-based and additive manufacturing technologies to produce innovative cutting-edge products. Our researchers work in the following areas:

- Minerals processing, with a particular focus on gravity separation and fines recovery
- Pyrometallurgy and pyrometallurgical modelling, with a specific focus on platinum group metals
- Hydrometallurgy, focusing on gold recovery and the development and recovery of next-generation battery materials
- Refractory materials
- The thermomechanical simulation of steel processes, from micro-alloyed to stainless steels
- Physical and mechanical metallurgy
- Welding engineering of advanced materials and repair of service-degraded alloys
- Additive manufacturing and laser processing
- Risk-based and forensic materials engineering
- The development of alloys resistant to hydrogen degradation
- The characterisation of materials degradation and corrosion, with a view to optimising resistance to degradation
- Light metals characterisation and development, including characterisation of environment-based degradation

DEPARTMENT OF MINING ENGINEERING

The Department of Mining Engineering has contributed greatly to the South African mining industry by providing it with world-class leaders in mining engineering. The Department focuses on numerical modelling and rock engineering, rock-breaking, environmental management, mine design and mine management, as well as cutting-edge technological innovations brought about by the Fourth Industrial Revolution. In addition, the Department places great emphasis on the development of soft skills and leadership in line with the demands of the industry. Our researchers work in the following areas:

- Mechanisation and automation
- Rock-breaking and explosives engineering
- Management and leadership
- Rock engineering
- Extended reality (XR) technology

#33

NO. 33 IN THE WORLD FOR MINERALS AND MINING ENGINEERING
(2021/22 QS World University Subject Rankings)

DEPARTMENT OF ARCHITECTURE

The Department of Architecture offers professional and research postgraduate programmes in the complementary fields of architecture, interior architecture and landscape architecture. Following an ecosystemic approach, the three programmes and our research focus areas are mutually supportive and often integrated in transdisciplinary research projects with partners in industry, government and local communities. The Department's research focus areas are built around the objective of creating resource-efficient, resilient and regenerative built environments, which respect both the landscape and cultural context, improving ecological integrity, while contributing to a sense of meaningful place and social-ecological wellbeing within rapidly changing local and global contexts. Our researchers work in the following areas:

- Architectural education
- Smart cities
- Urban resilience (with a focus on food security, biodiversity and climate change adaptation)
- Designed ecologies
- Heritage and cultural landscapes
- Participatory architectural research and design as an instrument of urban citizenship
- Identity and meaning-making in place and space

TOP 200 IN THE WORLD FOR ARCHITECTURE AND BUILT ENVIRONMENT
(2021/22 QS World University Subject Rankings)

DEPARTMENT OF CONSTRUCTION ECONOMICS

The Department of Construction Economics conducts research in the fields of construction management, quantity surveying and real estate. Our researchers work in the following areas:

- Project and facilities management
- Decision-making, real estate, feasibility studies, shopping centres
- Construction cost databases, escalation and indices, life cycle costing and standard documentation in construction
- Profiling and wellbeing in the built environment
- Green buildings
- Short-term building insurance and building cost modelling
- Contracts and Property Law
- Building information management, and virtual and augmented reality applications in construction
- Construction innovation and construction procurement
- Teaching, learning and human capital in the built environment
- Quantity surveying, public-private partnerships, 4IR, automation and robotics in construction, change management
- Future-proofing the real estate/construction industry, mobile applications in the property industry, nanotechnology in the built environment, blockchain in the property industry, drone technology in property development, sustainability and green building
- Cost prediction, Artificial Intelligence strategies in quantity surveying
- Real estate, green buildings and life cycle costing

DEPARTMENT OF TOWN AND REGIONAL PLANNING

The Department of Town and Regional Planning is a research-driven consulting partner of a wide range of state and non-state entities. These range from The Presidency to provincial governments, research councils and municipalities. The research has contributed to numerous legal and policy preparation and review processes. Our researchers work in the following areas:

- Reconsidering planning values, ethics, thought and language to facilitate radical spatial transformation
- Radical and innovative new planning methods to facilitate radical spatial transformation
- Planning in the context of climate change, plurality, scarcity, inequality and globalisation
- Different, diverse and novel understandings and interpretations of planning epistemologies and related philosophies and research approaches, styles and methods

SCHOOL OF INFORMATION TECHNOLOGY

DEPARTMENT OF COMPUTER SCIENCE

The Department of Computer Science fulfills a vital role within the broader Information Technology spectrum in South Africa, as well as internationally. Our main objective is to explore and research the scientific basis of new technologies. We furthermore promote the proliferation of reliable, robust and innovative computing and information technologies into the IT industry in South Africa.

Excellence in computer science education, the development of internationally and nationally recognised research initiatives and strong industry collaboration are the driving factors underpinning the Department's success.

Our researchers work in the following areas:

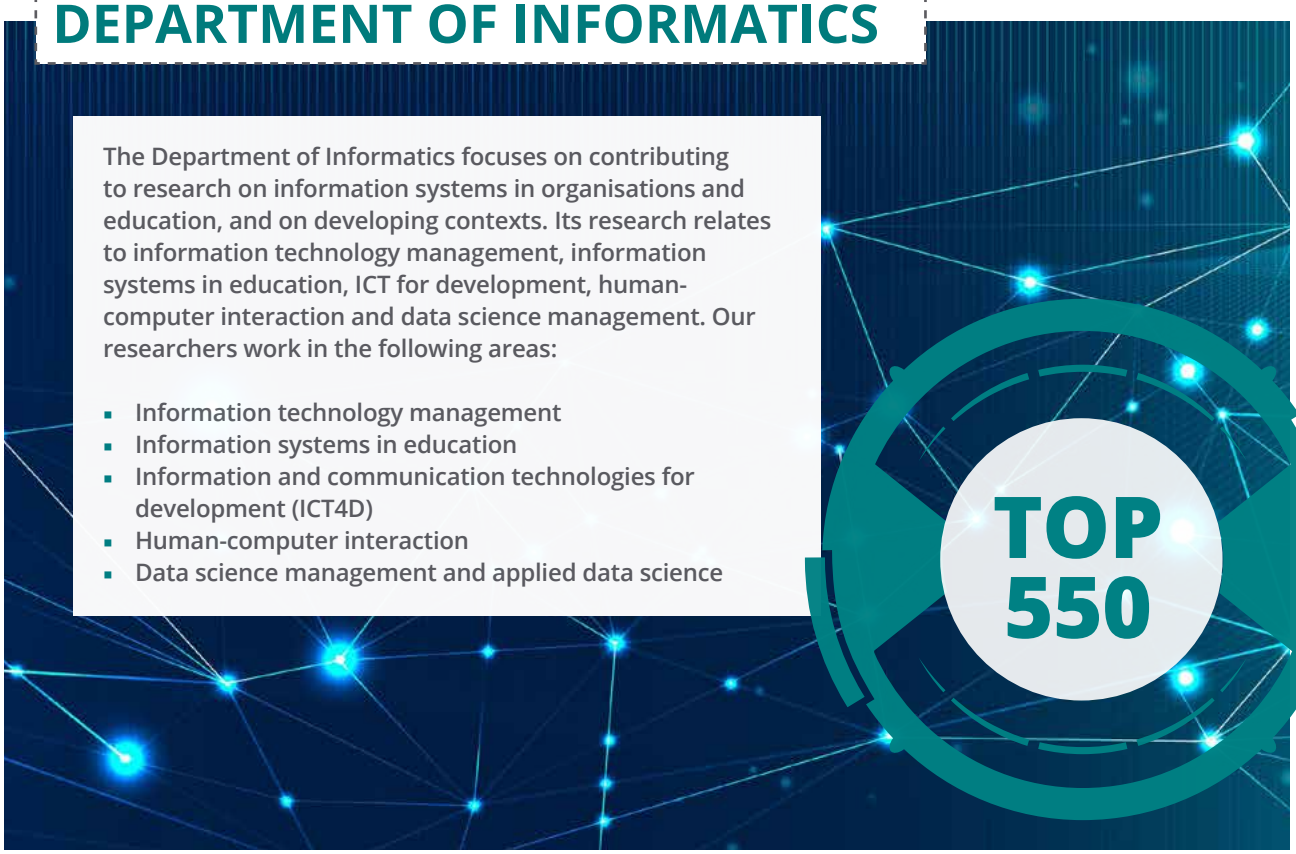
- Artificial Intelligence
- Computer and information security
- Digital forensics
- Computer science education didactics and applications
- System specifications and formal methods
- Software engineering and software architecture
- Data science

TOP 550 IN THE WORLD FOR COMPUTER SCIENCE AND INFORMATION SYSTEMS
(2021/22 QS World University Subject Rankings)

DEPARTMENT OF INFORMATICS

The Department of Informatics focuses on contributing to research on information systems in organisations and education, and on developing contexts. Its research relates to information technology management, information systems in education, ICT for development, human-computer interaction and data science management. Our researchers work in the following areas:

- Information technology management
- Information systems in education
- Information and communication technologies for development (ICT4D)
- Human-computer interaction
- Data science management and applied data science



TOP 550 IN THE WORLD FOR COMPUTER SCIENCE AND INFORMATION SYSTEMS
(2021/22 QS World University Subject Rankings)

DEPARTMENT OF INFORMATION SCIENCE

The Department of Information Science is concerned with how information is generated, organised, circulated and used in society. In today's knowledge economy and Fourth Industrial Revolution, information is a currency that is shared in written, audio and visual form, and in print and digital formats.

The Department houses programmes in the following three unique information-related fields:

Information science
Multimedia
Publishing

Our researchers work in the following areas:

- Knowledge management and competitive intelligence
- Information processes
- Meta-context of information
- Book and publishing studies
- Information ethics
- Virtual reality and augmented reality
- Interaction design and user experience design
- Game studies, serious games and gamification

GRADUATE SCHOOL OF TECHNOLOGY MANAGEMENT

The Graduate School of Technology Management (GSTM) houses the Department of Engineering and Technology Management. In this department, a strong focus is placed on high-quality research and excellent teaching and education. Research ensures relevance to the market in terms of increased national and international competitiveness, optimising product life cycles, technology transfer and positioning technological abilities within the international context. Our researchers work in the following areas:

- Technology and innovation management
- Project management
- Engineering management
- Energy and systems analysis

Engineering management at master's and doctoral level

Engineering management is the application of technology and other resources in engineering to provide products, systems and services for financial gain in the marketplace. The master's programmes aim to provide relevant management education to the practising engineer/scientist who is active in primarily technology-based enterprises. They focus on the process of value creation, i.e. product and system development, production and operations, and the maintenance of systems and related services in a business context. The question of strategically positioning the enterprise in terms of technological capability is paramount. These study areas distinguish our programmes from other postgraduate and business management degrees. At doctoral level, researchers can join the Engineering Management Research Group, which focuses on systems engineering and related fields.

Project management at master's and doctoral level

Project management continues to be one of the most sought-after skills in the modern professional society. The master's programmes empower graduates to apply scientific thinking and advanced interdisciplinary skills to manage projects over the project life cycle. They facilitate learning the fundamentals of project management so that learners can identify, develop, implement and close projects. They view projects as strategic initiatives with modules that consider the environment, people and the realisation of benefits. At doctoral level, researchers can join the Project Management Research Group, which focuses on project communication, agile and services project management, portfolio management, project knowledge management, project governance, project readiness and methodologies, project risk management, and organisational project management.

Technology and innovation management at master's and doctoral level

The technology and innovation management programmes introduce students to the aspects of technology that support the long-term goals of innovation and productivity within an organisation. The focus is on the introduction of new products, processes, services or systems to an organisation through the economic development and transfer of knowledge on the choice and application of technology and processes to secure the organisation's growth, competitiveness and sustainability. At doctoral level, researchers can join the Technology and Innovation Management Research Group, which focuses on technology and knowledge management, innovation management, technological entrepreneurship and commercialisation, technology and innovation strategy and future studies, as well as science, technology and innovation policy.

Society 5.0 and human-centred research: Future perspectives

Prof Alta van der Merwe

TECHNOLOGY MUST BE USED TO BENEFIT MANKIND, AND NOT TO THE DETRIMENT OF SOCIETY.

Humanity has experienced unprecedented technological developments during the past few decades. Few can argue that the lives we live and societies we are part of are undergoing vast, often unexpected adjustments and transformation. More and more voices are requesting researchers to rethink the relationship human beings have with technology in this new world.

Society 5.0 is the term that has emerged to describe the new society that is the result of the high convergence between cyber space and physical space, where economic advancement is balanced with the resolution of social problems by providing goods and services that address many latent needs, regardless of location, age, sex or language.

The concept was first introduced in 2015 by the Japan Science and Technology Agency, and forms part of that country's Fifth Science and Technology Plan. More recently, the socio-technical research communities have adopted the term to investigate the impact technology has on our daily lives and on society at large.

However, despite the relevance and importance of Society 5.0 in the socio-technical landscape, there is no coherent vision or research agenda that guides research and the adoption of Society 5.0. This is something that researchers in the University of Pretoria's Department of Informatics is set on addressing.

The research of Prof Alta van der Merwe, Deputy-Dean of Teaching and Learning in the Faculty of Engineering, Built Environment and Information Technology, together with research colleagues, Prof Hanlie Smuts, Head of the Department of Informatics, and Prof Aurona Gerber, a professor in the Department, is focused on developing a conceptual overview of Society 5.0. The landscape model that was developed was subsequently used as a baseline to develop a roadmap and research agenda for Society 5.0 studies.

Initial investigations indicated the inclusion of very diverse topics into different definitions and visions of Society 5.0. According to Prof Van der Merwe, 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.

How will this new world differ from the technological age known as the Fourth Industrial Revolution (4IR) or Industry 4.0?

We currently live in a society in which knowledge and information are used without sharing. In contrast, in Society 5.0, concepts that developed in the 4IR, such as the Internet of Things (IoT), will connect all people: data, information and knowledge will be shared, and new value contributions will be possible.

Prof Van der Merwe and her colleagues believe that Society 5.0 will overcome social disparities regarding access to goods. Drones will be used for the distribution of essential medical supplies, for example, to 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 based on the findings.

In 2019, Nakamura Michiharu, senior advisor to the Japan Science and Technology Agency, linked the vision of Society 5.0 to the United Nations' Sustainable Development Goals (SDGs). SDG 4, for example, 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 became highly pertinent during the worldwide lockdown periods brought about by COVID-19, when teachers and students had to adapt to remote learning.

"Society 5.0 is still a new concept," explains Prof Van der Merwe. Within existing literature, definitions and perspectives differ substantially, which motivated the research team's goal of establishing an overview of Society 5.0 with an associated roadmap and research agenda.

Two approaches were used to develop the conceptual overview: a social network analysis of the use of the term "Society 5.0" on Twitter to identify the communities and communication around Society 5.0, followed by content analyses of two document repositories: a set of academic publications and a set of articles in the popular press on Society 5.0.

The team's research found that the term Society 5.0 is not well adopted on Twitter, with very few detectable conversations or communities. When interactions are observed, it is usually around events advertised, and usually in Japan or Indonesia. However, there are many discussions, communities and interactions surrounding topics related to Society 5.0. This emphasises the need for a cohesive vision and landscape overview about what Society 5.0 entails in order to set a research direction and agenda.

Emerging themes were detected from the academic and popular press datasets that were analysed. When these themes were combined, the researchers were able to identify several key concepts that could be incorporated into a model of Society 5.0.

Prof Van der Merwe explains that the concept of Society 5.0 is linked to the theme of flexible futures, which is particularly pertinent within the context of reimagining teaching and learning in higher education. "Technology must be used to benefit mankind, and not to the detriment of society." In domains such as education, health and medicine, for example, technology can create opportunities that will improve livelihoods. In this way, technology can enable and serve human beings, instead of people serving technology, which was the focus of Industry 4.0.

The overarching concept of Society 5.0 is humanising technology. The foundational concepts are data and connectivity. Following growth in these foundational concepts, increasingly more technologies are enabled that can be used to make people's lives easier. Such technologies include elements of cyber space, as opposed to the physical space: Artificial Intelligence (AI), IoT and machine learning.

Through AI, machine learning and the use of Big Data, machines learn to recognise certain human preferences, and thereby learn to serve mankind. In the case of intelligent security systems, for example, technology learns to recognise threats, while in the case of intelligent tutor systems, technology learns to recognise prior knowledge, and in machine translation systems, technology learns to recognise patterns.

The impact of Society 5.0, with all its different aspects, not only presents a technical challenge, but also significantly changes organisations' structures and business processes. "In the past, technology was used to perform tasks," explains Prof Van der Merwe, "but with Society 5.0, the emphasis has changed, where the tasks now performed by machines must be able to benefit mankind and improve efficiency, while not being intrusive."

In the process of humanising technology, technology should not be a point of friction between products and people. Designers and software developers need to be more human-oriented to help

users streamline, simplify, evaluate, filter and better understand human needs, emotions and behaviour. As a human-centred approach, Society 5.0 will use technology to enhance the way we live, while it will be interwoven into everything we do. It will also be functional and improve service delivery.

Considering the different elements that emerged from the analysis, it is clear that Society 5.0 is still in its infancy. There is often confusion about exactly what it entails and how it can contribute to existing research being done in a field such as information systems. As the University of Pretoria is currently at the forefront of this emerging field, it is important to develop critical mass in research related to Society 5.0. Some emerging questions that are being considered include the following:

- What are the different technologies, technology themes, and integration and relationships between technologies that will influence the future of Society 5.0?
- How can technology be humanised, given the vision of Society 5.0?
- What is the impact of technology on society as a whole?
- What is the role of human beings in an advanced Society 5.0?
- What are society's considerations for Society 5.0 (for example, ethics, governance, individual rights and responsibilities)

Informatics research team delivers best paper at DESRIST 2022

A paper delivered by three researchers in the Department of Informatics, Prof Alta van der Merwe, Prof Hanlie Smuts and Prof Aurona Gerber, together with an associate from the University of St Gallen, Switzerland, Prof Robert Winter, received the award for the best paper at the 17th International Conference on Design Science Research in Information Systems and Technology (DESRIST).

The theme of the conference, which was held at the Mama College of Business in St Petersburg, Florida, USA, from 1 to 3 June 2022, was "The transdisciplinary reach of design science research". The paper they delivered, titled " 'Designing' design science research – a taxonomy for supporting study design decisions", formed part of the session on education and design science research. This was also the first time that they had presented a paper at this prestigious international conference.

Prof Aurona Gerber, Prof Hanlie Smuts and Prof Alta van der Merwe

According to the authors, the design science research (DSR) paradigm is highly relevant to the discipline of information systems because DSR aims to improve the state of practice and contribute design knowledge through the systematic construction of useful artefacts. Since study designs can be understood as useful artefacts, DSR can also contribute to improving the conceptualisation of a research project.

Prof Van der Merwe and Prof Gerber also chaired two of the sessions at the conference. In addition, Prof Van der Merwe served as one of the two conference chairs, while Prof Gerber served as one of the three programme chairs.

An exciting announcement is that DESRIST 2023 will be hosted at the University of Pretoria.

Tweets provide insight into the behaviour of social media influencers

Prof Aurona Gerber

Traditional forms of media used to communicate with society have changed over the years. Today, social media has become a valuable source of information. This became particularly evident during the riots that occurred in South Africa in July 2021, which had allegedly been instigated by Twitter messages under **#SouthAfricaIsBurning**. This gave rise to subsequent anarchy and looting, most notably in Gauteng and KwaZulu-Natal.

This observation emphasised the need to understand social media networks, conversations and communities, particularly as the alleged instigators of the looting were arrested based on their social media activity, specifically their use of Twitter. A study was therefore launched in the Department of Informatics to detect the social network structures and conversation patterns that were identified in Twitter datasets surrounding the political events in South Africa during 2021. The tool that was used to do this was social network analysis (SNA).

Social network analysis offers unique opportunities to study social networks, particularly as they manifest on social media platforms in our modern digital society. Social communities within complex societies are often distinguished by their social interactions. These interactions can range from simple conversations between family members and friends, to complex interactions that represent the flow of money, information or power.

Twitter is a microblogging platform that is characterised by the fast distribution of news. It is also used for social mobilisation, and is particularly popular for expressing political and controversial opinions. Twitter users can retweet a tweet, reply on a tweet, or mention a tweeter. These interactions, as well as the tweets, can be mined to detect how communities organise themselves online, as well as to identify conversation patterns between users and groups.

Twitter's application programming interface provides access to a valuable source of conversational data, which can be used for SNA. This can be particularly valuable when it comes to investigating political conversations and communities.

An important element in understanding societal interactions is the way in which communities form. Studies on the use and influence of the internet, technology and social media in society identify social media as one of the most significant means of communication in our digital society. It also plays an important role in determining people's views and opinions.

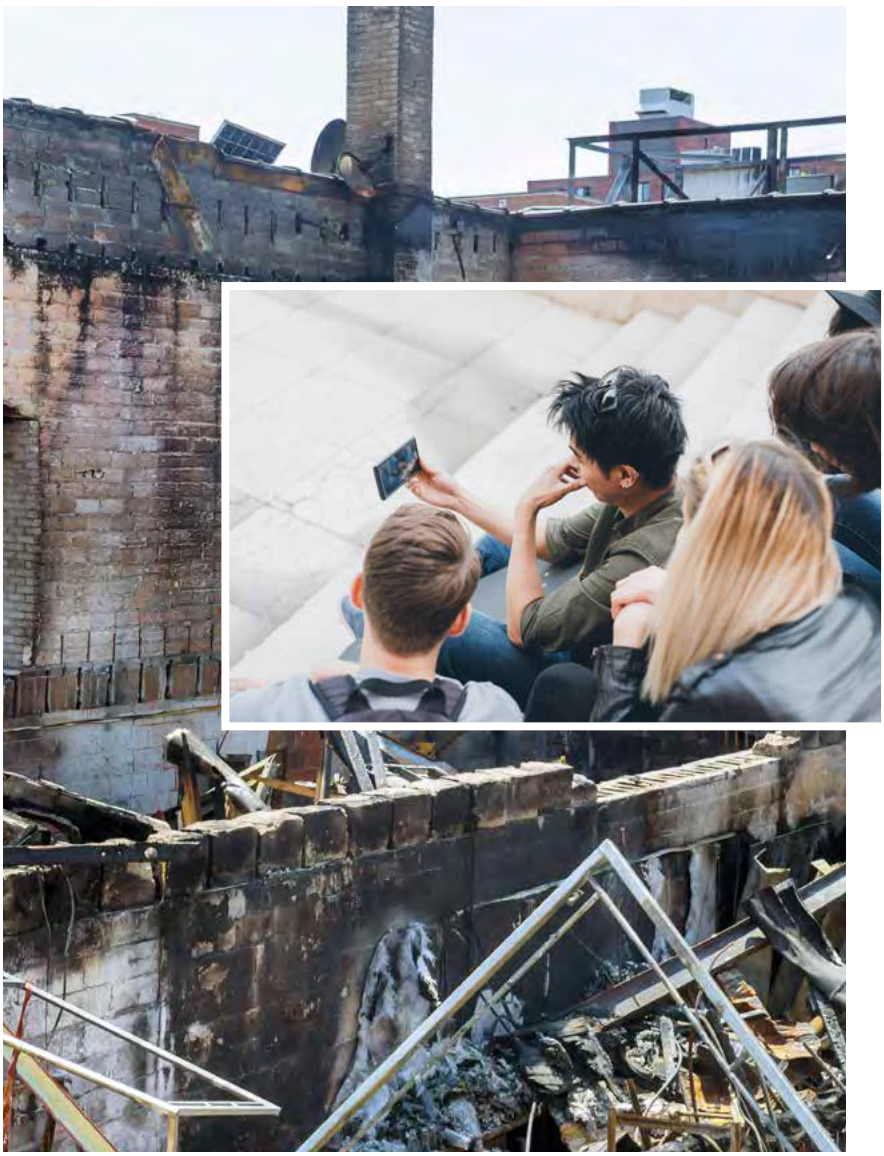
Social network analysis has emerged as a distinct research field to study conversations and communities. It is defined as the analysis of social (media) structures using network and graph theory. A set or group of social actors that interact create a complex network that can be studied to gain insight into the relationships between individuals and groups within societies.

When one studies social networks, the interactions and relations between the actors are considered, and not the properties of the actors themselves. The identification of clusters, communities or groups, given the interactions of actors, is an important objective of SNA, and groups are detected by analysing the interactions within a group, as well as the interactions between different groups or clusters. Understanding how online communities form and communicate allows one to interpret the flow of information and opinions, and to identify notable influencers. It can also provide useful insights into the dynamics of political communities. This is particularly important when it comes to gathering evidence of collective action observed globally, such as the action that resulted in such turmoil in South Africa in 2021.

By means of SNA, archetypal conversation patterns were detected using Twitter data. Once distinct conversation patterns had been identified in the datasets collected, certain information could be derived on specific political events in South Africa.

The group members' interactions with the other members of the social media community through the formation of networks was analysed to identify six distinct archetypical conversation patterns:

- The members rely on the group for information, but do not interact with each other by replying to or forwarding tweets or hashtags (the polarised crowd)
- The members have interactive conversations, even arguments, and exchange ideas and opinions. This is evidenced by the sharing of hashtags between groups (the tight crowd)
- The members only share information about well-known brands, topics, services or celebrities. Although the groups are small and interconnected, there is limited exchange of ideas (the brand clusters)
- The members form communities of medium-sized groups or hubs, which each have their own audience, influencers and sources of information (community clusters)
- The members participate in a network that resembles a broadcast information flow, typical of news distributed by a media outlet, influencer or agenda setter. Although the members are connected to the hub or centre of communication, no conversations about the topic take place (the broadcast network)
- The members participate in both incoming and outgoing information flow. This indicates responses from the hub to the spokes (the support network)

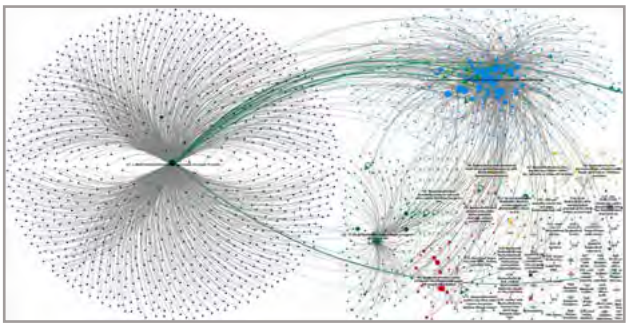


These conversation patterns provide a mechanism to understand social media communities and their conversations, and offer a unique opportunity to gain insight into the Twitter data surrounding specific political events in South Africa.

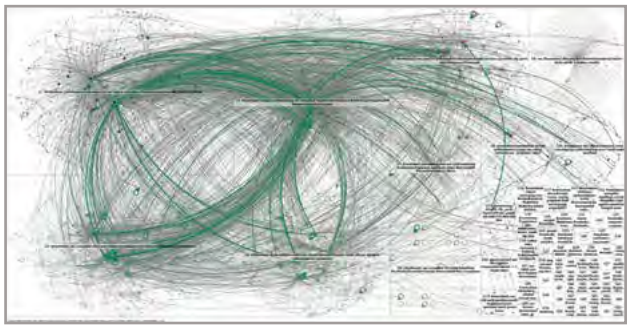
UNDERSTANDING HOW ONLINE COMMUNITIES FORM AND COMMUNICATE ALLOWS ONE TO INTERPRET THE FLOW OF INFORMATION AND OPINIONS, AND TO IDENTIFY NOTABLE INFLUENCERS. IT CAN ALSO PROVIDE USEFUL INSIGHTS INTO THE DYNAMICS OF POLITICAL COMMUNITIES. THIS IS PARTICULARLY IMPORTANT WHEN IT COMES TO GATHERING EVIDENCE OF COLLECTIVE ACTION OBSERVED GLOBALLY.

The following datasets were collected and analysed:

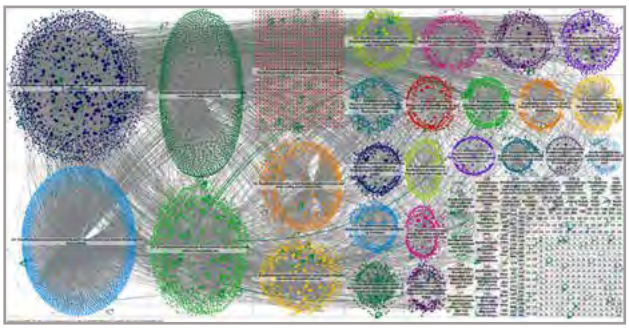
- **Tweets using #PutSouthAfricaFirst at the beginning of May 2021.** This hashtag was key in the political landscape during this period due to xenophobia discussions. It served as an example of a broadcast conversation pattern.



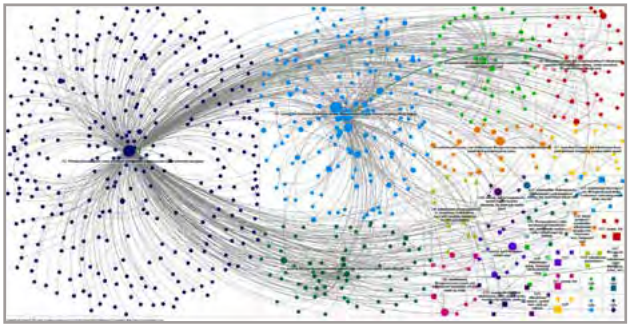
- **Two datasets under #VoetsekANC.** The first dataset was collected in the period around 24 August 2020, following the frustration experienced by South Africans after more than four months of lockdown, the perceived ineptitude of the government to handle the COVID-19 pandemic, and the constant emergence or allegations of corruption. The Twitter community constantly urged each other to use the hashtag every Friday, on the so-called #VoetsekANCFriday. As a result, a second dataset was collected eight months later in the period around 4 May 2021. The first dataset served as an example of a tight crowd conversation pattern, while the second dataset represented a community cluster.

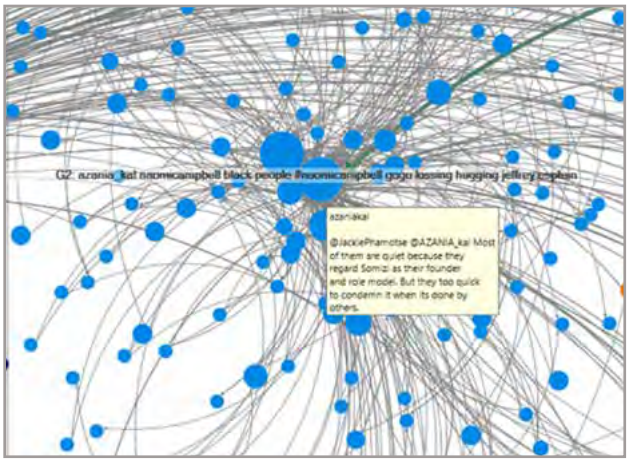


- **Twitter data surrounding the violent protests and looting in Gauteng and KwaZulu-Natal under #SouthAfricaIsBurning in July 2021.** Although it initially represented a community cluster pattern, this data later revealed a tight crowd pattern. This could be due to the topic, as news about the unrest was distributed quickly between groups. Even though groups have their own communities, breaking news would be shared between groups.



- **A dataset collected in early August 2021 under @TellUnknown or @AZANIA_kal, the Twitter accounts of two alleged instigators of the looting in July 2021.** This dataset was identified as a broadcast conversation pattern. The many interactions of this group suggest a dependency on the information distributed by the influencers to their followers.





The results of the research provided some interesting insight, while also indicating that conversations in the South African political landscape are less polarised than was expected. Conversations often manifest broadcast patterns from key influencers, in addition to tight crowds or community clusters. Tight crowds or community clusters, on the other hand, indicate intense conversation across communities. This exhibits diverse opinions and perspectives on a topic. It can thus be concluded that social media platforms are, at present, the most significant mechanism people use to communicate and express their opinions. Fortunately, social media platforms also allow researchers to capture and analyse data to understand networks or community structures formed by the users' interactions.

Preparing future IT leaders to manage disruption in globally distributed IT work

Prof Rennie Naidoo and Jean-Pierre van der Merwe

The rich diversity of digitally enabled and globally distributed organisational arrangements is changing the nature of information technology (IT) work. Advancements in global connectivity and digitisation capabilities are offering better affordances for new forms of global IT work arrangements. At the same time, these technologies and the new business models they enable are disrupting traditional work arrangements and are redefining established IT work roles. Unhindered by geographical barriers, real-time digital platforms provide organisations in a few emerging countries with new business opportunities in the rapidly growing IT sector.

However, digital technologies also exacerbate global inequalities in many emerging countries. For example, outsourcing IT enables both large companies, and small and medium enterprises (SMEs) in advanced and emerging countries to take advantage of lower personnel, software and infrastructure costs. Many of these organisations are downsizing their IT units by outsourcing parts or all of their IT services and software development needs to specialised providers. They are migrating and eliminating many IT jobs from their own countries.

Meanwhile, some IT providers have become large multinational conglomerates. They are made up of many subsidiaries and joint venture companies, and operate in different distributed modes. This ranges from working on-site at the client's premises, to working at offshore and nearshore locations. Similarly, existing multinational corporations in other industry sectors operate with multi-unit IT organisations in different locations.

The inter-site coordination, communication and synchronisation of IT work activities in internationally distributed environments are being enabled by sophisticated collaboration technologies. Globally distributed teams operate using a different mix of virtual and face-to-face contact with their local and remote counterparts to foster collaboration across locations and time zones.

These distributed modes of IT work are supported by virtual communication and collaboration technologies. For example, enterprise social network sites dramatically alter workplaces and workspaces familiar to IT workers, especially for those who have worked in collocated teams. While technologies have certainly created new IT careers and career paths, they also eliminate traditional careers and careers paths. New careers such as cloud engineers at cloud-based IT vendors can eliminate in-house IT workers at clients' organisations.

Working in globally distributed teams and performing global IT work has also led to the emergence of new work roles for and work role expectations of IT workers. For example, new coordination roles such as coordinating experts and multicultural brokers have emerged.

Given the knowledge-intensive nature of most IT work, the role of coordinating experts came about to address the complexity of sharing knowledge across geographically dispersed sites. Distributed IT teams also deploy multicultural brokers who are expected to use their cultural intelligence to "bridge" cultural differences between co-workers and sub-groups separated by geographical distance and other barriers. Managers in on-site-offshore organisations also expect IT workers to adapt quickly. They need to work at a home site in collocated teams and client sites in other countries.

These expectations can be very challenging for the typical IT developer working offshore, who has to contend with culture and language barriers, and the marked differences in the values, norms and behaviour of their clients and IT counterparts. These differences in shifting global IT work arrangements entail both the material assemblages (e.g. physical offices, virtual communication and collaboration technologies) and embodied experiences (e.g. collocated and virtual teams). These disruptive changes to global IT work arrangements and contradictory work-role demands and expectations can intensify work-role tensions and create a crisis of meaning.

Roles connect status and socially defined expectations with the patterned conduct and relationships that make up a social structure. For example, the Chief Information Officer's role set generally includes that of chief technology officer, chief security officer, head of Development Operations, the software development team, executive team members, end-users and IT vendors.

The psychological contract concept posits that both the workers and the organisation have reciprocal obligations. Since a psychological contract is an informal and subjective phenomenon, workers and employers may understand their mutual obligations differently.

Another important concept is work-role transitions, which refers to changes in a worker's "status passage" and job content. Rapid work-role transitions in global teams can explain why workers struggle to adjust to their new work roles.

In many IT environments, role expectations and enactments can be problematic when there is a lack of consensus and incompatibilities among or within work roles. These role incompatibilities can create dissatisfaction as workers desire stable roles and compatible role behaviours. IT workers in global teams arguably experience higher levels of role–related work stress.

Studies have linked stressors such as role conflict, role novelty, role ambiguity and role overload to the high turnover among global IT workers. The associated work-role tensions they face include technology change (e.g. new platform, ownership) and their embodied experiences (e.g. working from home, working away from home).

Work-role tensions are influencing the work lives of IT workers in globally distributed digital workplaces in indeterminate, contradictory and dramatic ways. Understanding how workers adapt to disruptive work environments and cope with emerging work role tensions has important practical applications.

Recent research in the Department of Informatics has shown that role changes sometimes manifest as a crisis in meaning for IT workers. These workers will resort to resilience strategies to recover or grow from the change. Some workers will bounce back and return to normal. Some will grow stronger. Some will remain unaffected by the disruption. Some will engage in persistent resistance, while others will find new work opportunities.

A dialogic and collaborative approach is suggested to reconcile the contradictory implications of changing global work arrangements on worker roles. This should also minimise or alleviate the negative influence of work-role tensions on worker experiences, and consequently improve IT unit performance. IT leaders who nurture IT employee relations through a dialogic and collaborative approach can significantly minimise or dampen the negative effects of work-role tensions such as unwanted or undesirable staff turnover, and promote psychological contract fulfillment.

Intense communicative interactions should lead to co-creating a shared understanding, which can address the tensions in changing global IT work-role transitions. For example, local teams empowered by local IT leaders to participate in some critical decisions seem to show marked improvements in global team and co-worker relationships. However, one of the downsides of overemphasising collaboration as a resilience strategy is that it may eventually become a vicious cycle by increasing group think among local team members. More research is needed to provide insights into how IT leaders can work through work-role tensions and strengthen the resilience of their teams in seemingly antagonistic and increasingly complex global IT work arrangements.

However, it is believed that IT leaders who produce a shared and mutual understanding of the change they are experiencing through richer forms of participation in global IT work are more likely to foster greater team resilience.

Resilience and information ethics

Rachel Fischer

Against the background of the Fourth Industrial Revolution, and particularly within the context of a human-centred university and faculty that is embracing disruptive technologies, resilience is emerging as an important concept.

According to the American Psychological Association, "resilience is the process and outcome of successfully adapting to difficult or challenging life experiences, especially through mental, emotional and behavioural flexibility and adjustment to external and internal demands"[1].

As a species, we are extremely adaptable and resilient. A university is not built of brick and mortar, but by its people: students, lecturers, staff, expert communities and other stakeholders. One could then ask, what is the role played by information ethics?

Information ethics can be viewed as a lens through which to interpret the world. It is also a measure of being resilient in a time that calls for digital productivity, as well as balance. It deals with the ethical implications of information and communication technologies (ICTs). In addition, it speaks to how ICTs influence human conduct and vice versa; how humans influence the design, implementation and use of ICTs.

ICTs have become so embedded in our life worlds and daily habits that it is no longer possible to extract them from our understanding of what it means to be human.

However, ICTs have also become a tool to foster our adaptability, and muster our resources, in the face of COVID-19. If it had not been for ICTs, the swift pivot to hybrid working, teaching, training and conducting our general lifestyles would not have been possible.

Let us then consider what it means to be resilient from a practical point of view. For me as a researcher, resilience is not static. It is an ever-evolving process that ebbs and flows from past experiences, current circumstances and future provisions. Being able to adapt by evaluating the causes of an event and its potential effects is the essence that allows us to add new perspectives to a project and make a valuable contribution to the body of knowledge in a specific discipline.

Just as information ethics found its roots in computer ethics, and is now evolving into intercultural information ethics and the ethics of Artificial Intelligence, so must our orientation to the world of ICTs evolve over time.

What does it therefore mean to be resilient and adaptable from an information ethics perspective?

INFORMATION ETHICS CAN BE VIEWED AS A LENS THROUGH WHICH TO INTERPRET THE WORLD. IT IS ALSO A MEASURE OF BEING RESILIENT IN A TIME THAT CALLS FOR DIGITAL PRODUCTIVITY, AS WELL AS BALANCE.

1 *https://www.apa.org/topics/resilience*

RESILIENCE AND ADAPTABILITY FROM AN INFORMATION ETHICS PERSPECTIVE

If ethics is concerned with the conduct or behaviour of humans, then what needs to be understood is whether the conduct is good or bad; right or wrong. One also needs to differentiate between appropriate and inappropriate behaviour in one's daily interactions with others through our utilisation of ICTs.

This is specifically where the importance of information ethics comes in.

In any psychological study of resilience, and how to build resilience, one must consider that there are many coping or adaptive strategies that can be utilised in daily practice.

This is done in the hope of becoming a more resilient and adaptive person. Notwithstanding COVID-19 causing a shift to a hybrid work environment, and having to deal with the uncertainties of local and global economics and politics, now is certainly a very good time to develop such resilience strategies. From an information ethics lens, one can consider asking oneself the following questions as a means of developing resilience in dealing with ICTs, and working through the effects ICTs might have in our lives:

- Why is technology causing me to feel stressed, and how is my current use of technology contributing to my wellbeing?
- How is technology currently influencing or supporting my work: am I becoming more effective or is it leading me to burn out?
- How is my work influencing my relationships, and how am I influenced by technologies?
- What steps can I put in place to navigate challenges?
- How often can I re-evaluate my work schedule and find a balance between virtual screen time and "real-life" time?
- How can I contribute to a more adaptive work and social environment?

Finally, perhaps we should ask whether we are not part of the problem? If we know we are under pressure due to expectations, and due to the pace of the growth in the use of ICTs, maybe we are the ones who exert pressure on others. We do so by placing the burden on our colleagues, friends and family to keep up with us. Maybe having ICTs fully integrated into our lifestyles may fit our personality and working methodology, but not other people's styles. How do we then adapt and pivot to not only becoming more efficient or effective, but also more ethical?

CONSISTENCY AS A FORM OF RESILIENCE

This year marks the 10th anniversary of the establishment of the African Centre of Excellence for Information Ethics (ACEIE) in the Department of Information Science. Promulgated by Senate in May 2012, the ACEIE transcended local borders to contribute to, and collaborate with an international community of partners in the field of Information Ethics.

Together with the ACEIE, the International Centre for Information Ethics (ICIE) seeks to foster relationships and partake in research projects and activities. Certainly, the opportunities to do so, and the methods through which this has been achieved, has changed much over the last 10 years. This is not only due to a decade passing, but accelerated by tumultuous global events.

While this article intends to increase our awareness of the concept of resilience, or our ability to adapt in the face of adversity, it is also grounded in information ethics by asking about our relationship with ICTs. This inevitably influences our relationship with these technologies, and these technologies influence our relationships with ourselves and other people.

Since 2012, researchers involved in the ACEIE have consistently contributed to the discourses on information ethics and digital wellness through this publication, *Innovate*. These articles, which are all available online, have included the following, which also represent highlights in the activities of the Centre over the past decade:

2012

African Centre of Excellence for Information Ethics established: The purpose of the ACEIE was to formally reflect on the activities and history of information ethics in Africa. Furthermore, this reflection was intended to contribute to research on the topic and allow networking with other academics in the field.

2013

Building an ethical information society in Africa: In 2007, a group of international academics in the fields of information technology, philosophy and politics formed an academic network to conduct research on information ethics. This network is now known as the African Network on Information

Ethics (ANIE). It identified a gap in the academic representation of the African continent on the global stage, specifically pertaining to information ethics. It therefore organised events to stimulate research on information ethics in Africa. The result of these activities and international collaboration led to a partnership with the national Department of Communication, the United Nations Education, Scientific and Cultural Organisation (UNESCO) and various universities across Africa.

2014

A local platform for international participation: The ACEIE engaged with international role players on four levels: the design and rollout of an information ethics curriculum across universities in Africa; meetings with relevant stakeholders; interaction with the UNESCO National Commission offices in the southern African region; and workshops and conferences at universities across Africa.

2015A

Collaboration and innovation create interesting undergraduate studies: University classroom activities inspired new content and research opportunities through the modules offered by the Department of Information Science, the lecturers presenting them, and interaction with government and industry.

2015B

ACEIE seals collaboration with UNESCO: The ACEIE signed a Memorandum of Understanding with the South African National Commission of UNESCO on 29 July 2015. Five UNESCO-sponsored projects support its goals:

- Learners with disabilities, cyberbullying and sexting
- Community rollout of information ethics within a volunteer programme
- Information Ethics school curriculum development
- Policy design workshop: digital safety and wellness in schools
- Conference on Digital Wellness in Africa

2016

A visual representation of key concerns relating to cyber safety for children: Digital wellness refers to the notion of "being well in a digital society". Nowadays, this is a very important consideration, especially due to the prevalence of ICTs.

2017

Celebrating 10 years of information ethics in Africa: Many academics, especially in library and information sciences, have been involved in information ethics since the 1990s. Their dedication to the field culminated in the first local ANIE Conference, which took place in Pretoria in 2007. ANIE's partnership with the South African government resulted in a renewed commitment to cyber safety, cyber security and digital literacy from all role-players in the context of information ethics. ANIE would retain its core objectives of research, developing partnerships and raising awareness in facilitating the World Summit on the Information Society (WSIS) Action Line C10, which dealt with the ethical dimension of information societies.

2018A

ACEIE engages in international policy dialogue: The ACEIE and UNESCO co-organised the International Policy Dialogue on Information for All Programme (IFAP) priority areas in the Brazil, Russia, India, China, South Africa (BRICS) countries. This conference, held in Cape Town from 4 to 6 July 2018, aimed to provide a platform for the International Policy Dialogue on IFAP priority areas and support the development of a sustainable dialogue group in BRICS, African countries and the Pacific Region. It also strengthened collaboration between the BRICS countries and revitalised the IFAP structures and networks.

2018B

Relaunching the International Centre for Information Ethics: After 20 successful years, the International Centre for Information Ethics (ICIE) was relaunched under a new administration towards a revision of the goals and mission of the ICIE community. Since the establishment of the ICIE by Rafael Capurro of the Stuttgart Media University, Germany, in 1999, the ICIE pioneered the advancement of the field of information ethics, offering a platform for the intercultural exchange of ideas and information regarding worldwide teaching and research in the field. Acknowledging its historically defined origins and looking at its current iterations, the ICIE community would consider the evolution of the field to identify core focal points as currently applicable.

2019

The role of information ethics in the 4IR: The Fourth Industrial Revolution, also known as the 4IR, has no doubt become a proliferated term. It seems as though academic institutions, industry, government and civil society organisations have all jumped on the bandwagon to partake in and contribute to the dialogue. Together with the en-masse publications comes the implicit – and indeed explicit

– call to duty. This call extends to practical considerations that ask: "How can we substantially contribute to society?"

2020

Artificial intelligence literacy and information ethics for a 4IR society: The term "Fourth Industrial Revolution (4IR)" often conjures up images of robots, drones, functioning e-government systems, e-passports and biometric scans. Klaus Schwab's vision of artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3D printing, nanotechnology, biotechnology, materials science, energy storage and quantum computing inspires endless opportunities for progress and development in a variety of spheres, including the physical, digital, medical and educational dimensions. What the 4IR specifically enables is the opportunity to conduct simple, everyday activities remotely, effectively and with less human intervention. The sense of individual agency is strengthened as citizens are no longer limited by bureaucratic processes vis-à-vis formal office space. The demarcation between formal and informal spaces has become blurred, presenting the possibility to reimagine "the office", "the university" and "the home".

2021

Providing relief to digital fatigue: 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. Improving basic, information and digital literacies in practice, ability and theory will bridge the responsibility and wellbeing dimensions in terms of information ethics. Together with this is the active promotion of core competencies that include the requisite skills, knowledge and abilities inherent in media and information literacy.

As is hopefully evident when reflecting on the aforementioned publications and activities, information ethics sought to be a consistent, and visible feature in the Faculty of Engineering, Built Environment and Information Technology. Consistency finds itself in the active endeavour to align behaviour with inner conviction, much like ethics is the questioning of good and bad conduct. If we do not question ourselves and our conduct, and we do not develop coping or adaptive strategies, not only will we fail as humans, we will also fail to ensure resilience in future developments. The same can be said of our human-centred institutions. Our adaptability and the prioritisation of what it means to be "digitally" well will be crucial in maintaining our humanness.

A FINAL REFLECTION ON RESILIENCE AND INFORMATION ETHICS

One would be remiss not to recognise the profound impact COVID-19 has had on every level of society since 2020. Not only did it have a major economic and socio-political impact, it also had financial, psychological and emotional implications on individuals and families. The landscapes of employment and education have been altered irrevocably, and so has our relationship with ICTs. This year, we have also seen global social, political and economic shifts caused by the Ukraine-Russian war. Locally, South Africa is grappling with the dual crippling effects of state capture, as reported in the Zondo Commission reports, and Eskom's loadshedding. We would be naïve to refute how these events have debilitated our capacity to build and be resilient.

Being resilient requires us to acknowledge difficult and challenging circumstances. We should identify effective coping strategies to transcend the borders of the new hybrid ways of working and being. Finally, information ethics has the responsibility to continue to evolve as a discipline that accommodates the need for applicable resources that will enable us to best deal with the challenges and opportunities brought to the fore by ICTs. This seems like a daunting task.

We achieve this by placing humans at the centre of a university that embraces disruptive technologies to enhance our ability to live well.

Learning from nature to solve real-world problems

Prof Nelishia Pillay

The Department of Computer Science is solving real-world problems using machine learning and optimisation techniques that take analogies from nature, such as genetic algorithms and neural networks. This is the focus of its Nature Inspired Computation Optimisation Group (NICOG). Its application areas include improving the diagnosis of diseases using machine learning.

Since the inception of Artificial Intelligence (AI) in the 1950s, it has made great strides in disease diagnosis. Initially, expert systems were used to diagnose diseases. These systems stored information about diseases from medical experts to perform diagnoses. However, such expert systems could not diagnose cases that were not very similar to those included. More importantly, these systems could not learn and adapt.

The introduction of machine learning (ML) – as a subfield of AI – led to the rapid advancement of the field. Machine learning approaches were found to be effective at diagnosing diseases from both quantitative patient data, as well as images. With the discovery of deep neural networks, diagnoses from images were improved even further.

Despite these advancements, the application of ML approaches for disease diagnosis has not been without its challenges. Deep neural networks are computationally expensive and require a lot of data from which to learn. Supervised learning approaches require annotated data, which involves a time-consuming labelling process.

Designing ML techniques to diagnose diseases, including deciding which approaches to use and how to configure them, is not a trivial task and is itself an optimisation problem. Furthermore, some of the approaches that are effective for disease diagnosis are what are

called "black-box techniques", i.e. details of how these approaches have arrived at the particular outcome is not evident. These are some of the challenges that the NICOG is attempting to resolve.

The research group has already applied ML techniques to effectively diagnose various diseases, including COVID-19 (with 98% accuracy), heart disease and depression. This research has also led to interesting interdisciplinary projects within the University of Pretoria. In collaboration with the Department of Chemical Pathology, ML has been successfully employed to emulate chemical pathologists in diagnosing multiple myeloma, while a project conducted with the Department of Periodontics and Oral Medicine has used ML to detect oral lesions.

This research has also led to advances in the automated design of ML techniques and learning from unlabelled data.

Addressing global challenges through machine learning

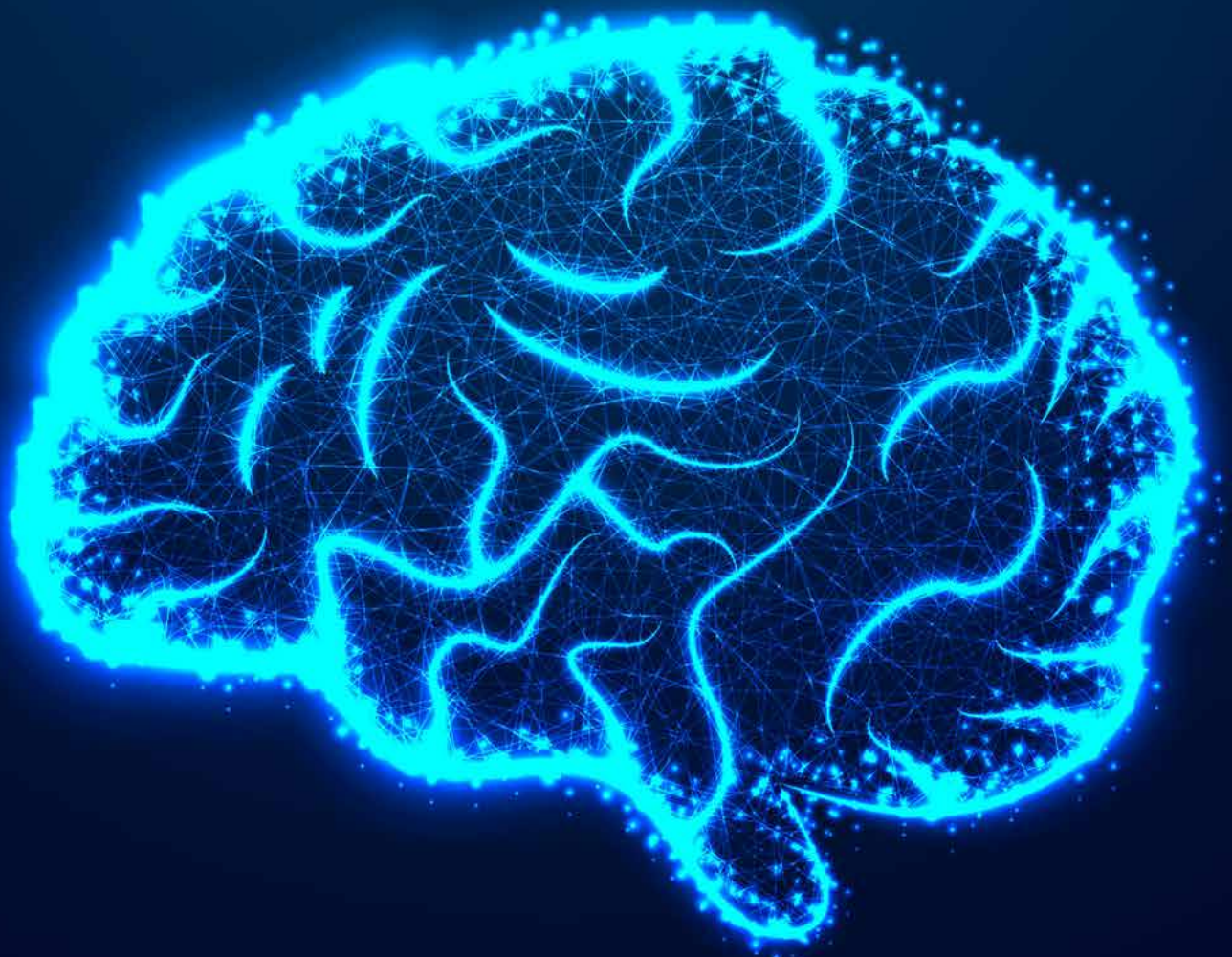
Mia Gerber

Research conducted in the Department of Computer Science is not only making Artificial Intelligence (AI) more accessible, but can also be applied to areas that are relevant to the United Nations' Sustainable Development Goals (SDGs), especially in the fields of disease diagnosis, spam detection and sentiment analysis.

Under the supervision of Prof Nelishia Pillay, master's degree student Mia Gerber investigated automating the design of the deep neural network pipeline to address problems related to the Fourth Industrial Revolution using AI. This research was conducted within the Department of Computer Science's Nature Inspired Computing Optimisation Group (NICOG).

Deep neural networks are machine learning (ML) techniques that mimic the way the brain works. When applying these networks to a new application, the design pipeline involves several tasks, such as determining the most suitable neural network architecture. However, this is time consuming and requires expert knowledge.

According to Gerber, deep neural networks have been shown to be very effective for image and text processing. More and more non-experts are starting to make use of deep neural networks in their daily lives, but do not have the expertise to construct optimal deep neural network pipelines. In her study, Gerber therefore used a single-point hyper-heuristic (SPHH) to automate the design of the deep neural network pipeline.



Mia Gerber

The SPHH methodology can construct a deep neural network pipeline design by selecting techniques to use in the various stages of the pipeline. "This work also investigated transfer learning by using a design that was created for one dataset as a starting point for the design process for a different dataset," says Gerber. She furthermore evaluated its effect and tested the reusability of the designs themselves.

The SPHH designed pipelines for both image and text processing. Image processing covered the detection of maize diseases and oral lesions, while text processing focused on sentiment analysis and spam detection. Multiple datasets were used for these tasks. The pipeline designs that were created by means of automated design were then compared to manually derived pipelines from the literature for the given datasets.

Gerber conducted three experiments to test the objectives of her study. Her findings revealed, firstly, that the automated design of a deep neural network pipeline using a selection perturbative hyper-heuristic is effective for both image and text processing. Secondly, transfer learning was found to produce results comparable to or better than the results achieved when using the SPHH without transfer learning. However, transfer learning is only effective when the correct target and source are chosen. For some target datasets, negative transfer occurs when using certain deep neural network pipeline designs as the transfer learning source. Negative transfer occurs when the accuracy of the designed deep neural network pipeline decreases, while positive transfer occurs when the accuracy of the design deep neural network pipeline increases or the SPHH converges on an equally well-performing design at an earlier iteration. In the third experiment, which sought to determine whether the designs produced by the SPHH are disposable or reusable, she found that reusing designs do not perform as well as creating a design specifically for a particular dataset. The designs are therefore not reusable for either image or text processing, and deep neural network pipelines must be designed for each dataset individually to achieve acceptable results.

Future work in this field will include applying the automated design approach to more domains, and making the designs reusable.

The transfer learning process will also be automated in future work to make sure that positive transfer occurs.

Developing a machine learning interface for low-resourced languages

Prof Vukosi Marivate

A natural language processing (NLP) machine translation system for low-resourced languages has been making great strides in its use of machine learning to develop an electronic translation application for languages that are not catered for by systems developed in the North America and Europe. The application is similar to the popular Google Translate, but focuses specifically on the African languages for which accommodation is not made in existing machine translation tools.

The system, which forms part of the Masakhane NLP research project, was developed by the Data Science for Social Impact (DSFSI) research group in the 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. Prof Vukosi Marivate, holder of the Department's Absa Chair of Data Science, is one of the chief investigators on this project.

This translation web interface for African languages was awarded the inaugural Wikimedia Foundation Research Award in 2020, as well as the Google AI Research Scholar Award in 2022. The financial support received from Google will enable Prof Marivate and his team to consolidate their research related to models and tools for South African languages, in particular.

Despite the fact that 2 000 of the world's languages are African, African languages are barely represented in technology, despite the fact that language plays a very big role in the Fourth Industrial Revolution. This is 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 a technological space that does not understand African names, cultures, places or history.

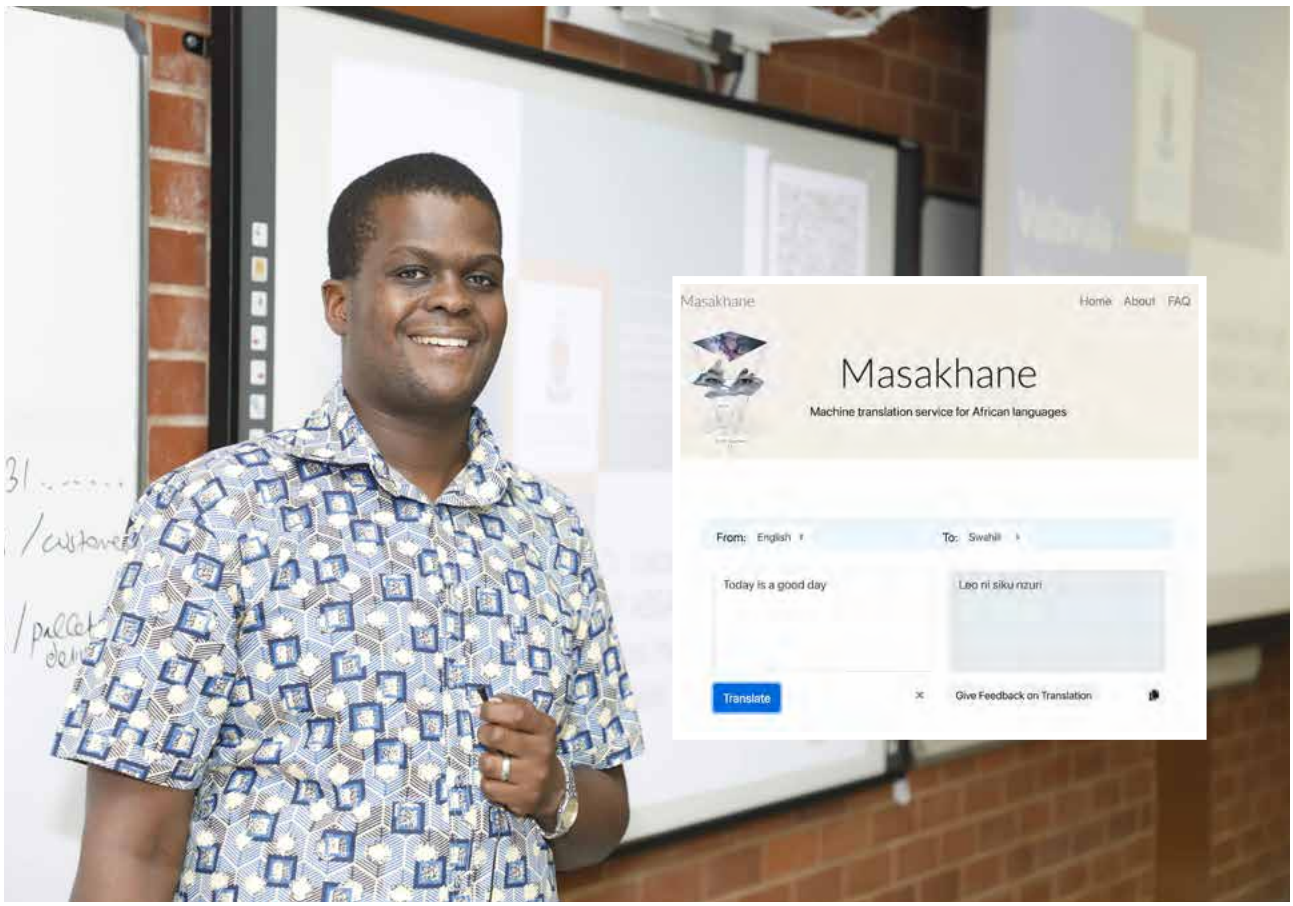
According to Prof Marivate, recent advances in NLP have largely benefitted well-represented languages, necessitating research into lesser-known global languages. This is, in part, due to the availability of curated data and research resources, as well as NLP algorithms that can exploit this abundance of data. Languages with fewer resources have the double challenge of small amounts of data and algorithms that do not cater for this paucity of data.

The idea of a machine learning model to assist in the translation of 50 of the continent's regional languages was first ideated at the NLP Workshop at the 2020 Deep Learning Indaba. This is an organisation focused on strengthening African machine learning and supporting Africans to be the 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.

The research that formed part of the development of this machine translation tool aimed to fundamentally change the approach to "low-resourced languages" in Africa.

Its novel approach to machine translation for African languages illustrates 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 solution of these challenges is not only an academic exercise, but will benefit society as a whole.

The work of the research team over the past five years has focused on investigating ways to improve the tools and resources available for resource-poor languages so as to ensure that African-language and local-language tasks count.



Prof Vukosi Marivate

This entails new approaches in modelling, data collection and community building to create the perfect environment for creativity, innovation and archiving across South African languages and beyond.

"Given our location, we focus on South African languages as a base for our research," says Prof Marivate. "This has involved the creation, curation and classification of datasets for low-resourced languages, such as Setswana and Sepedi, improving short-text classification through global augmentation methods, and fine-tuning language models and embeddings in low-resourced scenarios, using Setswana as a case study."

The team's current research is focused on consolidating what it has learnt about NLP for low-resourced South African languages, engaging with linguists to audit NLP models from a linguistic perspective, and releasing new or updated models and datasets. Researchers in African languages need a full end-to-end guide on how to look at an NLP task, how to curate the correct data, how to decide on the best models, and how to train and evaluate these models. "To this end, our work aims to document and create a reusable template for tackling low-resourced language tasks through an African language lens." Prof Marivate believes that this research can really make a change to society by enabling speakers of African languages to make better sense of our world.

Machine learning and AI have been responsible for a number of NLP breakthroughs that are already in use, such as a cell phone's virtual assistant, text-to-speech applications and chat bots. The challenge of developing such tools for African languages lies in the fact that these resources are not only limited in number, but are hard to discover. There is also a lack of scale and complexity. "This is admittedly an expensive exercise, but the longer we wait, the more expensive it becomes. By engaging in this work, we are hoping to encourage other organisations to support similar initiatives."

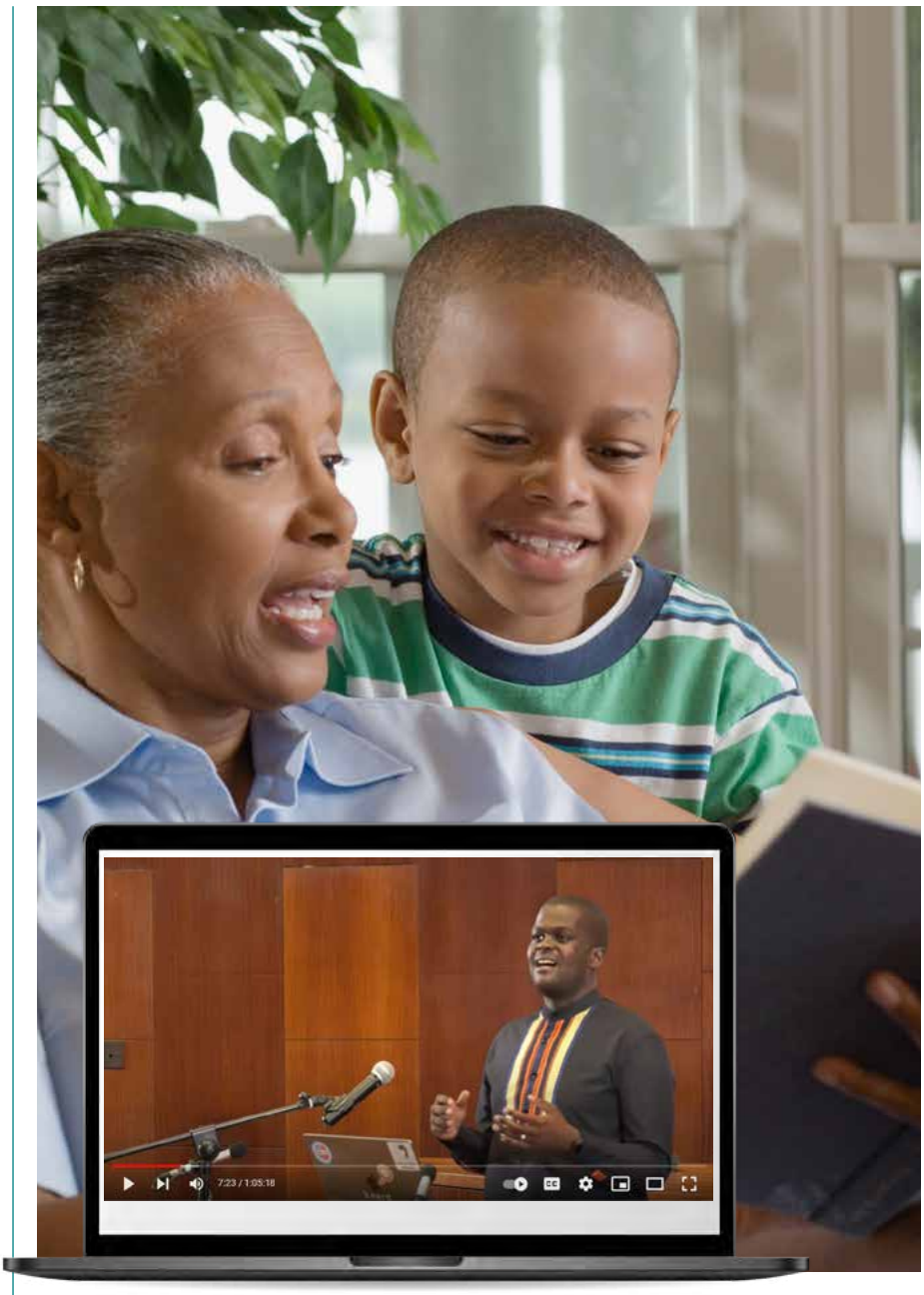
OUR WORK AIMS TO DOCUMENT AND CREATE A REUSABLE TEMPLATE FOR TACKLING LOW-RESOURCED LANGUAGE TASKS THROUGH AN AFRICAN LANGUAGE LENS. THIS RESEARCH CAN MAKE A CHANGE TO SOCIETY BY ENABLING SPEAKERS OF AFRICAN LANGUAGES TO MAKE BETTER SENSE OF OUR WORLD.

On 27 July 2022, Prof Marivate was invited to deliver the 30th UP Expert Lecture, hosted by University of Pretoria Vice-Chancellor and Principal, Prof Tawana Kupe. The title of his lecture was: *"Riendzo ri lehile: Tackling natural language processing for African languages to make better sense of our world"*.

This lecture enabled Prof Marivate to communicate the outcomes of his team's research to a wider audience. This lecture series provides a public platform for UP researchers to engage with a general audience on significant developments in their fields of expertise that are likely to have an impact in the future.

In his lecture, Prof Marivate explained that low-resourced languages pose an interesting challenge for ML algorithms, representation, data collection and the accessibility of ML in general. "Language presents a rich interface with which to share information and interact with machines," he explains. For African languages, this challenge coincides with the challenges of shaping the current revolution in AI with the global landscape.

"Over the last few years, there has been an increase in grassroots organisations involved in NLP in the Global South. They have brought with them a renewed energy and a focus on low-resourced languages," says Prof Marivate. His passion for strengthening ML across Africa therefore led to him co-founding the Deep Learning Indaba, an organisation that recognises excellence in ML and AI across Africa, and the Masakhane NLP project, a grassroots organisation



that encourages NLP research in African languages by Africans for 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 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 project's research, and comprise individuals from a range of relevant professions, including data scientists, researchers, language practitioners, translators and software developers.

Find out more about the work of the Data Science for Social Impact Research Group at **https://dsfsi.github.io/**

Driving demand for AI development in Africa

Prof Vukosi Marivate has been involved in machine learning (ML) since 2007. While pursuing his PhD in Computer Science at Rutgers University in the USA, he found an engaged student body. Graduates were being drafted to some of the most influential technology companies in the world, helping to inform and design next-generation technology solutions in Artificial Intelligence (AI) and similar breakthrough technologies.

Upon his return to South Africa, he saw the same level of talent potential, interest and demand from the workforce pipeline of AI and Data Science, yet despite the hunger for opportunity, meaningful research and development (R&D) was largely absent in Africa. He found this to not only be a matter of ineffectively leveraging talent. "I saw, time and again, that when technology is developed in the West, and then brought to Africa, it often doesn't work for communities that look different from the ones in which the so-called solutions were developed," he remarked.

His primary concern was that, without participation from communities, how was one going to succeed in protecting them from the harms of AI and data-driven technology? Language accessibility was one such challenge. As a specialist in machine learning and natural language processing (NLP), his concern was that, if a tool is developed without insights, support and feedback from a broader and more diverse group of stakeholders, it can be rendered useless in these communities, particularly by those that are not English speaking. He needed a solution to ensure that African languages were included in the AI revolution.

"Artificial Intelligence should not be something that gets dumped on the continent, but something we can shape; Africa needs to adopt AI on its own terms."

Prof Marivate realised that it was going to take time to bridge the gap and foster more R&D on the African continent. This led him to launch the **Deep Learning Indaba** with a group of scientists with a similar passion in 2017. The Deep Learning Indaba is both an event and an organisation, which is committed to empowering Africans to not only be observers and receivers of the ongoing advances in AI, but also active shapers and owners of these technological advancements. It also makes the content of talented young Africans available for free online, eliminating barriers to access and working to grow their community of practice across the continent.

The Deep Learning Indaba is an organisation whose mission is to strengthen machine learning and artificial intelligence in Africa.

An indaba is a Zulu word for a gathering or meeting. Such meetings are held throughout southern Africa, and serve several functions: to listen and share news of members of the community, to discuss common interests and issues facing the community, and to give advice and coach others. This is one of many words we have, including an imbizo (in Xhosa), an intlanganiso, and a lekgotla (in Sesotho). And by other words in other parts of the continent, such as a baraza (in Kiswahili) in Kenya and Tanzania, and padare (in Shona) in Zimbabwe. And of course this connects us to community gatherings that are similarly held by cultures throughout the world.

This spirit of coming together, of sharing and learning is one of the core values of our organisation, and hence, the best choice of name for it.

Top: Delegates at the Deep Learning Indaba 2022 in Tunis, Tunisia.
Bottom: Some members of the Data Science for Social Impact laboratory at the Indaba.
Photo courtesy of Deep Learning Indaba

When the organisers planned the first conference in 2017, they expected an audience of about 50 delegates, but were surprised to receive 300 entrants. The numbers doubled the following year. By 2019, the conference had grown to include workshops on computer vision, language, start-ups and ethics. Spin-off groups were developing organically as a critical mass of AI and Data Science experts and leaders began to drive ongoing conversations about the future of AI and, increasingly, Data Science for social impact.

Due to the impact of COVID-19, the conference could not be held in 2020 and 2021, so it was with great excitement that the African ML community looked forward to the Deep Learning Indaba 2022, which was held in Tunis, Tunisia, from 21 to 26 August. It featured a week of teaching, research, exchange and debate around the state of the art in ML and AI in Africa. Industry sponsorships enabled the organisers to offer students free attendance, as well as travel and accommodation grants to as many people as possible.

In addition to keynote talks from thought leaders in the fields of ML, AI and ethics, delegates could learn new skills in practical programming sessions, and could benefit from mentorship opportunities. Workshops were also presented on topics such as NLP, AI in health care, reinforcement learning, learning at the edge, and AI governance and policy.

With an upsurge of support and a growing pipeline of talented Data Science leaders and innovators, there has been measurable progress in this field. “Not only is the demand for academic programming and research opportunities for students increasing, but big tech is finally catching up,” says Prof Marivate. “The growing presence of large organisations like Google and Microsoft on the continent indicate that they are also benefitting as they now have a large pool of talent they can use, and both the research and the work can be done here.”

Using AI and ML to develop more accurate design formulae in civil engineering

Prof George Markou and Nikolaos P Bakas

The landscape of structural design, which aims to develop safe and sustainable structures, has been formed by applying a specific methodology that foresees the use of empirical and semi-empirical knowledge. This methodology studies experimental data and observations in an attempt to develop design formulae.

This is also the approach that was used to develop the numerous national and international design codes that are currently used in the design of any civil engineering structure. When adopting such an approach, there is an inherent uncertainty and lack of accuracy and objectivity when civil engineers try to predict the strength of their structural members. This uncertainty derives from the proposed design formulae that are available since they were developed through limited data. It is therefore necessary to use high safety factors during design.

This is an outcome that is directly connected to the inability to produce a plethora of experimentally obtained data to cover a sufficient spectrum of results related to a specific problem, while allowing for the development of more accurate and objective predictive design formulae. For example, one cannot get one million results by performing three- or four-point bending experimental tests to obtain the shear capacity of reinforced concrete (RC) beams without stirrups, or measure the fundamental period of steel structures that account for the soil-structure interaction (SSI) phenomenon. It is simply impossible from a practical and economical point of view. In addition to the above, there are cases where the design codes do not propose any formulae to predict the mechanical response of structures, as in the case of the expected deflection of curved steel I-beams.

In order to overcome these limitations, a pilot research project was initiated in 2018 that aimed to combine state-of-the-art 3D detailed modeling with Artificial Intelligence (AI) and machine learning (ML) algorithms for the development of predictive models that can compute the shear capacity of RC beams without stirrups.

The main idea behind this research endeavour was to replace the actual physical experiment with a numerical experiment, decreasing the cost of performing an actual test by 100%.

To achieve this, research software developed by Prof George Markou of the Department of Civil Engineering, Reconan FEA, was used to perform tens of thousands of non-linear analyses on RC beams, where the digitally computed shear capacity of different RC beams was recorded.

The numerically obtained data was then used to train and test predictive models through the use of AI and ML algorithms without the use of any experimentally obtained results. Thereafter, the proposed approach used actual physical specimens that were experimentally tested in laboratories around the world to validate the ability of the proposed predictive models to calculate the shear strength of these real RC beams.

The proposed predictive models were found to have the ability to outperform the currently available predictive abilities of international design formulae such as those of ACI and Eurocode. This came as a surprise, since the development of the proposed AI models was performed entirely through the use of numerical analysis, and not a single experiment took place or single specimen was broken in the process. The pilot research concluded that the replacement of the physical experiment with advanced finite element analysis was feasible.

This paved the way to investigate more structural-related problems.

Furthermore, the success of this pilot research led to the implementation of the proposed methodology to develop predictive models for the following problems:

- The shear capacity of RC deep beams without stirrups that are reinforced with fibre-reinforced polymer bars
- The fundamental period of RC structures with and without accounting for the SSI effect
- The fundamental period of steel structures with and without accounting for the SSI effect
- The deflection of curved steel I-beams for specific boundary conditions
- The section rotation of curved steel I-beams for specific boundary conditions

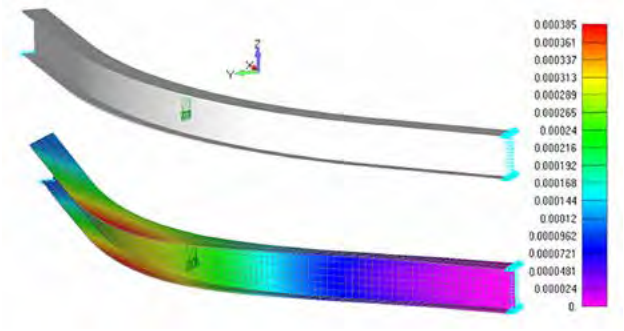


Figure 1: The steel I-beam model: undeformed and deformed shape, with displacement contour after loading

Figure 1 shows one of the models that was developed to capture the mechanical response of a specimen curved steel I-beam that was fixed at one end and had a pin-like support at the other. It is important to note that, in the research projects that were performed for the different problems revealed so far, the proposed predictive models developed through AI technology outperformed the existing design code formulae, while exhibiting significant accuracy when used to predict the magnitude of the shear capacity, deflection or fundamental period of the structures.

Currently, additional research is being performed on the development of predictive models to calculate the maximum capacity of RC piles embedded in clay that are loaded horizontally (see Figure 2). Furthermore, the research activities foresee the development of predictive models to provide civil engineers with the necessary tools to determine the stress level that will develop within the soil domain due to the horizontal loading of RC piles, calculating the corresponding expected mechanical response of the soil that is found at the location of the pile.

There is currently no closed-form solution in any design code in the world that can provide predictions about what to expect from this type of problem.

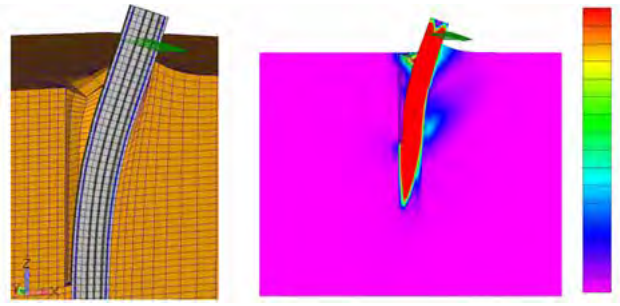


Figure 2: The deformed shape and strain contour of an RC pile prior to failure

Furthermore, new advanced AI and ML algorithms are being developed, as are new algorithms to train and test the accuracy of the predictive models by developing parallel processing to improve the technology that is developed to perform the training and testing of the predictive models. A publication is currently being prepared based on this research, which proposes a comprehensive approach to developing predictive models through distributed computations, which can be applied to any structural-related problem.

The use of supercomputers is an important field that can significantly accelerate the computational time required to obtain these predictive models. This is also being addressed in the upcoming publication, where 64 Tesla graphics-processing units are used to train and test the predictive models.

Furthermore, the team is developing Windows-based software, which is expected to enable other scientists to implement the proposed concept, thus allowing them to develop more accurate design formulae related to structural design. This software will not only perform the training and testing of predictive models through the use of any dataset, but will also provide a deeper insight into the analytics and error-related performance of the predictive models that have been developed during both phases of training and testing. This is something that is not currently available to the civil engineering scientific community or industry.

The proposed approach has no limitations in terms of the type of structural problem that one requires to develop more accurate design formulae, but requires the proper validation of the numerical models that are used to substitute the process of experimental testing.

With the proper validation of the models and the methodical development of datasets, the training of new, more accurate predictive models to help civil engineers design more sustainable and safer structures is now a reality.

Modelling tailings dam failures in the geotechnical centrifuge

Prof SW Jacobsz and Arno Crous

The mining industry throughout the world is considered one of the largest producers of solid and liquid waste. Due to the expanding market for mineral commodities, mining companies have started to exploit lower-grade ore bodies. This expansion of mining activities has resulted in a proportional increase in mining waste (tailings).

The sheer volume of tailings produced leads to the necessity of constructing tailings storage facilities, also referred to as tailings dams, to dispose of tailings. Because of the hydraulic deposition method used to construct these tailings dams, the tailings are often found to be in a loose and wet state. As a result, these geotechnical structures exhibit relatively high failure rates. The consequences of such failure sometimes result in significant loss of life and damage to the environment and property.

In 1994, the Merriespruit tailings dam in South Africa experienced a failure, where 600 000 m^3 of fluidised tailings flowed through the town of Merriespruit, killing 17 people. In January 2019, the Brumadinho tailings dam in Brazil failed very dramatically, with video footage recorded on camera, releasing 12 million m^3 of tailings into the environment and tragically killing 270 people. This was preceded four years earlier by a similar failure at Fundão, also in Brazil.

When loose fine-grained saturated soils are subjected to shear stresses, they show a tendency to reduce in volume or contract. This causes the generation of positive excess pore pressures, which, in the presence of poor drainage, results in a dramatic decrease in the shear strength of the soil, ultimately causing the soil to flow like a viscous fluid. This may have disastrous consequences.

Although static liquefaction is known to be a failure mechanism behind such tailings dam failures, a trigger mechanism is usually required for soil to liquefy. Much uncertainty exists about the nature of the triggers required to initiate such failures. Mechanisms are often hypothesised and based on post-failure investigations and eye-witness reports, with few of these events being captured on visual record. The triggers of liquefaction failures are still a subject of much debate.

South Africa has many hundreds of tailings dams. Given the disastrous consequences of a large liquefaction failure, there is major concern in the mining industry about the risk of the liquefaction failure of South African tailings dams. Tailings dams have traditionally been designed using drained stability analysis, where the mechanism of liquefaction was not considered.

The recent failures in Brazil have shown that the undrained behaviour of tailings also needs to be considered, as it is undrained behaviour that results in liquefaction. However, the understanding of the undrained behaviour of tailings is not well developed, resulting in conservative assumptions being adopted for the undrained stability analysis of tailings dams. Such analyses often show unsatisfactory factors of safety. This results in many tailings dam owners embarking on very costly stabilisation measures, which often impact on the financial feasibility of the affected mining operations. The question is: Are these stabilisation measures really necessary in South Africa? We have many hundreds of tailings dams and liquefaction failures are extremely rare.

Given the risk associated with tailings dam failures, significant effort has been undertaken in researching failure mechanisms. Centrifuge modelling, which involves the testing of physical models at high accelerations, has become a relatively common method to investigate slope failures. However, it has previously been noted that it is difficult to physically model slope failures, specifically static liquefaction failures. To study liquefaction failure mechanisms and their potential triggers, a series of centrifuge tests was conducted on model tailings dams at the University of Pretoria's geotechnical centrifuge facility, in collaboration with Prof Charles WW Ng from the Hong Kong University of Science and Technology.

Model tailings dam slopes were constructed from gold tailings in a model container using moist tamping. This method creates a contractive and brittle soil fabric, which maximises the potential for liquefaction. Figure 1 shows a schematic diagram of the centrifuge model used in the tests, along with the general dimensions of the model slopes. The slopes were constructed at 35°, near the friction angle of the tailings, which created marginally stable slopes.

A perforated plate, covered by geotextile, was installed immediately upstream of the model slope, creating a reservoir in which the fluid level could be maintained. During testing, the model was accelerated to 60 g. Once at the design acceleration, a viscous fluid (a water-glycerine mixture) was used to fill the reservoir, providing a hydraulic head upstream of the slope. The viscous fluid then seeped into the slope, gradually raising the water table.

A viscous fluid was used for two reasons: firstly, to satisfy the various scaling laws associated with static liquefaction in centrifuge modelling; secondly, to increase the chances of failure occurring. During a slope failure, excess pore pressure is generated. If a higher viscosity pore fluid is used, the excess pore pressure takes longer to dissipate, resulting in a higher possibility of static liquefaction.

During slope failure, a sudden increase in pore pressure will indicate a loss of shear strength of the soil, which translates into static liquefaction. Thus, it was important to measure the pore pressure response during the centrifuge tests. To monitor the response of the pore fluid pressure, tensiometers developed at the University of Pretoria were constructed. The tensiometers are able to measure both positive and negative pore fluid pressures. The tensiometers were installed at various locations throughout the model slopes to give a comprehensive view of the slope response throughout the tests.

Displacement sensors were installed at the crest of the slope to monitor crest settlement during the tests. Each test was monitored using a number of cameras.

A high-resolution digital camera was used to capture photographs of the side profile of the slope every five seconds. The images from the digital camera were used for particle image velocimetry, accurately tracking the deformation of the model slopes. Two webcams were also used to observe, one to monitor the side profile of the slope and the second to monitor an oblique elevation of the slope. A high-speed camera, capable of recording 180 frames per second, was used to capture the side profile of the slope failure in slow motion.

The range of instrumentation and cameras requires sophisticated data acquisition capabilities on the geotechnical centrifuge. For data management purposes, the centrifuge is equipped with two on-board solid-state computers, with the entire system controlled remotely through the centrifuge's fibre optic network.

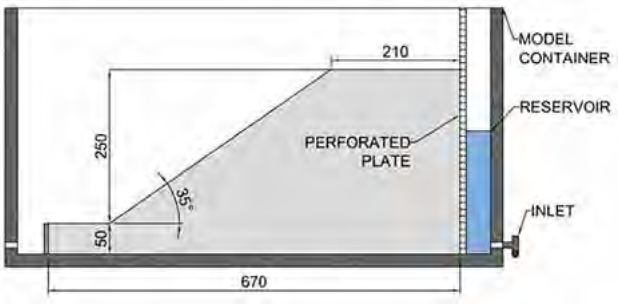


Figure 1: General centrifuge package

During the initial two centrifuge tests, the fluid level in the model slopes was raised gradually until slope failure occurred. For the third test, the trigger of the Brumadinho tailings dam failure suggested by Prof Antonio Gens from the Universitat Politecnica de Catalunya in 2021 was studied. At the time of failure, borehole drilling was taking place on the Brumadinho tailings dam. During the borehole drilling process, water was used to transport cuttings to the surface and to cool and lubricate the drill string. Prof Gens suggested that, during the drilling process, a permeable layer approximately 60 m beneath the surface was reached and water was subsequently injected into the slope. This resulted in a significant increase in the pore pressure within the slope, triggering the slope failure.

To simulate this in the centrifuge, a layer of sand was incorporated within the model slope near the bottom of the model container, shown in Figure 2. A standpipe was installed within the slope, which ended in the sand layer. In this test, a fluid level was initially established in the slope, similar to the methodology of the first two tests. Once the slope started showing signs of distress, a valve connected to the standpipe was opened, filling the standpipe with the viscous fluid and injecting the fluid into the sand layer.

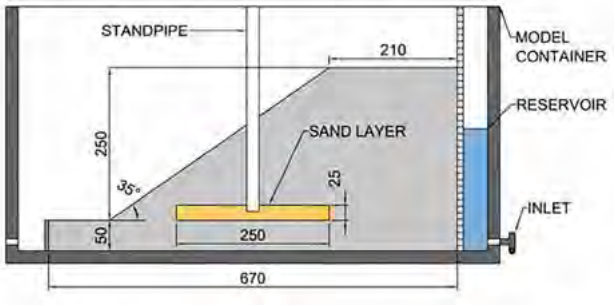


Figure 2: Centrifuge package for the model slope with a standpipe

Three different failure mechanisms, with their respective triggers, were observed during the centrifuge tests. In the first test, seepage caused sloughing at the toe of the slope. The initial rapid drained instability at the toe induced significant positive excess pore pressure, triggering localised liquefaction at the toe (an undrained response). Evidently, and eventually, the tailings at the toe could not support the tailings slope upstream of the toe, which triggered a rapid retrogressive flow failure. Figure 3 shows the side profile of the slope after the failure, along with the observed failure surface.

In the second test, a slope failure occurred due to drained instability, i.e. a circular slip failure occurred once the drained factor of safety approached unity. This drained slip failure triggered a slide-to-flow failure. However, no liquefaction was evident due to a slower rate of shearing. The side profile of the slope in the second test, just after failure, is shown in Figure 4, along with the observed slip surface.

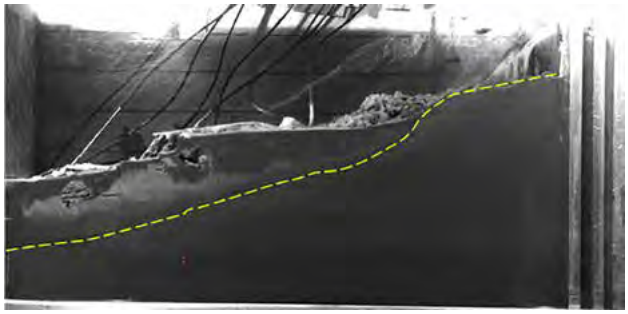


Figure 3: Side view of the model slope after failure in the first centrifuge test

Figure 4: Side view of the model slope after failure in the second centrifuge test

In the third test, a slope failure developed in the sand layer immediately after the fluid was injected into the slope. The slip initiated where the outlet of the standpipe was located, indicating that the soil in this region experienced some degree of loss of shear strength. The slope failed along a circular slip surface. The bulk of the failed soil mass eventually settled around the original toe region of the slope. Figure 5 shows the side profile after the slope failure, along with the observed slip surface.

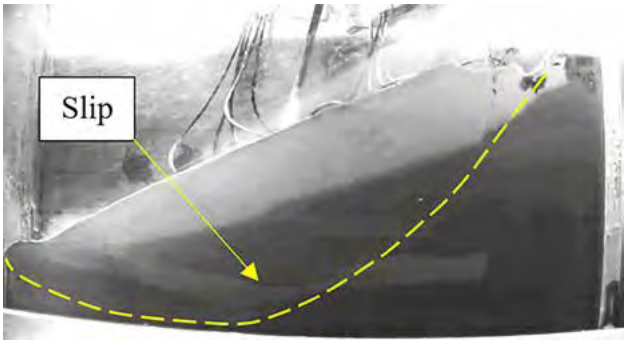


Figure 5: Side view of the model slope after failure in the third centrifuge test

This work is being expanded to study other triggers, such as the loss of confinement (similar to rapid erosion events) and overtopping events. The centrifuge modelling techniques are also being modified to improve the pore pressure measurement during the tests, along with methods to monitor surface deformation.

These centrifuge tests are excellent examples of how physical modelling using a geotechnical centrifuge can provide valuable insight into events that may potentially trigger tailings dam failures and how the failures eventually progress. Obtaining a better understanding of why and how these structures fail can potentially lead to the development of methods to improve the stability analysis and safety of tailings dams and hopefully demonstrate that the stability of the vast bulk of South African tailings dams is satisfactory without the implementation of cost-stabilisation measures.

Centrifuge modelling has become a relatively common method to investigate slope failures. However, it has previously been noted that it is difficult to physically model slope failures, specifically static liquefaction failures. To study liquefaction failure mechanisms and their potential triggers, a series of centrifuge tests was conducted on model tailings dams.

Prof SW Jacobsz and Arno Crous

CENTRIFUGE TESTS ARE EXCELLENT EXAMPLES OF HOW PHYSICAL MODELLING USING A GEOTECHNICAL CENTRIFUGE CAN PROVIDE VALUABLE INSIGHT INTO EVENTS THAT MAY POTENTIALLY TRIGGER TAILINGS DAM FAILURES AND HOW THE FAILURES EVENTUALLY PROGRESS.

Using system dynamics tools to study mining systems

Dr Sezer Uludag

The mining process, once established, becomes a complex business to plan, measure, control and report on. The complexity and cyclic nature of mines are further exacerbated by their size, fleet sizes and geology. Various systems are in place to manage mines. However, the quality control of these processes is often very cumbersome and an oversight.

Numerous optimisation studies are carried out during the life of a mine. New equipment, technology and systems may need to be introduced into an existing system from time to time. Information obtained from the vast data generated is often limited due to resource limitations and possibly the size of the mine operation. The formal communication or data flow between processes may be interrupted due to the introduction and adoption of new systems or technology. This is probably one of the main drawbacks of adopting better systems and technologies due to limited trust in the change and/or uncertainty of the level of disruption in the rest of the system.

The introduction of modern technology, changing systems and the intervention of other processes have an impact on downstream processes in mining due to its cyclic nature. It is possible that the impact of any of these changes is either over-estimated or under-estimated. Common experience suggests that it could be difficult to quantify the benefits or the lack thereof. Decisions must often be made without quantifying the overall impact, therefore the mining industry is often slow to adopt modern technology or systems, and managers are often reluctant to make such decisions due to the high risks attached to these changes.

Doctoral research was therefore carried out to quantify the effects of a recent technological change in an open-pit mine that typically has intricately connected sub-processes and very cyclic processes in general. The idea was to simplify and reduce the hard data requirements needed to study the effects of a new technology to be adopted by using causality and statistical descriptions based on a planned production profile and a mine setup using system dynamics modelling techniques.

The reasons for the failure to adopt modern technology, such as automation, is that it is complex, has too many qualitative attributes or there is a high risk in its implementation.

It was necessary to include a combination of operational, design and depositional factors in the simulation model. Operational factors are typically the cycle times of major mining machines, such as drill rigs, loaders and haulers. It is difficult to calculate return on investment as a typical measurement after the implementation of automation solutions. The basic cost of the solution can easily be calculated, but the benefit of the resulting solution is a challenge.

The research did not consider the implementation challenges of switching to automated drilling. Operational parameters included the metres of drilling required to meet the planned production and other key performance indicators around engineering downtime, operational downtime, productivity, utilisation, metres drilled, bit life, rod life and penetration rates per drill bit of rock type that are easier to quantify.

One challenge is that of differentiating the consequences or direct impact of a normal drill compared to an automated drill rif is challenging if there are a number of them as mixed type of fleet at a mine. Therefore, an extensive literature review was conducted to find representative numbers for the simulation design and setup.

In addition to drilling, many other processes need to be quantified, as well as the level that is representative of the case study used. Therefore, the study was extended to all the other processes to capture the direct impact of the automation of drilling machines. The problem-solving process using system dynamics modelling also requires a systematic approach.

Firstly, the model is conceptualised to make sure that all relevant technical parameters are captured in the model that makes up the model boundary. There are two types of variables. Endogenous variables are the dynamic variables involved in feedback loops, and exogenous variables are the components of a system that are not directly affected by the system. Exogenous components can be constants or time-varying constants, which are not stocks and flows.

The rest of the model is constructed with the analogy of stocks and flows in mind, using VENSIM to model an open-pit mine environment. VENSIM is typically used for time-based integration modelling to simulate over a set period of time.

The analysis of the case can be done at various levels or details. For example, the effect of fragmentation after the rock has been blasted can be measured by simulating the level of fragmentation and integrating the outcome with other sub-models, such as loading, hauling, the production profile and costs.

The final model is capable of simulating any surface mine, provided that the mine's operational auxiliaries are entered into the model. It was interesting to note how sensitive the model was towards the determination of available direct drill time per year and the effect of parameters influencing the drill time. It could be an eye-opener to mining engineers that even simple "hot seat change" time gains at the drill rigs result in considerable gains in production momentum.

Direct cost implications or savings are immediately captured and can be compared to the baseline established within the newly established system dynamics model. The step-by-step approach from the definition of the behaviour to the building of the entire model required one to understand patterns of behaviour.

A value attached to automation-related gains or losses was successfully captured upon the finalisation of this study.

Research team strives to conserve South Africa's non-renewable resource: water

Nationally recognised research conducted by the Department of Chemical Engineering's Rand Water Chair in Water Utilisation is focused on solving South Africa's problems related to water scarcity, while at the same time investigating the viability of using solar energy instead of coal-fired electricity in desalination and waste-water reclamation projects that are aimed at "creating water" for household use. This is a major breakthrough for a water-scarce country like South Africa.

As the Chairholder of the Rand Water Chair, as well as Head and Programme Coordinator of the Department's Water Utilisation and Environmental Engineering Programme, Prof Evans Chirwa leads one of the most productive research groups in the Faculty of Engineering, Built Environment and Information Technology. Its outputs have increased exponentially over the past few years. Projects on advanced water treatment have yielded several innovative developments that have the potential of being taken up by industry.

Prof Chirwa believes that engineering can be made simple and more impactful by observing and understanding how organisms in nature solve eminent problems. An example is how micro-organisms extract energy from basic materials and defend themselves against toxic substances at a molecular level. Another example is how green plants can thrive without organic food inputs using the complex photosynthesis process to launch a biochemical food chain. "We have seen bacteria multiplying in diverse environments; some even unimaginable for life to exist," he says.

Some of the groundbreaking research projects conducted under his supervision have included the processes utilised by bacteria to detoxify their environments, the generation of heterogenous nanoparticle materials for photocatalytic reactions, the recovery of water through solar desalination, the 3D printing of graphene onto nanoparticles for solar desalination, and the separation of uranium and gold ions from polluted water.

How plants use the energy from the sun to split water into hydrogen and oxygen atoms is still the subject of intensive research. "If a material can be found that is capable of releasing hydrogen from water, we can solve the world's energy crisis for the next millennia," he remarks.

His research team has also developed methods of metal reduction for the purpose of detoxification. It is furthermore evaluating the possibility of mimicking the biophysical process of forward osmosis and the use of proton-selective membranes to enhance the operation of microbial fuel cells.

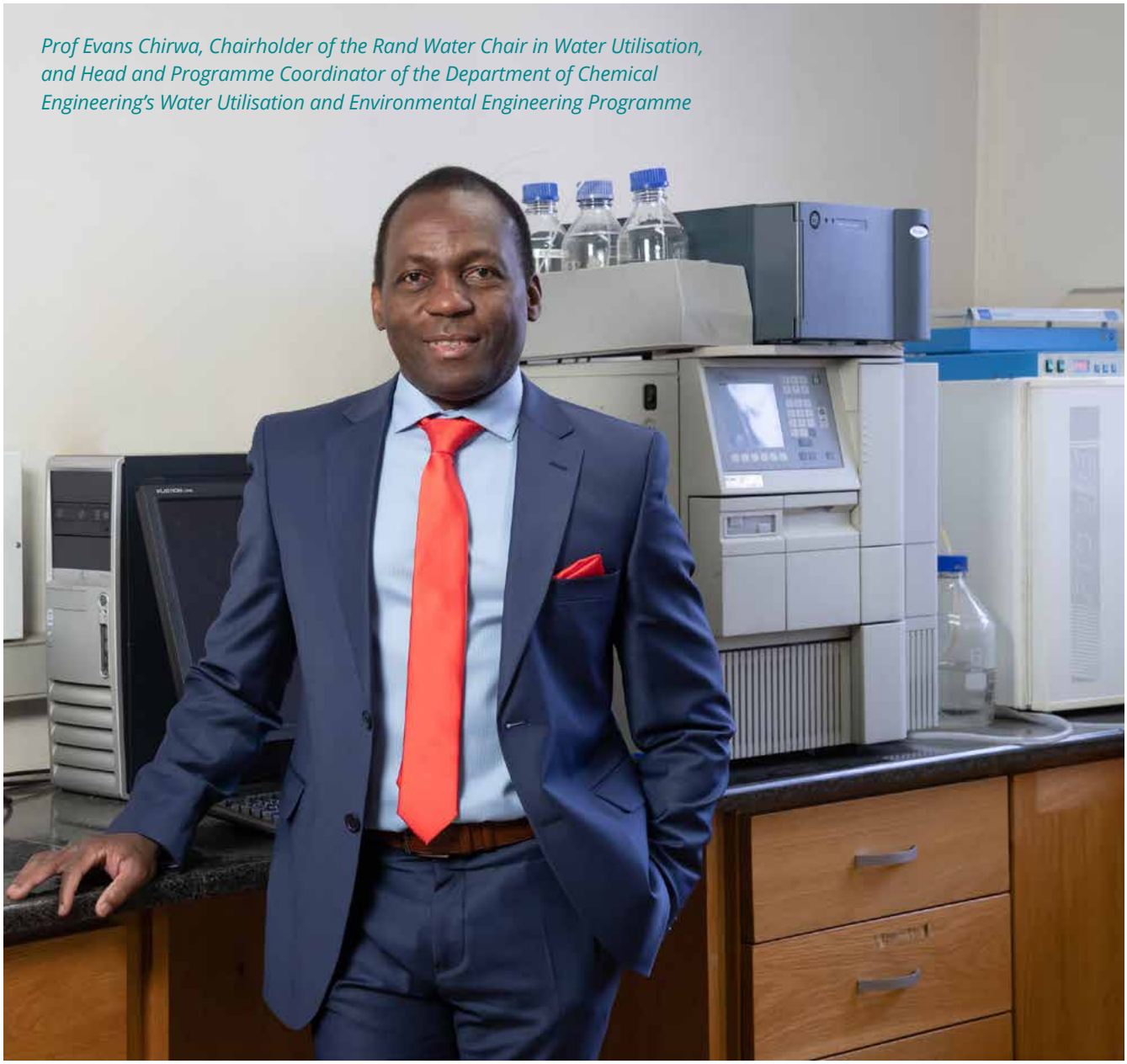
Achievements of these projects, as well as their commercialisation potential, include the following:

- A project on heterogeneous photocatalysis for the degradation of recalcitrant organic compounds in water has progressed to the pre-pilot stage. The synthesis of the novel photocatalysts has advanced to the point where the production processes have been standardised. A range of products is ready for testing at a pilot scale.
- A 3D-printed graphene solar desalination, and uranium and gold adsorption project has succeeded in achieving the 3D-printed synthesis of

graphene oxide for use in solar desalination and the separation of uranium and gold ions from polluted water. Both these applications have proven to be novel and promising in the construction of low-cost advanced materials for possible use in the treatment of saline water resources.

- A project to develop low-cost engineered forward osmosis membranes utilising the natural process employed by plants has succeeded in extracting pure water from saline water into a polymeric draw solution, followed by isocratic reversal, resulting in the release of water from the draw solution, and the further reuse of the draw solution.
- A project to develop microbial fuel cells that can be used in large-scale plants such as sewage treatment plants and in minute applications such as powering implants in the human body is making good progress. The power output in the microbial fuel cells has improved by reducing the internal resistance of the fuel cell. A further improvement was achieved by eliminating the cathode chamber and replacing it with an air cathode chamber. The latter further reduced the internal resistance of the microbial fuel cell. The next target is to test the high-power output microbial fuel cells on a pilot scale.

According to Prof Chirwa, South Africa's water and energy problems are linked. "As energy is required to perform water salination and waste-water treatment activities, we run the risk of depleting one non-renewable resource through the creation of another." His research is therefore focused on uncoupling the water-energy nexus by removing thermal coal from the energy budget of southern Africa.

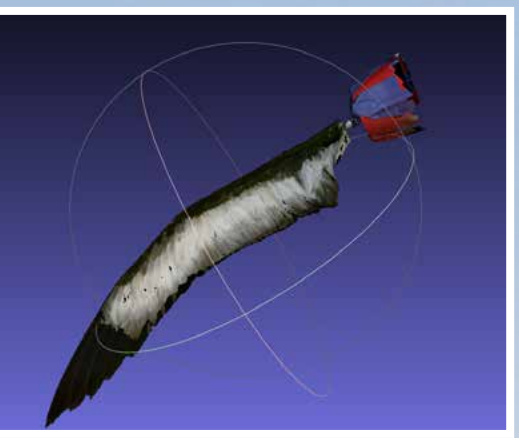


Prof Evans Chirwa, Chairholder of the Rand Water Chair in Water Utilisation, and Head and Programme Coordinator of the Department of Chemical Engineering's Water Utilisation and Environmental Engineering Programme

Fledgling aeronautical engineers learn from nature's aviators

Dr Lelanie Smith and Janine Schoombie

Researchers in the Department of Mechanical and Aeronautical Engineering are finding ways to make air travel cheaper, cleaner and faster. In their quest to develop an aircraft that automatically adapts its flight behaviour as it encounters unpredictable weather, they are studying the behaviour of the albatross, one of the most energy-efficient travellers in the animal kingdom. In the process, technology and transdisciplinary collaboration is allowing nature to inspire design.



The albatross is one of the largest, most efficient flying birds in the world. It uses its exceptional wingspan to glide and soar across entire oceans. Its real talent lies in its ability to sense the smallest changes in air pressure and wind direction, particularly as circulation patterns are affected by climate change.

The albatross has a special tendon in each shoulder that allows it to lock its wings in place. This allows the albatross to fix its wings in a fully outstretched gliding position and maintain that position without using its muscles. This saves the bird a lot of energy. While locked in, the albatross cannot move its wings up and down, which allows one to assume that, if one were to spread the wing out to its full extent in the laboratory, one could obtain a good representation of the wing in glide mode.

A more complicated issue is defining the wing angle of attack of a bird in flight when the shape of the wing is expanded. In aerodynamics, the forces acting on a wing are defined relative to the speed and angle of attack. Usually, when an engineer designs a wing, they will define the twist and dihedral angles, and choose a reference along the wing. Thus, one will always know the angle of attack of a section of an engineered wing relative to the designed reference. In the case of the albatross – or any other avian creature – the challenge lies in the fact that this information is unknown. Understanding the physical principles that explain the behaviour of an albatross's wings would therefore help engineers redesign the wings of aircraft.

The feathers of a bird's wing define the shape that generates lift. When in flight, the wing is subjected to pressure that acts on the feathers.

It is not easy to accurately measure an albatross's wing under various conditions in order to replicate its design. While the grey-headed albatross has a wingspan of 2.2 m, the wandering albatross has a formidable wingspan of 3.5 m. Making a high-quality scan of a single albatross wing requires 115 million cloud points.

A common method used to measure aerodynamic forces on an engineered wing is to emulate flight in a wind tunnel and measure the pressure distribution on the wing. This involves drilling small holes on the surface of the wing and attach tubes to the holes running along the inside of the wing to measurement equipment outside a wind tunnel. Lift and drag forces can then be inferred from these surface pressure measurements, which are important in defining the aerodynamic properties and flight envelope of the aircraft.

This method cannot be used with feathered wings without inadvertently changing the shape of the wing as tubes running underneath the feathers may increase or hamper their deflection. The solution is therefore to measure the aerodynamic loads using a load balance, a complicated piece of equipment that requires precision engineering. Not many facilities have this capability, and those that do may not be large enough for an albatross's wing.

Although one can quite successfully manipulate the bones and tendons of the bird's wing into its gliding position, dried skin and tendons may change how much the feathers and bone deflect when air moves over it during flight. Wind tunnel experiments with dried birds' wings are not uncommon. It has been well documented that more flow separation occurs in the wind tunnel than is observed in nature. Although this is a clear obstacle, it is in some cases the only option if one wishes to improve one's understanding of aerodynamics.

A valuable tool in aerodynamic investigations is the combination of wind tunnel experiments with computational fluid dynamics (CFD). However, a computer-aided design model of the wing is necessary to perform the simulations. The Department's researchers took an innovative approach to this challenge by making use of the Makerspace in the University's Library. This is a collaborative space that is synonymous with innovation, transdisciplinary research and creativity. Staff of the Makerspace suggested capturing an accurate 3D digital representation of the albatross's anatomy for detailed study. Since the feathers are flexible, they compress and deflect relative to the pressure acting on the wing. The cross-section of the wing is the most important part of the wing's design, and the most difficult to estimate accurately on a feathered wing.

The initial scanning was performed in a static environment in the Makerspace to generate a still scan of the wings and feathers. Later, another scanning session took place in the wind tunnel facilities in the Department of Mechanical and Aeronautical Engineering to compare the differences in flex and shape under flying conditions. This provides quantitative data on the aerodynamic forces acting on the wings of the grey-headed albatross under varying conditions.

The main aim of the wind tunnel testing was not to perfect load measurements, but to create an environment that mimics a bird's wing in flight, so as to extract its shape using scanning technology. While 3D scanning is quite common, it is the fusion of biology and mechanics that makes this collaboration so novel. After creating digital models of the albatross's wings, the study can be expanded even further using computational simulations.

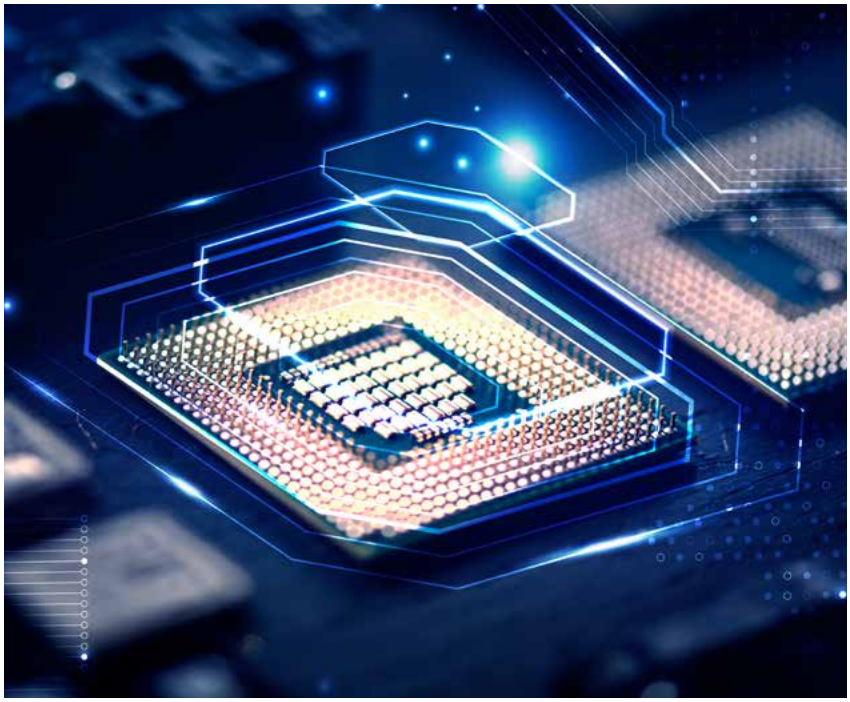
The findings will have various implications for the aerospace industry, where aerodynamics plays a vital role in the design of next-generation aircraft. Other applications of the impact of a technique that simulates the albatross's efficiency could be its use in unmanned aerial vehicles in remote locations that need to be constantly airborne to receive radio or telemetry signals.

The research team hopes to determine industry interest in these findings with a view to the developed technique's eventual commercialisation.

Pockets of research excellence in EEC engineering

The Department of Electrical, Electronic and Computer (EEC) Engineering has contributed to the University of Pretoria being ranked No. 1 in South Africa for electrical and electronic engineering for three years in a row according to the QS World University Subject Rankings. Many of its graduates are top inventors and entrepreneurs, and its lecturers are world-class researchers. Its excellent laboratories provide a platform for innovation of the most meaningful solutions to the world's most pressing problems.

The Department's various industry-funded research chairs, institutes, centres, hubs and specialised research groups are focused on research on advanced sensor networks, bioengineering, control systems, electromagnetism, electronics and microelectronics, energy systems, intelligent systems, power systems, and telecommunications and signal processing.



RESEARCH CHAIRS

EXXARO CHAIR IN ENERGY EFFICIENCY

The Centre for New Energy Systems hosts the Exxaro Chair in Energy Efficiency. The Chair leads research in the broad field of energy security for energy efficiency improvement. Its primary focus is demand-side energy efficiency studies in the mining, manufacturing, commercial and residential sectors. With cooperation from Exxaro, the research is put to immediate use; hence, the training of PhD and master's students in applying advanced tools in the study of energy efficiency demand-side management improves the University's international reputation through research results published in leading international journals and speeds up research in the field of energy security in our country.

MULTICHOICE CHAIR IN MACHINE LEARNING

The MultiChoice Chair in Machine Learning was established in 2018 in recognition of the key role that Artificial Intelligence (AI), specifically machine learning (ML) and deep learning, will play in unlocking a truly digital future. It is co-hosted by the Department of EEC Engineering and the Department of Computer Engineering. The chairholders are Prof Pieter de Villiers and Prof Nelishia Pillay.

It strives to address the global skills shortage in machine learning development skills. Opportunities and projects that have been identified to apply AI and ML include content creation, understanding what content to offer customers (recommender systems), customer service and improving interactions with customers.

These opportunities are addressed through 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 projects relate to satellite broadcasting and video streaming. Other topics include 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.

RAND WATER CHAIR IN ELECTRICAL ENGINEERING

The Rand Water Chair in Electrical Engineering was established in 2021 to effectively manage diverse research projects in the field of electrical engineering, with particular emphasis on the corrosion of pipe materials. The Chairholder is Prof Raj Naidoo.

The primary activity of a water board is to provide water services to other water services institutions within its service area. As one of the largest water boards in the world, Rand Water endeavours to keep abreast of global trends and technological advancements in the field of water services, and has an insatiable thirst to break new ground in all sectors of operations.

The Rand Water Chair was established to develop a research niche that is relevant to the South African water supply sector. This will position the University of Pretoria and Rand Water at the forefront of local and international developments.

A particular emphasis of the research conducted in the Chair is the corrosion of pipe materials. Of more importance is the possibility of Rand Water generating power using its own water to supply the current used in the presently impressed system.

Activities include teaching at the advanced undergraduate level, being a study leader for undergraduate and postgraduate research projects, liaison with Rand Water, performing investigations and research for Rand Water, and the supervision of support staff.

The primary role of the Chair will be the development and execution of projects with clear measurable objectives in response to research questions raised by Rand Water. Other objectives include the development of human capital, achieving operational integrity and using best-fit technology, and helping Rand Water maintain financial health and sustainability.

OUR RESEARCH AIMS TO DEVELOP SUSTAINABLE TECHNOLOGIES FOR INCLUSIVE SOCIETIES. WE ARE RISING TO THE CHALLENGE BY ALIGNING OUR RESEARCH TO THE SUSTAINABLE DEVELOPMENT GOALS (SDGs) OF THE UNITED NATIONS.

SENTECH CHAIR IN BROADBAND WIRELESS MULTIMEDIA COMMUNICATIONS

The Sentech Chair in Broadband Wireless Multimedia Communications (BWMC) offers a world-class research environment with state-of-the-art research facilities and collaboration with industry and internationally renowned researchers in the field of wireless broadband multimedia communications for the benefit of Sentech, the University and South Africa in general. Its Director is Prof Sunil Maharaj, the University's Vice-Principal of Research and Postgraduate Studies.

It promotes postgraduate study and research in the field of mobile broadband multimedia communications networks, products and services, and encourages the further interaction between academic institutions and industry in general, and specifically between the University of Pretoria and Sentech.

It emphasises research and product development in the fields of radio frequency communications, digital transmission technology, digital network technology, telecommunications and speech processing.

Furthermore, it strives to develop high-quality technical skills and expertise for industry and the research fraternity, and to contribute to the global competitiveness of Africa and South Africa, in particular.

INSTITUTES

CARL AND EMILY FUCHS INSTITUTE FOR MICROELECTRONICS

The Carl and Emily Fuchs Institute for Microelectronics (CEFIM) has been active in the field of microelectronics research and specialist training since 1981. It is a centre of expertise in microelectronics. It provides expert human resources for southern Africa, performs research, and serves the community in these and related fields. Its Director is Prof Trudi Joubert.

The Institute specialises in the design of integrated circuits, especially analogue signal processors, radio frequency circuits and optical receivers using complementary metal-oxide semiconductor (CMOS) technology. It also investigates devices in advanced semiconductor materials and process technologies.

It is a knowledge hub for microelectronics in integrated sensor microsystems and mm-wave systems – on-chip, off-chip and in hybrid implementations using modern additive manufacturing technologies, such as printed electronics. These will find applications in point-of-need sensing scenarios, and in future 5G backhaul networks and point-to-point connectivity solutions.

Its prominent research focus areas include the following:

- Integrated microelectronic sensor systems
- Embedded signal processing systems
- Microwave and millimetre-wave (mm-wave) systems

RESEARCH CENTRES

CENTRE FOR CONNECTED INTELLIGENCE

The Centre for Connected Intelligence was established in 2004 as the Centre of Excellence in Teletraffic Engineering (CeTEIS). It is funded by two industry partners: Telkom and Redshift Cyber Security. Its Director, Prof Herman Myburgh, has a C2 rating with the NRF.

Initially focused on research in the field of telecommunications, its emphasis has gradually expanded to include a number of related fields such as the Internet of Things (IoT) or machine-to-machine communication, Data Science, data security and the use of machine learning for various relevant estimation and optimisation problems.

Its main aim is the production of impactful research in all the fields that form part of IoT, which is considered the next step in the evolution of the internet. This includes applications such as smart phones, wearable sensors, smart home systems and intelligent vehicles through the management and presentation of data to the end-users.

Among the applications the Centre has been working on over the past few years include underground communication and sensing systems for use in mines, intelligent water resource monitoring and management, intelligent transportation systems, low-cost mobile audiological screening, diagnosis and patient management, robotic vision and scene understanding for autonomous operation, medical data analysis, disease onset prediction and patient management, and intelligent farming in the dairy industry.

CENTRE FOR ELECTROMAGNETISM

The Centre for Electromagnetism was established in 1996 and conducts research on electromagnetism in its comprehensive measurement facilities. Its Director, Prof Wimpie Odendaal, has a B3 rating with the NRF. Over the years, the Centre's researchers have developed very strong computational abilities in various aspects of electromagnetism. Research is focused on achieving a high level of excellence in electromagnetic technology, particularly the design, development and evaluation of microwave antennas, radar backscatter and antenna measurements.

Its research and development initiatives focus on electromagnetic analysis, synthesis, verification measurements and measurement metrology. Research highlights include the development of improved calibration techniques for cellphone base station antenna gain measurements, and an active calibration target for full polarimetric monostatic and bi-static radar cross-section (RCS) measurements.

It has established a national measurement facility – the compact antenna range at the University of Pretoria – that is accessible to various role players in industry. This is a state-of-the-art system that can measure the radar scattering characteristics of objects as large as 1.8 m or as small as a golf ball. It can also perform the task of measuring radiation characteristics of antennas.

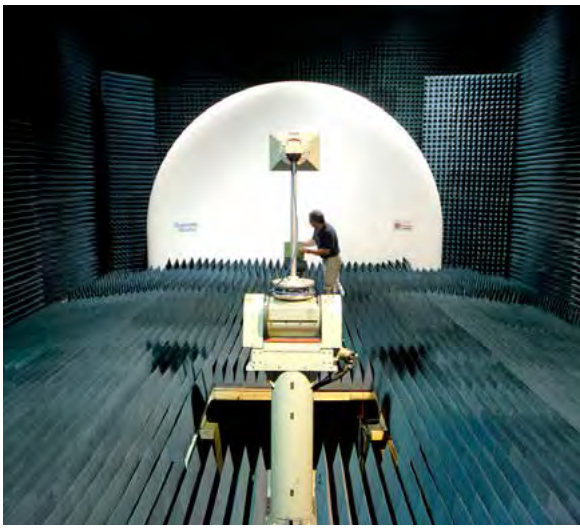
CENTRE FOR NEW ENERGY SYSTEMS

The Centre for New Energy Systems has gained a reputation as a premier research institute in energy management both nationally and internationally. Its mission is to be a world-class centre of excellence that addresses the research, education, development and industrial applications of energy optimisation and management. Its Director, Prof Xiaohua Xia, has an A rating with the NRF.

The Centre's thematic focus on energy management includes both supply-side and demand-side management. The cost-effective supply and end-use of energy are promoted through cooperative research within the Energy and Control Group of the Department of Electrical, Electronic and Computer Engineering. Its research forms the interface with energy systems, econometrics, control theory and financial mathematics.

The Centre collaborates with research centres on energy management within and outside the country. It prepares courses and seminars to improve opportunities for students, researchers and engineers, organises national and international meetings, workshops and conferences on topics related to energy optimisation and management, and promotes theoretical research and technology transfer.

The Centre's research focus areas include industrial energy optimisation, energy efficiency and management in buildings, transport efficiency, new methodologies in energy optimisation, energy system performance evaluation, and classical and renewable power systems and electricity policy. It also hosts both the Postgraduate Programme in Energy Efficiency and Demand Side Management (EEDSM) Hub and the Exxaro Chair in Energy Efficiency.



HUBS

NATIONAL HUB FOR ENERGY EFFICIENCY AND DEMAND-SIDE MANAGEMENT

The South African National Development Institute (SANEDI), a joint initiative of the Department of Science and Innovation and the Department of Mineral Resources and Energy, selected the University of Pretoria to house the Energy Efficiency and Demand-side Management (EEDSM) Hub. It has identified energy efficiency and demand-side management as key research and development themes for South Africa. The EEDSM postgraduate programme was initiated as one of the targeted, government-funded programmes to generate high-quality master's and doctoral graduates who are specifically trained to meet the needs of an expanding and sustainable energy industry in South Africa.

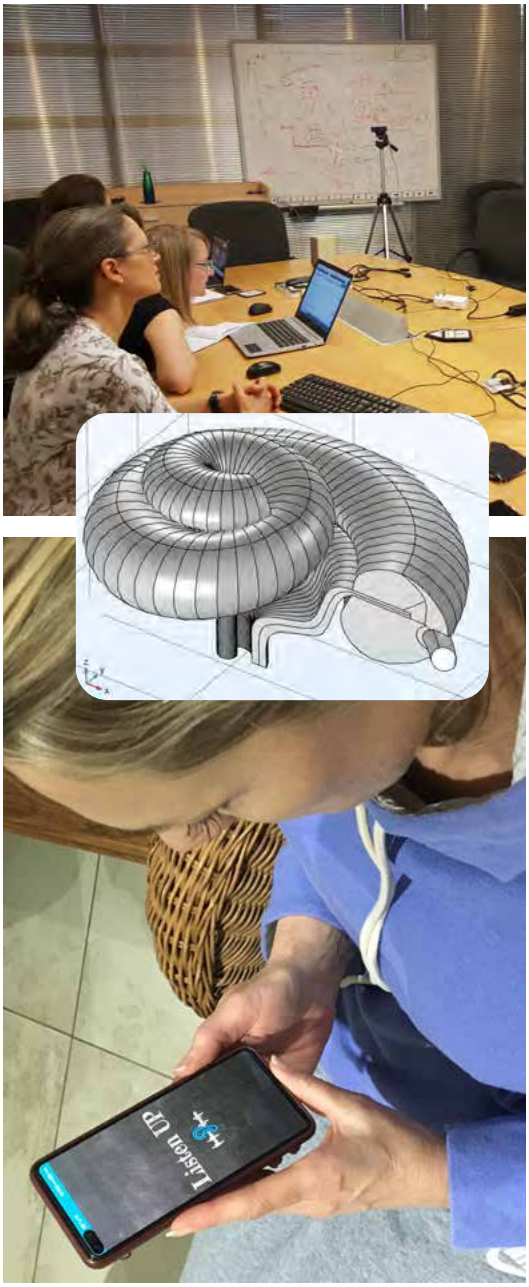
SPECIALISED RESEARCH GROUPS

BIOENGINEERING RESEARCH GROUP

The Department's Bioengineering Research Group performs research in the wide subject area of medical and biological engineering. Its core work is in the field of sensory prostheses, with a primary focus in auditory neuroscience and cochlear implants for the deaf. As a specialist field, bioengineering includes medical or biomedical engineering and biological engineering, built on a foundation of electronic engineering. The research group is led by Prof Johan Hanekom.

The group's research focuses on understanding human sensory processing and solving problems related to neural prostheses. Recent research topics include the following:

- Cochlear stimulation electrodes, electrical fields and nerve activation
- Computer modelling of the normal and electrically stimulated auditory system
- Psychoacoustic research involving normal hearing people and cochlear implant users
- Acoustic models of cochlear implants
- Medical imaging and visualisation
- Speech processing
- Computational auditory neuroscience



CONTROL SYSTEMS RESEARCH GROUP

The Control Systems Research Group strives to address industrial needs through the application of the most recent advances in control theory. The aim is not only to promote, but also to apply automation and control for the benefit of humankind. Research areas of specific interest include model-based control and optimisation in the process industries, and the model-based control of disease networks. The research group is led by Prof Ian Craig, who has a B2 rating with the NRF.

Performance metrics for processes can be incorporated into economic objective functions that form part of a network of advanced process controllers. Additional criteria such as overall equipment effectiveness, energy efficiency, water management, and medium and reagent usage can be included in these objective functions. Information and communication technology, smart mining and industrial internet solutions can be used to optimally integrate the mineral processing supply chain in the form of a distributed network of advanced process controllers. Smart mining concepts such as material tracking and supply chain integration will play a significant role in assisting process controllers to reduce disturbances and to extract more benefit from the mineral processing value chain. Control systems theory also has the potential to provide significant benefits to the medical industry.

INTELLIGENT SYSTEMS GROUP

The Intelligent Systems Group specialises in the theory and application of systems that perceive, reason, learn and act intelligently. The aim of the group is to create real-world, intelligent systems that are applicable in the South African context. It endeavour is to develop complex systems that not only incorporate various knowledge fields, but exhibit the ability to reason about, and interact with, the environments in which they must operate. The research group is led by Hans Grobler.

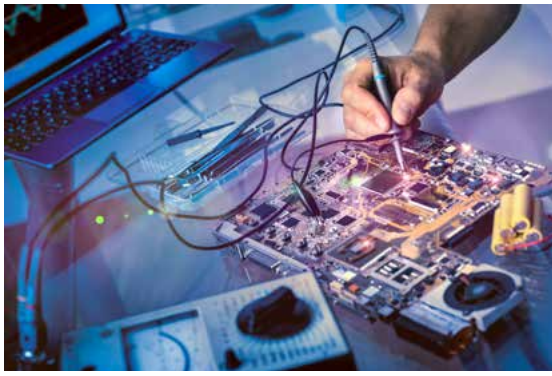
Its research focus lies in the theory and methods whereby various degrees of intelligence can be simulated in systems. Although intelligence can be applied in various real-world applications, and the Group's activities include such applications, its focus is the development of new approaches to simulated intelligence. The assumption is that such new approaches will be tested in various applications, ranging from the obvious, such as robots, to the less obvious, such as music and planning systems.

POWER SYSTEMS RESEARCH GROUP

The Power Systems Research Group focuses on integrating renewable energy generation, such as wind or photovoltaic (PV) power, into traditional grids, as well as reducing inefficiency and emissions. This is at all levels, from small energy sources like a home PV cell to large sources like a wind energy farm. The research group is led by Prof Michael Gitau, who has a C2 rating with the NRF.

Its work on renewable energy includes diagnostics for renewable energy systems, assessing and optimising energy storage solutions, utility-scale energy storage and optimisation, distributed energy storage and value chains, and developing and delivering energy storage projects.

The Smart Grid Laboratory has established itself as a leader in smart grid research. Hosted by the South African National Energy Development Institute (SANEDI), it delivers high-quality research, products, services and capabilities that fill the widening gap between end users and electricity suppliers across the African markets. Some of the practical applications and opportunities for research include renewable energy integration, smart prepaid metering (with time of use), AMI security and active network management. The Smart Grid Laboratory offers a fresh approach to smart grid research that empowers the end-users, delivers savings and benefits utilities and municipalities. These benefits will be realised across the industrial, commercial, and residential sectors.



The additive manufacturing of electronic systems

Prof Trudi-Heleen Joubert

In its flagship project on additive manufacturing for electronic systems (AMES), the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) in the Department of Electrical, Electronic, and Computer Engineering is on a quest to establish integration strategies that best exploit modern additive manufacturing technologies for electronic systems at the micron scale.

CEFIM aims to develop low-cost, simple and efficient additive manufacturing processes, and to research the design techniques, modelling methods and tools that can collectively support the reliable integration of systems. AMES enable the realisation of novel solutions in optical, electrochemical, mm-wave, and microfluidic sensor systems that can impact on society, while contributing to and competing in the global knowledge ecosystem.

A growing demand for inexpensive, rapid, flexible and easy-to-use point-of-care diagnostics has resulted in the rapid growth of the field of printed electronics globally. While research continues to develop the processes and components for printing complete electronic systems, the hybrid integration of off-the-shelf components on low-cost substrates, such as paper and plastic, is important in this domain.

As an example, a low-cost microcontroller-based electronic nose (e-nose) was developed using an array of gas sensors and machine learning algorithms. The instrument must be portable and, therefore, battery powered. Equipping the device with Internet of Things (IoT) capabilities enables valuable distance monitoring. An application investigated for the e-nose is in the field of smart agriculture: the semi-quantitative monitoring of an Amitraz insecticide concentration in a cattle dip solution.

On the one hand, an inadequate concentration is ineffective as an insecticide, but on the other, careful concentration control is necessary because tick resistivity against the acaricide is becoming a problem. This device is not only useful at the dipping troughs of affluent farms, but can positively impact on rural African agriculture by making the monitoring of plunge dipping tanks accessible to rural farmers. In future, CEFIM will use functional printed electronics to explore the component development of metal-oxide gas sensors for tighter integration and size, weight and cost efficiency.

Integrated circuit design is an established strength of CEFIM's research, and additive fabrication processes are explored to heterogeneously integrate CEFIM's custom mixed-signal integrated circuit chips into microsystems. For example, the team is working on integrating CMOS sensor readout chips into a 3D-printed microfluidics lab-on-chip microsystem implementation.

An example complementary metal oxide semiconductor (CMOS) design is a capacitive sensing array as part of a non-flow biosensing microsystem for whole-cell counting applications. The microfluidic channel can be printed into the device's housing by stereolithographic (SLA) resin-printing technology. The integrated microsystem will be employed to detect water contamination by bacteria such as *Escherichia coli*, which is the standard indicator organism of faecal pollution.

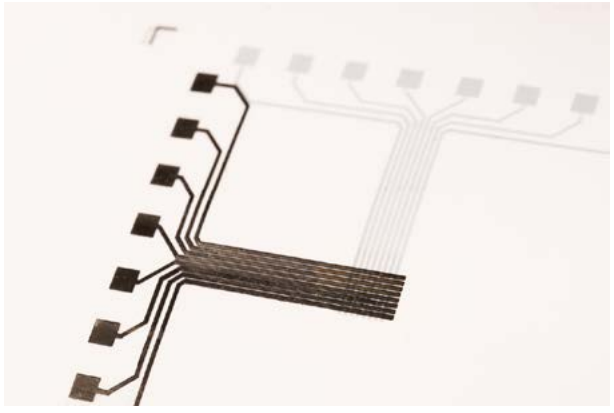
Another application of additive manufacturing addressed at CEFIM is the creation of low-

cost, lightweight, high-frequency antenna components for satellite systems. Here, Alex Simonovic, an MEng student at CEFIM, has been exploring different methods of creating antenna assemblies using readily accessible SLA resin-printing technology, and plating the finished parts with non-toxic silver and copper processes. This process reduces the production lead time and environmental impact of these critical components, while making them light enough to be launched from low-cost CubeSat platforms. Initial results are extremely promising, with waveguides in the 18–26 GHz frequency range, achieving electrical performance comparable to their brass extrusion counterparts.

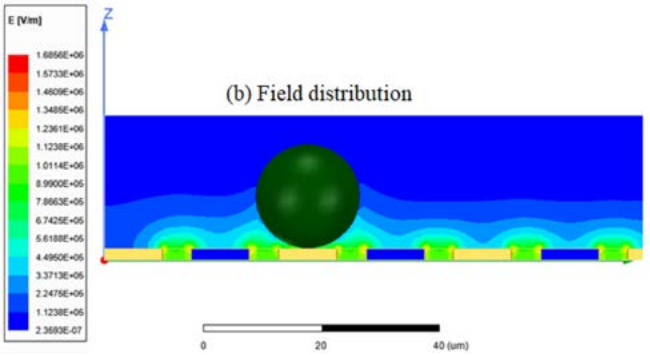
The additive technologies CEFIM is currently using include planar and 2½-D processes, but CEFIM is looking forward to the flexible, true 3D conformal printing of fine features with a wide range of materials, potentially for fully printed integrated electronic devices.

Expanding the use of materials and processes that facilitate sustainable and responsible production approaches will contribute considerably to the achievement of sustainable development. Our consideration of low-cost, low-volume production technologies is envisaged to enhance scientific research and support domestic manufacturing infrastructure, extending to small-scale industrial enterprises.

Through the additive manufacturing of electronic systems, CEFIM's transdisciplinary research will help to innovate our tomorrow in the domains of health, water, wireless communication and climate sciences.

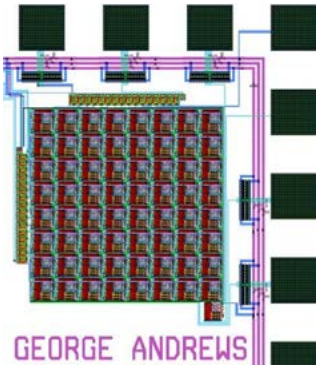


Paper-based printed electronics



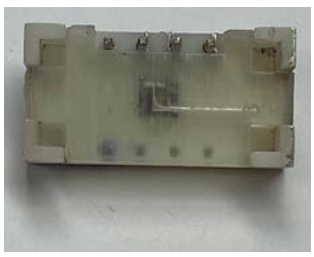
Finite-element simulation of a bacterial cell on electrodes in capacitive sensing (by George Andrews)

Resin-printed antenna array components plated with a non-toxic copper process (by Alex Simonovic)



CMOS layout of a capacitive sensing array (by Trudi Joubert)

An e-nose for monitoring the Amitraz concentration in a cattle dip tank (by Archibald Rohde)



A CMOS integrated circuit in an additively manufactured microfluidic device (by Abraham Salom)

Detecting stink bugs without the aid of olfactory perception

Prof Trudi-Heleen Joubert

Research at the intersection of microelectronic sensor systems and biochemical ecology contributes to integrated pest management practices. The electronic monitoring of insects in the field assists to optimise the amount of insecticide that is necessary for pest control, saving costs and minimising the risk of insecticide resistance developing in the pest population, while moderating the effects of the toxic control substances on the environment.

As an example, the two-spotted stink bug is regarded as the most damaging pest in macadamia orchards, costing the industry millions annually. Currently, the presence of stink bugs in an orchard is monitored via manual scouting after insecticide application on a few trees.

As their everyday name implies, these bugs do not emit a very pleasant odour, which suggests an olfactory mode of electronic detection. Recently, a team from the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) in the Department of Electrical, Electronic, and Computer Engineering and the Macadamia Protection Programme (MaPP) at the University of Pretoria's Forestry and Agricultural Biotechnology Institute (FABI) obtained promising results by detecting gas signatures of the stink bug's alarm pheromone.

Dr Gerda Fourie leads the MaPP, with its major research focus on macadamia plant diseases and pests. Within this research programmme, the alarm pheromone of the *Bathycoelia distincta* stink bug was identified and characterised by Elisa Pal during her PhD studies.

Under the supervision of CEFIM's director, Prof Trudi Joubert, postgraduate student Archie Rohde developed an electronic nose (E-nose) platform for water quality monitoring applications. The core of an e-nose is an array of non-specific gas sensors that can be trained with a machine learning algorithm to classify odours. Undergraduate student Nolan Hermann is designing and implementing an e-nose for the stink bug detection application.

CEFIM is looking forward to making an impactful contribution to the macadamia industry in South Africa with this globally relevant transdisciplinary research at the interface between biology and engineering.

Electrical impedance monitoring of bacterial metabolic activity towards continuous lead biorecovery

Prof Trudi-Heleen Joubert

In the research field of integrated microelectronic sensor systems, pursued by the research group of Prof Trudi Joubert in the Carl and Emily Fuchs Institute for Microelectronics (CEFIM), the electrochemical method of electrical impedance spectroscopy (EIS) holds immense potential for transdisciplinary applications.

Johan de Beer is a PhD candidate who developed novel algorithms for excellent performance in a custom, low-cost impedance analyser. He is currently doing complementary metal oxide semiconductor (CMOS) integrated circuit research towards the miniaturisation of the EIS device. The working principle for EIS it to apply a small amplitude sinusoidal potential across a range of frequencies and measure the resulting current to determine both the magnitude and phase of the electrical impedance across a large range of frequencies.

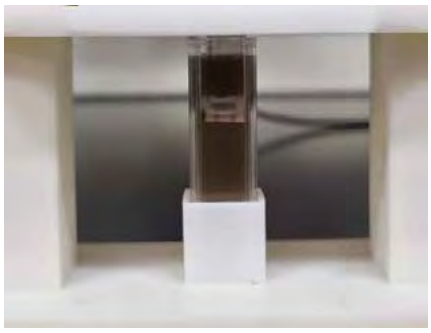
EIS can quantify complex electrical interactions due to the presence of unknown concentrations of suspended ions and proteins in solution. Sensitive measuring techniques can be developed to detect a single bacterium, and even different cellular structures.

George Andrews is a master's degree student who is doing research on the detection of whole-cell bacteria via capacitive sensing. A joint research project was launched between the Department of Electrical, Electronic and Computer Engineering, and the Department of Chemical Engineering to investigate the feasibility of the impedance monitoring of bacterial cell growth in a bioreactor. Bioreactors with lead-precipitating bacterial species can be used in lead recovery. The Chemical Engineering group of Dr Deon Brink and Prof Evans Chirwa has identified *Klebsiella pneumoniae* and *Paraclostridium bifermentans* as potential species for the bioprecipitation of lead.

Master's student Olga Neveling is conducting research on the metabolic activity of the lead-precipitating bacterial species. Real-time inline monitoring is crucial to large-scale continuous lead-recovery processes, and the correlation of impedance measurements using the custom low-cost impedance analyser with other metabolic activity data is promising in this regard. A direct correlation is found between the extracted supercapacitance from the EIS data and the number of colony-forming units during the exponential growth phase, and a qualitative correlation is found between all elements of the measured reactance outside the exponential growth phase. From this study, strong evidence is found that Pb(II) ions act as an anaerobic respiration co-substrate for both cells observed.

The adverse health effects of the presence of lead in wastewater streams is well documented. In addition to the environmental and human health risks posed by lead, the world's lead reserves are rapidly declining, with only an estimated supply of 20 years remaining. The bioreduction of Pb(II) ions to elemental lead is of industrial importance as it provides a potential route for the valorisation of lead.

Conventional methods of lead recovery and removal suffer from disadvantages such as a high energy cost, the production of toxic sludge and low lead selectivity. The inline integration of a miniaturised custom EIS device into a bioreactor opens up opportunities for future scaling via the monitoring and control of the biorecovery process.



A fluid sample from a lead biorecovery reactor in a microcuvette interfacing with the EIS electrodes in a custom 3D-printed housing. The dark fluid colour is due to the precipitation of elemental lead.

Integrative green infrastructure planning improves quality of life in the city

Dr Ida Breed

As populations grow and cities densify, there is an increased need for the planning and design of more environmentally healthy cities. Green infrastructure is important to protect the biodiversity and ecological resources that provide ecosystem services, such as climate regulation or flood control, at different scales. Quality open spaces can provide benefits to surrounding developments and could be the catalysts for economic and recreational activities that meet residents' needs.

South Africa's urban population of 66.4% is projected to reach 79.8% by 2050, according to the United Nations Department of Economic and Social Affairs Population Division. Most of the urbanisation is taking place in the form of informal settlements, where people are living in poverty and basic facilities and services are lacking. Added to this is the risk of projected climate change, manifesting as extremes in temperature and flooding patterns, threatening the health and wellbeing of under-privileged populations. The task of built environment professionals and local government to manage the trade-offs between social livelihoods and ecological infrastructure is complex.

Under apartheid, planned vacant green spaces operated as barriers to opportunities, separating neighbourhoods and communities. Today, this spatial segregation remains evident in the urban fabric, while there is a great need for access to well-designed, multifunctional urban green infrastructure. Planned as dormitories, former "townships" still need mobility and green infrastructure to turn them into well-connected, healthy, mixed-use neighbourhoods. Open spaces are often of a low quality and are consequently perceived negatively by local residents.

Purposeful planning, design and managed interventions are required to provide accessible, multifunctional and high-quality urban green infrastructure. A better local understanding of long-term socio-economic benefits from urban green infrastructure and possibilities for co-management is required, including the responsible development of a green economy, biodiversity protection, climate adaptation, increased social cohesion and enhanced equity.

To address this challenge in the City of Tshwane, an integrative green infrastructure planning research project (GRIP) was conceptualised by the Department of Architecture at the University of Pretoria in collaboration with the Department of Biology at Aarhus University. Funded by the Danida Fellowship Centre under the Danish Ministry of Foreign Affairs, it aims to bring about a strategic transformation of the social and urban landscape in the City of Tshwane through guidelines inspired by the City of Aarhus in Denmark for the improved planning and management of green infrastructure, such as public parks and conservation areas.

Purposeful planning, design and managed interventions are required to provide accessible, multifunctional urban green infrastructure.

The GRIP study sites are typical apartheid "green buffer zones" that segregate communities. This area is in Mabopane along the Sand River. (Photo: S Kusel)

Green infrastructure promotes multifunctionality, which means that the same area of land can perform several functions at the same time. The research project is providing new in-depth knowledge of local opportunities for the multiple ecological and social benefits of green infrastructure. It is also promoting the integration of governance and justice perspectives, and the development of concrete landscape design proposals to improve green infrastructure access, functioning and socio-economic opportunities.

Together with urban planners from Aarhus and Tshwane, private partners and students, the main research partners from Aarhus University and the University of Pretoria are co-creating knowledge and strengthening research capacities through the exchange of expertise. This relates to the question posed by UP's Landscape Architecture Programme about how urban planning can improve and protect existing green infrastructure to supply more ecosystem functions and services for both ecological and socio-economic benefits.

In 2021 and 2022, the GRIP honours studio focused on two sites in the City of Tshwane, comprising green spaces in Atteridgeville and Mabopane along rivers with informal social activities. The studio's aim was to map and develop integrated multifunctional green infrastructure networks for each of the areas to improve their long-term environmental and social health.

The studio also helped prepare young built environment designers to balance urban social and environmental needs and learn how these can be integrated into city planning and design. The studio proposed ecological and social network maps, and formulated strategies to improve access and socio-economic activation, rehabilitation and the ecological protection of sections of the open space, with a set of supporting design guidelines.

The students engaged with the international research team, officials from the City of Tshwane, the local community and private consultants to formulate and develop their proposals.

Detrimental conditions of dumping, littering and a lack of infrastructure that prevails on many green spaces in South Africa (Photo: left – EYEscape Studio; right – I Breed)

Students from the Department of Architecture documenting conditions on the study sites (Photo: top – I Breed; bottom – EYEscape Studio)

The studio analysed and proposed how existing urban green infrastructure could connect to a network of ecological support areas as corridors for biodiversity habitat enhancement, and as "greenways" that provide access for improved non-motorised transportation and recreational activities.

By responding to and building on broad-based existing spatial frameworks and geospatial data, on-site observations, and consultation with the residents, the studio sought to conserve biodiversity, improve environmental quality, reduce the urban ecological footprint, assist with climate change adaptation, promote social cohesion and make the shift towards a greener economy.

This included design thinking for climate and flooding regulations, generating a sense of place and local identity, and providing opportunities for green economic activities, such as recycling and urban food production.

Students from the Department of Architecture engaging with the community on their ideas, to understand the local conditions and environments better (Photos: I Breed)

Important principles for green infrastructure planning include the following:

- **Connectivity:** Green spaces should be connected in a network to provide ecological support areas as corridors for biodiversity habitat enhancement, and to serve as greenways that provide access for improved non-motorised transportation and recreational activities.
- **Multifunctionality:** Open space cannot function in isolation. It needs to be integrated into the surrounding amenities and economic opportunities to attract people. This green infrastructure could increase residents' quality of life in the city by making the sites more liveable, health-promoting, equitable, biodiverse and climate resilient.
- **Green-grey integration:** Green-grey measures could assist to create habitats for plants and animals, as well as with flood retention, urban cooling and reduced energy consumption. All of this can reduce the cost of conventional grey infrastructure.
- **Social inclusion:** Designers should be fostering an awareness of biodiversity values through collaborative urban green infrastructure planning that considers local needs and demands, and allows for co-creation and co-management.
- **(Storm)water management:** South Africa is a water-scarce country. If well integrated and well designed, stormwater could have a beneficial use and function within natural and human-made systems. All open spaces along rivers need to consider stormwater and floodwater for safety, environmental functioning and potential system benefits.

Student design examples of green-grey integration and multifunctionality (Images: top – B Lennox; bottom – C Mackenzie, 2021)

Student design examples of a community clinic that could integrate food gardens with cultural practices and medicinal use of plants (Images: L Cloete and C Swart, 2021)

GREEN INFRASTRUCTURE PROMOTES MULTIFUNCTIONALITY. THE RESEARCH PROJECT IS PROVIDING NEW IN-DEPTH KNOWLEDGE OF LOCAL OPPORTUNITIES FOR THE MULTIPLE ECOLOGICAL AND SOCIAL BENEFITS OF GREEN INFRASTRUCTURE. IT IS ALSO PROMOTING THE INTEGRATION OF GOVERNANCE AND JUSTICE PERSPECTIVES, AND THE DEVELOPMENT OF CONCRETE LANDSCAPE DESIGN PROPOSALS TO IMPROVE GREEN INFRASTRUCTURE ACCESS, FUNCTIONING AND SOCIO-ECONOMIC OPPORTUNITIES.

Student design examples of stormwater use in a recycling centre that could deal with waste and create socio-economic opportunities
(Image: M Read and C Mackenzie, 2021)

The studio's outputs were presented and shared with the research team and with officials from the City of Tshwane's Environmental Planning Department. Two student projects from the 2021 GRIP studio won a first and third place, respectively, in two international design competitions. Four current master's degree students are completing their design projects on the GRIP study sites.

With their design developments, they wish to illustrate how planning and design initiatives could become catalysts for community co-management and increased social and ecological benefits. From a management perspective, integrative green infrastructure planning aims to co-create planning guidelines that could assist with a unified green spatial planning vision that includes city officials, private developers, the community and designers.

The long-term objective is that GRIP research will facilitate an improved quality of life in urban communities in the City of Tshwane by moving towards a more climate-resilient, health-promoting, biodiverse and liveable city.

Student design shows a vision where people and nature are more closely integrated in South African cities
(Image: C Swart, 2021)

Can a living wall combine landscaping aesthetics with urban food production?

Karen Botes and Ida Breed

Green wall systems have greatly advanced over the past few decades, and hold important potential for the future in light of predicted urban population growth, densification and climate change.

INCORPORATING URBAN AGRICULTURE THROUGH LIVING WALLS TO COMPACT URBAN ENVIRONMENTS WILL ENHANCE THE AUTO-EFFICIENCY AND WELLBEING OF COMMUNITIES, AND COULD MAKE FOOD PRODUCTION MORE COST-EFFECTIVE AND SUSTAINABLE.

A recent study on the different living wall systems that are currently available in South Africa, using a case study review of three recently implemented edible living walls in Gauteng, suggest that living walls have indirect commercial value through customer experience and satisfaction, as well as educational value. Should the scale, economic feasibility and resilience of living wall systems be enhanced, they even have the potential to improve urban food production. According to the researchers, this could be achieved in the Global South by using simplistic technologies with lower-cost living wall infrastructure systems. When deployed on a large scale, with climate-tolerant indigenous and edible plants in exterior systems, productivity could be improved.

Initially sought after for their unusual aesthetics, living walls have proven to provide much-needed present-day urban ecosystem services and make a perceived value contribution to biodiversity. A prime contemporary research focus is the potential of living walls to improve the urban microclimate through thermal insulation and cooling by means of evapotranspiration, wind or sun screening.

A second forthcoming area of interest is urban small-scale, vertical outdoor food production, which is increasingly serving as an extension of rural food production. In inner cities with limited, expensive or unsafe ground space, the extent of the latent area for façade greenery is almost double the footprint of buildings, with the prospect of offering more environmental benefits than green roofs.

As the performance of outdoor living walls depends on the local climate and socio-cultural needs

and values, more context-specific system reviews are required, which are specifically aimed at cost-competitive and logistically practical food production technology.

Climate change is predicted to pose significant challenges to people's dependence on the environment because of regional economic imbalances, with limited diversified economies, inequalities and poverty. It is predicted that Africa will experience an increase in droughts and an intensification in hot extremes, as well as more frequent and longer heat waves. In South Africa, this must be understood in relation to the expected acceleration in urbanisation from 66.4% in 2019 to an anticipated 79.8% in 2050 according to the United Nations Department of Economic and Social Affairs Population Division.

Despite initiatives such as C40 Cities to promote climate action and combat the effects of climate change, urban greening is not a high priority in southern African cities. Innovative thinking in terms of greening and cooling is required from designers and planners to mitigate the forthcoming impacts of global warming. Such ambitions could include novel approaches to living walls, which include urban food production based on local needs.

Living wall infrastructure systems that have been developed over the past few decades to achieve improved technical solutions and benefits are classified into continuous and modular systems. A continuous system entails lightweight screens without a substrate for plant growth, while modular systems include substrates and comprise containers with specific dimensions, and varied composition, weight and assembly methods.

In South Africa, both local and imported products have been used in living wall projects, with local products being more cost-effective. Modular living wall systems are currently the most widely used, mainly because of the instant impact after installation. Plants can be pre-grown off-site in advance, and individual plants can be replaced with minimal effect on the aesthetics or adjacent plants because of the separate modules provided for each plant.

In general, the local installation and popularity of living wall systems have primarily been as an embellishment or environmentally friendly feature. They have mostly been used to enhance buildings' indoor environments. However, more sustainable systems and plant species have been introduced that contribute to greater longevity, functional value and use.

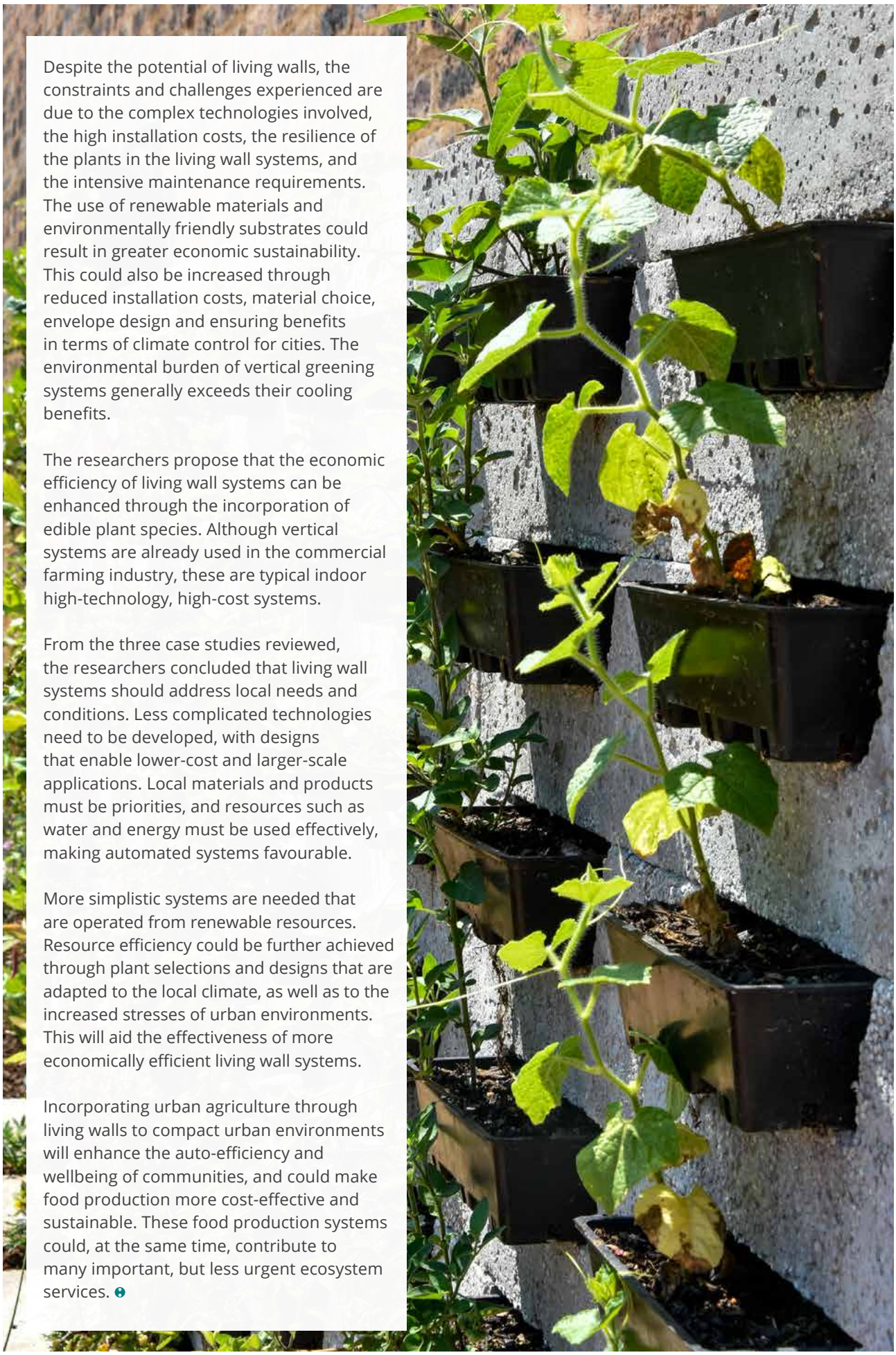
This phenomenon has mainly manifested in three ways: the use of local indigenous species for a local African identity; the use of indigenous and diverse plant species to attract biodiversity; and the establishment of edible vertical gardens for human consumption.

Three case studies were selected to consider the current use of living walls for edible plants in Gauteng: the Doppio Zero @ Hobart edible living wall at the Grove Shopping Centre in Bryanston, Johannesburg; the living wall at the Mix cocktail bar at the Mesh Club, Trumpet Building, Keyes Art Mile in Rosebank, Johannesburg; and the Neighbourgoods Market in Juta Street, Braamfontein, Johannesburg. These edible living wall systems were evaluated for system resilience, economic efficiency and the possibilities of the edible plant palette.

The researchers found that automated irrigation and natural light sources reduce the risk of human inconsistencies. This improves the resilience of the living wall system, but heightens the cost. Modular systems were found to be more durable in dry climates. The appropriate selection of the type, volume and agents of the growing medium plays a vital role in plant survival, ensuring effective moisture retention and optimal growth according to root expansion.

The right exterior aspect and addressing the specific light quality and duration requirements of plant species in the living wall systems also impact on plant performance. Local indigenous plants are often better adapted to local conditions such as direct sun exposure, air humidity levels and precipitation, and require lower running costs and less maintenance. While the use of local species enhances system resilience, it also creates local environmental awareness and appreciation, while attracting customers by offering a unique experience.

INNOVATIVE THINKING IN TERMS OF GREENING AND COOLING IS REQUIRED FROM DESIGNERS AND PLANNERS TO MITIGATE THE FORTHCOMING IMPACTS OF GLOBAL WARMING. SUCH AMBITIONS COULD INCLUDE NOVEL APPROACHES TO LIVING WALLS, WHICH INCLUDE URBAN FOOD PRODUCTION BASED ON LOCAL NEEDS.



Despite the potential of living walls, the constraints and challenges experienced are due to the complex technologies involved, the high installation costs, the resilience of the plants in the living wall systems, and the intensive maintenance requirements. The use of renewable materials and environmentally friendly substrates could result in greater economic sustainability. This could also be increased through reduced installation costs, material choice, envelope design and ensuring benefits in terms of climate control for cities. The environmental burden of vertical greening systems generally exceeds their cooling benefits.

The researchers propose that the economic efficiency of living wall systems can be enhanced through the incorporation of edible plant species. Although vertical systems are already used in the commercial farming industry, these are typical indoor high-technology, high-cost systems.

From the three case studies reviewed, the researchers concluded that living wall systems should address local needs and conditions. Less complicated technologies need to be developed, with designs that enable lower-cost and larger-scale applications. Local materials and products must be priorities, and resources such as water and energy must be used effectively, making automated systems favourable.

More simplistic systems are needed that are operated from renewable resources. Resource efficiency could be further achieved through plant selections and designs that are adapted to the local climate, as well as to the increased stresses of urban environments. This will aid the effectiveness of more economically efficient living wall systems.

Incorporating urban agriculture through living walls to compact urban environments will enhance the auto-efficiency and wellbeing of communities, and could make food production more cost-effective and sustainable. These food production systems could, at the same time, contribute to many important, but less urgent ecosystem services.

Providing experiential learning opportunities in an online environment

Karen Botes

Karen Botes is a lecturer in the Department of Architecture who is translating her research passion into an experiential learning opportunity for third-year students specialising in landscape architecture. She believes that students learn best by adding real-life experiences to their theory through multidisciplinary collaboration. Her teaching has enabled her to transfer her interest in sustainable design and novel approaches to the creation of green infrastructure, and to enhance ecosystem services through design.

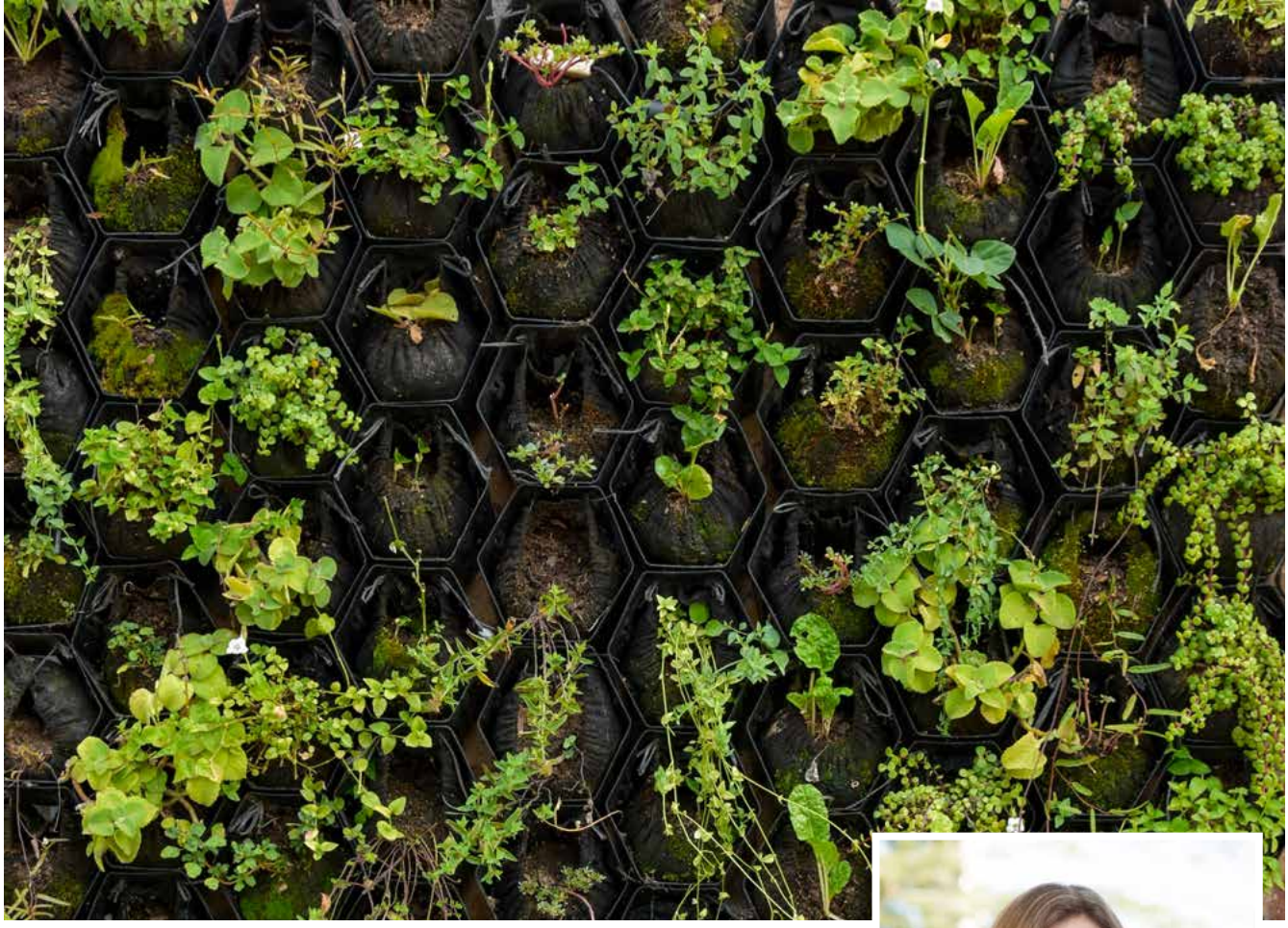
The teaching and learning initiative for which Botes received the Faculty of Engineering, Built Environment and Information Technology's Teaching and Learning Award for 2021 started as an innovation in 2020 for the third-year Plant Science module (PWT 322). This module emphasises plant community conservation based on ecological principles in the urban environment, including the technical aspects of planting in these complex environments. During the Integrated Design examinations in the previous year, she identified a gap in students' ability to apply the theory they had learnt in practice. Her approach was therefore to address these knowledge gaps through student-centred, experiential learning, coupled with multidisciplinary collaboration.

In 2020, Botes received a Scholarship of Teaching and Learning (SoTL) Grant from the Department of Higher Education and Training (DHET) for a project titled "African food crops in living wall systems". To assist students to gain a better understanding of the learning outcomes of PWT 322, she exposed them to two real-life projects in which green principles were implemented to support ecosystem services: one on the Menlyn Maine precinct in Pretoria East and the other at the University of Pretoria's Future Africa campus. She also included a real-time case study to attune students to the local context through the planting of African food crops on the Future Africa campus in two different typologies of green wall systems.

However, the lockdown regulations that were imposed to manage the COVID-19 pandemic compelled Botes to reflect on what she wanted her students to achieve online. This led to a collaboration with the Faculty's Head Education Consultant, Dr Adriana Botha, who provided a different perspective on how to achieve set outcomes in the online environment. This, in turn, led to the application of novel teaching and learning methods.

Botes made use of her SoTL Grant to purchase a 360° camera, which enabled her to make use of Blackboard's interactive video function. By recording the construction of projects that showcased green infrastructure, the students could witness the process virtually, which assisted them in understanding the module outcomes as an alternative to physical site visits.

The objective of the SoTL Grant was to analyse and define student learning by engaging virtually with real-life projects and transdisciplinary collaboration. Botes applied Kolb's experiential learning cycle to her teaching. This entailed involvement in the concrete experience, reflecting on the experience, learning from the experience and solving problems based on the experience. As such, she engaged with her students through collaborative assignments, workshops and discussions to understand different viewpoints, followed by constructive feedback. Students also collaborated with each other and the lecturer through a WhatsApp group. Finally, self-paced learning took place through interactive videos, with in-video assignments and quizzes.



The activities that formed part of this initiative required the students to conduct research and present their outcomes to their peers through ClickUP. In the process, Botes was able to create an awareness of African food crops and the role of designers in addressing the United Nations' Sustainable Development Goals (SDGs) in the South African context. Botes alternated between teaching methods to keep learning vibrant, and included the flipped classroom model, case studies, experiential learning, asynchronous and interactive videos, cross-disciplinary discussions and synchronous lectures via Blackboard Collaborate.

Botes facilitated student learning by engaging her students in four intentional activities to achieve the module's learning outcomes. The first activity entailed real-time online interviews with suppliers, horticulturalists and landscape technologists to discuss different living wall systems. The various professionals introduced the students to different prototype living wall systems.

This enabled the students to develop an insight into the benefits and disadvantages of each system. The second activity involved students reflecting on their experience in teams, where each team had to investigate a different prototype of a modular living wall system. Botes divided students into groups, which comprised a mixture of students on different academic levels. The groups were required to conduct research and compile the technical specifications of each system, and analyse the resilience, sustainability, economic feasibility, social benefits and provision of ecosystem services in the South African context. The third activity entailed a discussion between different student teams, where they debated the advantages and disadvantages of the different systems. The fourth activity was the students' examination assignment. Here the students had to implement what they had learnt by selecting a constructed wetland, living wall or rooftop garden system to enhance ecosystem services as part of their design project.

Finally, Botes held project workshops, followed by online engagement with each student on a one-to-one basis to ensure that the learning outcomes were fully achieved. Due to the small number of students enrolled for this module, she was able to pay personal attention to each student, thereby focusing on their wellbeing, which is vital in a creative learning environment.

Human-centred and disruptive pedagogy in the Architecture studio

Dr Anika van Aswegen

Human-centred design focuses on immersive and connected approaches and prioritises the needs and requirements of users in the design process. The human-centred design studio in the honours programmes of the Department of Architecture introduces disruptive ways of engagement as progressive and transformative design pedagogy.

The interdisciplinary studio matrix of the honours design modules integrates students from the three spatial disciplines of interior architecture, architecture and landscape architecture. A human-centred focus can thus be considered as design for human scale across the various disciplinary areas of design in the built environment. When designers zoom in, becoming aware of the particularities of complex issues affecting people directly, they are able to obtain deeper insight into societal challenges. Human-centred design is a facet of design thinking for innovation (IDEO, n.d.).

The design projects require students to shift their perspective from that of expert designer or architect to the experience and point of view of the user or community. This process of dissociation (Panero et al., 2019) is a disruptive challenge that deliberately considers empathy (Kouprie & Visser, 2009) to imagine or assume another person's reality. This is not an easy process and requires time. Empathy mapping and the creation of personas are used to make the shift to reveal aspects related to spatial psychology, emotional attachment and subjective meaning-making. Personas are fictional characters based on detailed contextual mapping and are representative of real-life contexts. Access to and the participation of direct users and stakeholders are not always possible in all projects.

Empathy mapping and the creation of personas are used to reveal aspects related to spatial psychology, emotional attachment and subjective meaning-making

Over the last three years, this studio approach has shown that students are able to expand the conventional design process to frame projects more holistically. They can identify issues beyond preconceived problems and propose responsible design scenarios as alternatives to the current conditions. Intangible concerns related to wellbeing, identity formation and cultural exchange are integrated into project details, which are not always addressed in a traditional sense. Furthermore, students critically reflect on their own world view as part of this studio practice. The role of the expert is probed, and a bottom-up approach is used to balance out familiar top-down tactics.

Research has shown that, although empathy has been criticised (Bloom, 2016), it has an increasingly important role to play for designers and architects to discard their personal and professional bias and prejudices. Very often, single solution-driven processes are unable to reveal the finer nuances embedded in the realities of temporal living scenarios and of the human condition (Van Aswegen, 2021). A human-centred focus disrupts the status quo towards deepening the understanding of people-environmental needs and inter-relationships. The human-centred design studio considers the process of knowing to be as important as the creation of knowledge. Projects shift from an object-focused approach as an architecture of form, to an awareness of and response to the dynamic and fluid conditions of living as the drivers of spatial design.

A previous collaboration with Emile Cronjé and Gert van der Merwe of the Tshwane Arts Union and the Freedom Gallery introduced other hybrid and open-ended approaches. Character cards, objects of agency and personas were used in role-play to better understand complex scenarios. Other human-centred studios were facilitated, dealing with the interface between people, spaces and objects. In these studios, fine art activities and immersive food experiences were used as embodied ways to expand empathy towards a relational understanding of human-environment conditions. Current projects include music as a metaphor for storytelling and the development of spatial narratives focused on emerging creative industries and intangible heritage.

A human-centred focus is not only considered in design, but also in one honours research methodology project. Students were required to map human traces in the city by including poetic narratives from the perspective of the urban dweller, as well as from the view of the designer or architect. Students imagined the various perspectives by responding in poetry and vignette drawings, as quick spatial impressions of what is observed in public spaces. A rigorous data analysis process, as inductive research, allowed for a process of triangulation and the construction of multiple realities.

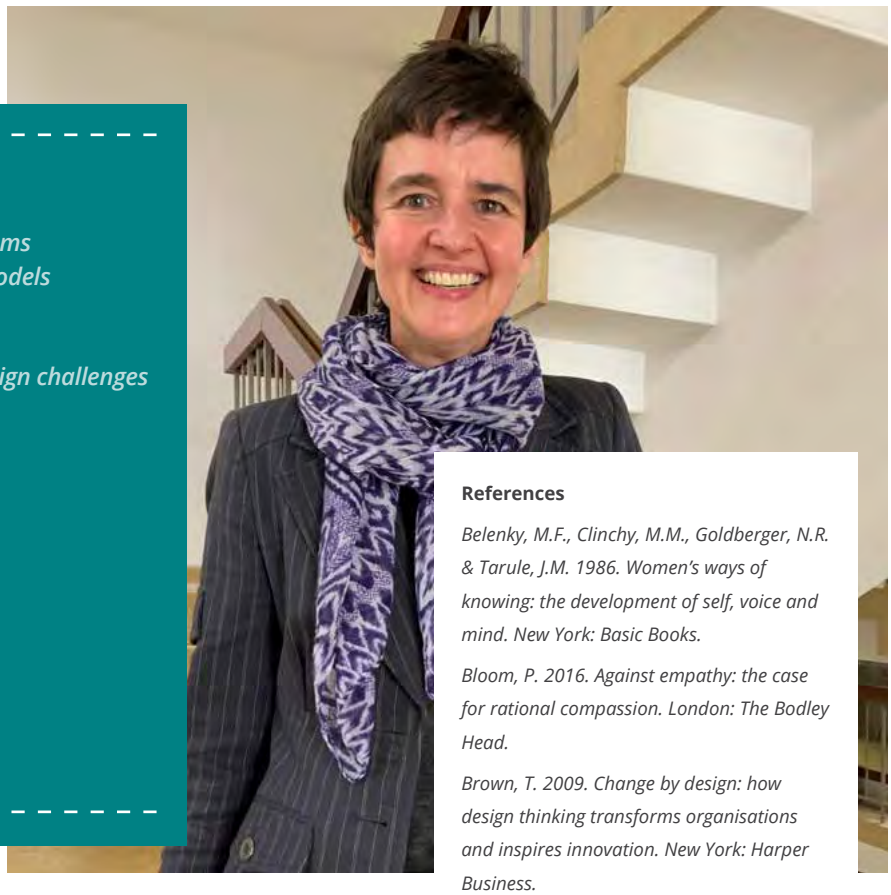
As constructivist research, it enabled transformative learning (Mezirow, 1991) through the students' academic report writing.

Dr Anika van Aswegen's recently completed her PhD research into human-centred design. Disruptive approaches and transformative learning set the foundation for the honours human-centred design studio and the research project. The research findings of this constructivist study, with qualitative, thick descriptions, reveal the importance of exposing students to unpredictable scenarios that are increasingly difficult to frame. This complex world offers many incidents where designers and architects can be caught in preconceived ideas, which are detrimental to real-life projects. However challenging it might be to adopt other points of view, the transformative journey towards inclusion offers the acquisition of softer skills to act respectfully to all living creatures.

The study found that hybrid ways of engagement promote connected knowing (Belenky et al., 1986) and learning to address complex societal challenges. This progressive approach includes aspects of social, cultural, economic, psychological and environmental concerns. This is made possible by not only focusing on cognitive learning, but deliberately including the affective domain that incorporates values and attitudes (Krathwohl et al., 1964). An integrated understanding of both design thinking (Brown, 2009) and designerly thinking (Cross, 2006) is proposed to develop a rigorous and holistic approach towards positive change through design.

Dr Van Aswegen's thesis presents the following provocation:

this is an interdisciplinary study
it is speculative
it does not attempt to solve any problems
or create any toolkits, guidelines, or models
this study asks questions
it probes and explores
it investigates how we engage with design challenges
it does not give answers
but
it shows what can happen
if we challenge outdated old grooves
through disruptive action
this study cares to make a difference
it hopes to reach beyond the surface
to enable change
it puts people first
by embracing various voices
it asks who, how, why
this is a provocation



The contribution of the research concludes by highlighting the interdisciplinary context in which the findings are relevant:

- Individual student development
- Students in a community of peers
- Lecturers' personal teaching development
- Lecturers in an academic community
- Design education or pedagogy
- Design practice or profession
- Impact on the larger society

The value of the research, using productive disruptors, is the focus on transformative learning to prepare students as future practitioners and change agents. These findings are in conflict with the requirements of accreditation bodies. The needs of the profession are changing, and design education is adapting to these societal contradictions and ambiguities. Architecture is no longer defined by established typologies, but by the hybrid nature of living and working in an increasingly complex world with advanced technologies.

In 2019, Prof Hennie Reynders invited Dr Anika van Aswegen to present a lecture and facilitate a disruptive workshop at the School of the Art Institute of Chicago. She published a book chapter, "Refocusing the interior lens: other methods of critical and creative inquiry in the architecture studio" in the book ***Progressive pedagogies: Examples from architecture and allied design fields*** *(2021). In 2021 and 2022, she co-presented two online lectures with Dr Carin Combrinck as part of the Reality Studio of Chalmers University of Technology on citizenship design, and human-centred design and empathy. She recently graduated with her PhD in Interior Architecture with a thesis titled "Disruption by dissociation: Human-centred design through transformative engagement in the spatial design studio" (2021). She received the Neill Powell Neill Award for the best completed postgraduate study by research in the Department of Architecture in 2022.*

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The construction professional of the future

Elzane van Eck and Derick Booyens

The construction industry is evolving rapidly due to the innovative use of technology. The use of drones, building information modelling, virtual reality and nanotechnology are no longer foreign concepts. Digitalisation is the order of the day as companies strive to become more efficient and remain relevant in an evolving industry.

Future construction professionals will come from the Generation Z cohort, also referred to as the first digital natives. Millennials were considered digital pioneers, but Generation Z was born into a world filled with technology. Generation Z's focus when coming to university is to acquire the skills necessary for their future careers. The way in which they prefer to learn and acquire such skills will be different to those adopted by Millennials. Generation Z graduates might also have a stronger desire for self-employment as a career, and it is important to equip students with the skills that will enable them to do that.

Academic knowledge will remain the foundation of any degree, but the Department of Construction Economics at the University of Pretoria aims to deliver graduates who are able to apply such knowledge in context.

The next generation of construction professionals will need to have a sound knowledge and understanding of construction technology and be able to use it. Graduates must be able to adapt to change, as they will work in an environment that is continually disrupted by the economy, politics and technology. Despite having obtained the required academic knowledge and being tech-savvy, young graduates will also have to acquire soft skills such as communication, conflict resolution, teamwork and leadership to be able to navigate the complexities of the construction industry.

Some of the construction technologies that future construction professionals need to know about include the following:

BUILDING INFORMATION MODELING (BIM)

This is the process of holistically creating and managing the information required for a building's construction. BIM integrates structured, multidisciplinary data through a cloud platform to produce a digital representation of a building or development across its entire lifecycle, from concept design through to the construction and operation phases. The application of different software developed by Autodesk, such as Navisworks, is but one of many examples of how BIM is utilised in industry.

VIRTUAL REALITY (VIRTUAL SITE INSPECTIONS)

Through the application of the "Core" software developed by "Openspace.AI", real-time site inspections can be performed by creating visual records. This application is based on Google Street View, but for the construction site. These records are then compared to the BIM design.

DRONES

The use of drones in the construction industry is gaining momentum. In the construction industry, drones are currently used for aerial photography, surveying, progress reports through visual aids, and safety and security

monitoring. A high-resolution camera attached to the drone captures overlapping areas of the construction site, and processing software allows for the use of photogrammetry to construct 3D models, which depict height, depth, colour and texture. Construction professionals need a basic understanding of the legal responsibilities, essential pilot capabilities and qualifications, the necessary equipment, as well as the processing software required.

CONSTRUCTION SOFTWARE

There are various types of construction software available, such as estimating and measuring software, construction management software and project management software. The use of construction software will continue to increase efficiency and collaboration between members of the professional team. Some construction software suites can also link to a project's BIM and can be used in conjunction with other software, such as Openspace.AI.

NANOTECHNOLOGY

This is the study and application of manipulating materials' properties on a nanoscale by quantum physics. Nanotechnology could improve the properties and functionality of traditional construction materials and can potentially reduce the energy consumption and environmental impact associated with construction.

The construction industry will continue to evolve, and so will teaching and learning. It is the responsibility of lecturers to respond to the latest industry trends, especially technical innovation. By doing this, we will be able to deliver work-ready graduates who are able to face the demands of the construction industry.

THE NEXT GENERATION OF CONSTRUCTION PROFESSIONALS WILL NEED TO HAVE A SOUND KNOWLEDGE AND UNDERSTANDING OF CONSTRUCTION TECHNOLOGY AND BE ABLE TO USE IT. GRADUATES MUST BE ABLE TO ADAPT TO CHANGE, AS THEY WILL WORK IN AN ENVIRONMENT THAT IS CONTINUALLY DISRUPTED BY THE ECONOMY, POLITICS AND TECHNOLOGY.

Training the next generation of XR developers

Isak de Villiers Bosman, Kwan Sui Dave Ka and Annique Smith

With the resurgence of eXtended Reality (XR) technologies over the last 10 years, especially virtual reality (VR) and augmented reality (AR), the potential of these technologies is starting to be realised in a variety of contexts, including training and simulation, exposure therapy, entertainment, remote surgery, psychotherapy, physiotherapy, real estate marketing, remote travelling and historical landmark preservation.

As the global market for these applications grows, there is also a growing need for skills acquisition regarding the mediums themselves, not only in terms of the programming and asset development requirements, but also towards understanding how to design human-centred interaction.

When interacting with elements in the virtual space, many aspects of interaction need to be reconsidered. For example, since interaction is primarily done using motion-tracked controllers, text-entry becomes a problem. Furthermore, the field of regard in which users interact with the software is no longer a flat screen, but an omnidirectional environment. These aspects pose a unique set of challenges that are currently core research areas within the field of XR. This gives rise to the potential to ideate and define new interaction methods as the technology evolves.

The BIS Multimedia Honours degree, presented in the Department of Information Science, has placed significant focus on XR design and development since 2016. The degree is well situated to focus on this area, since BIS Multimedia undergraduates learn a variety of skills that are directly applicable, including software development, authoring tools, human-computer interaction and game design. Third-year students' experience with designing and developing a full-fledged digital game is especially relevant here, since the two applications use similar development tools and both focus on human-centred goals.

The virtual reality and interaction (VRI) lab provides access to state-of-the-art XR equipment, as well as a workspace for students of the BIS Multimedia Honours degree, and other students in the School of Information Technology. The BIS Multimedia Honours degree also has modules that focus on XR theory and create opportunities for students to explore XR applications they are interested in. This has led to a wide variety of applications being developed, including games, simulations, visualisations and training applications.

Through access to the technology and focusing on medium-specific interaction issues in their degree, BIS Multimedia Honours students are given the opportunity to be creative in exploring potential solutions. This gives students the opportunity to solve problems that are relevant to both the industry and the research community.

By providing students with access to the latest technologies and equipping them with the skills to create applications that solve real problems, graduates of the BIS Multimedia Honours degree at the University of Pretoria are able to enter the workforce of the future. In the fast-changing world of technology, students not only need to learn how to use current technology, but also how to stay up to date with new technologies.

The ubiquity of technology in our lives and the highly competitive nature of the tech market necessitates a user-centred approach, where technology not only solves problems, but also provides a positive experience for users.

Solving an industry problem through the development of a business system

Dr Lizette Weilbach and Dr Marie Hattingh are lecturers in the Informatics 370 (INF 370) module in the Faculty of Engineering, Built Environment and Information Technology. This module focuses on the application of systems analysis and design in a practical project, programming and the use of computer-aided development tools. The culmination of the module is a capstone project, which brings together all the knowledge the students have gained in their first three years of study.

The project entails the development of a business system for an actual client to solve an industry problem. This enables the Department of Informatics to produce industry-ready graduates who have mastered certain technical skills, are able to work in teams, and have leadership skills, creativity and adaptability.

According to the course coordinator, Dr Weilbach, the students work in teams for a real-world client, who must work through and sign off on each of their deliverables to solve actual problems by analysing, designing, developing and implementing a solution that supports the client's real-world problem. "In the process, we expose the students to the pressures of working in teams, practising their leadership skills, resolving conflict, adhering to strict deadlines and managing their time between the project and their other academic and social commitments."

The lecturers focus on three important aspects: fostering student engagement, stimulating intellectual development and building student rapport. In 2021, 185 students worked in 37 student teams of five students each to complete 12 deliverables in their projects' life cycle. These included a project proposal, functional and technical specifications, a prototype, the internally tested system, the final system documentation, user and training manuals, a team video introducing the groups, their clients and their solutions, a project repository to showcase their systems, and an exhibition at the Department's annual Project Day.

Examples of projects conducted included the following:

A FOOD MANUFACTURING AND POINT-OF-SALE SYSTEM FOR A FROZEN FOOD MANUFACTURING COMPANY

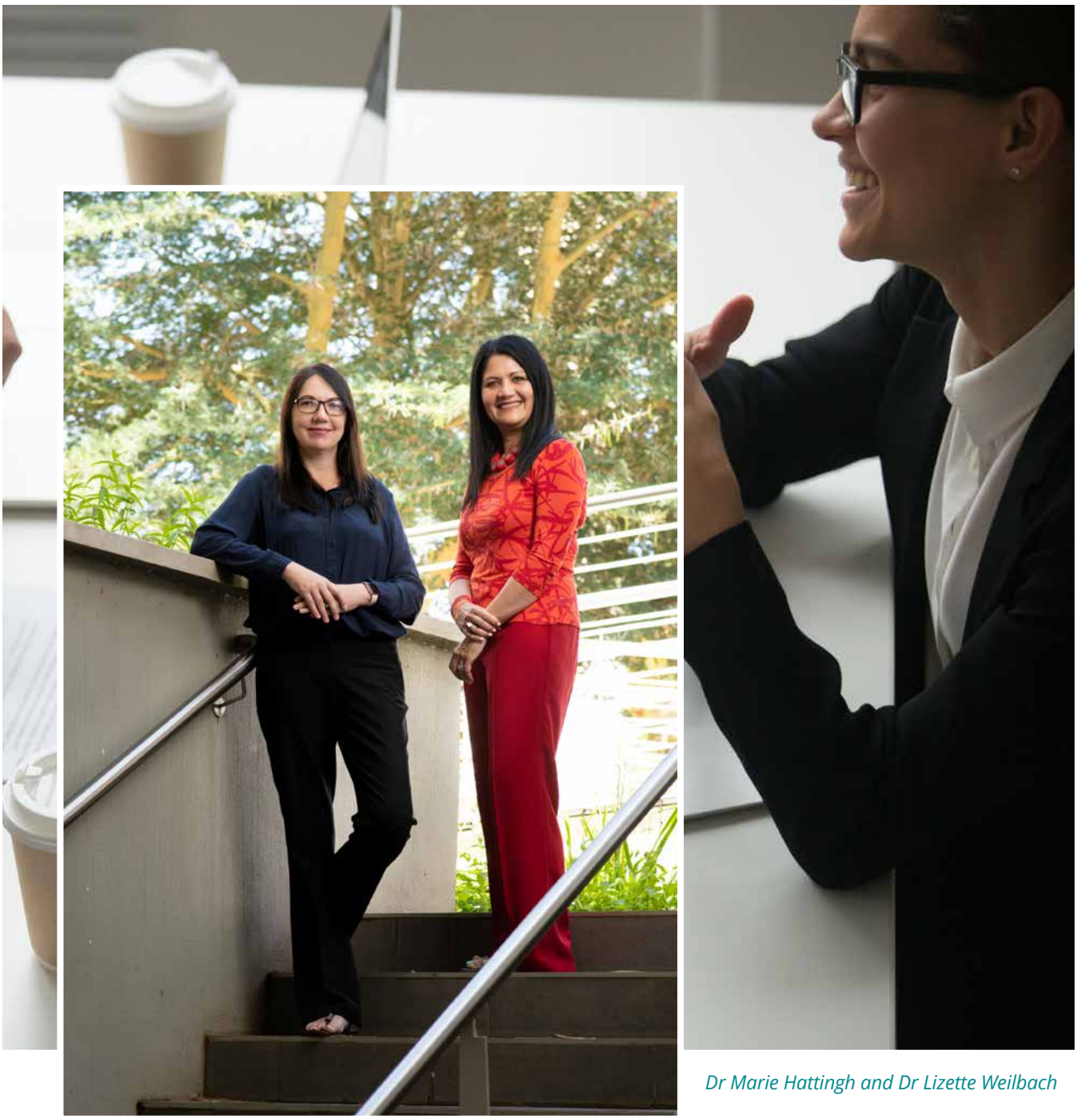
The system that was developed provided management with an integrated view of all operations across its various branches. It allowed for stock tracking, setting up and managing cooking batches for food manufacturing, and selling the final product to the public. It also streamlined employee training activities. In addition, a mobile app was developed for customers to view their product list, place orders and arrange for order delivery.

AN EMERGENCY RESCUE INVENTORY MANAGEMENT SYSTEM FOR PARAMEDICS

The system that was developed was tailored to assist the client to keep track of inventory items stored at its basecamp and on its emergency response vehicles. When the crew went out on a call, they could use the mobile app to keep track of the items used and update the vehicle's inventory levels accordingly. The system also helped the client to perform vehicle inspections, manage supplier orders and manage its employees.

THE DEVELOPMENT OF A MUSIC CENTRE MANAGEMENT SYSTEM FOR A PRIVATE COLLEGE

The system that was developed was capable of handling automatic and manual billing, online payments, class scheduling via an assistive timetable that mapped students to their class schedules, assigning and managing merits, and the option to generate award lists. It could also generate customisable contracts and various reports, providing insight into the music centre's operations.



Dr Marie Hattingh and Dr Lizette Weilbach

Dr Weilbach observes that the INF 370 students are diverse in skill set and background, and come with their own passion and interest when they commence this module. Although they have all completed the same foundational courses, which include programming, advanced programming, relational database design and the design of information systems, they have followed different electives, and have different skill levels. As the project requires the students to work in teams, it is often very difficult for the students to work together, under pressure, and with a real-world client who adds more pressure.

These stresses were compounded as the students also had to work online during lockdown. Part of the challenge therefore includes accounting for the diversity of students, both in skill and in resources.

Dr Hattingh, who joined Dr Weilbach to present this module in 2021, says that completing the capstone project online presented a number of additional challenges, as lecturers had to improvise the way they consulted, provided feedback, assessed and showcased the students' work to industry. However, the success of the virtual project day showed that the time and effort had paid off.

This programme is one of the only of its kind in South Africa. An important outcome is the Department's excellent reputation in industry, which leads to almost all its students obtaining employment upon graduation.

Collaborative projects prepare engineering students for the future

Dr Lelanie Smith

Students are more engaged if they are involved in real-world challenges. It is also important for students to experience the wide extent to which their degrees in mechanical and aeronautical engineering can be applied. Since 2021, two projects, in particular, have provided final-year students working on their research projects with such opportunities. The first involved collaboration with students from the University of Tromsø in Norway, while the second involved collaboration with a local engineering design company, TowerWing.

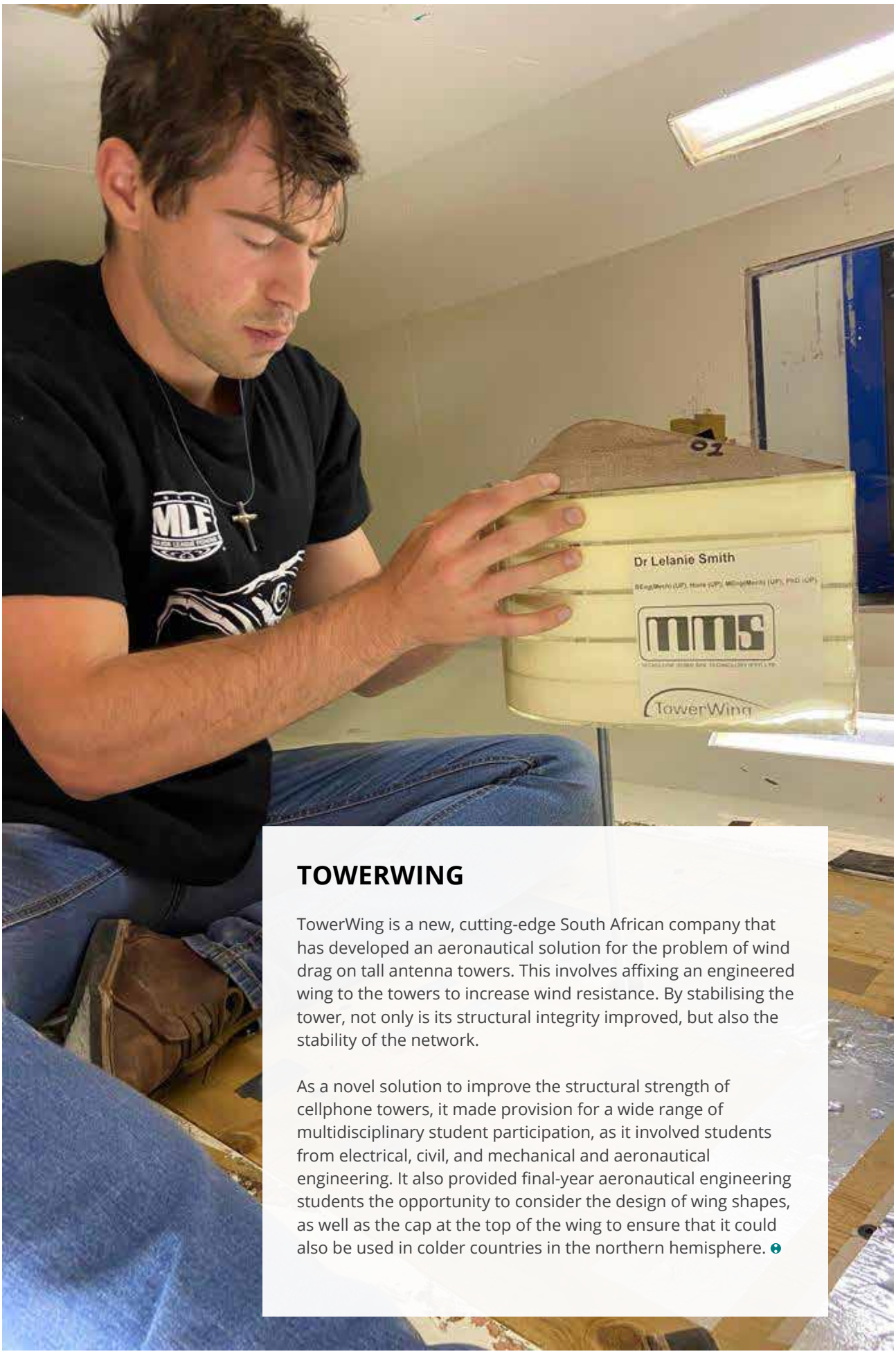
UNIVERSITY OF TROMSØ

As part of a larger project, SARex3: Evacuation to shore, survival and rescue, students from the University of Pretoria's Department of Mechanical and Aeronautical Engineering partnered with their counterparts from the University of Tromsø to develop an evacuation strategy for Arctic maritime disasters. The University of Tromsø is also known as the Arctic University of Norway, and is the world's northernmost university.

The evacuation of people in distress in the Arctic waters is thus a pressing real-time, real-world issue for the Norwegian students.

The students collaborated on the conceptual design of a lifeboat evacuation system that makes use of a life raft as a shuttle to evacuate persons safely to dry land.

A final-year student from UP validated the design using computational fluid mechanics, as well as basic experiments to predict the strength of towing cables in a variety of Arctic conditions. Design alterations were proposed to enhance the mobility and manoeuvrability of the concept. The second iteration of this project has been developed, with the potential for students to participate in a real-life emergency evacuation exercise on Svalbard, north of Norway.



TOWERWING

TowerWing is a new, cutting-edge South African company that has developed an aeronautical solution for the problem of wind drag on tall antenna towers. This involves affixing an engineered wing to the towers to increase wind resistance. By stabilising the tower, not only is its structural integrity improved, but also the stability of the network.

As a novel solution to improve the structural strength of cellphone towers, it made provision for a wide range of multidisciplinary student participation, as it involved students from electrical, civil, and mechanical and aeronautical engineering. It also provided final-year aeronautical engineering students the opportunity to consider the design of wing shapes, as well as the cap at the top of the wing to ensure that it could also be used in colder countries in the northern hemisphere.

International student team contributes to South Africa's anti-poaching operations

Dr Lelanie Smith

Since 2014, undergraduate students at the University of Pretoria have been part of an international student team, Aircraft for Rhino and Environmental Defence (AREND). This team has formed a multidisciplinary, multinational, vertically integrated collaboration to design, build and fly an electric unmanned aerial vehicle (UAV) in support of South Africa's anti-poaching operations.

Although the intention of the project was to consider a custom-designed UAV that could conduct the remote surveillance of large conservation areas with diverse intelligence-gathering sensors, along with a network of ground sensors, the primary focus of the project has moved to the UAV itself. After the first successful flight of the AREND UAV in 2017, the technical focus has moved to developing subsystems complete to product level for the UAV and to experiment with various aircraft configurations as part of the modularity the initial design allows.

The education focus has been on cultivating innovative attitudes, professional skills and early cross-subject synthesis in participating students. The co-curricular nature of the project has evolved over the years, and now fosters robust articulation with project-based and work-integrated learning modules in the formal curriculum at the University of Pretoria, with a variety of international student internships and collaboration with local industry. It is therefore an experiential learning initiative that is aligned to a real-world challenge.

The project's international team comprises students from three universities on two continents: the University of Stuttgart, Germany; The University of Tromsø, Norway; and the University of Pretoria, South Africa. These teams provided complementary technical skills.

Experiential learning can easily become ineffective in large cohorts (800 students or more) if there is an insufficient scaffolding of the skills required of students. Therefore, a co-curricular framework was developed with containment modules within the existing curriculum. This would enable the programme to become integrated and offer opportunities for local and international students.

Since the inception of the project, it has covered various phases in the development of the UAV: from the design and evolution of the aircraft to the launch system, landing systems and power systems.

What is also of significance, along with the progress that has been made in designing a technological solution to aid park rangers in protecting the endangered rhino from poaching, is the impact it has had on the students participating in the experiential learning initiative.

Student participants in the AREND project

Four students from the University of Pretoria, who have since graduated, reflected on their involvement in the project, as well as the skills they developed during the project. These included agility and adaptability, creativity and innovation, developing qualities of empathy, trust and humility, as well as interdisciplinary systems thinking, self-awareness, self-management, teamwork and goal achievement.

Keanan van Dyk, who graduated in 2021, is currently doing his master's degree in Aerospace Engineering at the University of Stuttgart in Germany. He believes the AREND project to be a prime example of what work in industry is like. "The independence, patience and stress control one needs while working on AREND is something one typically learns in the workplace." For industry, he considers the benefit of AREND to be that more students are properly prepared to enter the workplace as engineers rather than graduates.

His participation in AREND taught him the fine skill of assigning priority to certain deadlines and goals, which is a fine art in the world of engineering. "As engineers, we always have to find the balance between achieving the unthinkable, while remaining reasonable. Setting impossible goals and timelines is something we have to avoid, but cannot always manage." AREND taught him to achieve great things in a limited amount of time. This is a lesson he still takes with him today.

In terms of his personal growth, he believes that the hard and soft skills that he learnt along his journey on the project is benefitting him to this day. He also met a student from the University of Stuttgart who was part of the team and convinced him to enrol for postgraduate studies at that institution. This is something he would not have considered had it not been for the relationships that developed during the project.

Nathanael Tom, who also graduated in 2021, worked as an aeronautical engineering intern for a medical deliveries drone company after graduation, and is planning to pursue his postgraduate studies in 2023. He considers the project to be invaluable and of immense benefit to students who need to fulfil their academic requirements of industrial training.

"It exposes students to the workplace setup, to teamwork, and to collaboration by providing them with work-readiness training. This assists them to make a smooth transition from studying to the work environment." He believes that industry also benefits by

receiving graduates who have been adequately trained in their respective engineering disciplines.

In terms of his personal growth, he considers the most striking benefit he obtained from the project to be the teamwork skills, collaborative drive in partnering with colleagues from various disciplines and time management skills he obtained. As the team members came from diverse social, ethnic and academic backgrounds and from different skill levels, it taught him to function seamlessly in a team by exercising tolerance and developing conflict resolution abilities.

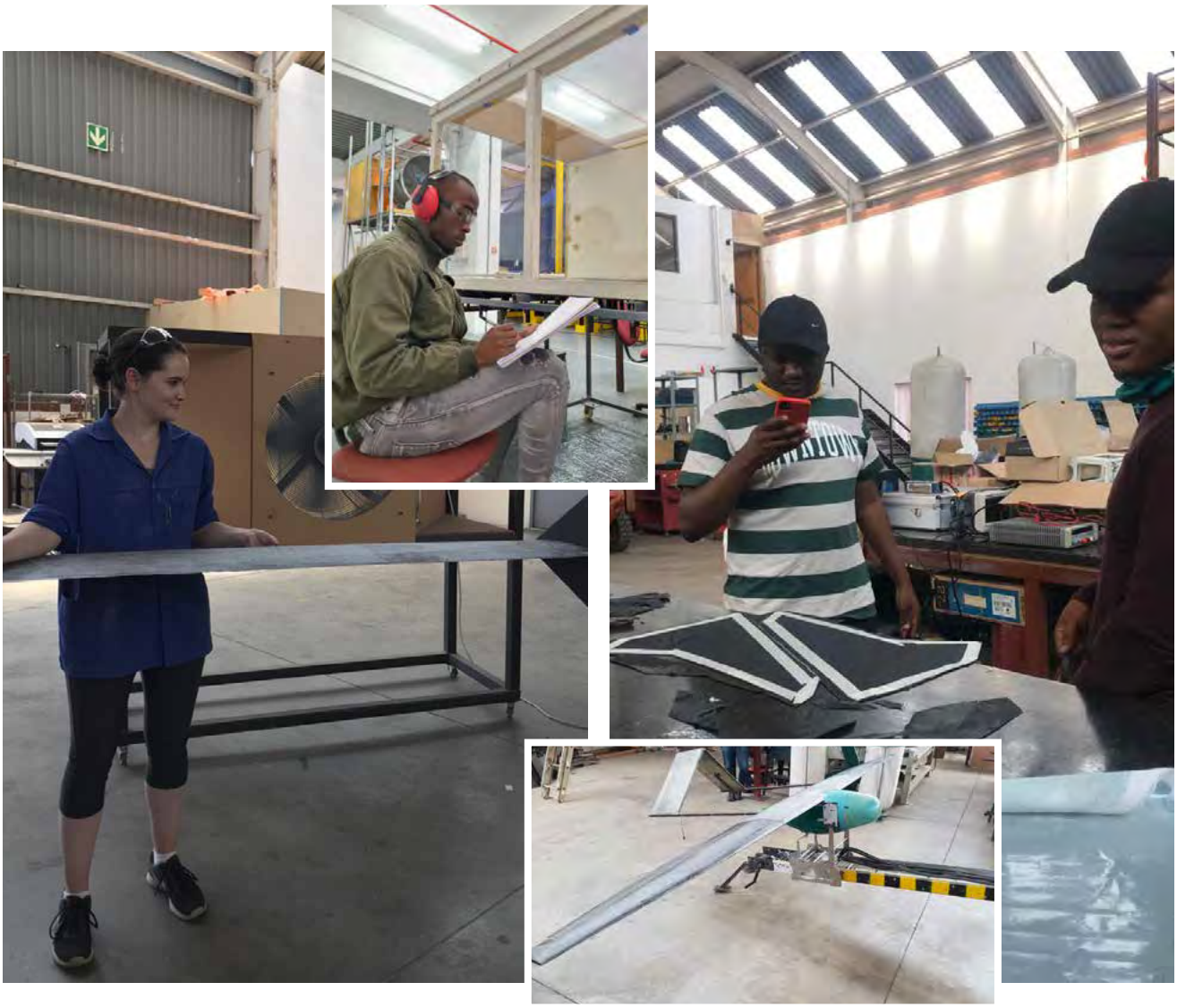
His advice to students considering participating in the AREND project is that they should join the team with an open mind, ready to amass as much knowledge, skills and experience from the project as they can.

Ankit Sharma graduated in 2022 and is currently embarking on his PhD in Germany. He believes that AREND provides the perfect opportunity for students to apply their knowledge in a more hands-on manner. "Personally, I enjoyed the entire design, build, prototype and test cycle." He considers the most significant benefit he obtained from the project to be that it taught him to learn from his mistakes. "It taught me to be open to new experiences and to have a growth mindset."

His advice to students considering joining the project is that they should think "out of the box". "This is your opportunity to learn and make mistakes in a fail-safe environment."

Serena Bruni graduated in 2019 and is currently working as a junior engineer in a control system design and project commissioning company. In her experience, she found that the project gives students an idea of working in industry. "It gives one exposure to more practical issues." It taught her to manage her time better, and to focus on achieving the objectives that had been set out, or to adjust the objectives to better suit the problem at hand.

Her advice to prospective participants is to "jump straight in". "You will understand the problem better, and what is required to solve it when you start tackling it. Also, don't forget that literature is a great resource, but so are people with practical knowledge."



Technology offers myriad options for online assessment

In the transition to online learning, not all the challenges experienced by students and lecturers were related to the virtual presentation of course material. The evaluation of the final output of the teaching process also proved to be problematic. The summative assessment upon conclusion of a module not only determines whether students have mastered the course material, but also whether they are able to proceed to the next level.

In the Faculty of Engineering, Built Environment and Information Technology, lecturers were encouraged to determine the assessment method that worked best for their particular circumstances. It soon became clear that a method that worked well for a small group would not be suitable for a large group of students who all needed to be assessed simultaneously.

Ken Craig, a professor in the Department of Mechanical and Aeronautical Engineering, decided to investigate tools that were available in the software programs to which students and lecturers had easy access and were already using.

"I was looking for a system that students could use effectively, that was time-efficient for both students and marking staff, and would streamline the academic process," he said. As all students and staff members had access to the full set of Google tools, including an institutional Gmail address, he investigated what was available on this platform that could perform the same functions as other online assessment tools.

He discovered that by using Google Forms for online assessment, he could include multiple-choice questions, as well as text and numerical answers, allow file uploads and do automatic grading.

To ensure that students would be familiar with using this tool by the time it came to semester tests and examinations, Prof Craig introduced Google Forms early in the semester. He launched it in a trial run with quizzes that did not count for marks, followed by a multiple-choice class test and an ordinary class test. An added benefit for students was the fact that Google Forms could be accessed from any internet-connected device. They therefore did not need a desktop computer, but could use their smart phones wherever they were able to access the internet. They did not need expensive scanning equipment either, only a piece of paper that could be scanned using a mobile camera scanning app. The students' phones proved to be the most efficient means of scanning material for uploading, as the resulting files were small and easy to transfer with limited data.

Prof Craig required the students to register on Google Forms in the first 30 minutes of a test or exam. For this, they needed to upload a scan of a written page with their signature, initials, surname and student number to confirm their attendance, and to ensure that connectivity had been established.

While the students were completing their questions electronically on Google Forms, the lecturer or teaching assistant could view a live Google Sheet with pertinent information about the assessment event. This sheet could then be downloaded as a Microsoft Excel file. Statistics related to the question paper was also available. Lecturers could also use Microsoft Excel for the automatic marking of multiple-choice or typed answers. To assist with the marking of uploaded answers, lecturers made use of Adobe Acrobat to generate fillable pdf forms. This process was assisted by a template generated using Microsoft Word, which included the marking rubric. Once the questions had been marked, students received feedback in the form of the rubric and their mark breakdown.

By making use of this process, Prof Craig found the students' post-test perusal process to be more efficient, and to require fewer modifications because of the transparency of the assessment process. Significant time was saved in capturing and processing the marks, and the feedback time to students was significantly reduced. Fillable pdf forms were also used for marking practical reports, which saved time with the capturing of marks. Students' assessments could also be easily shared with external examiners by giving them access to the Google Drive folder and the summary documents.

Creating a sense of community in the online space

In the Faculty of Engineering, Built Environment and Information Technology (EBIT), the dedicated Faculty student advisors play an indispensable role in ensuring students' emotional wellbeing and making sure that they are able to cope with any feelings of anxiety that might be hindering them from performing their best academically. This was no exception when lectures could no longer take place in person.

In 2021, the Faculty's enthusiastic team of student advisors made use of an innovative online student support platform, known as Kumospace, to ensure that students did not feel isolated, and could interact with other students who were experiencing similar challenges in the online environment. This intervention could be accessed by all the Faculty's undergraduate students via the EBIT undergraduate module on ClickUP.

Kumospace is a free online platform that allows students to move between virtual rooms that simulate a friendly, welcoming space that is not intimidating, and allows them to speak their minds, or even just relax with a virtual lemonade. This provided students with the best replica of a social engagement group that was possible in the online space.

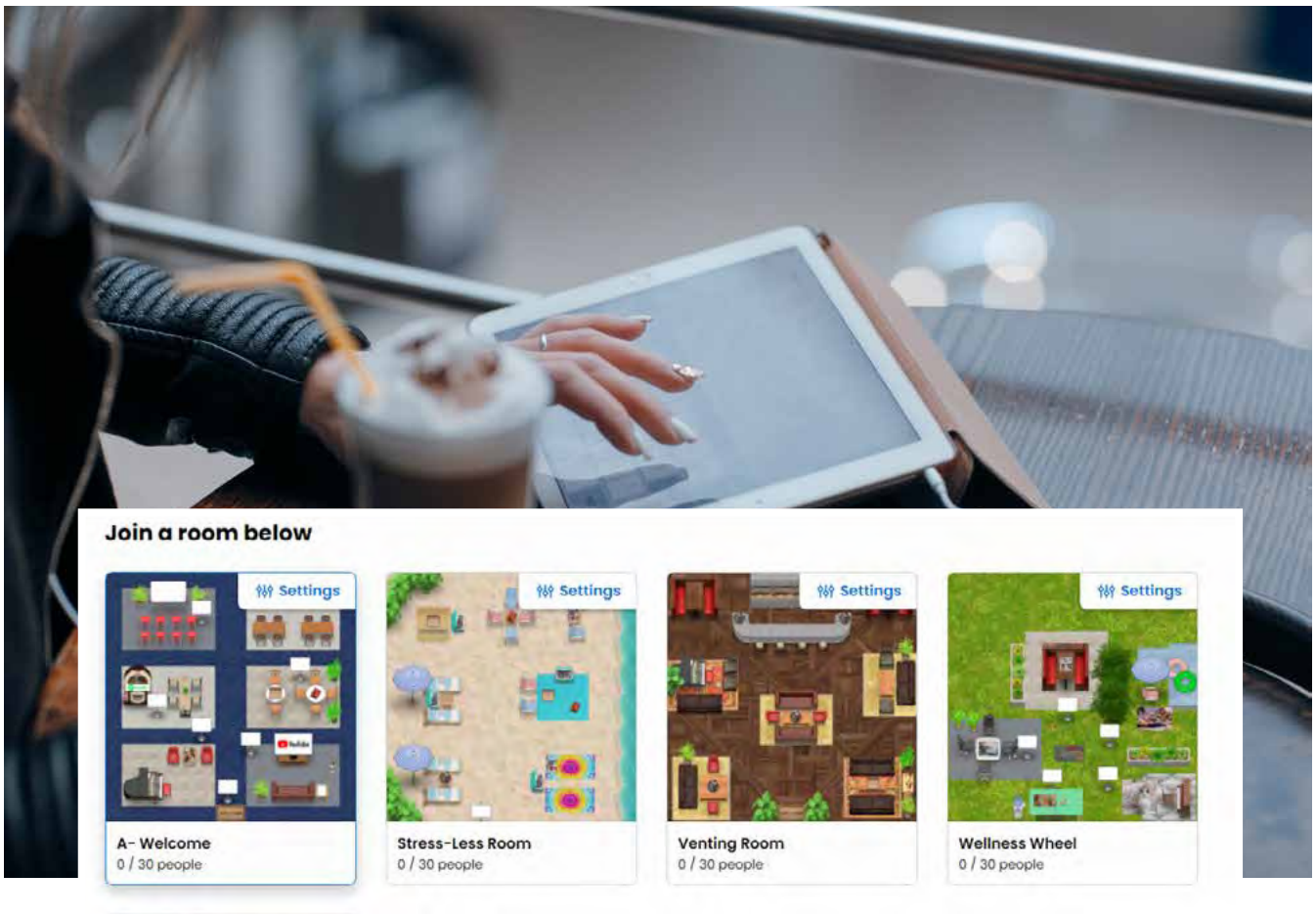
The intervention, which was launched following the identification of the need for face-to-face contact to assist undergraduates who were dealing with emotional and academic challenges, had a number of specific aims. These included providing support with stress and anxiety, increasing lecture attendance and engagement, study time, and motivation and mindset.

Students self-enrolled into groups of no more than 25 students to participate in this four-week intervention. The groups comprised students from various EBIT degrees and year groups. The Kumospace sessions were scheduled whenever a student had an available slot of 30 minutes to an hour available on their time table.

According to Caitlin Vinson, one of the Faculty's senior student advisors who designed the unique virtual rooms for this programme, there was more interest from senior students in this intervention. "They wanted an online platform where they could mingle, in the same way as they would on the lawns in front of the Engineering Building on Hatfield Campus."

The initial contact with the students was through a Google Form, where they were asked to identify topics that they would like to discuss. These included topics such as balance and holistic wellness, stress management, loneliness, the impact of COVID-19 on student life and lack of motivation. The students then received a welcome pack so as to obtain as much information about their needs as possible. This included a set of pre-test questions, and also the housekeeping rules and a disclaimer that this was not a private space, so the students should not assume that anything they said would be confidential.

Some of the pre-test questions proved to be quite revealing, and provided the Faculty student advisors with a good perspective on the challenges students were experiencing. In addition to asking them how they felt the semester was going and whether they were attending lectures, they were asked how anxious they felt (38.1% of the respondents indicated that they felt



very anxious) and whether they felt part of the UP community (42.9% indicated that they felt isolated from the UP community). As one respondent said when asked what made him decide to join the group: "I want to believe I am not the only one struggling."

Each of the Kumospace rooms was designed differently. In the first week, the students were introduced to the Welcome Room. Here they could break out into different spaces to chat. They encountered several non-invasive questions, which gradually became more personal, but provided them with the option to just relax, or to chat with others who were encountering a similar challenge, but still within a neutral space. This led to the students warming up and being more open.

In the second week of the intervention, they were introduced to the Wellness Wheel. Here they encountered the five pillars of wellness: social, emotional, spiritual, physical and academic. They split up into smaller groups, where they could talk about each pillar, identify what they were good at, and what they were prepared to commit to achieving. Student peer advisors were available to provide guidance, and if a student was identified as being in need of counselling, they received a private message referring them to these services, and following up on them later.

The third week introduced students to the Stress-less Room. As students experience different causes of stress, they were encouraged to share what it was that was causing them stress. They were also given coping strategies to manage their stress that were helpful and effective.

The last week introduced the students to the Motivation Room. This is where they were encouraged to focus on the reason why they were studying a particular degree, and to identify their values, goals and future plans. By visualising their future role as a professional, the student advisors could improve their motivation to study and complete their degrees.

Upon conclusion of the intervention, which took place in the middle of the second semester, just prior to their final examinations, the students admitted to feeling less isolated, more motivated towards their studies, and more inclined to attend lectures. Some of them revealed that they just needed a platform where they could talk to their fellow students.

As this was the first time that this intervention was practiced, the Faculty's student advisors learnt a couple of lessons that they can apply during a future application. However, the benefit gained by the students who participated certainly proved it to be a useful tool to improve students' emotional wellbeing during challenging times.

Collaboration is the secret to successful community engagement

Dr Lelanie Smith

One of the cornerstones of the development of students in engineering, built environment and information technology into socially responsible graduates is their participation in community engagement projects. The starting point is their participation in the Community-based Project (JCP) module. This is a compulsory module for all undergraduate students in the Faculty.

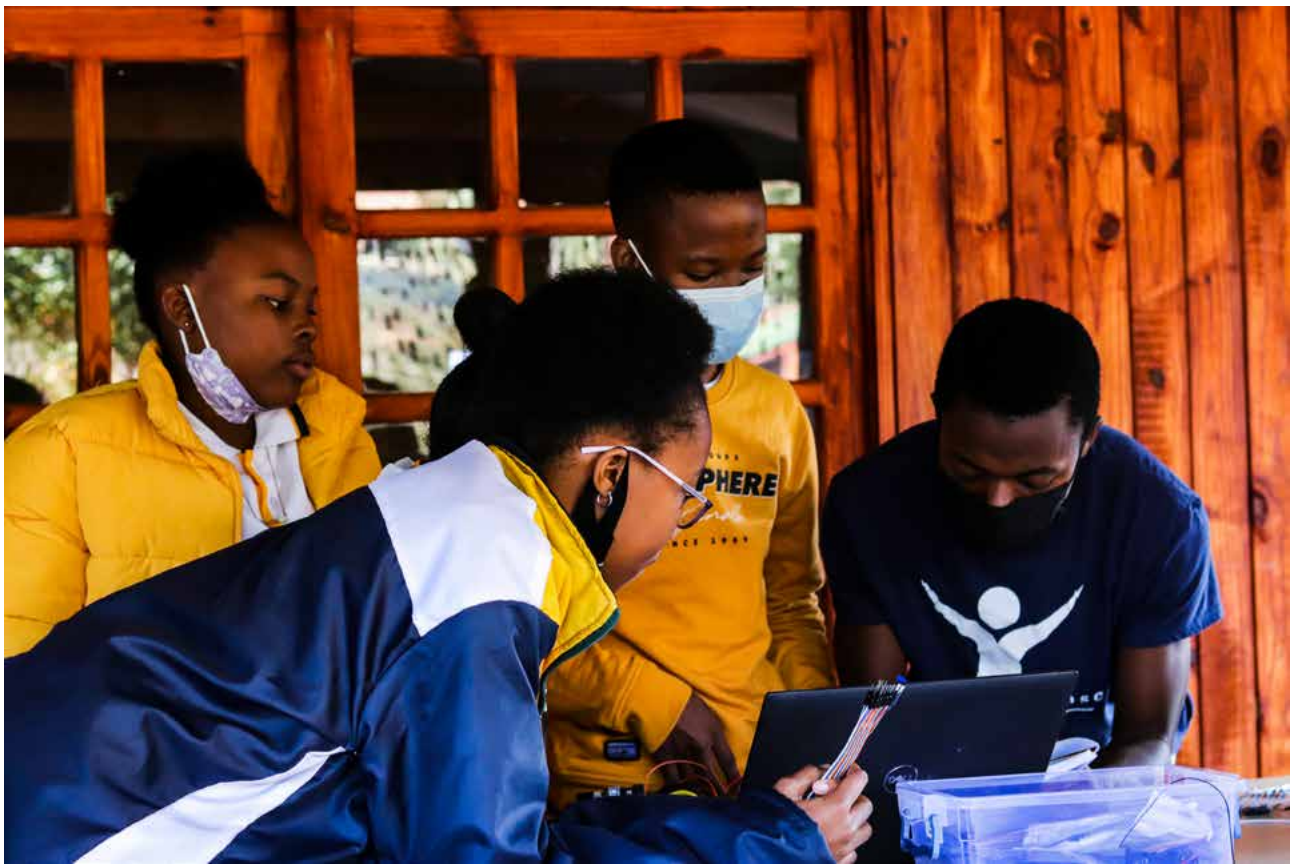
40 hours
OF COMMUNITY WORK FOR EBIT STUDENTS

Students are required to complete 40 hours of community work, followed by various reflection assignments and a video report in the form of a YouTube video.

The main objective of the module is to engage with a community, ideally one that is different from the students own social background, and to collaboratively develop a project within the students' discipline that directly contributes to or impacts on the community.

The module aims to develop an awareness of personal, social and cultural values, as well as life skills, such as communication, interpersonal development and leadership skills.

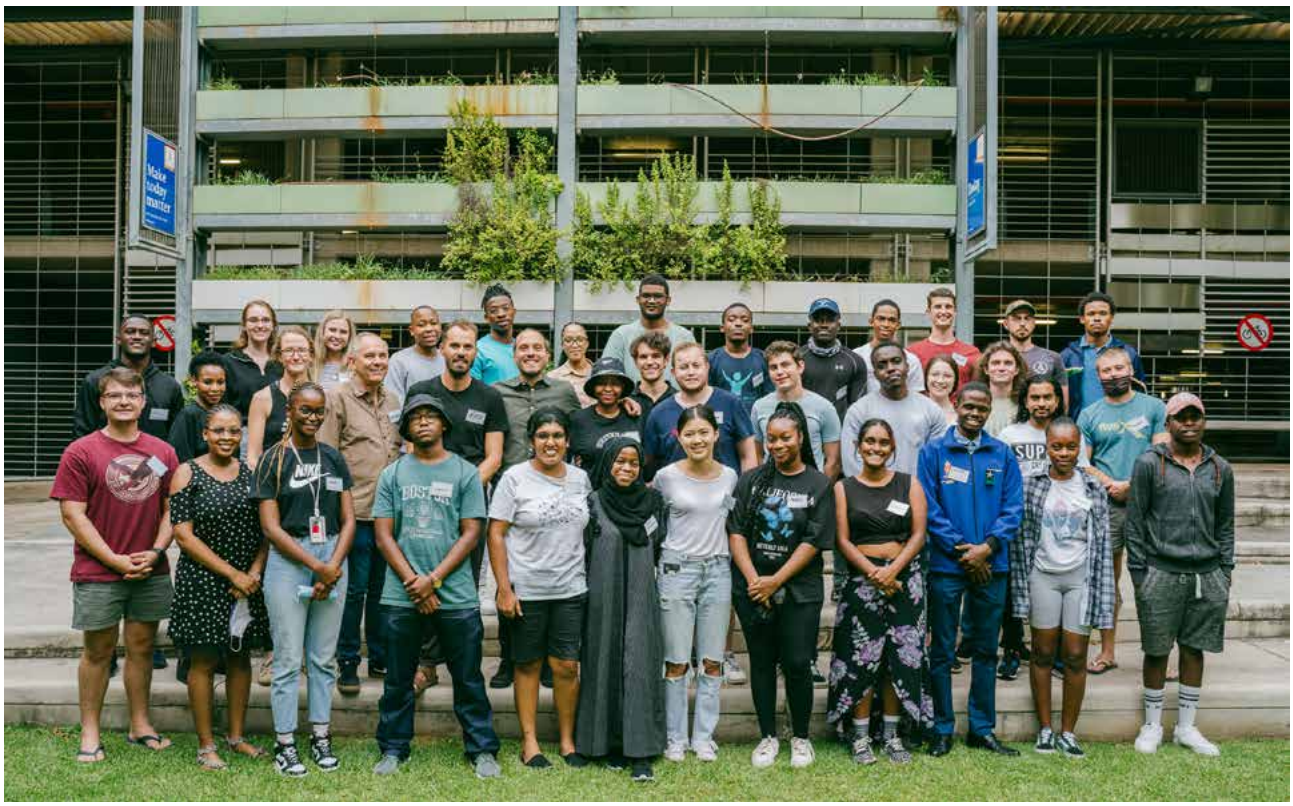
In 2021, the existing structure of the module was expanded to include two new components: peer learning and mentor guidance, and collaboration with staff members in the Faculty and members of industry to jointly develop projects that can benefit industry, as well as individuals in the community.



Students, forming multidisciplinary teams, benefit from the guidance of a mentor, who has previously participated in a JCP project as a student, and a community partner. They work towards a specific outcome that reflects the potential impact of their discipline. Thirty-five mentors have been trained, together with coaches from the Curiosity Campus, who serve as early-career mentors. Each mentor works with 10 group leaders, who ensure that the objectives of the project are achieved. The ultimate aim of the mentorship programme is to build a peer learning community, where current students return to serve as mentors themselves.

Following an invitation to staff members and industry representatives to collaboratively develop community engagement opportunities with students, the module has seen renewed enthusiasm among students who are keen to see how they can impact on communities with their discipline-specific skills.

Several such collaborations are already underway. In the Robot School and Sensor School, developed by the Department of Electrical, Electronic and Computer Engineering, as well as the Drone School, developed by the Department of Mechanical and Aeronautical Engineering, JCP students help teach high-school learners new skills.



The first group of JCP mentors trained in collaboration with Curiosity Campus

The JCP module has also collaborated with the Keep That Gold Shining initiative on campus, a student-initiated community-based organisation that aims to unleash the potential of high-school students and make them realise the importance of education.

The students are involved in giving motivational talks at high schools, as well as tutoring activities in Mathematics, Science, Information and Communication Technology (programming) and Robotics. They also participate in career guidance activities and serve duty at science fairs.

The Department of Civil Engineering has offered opportunities for JCP projects in the York Timber Laboratory in the Engineering 4.0 Complex, where students can explore their wood-building skills to support community projects .

The Department of Architecture is involving students in its Urban Citizenship Project, which facilitates the upliftment of communities in Plastic View, an informal settlement to the east of Pretoria. This project is already the source of great collaboration with the community, and has expanded to include students in different academic years. Plans are developed by the third-year students, while the second years do the construction, and the final-year students build relationships with the communities for the sustainability of the projects.

The Department of Industrial Engineering is involved in a community project called WhereIsMyTransport, in which students assist in mapping routes and providing mobility and location data to develop this into a successful venture to ensure the availability of transport to all citizens who need to make use of public transport .

The module is also partnering with the Faculty of Health Sciences with two opportunities for JCP students: one in the Department of Family Medicine's Community-oriented Substance Abuse Programme and one in the Department of Occupational Therapy, where students provide assistance with the provision of items that are required for therapy, such as setting up reading centres and building outdoor play equipment.

In the true spirit of the African proverb "It takes a village to raise a child", the JCP module is working together to form our students and facilitate meaningful engagement with communities.

This approach allows for inclusive transdisciplinary engagement and an ongoing open invitation to staff, students and the industry to connect and work together on projects that are sustainable and mutually beneficial for our communities, as well as our students' development into ethical leaders of the future.

The main objective of the module is to engage with a community, ideally one that is different from the student's own social background.

Stitching the city with a new collaborative data library

Prof Chrisna du Plessis

Architecture (and other) students routinely collect fine-grained visual and qualitative spatial data while working on projects. This data is collected through transect walks, participatory action research, community mapping and participatory geographic information system (GIS) methodologies. It is often collected in the same areas year after year. What if all this data could be captured, geo-located and made available for future studies?

This is the question that inspired the architecture departments of the University of Pretoria and Chalmers University of Technology in Sweden to collaborate on a project funded by the National Research Foundation (NRF) and the Swedish Foundation for International Cooperation in Research and Higher Education (STINT).

The *Stitching the City – from micro-data to macro views* project involved the collection and sharing of traditional and non-traditional spatial data at a street and precinct level in a georeferenced online platform. This cross-disciplinary micro-data can then be layered and easily accessed by researchers from different disciplines, as well as stakeholder partners.

Each year, students gather remarkable amounts of data on an ad-hoc basis and in many formats, which is not adequately stored and cannot be re-used for other purposes or by students working in the same area in subsequent years. To overcome this absence of systematisation, a methodological framework for knowledge facilitation has been developed to enable the effective collection and storage of meaningful and useful visual, and place- and human-based spatial data that can accommodate different types of micro-scale data.

The framework consists of a shared data collection methodology for the effective collection and storage of fine-grained multi-format geolocated data for interdisciplinary use (the ukuDoba method) and a collaborative data library for educational purposes. In isiZulu, the word “ukuDoba” means “to fish”. The rationale behind this method is thus to help researchers to “fish” for the data they need and – over time – contribute to the larger data “pool”. In this way, a digital commons is created for research related to communities, cities and environments.

A digital platform or toolbox was first established for the collection, maintenance and analysis of the data identified in the methodological framework through the combination and integration of existing open-source tools and technologies such as smart phones, tablets and digital cameras. The collaborative data library was then tested at two urban sites in which the partner universities are already active: Mamelodi East, a township in the City of Tshwane, and Hammarkullen, one of ten city districts in Gothenburg, Sweden.

The testing and development of the toolbox took place in the University of Pretoria’s Urban Citizenship Studio in Mamelodi and in Chalmers University of Technology’s Social Inclusion

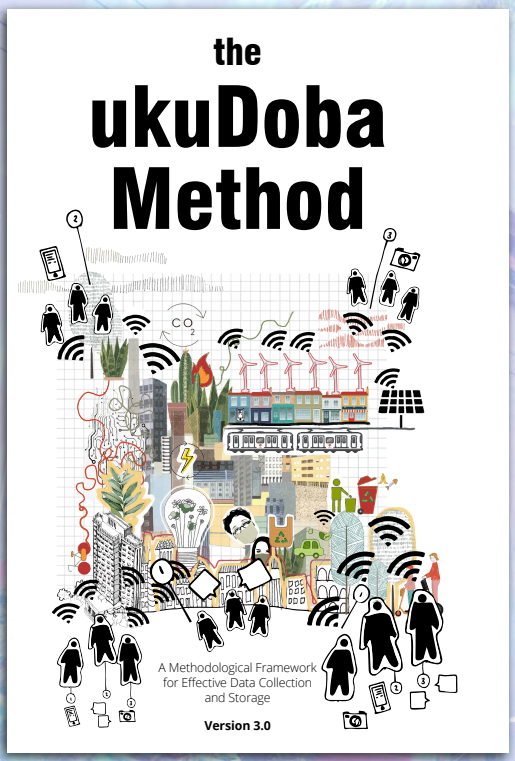
Design Studio in Hammarkullen. Researchers in the University of Pretoria's Department of Geography, Geoinformatics and Meteorology were also involved in the development of the toolbox. The outcome of the collaborative project was the publication of a manual on the ukuDoba method, which outlines the methodological framework.

The manual presents a step-by-step guide on the ukuDoba method to effectively collect, convert and store different types of data digitally on an online platform. These steps include research design, form design, data collection, data conversion, data analysis and interpretation, and the storage of the data in a data warehouse or GeoNode.

The collaborative data library that is an outcome of this method has the benefit of being able to provide a very rich longitudinal dataset that can be used by planners and policy makers to make decisions based on more than just demographic data. This is particularly relevant in the new world of Big Data analytics and digital twinning.

It has already assisted in the implementation of several innovative digital twinning and visualisation projects. In addition to the Hatfield Digital Twin City initiative, the method has found application in the development of the Digital Twin City centres at Chalmers University of Technology, and the VisLabs visualisation centre at the Universeum public science centre and museum in Gothenburg, Sweden.

The ukuDoba method and its related work efforts, experiments and data repository development contribute directly to a larger conversation about how to construct meaningful digital commons related to our cities, communities and environments to support 21st-century concerns. Commenting on the development of the method at its launch at the University of Pretoria's Future Africa Research Centre on 15 November 2021, Prof Chrisna du Plessis, Head of the University's Department of Architecture, remarked that this innovative platform is opening up opportunities for transdisciplinary decision making that have not been possible in the past. This will enable policy makers and researchers to obtain information at the right time, with all the finer detail that is required to make appropriate and relevant decisions.



The ukuDoba Manual is available for download.

The Department of Architecture welcomes feedback and enquiries.

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The collaboration between the University of Pretoria and Chalmers University of Technology that led to the development of this method is being taken a step further with planned future collaborations on digital twinning, as well as a lively staff and student exchange programme.

In 2022, 14 Chalmers students and four staff members spent six weeks working with UP students on an ukuDoba project as part of the Chalmers Reality Studio, and four UP students will be completing their honours year at Chalmers

UP engineer develops a new off-road ABS algorithm

Considering the high impact that vehicle accidents have on human health, the recent progress within the Department of Mechanical and Aeronautical Engineering in developing a new antilock braking system (ABS) algorithm that is particularly suited to bad roads is encouraging for future drivers.

Vehicle safety has a significant impact on the health of humans globally. According to a World Health Organisation (WHO) report on road accidents, more than 3 700 people die on the world's roads every day, and tens of millions of people are injured or disabled every year. Road traffic injuries are the eighth leading cause of death in all age groups, and more people die because of road traffic injuries than from HIV/AIDS, tuberculosis or diarrheal diseases.

Furthermore, the risk of road traffic death is more than three times higher in low-income countries than in high-income countries, as road infrastructure is strongly linked to fatal and serious injury causation in road traffic collisions.

Unfortunately, there has been no reduction in the number of road traffic deaths in any low-income country since 2013. Vehicle safety is increasingly critical to the prevention of crashes and has been shown to contribute to substantial reductions in the number of deaths and serious injuries resulting from road traffic crashes. Features such as electronic stability control and advanced braking are examples of vehicle safety standards that can prevent a crash from occurring or reduce the severity of injuries.

Low- and middle-income countries typically rely on agriculture and mining to generate an income, meaning that the economically active portion of the population is often located in rural areas with poorly designed roads and other infrastructure. The limited application of modern safety technology to challenging driving environments needs to be addressed to maximise the benefits of these systems.

Significant advances have been made towards vehicle safety over the last few decades. One such advance is the development of ABS. This braking system is becoming more and more prevalent, driven largely by legislation in the European Union (EU) and the USA that requires ABS on almost all vehicles. These modern vehicles are also being sold in developing, low-income countries, often without adapting them to the challenging environmental conditions typical of roads in these countries.

Ricardo de Abreu, who recently completed his master's degree in Mechanical Engineering at the University of Pretoria, has developed a new ABS algorithm, designed specifically to be used on bad roads. This new ABS algorithm makes use of Artificial Intelligence and machine learning to improve emergency braking on rural roads without compromising braking performance on urban roads. His new algorithm has reduced the amount of wheel lock-up during straight-line braking, and when braking in a turn. De Abreu says: "The successful application of an intelligent algorithm to a difficult, real-life scenario has many future applications. While intelligent algorithms are complex, it remains important to understand the fundamentals of the problem at hand to ensure that the algorithm can be as successful as possible."

It is anticipated that the new algorithm will enhance vehicle safety in more challenging environments. The next steps are to further improve the performance of the new ABS by including stability control and validating its performance experimentally.

THE SUCCESSFUL APPLICATION OF AN INTELLIGENT ALGORITHM TO A DIFFICULT, REAL-LIFE SCENARIO HAS MANY FUTURE APPLICATIONS. WHILE INTELLIGENT ALGORITHMS ARE COMPLEX, IT REMAINS IMPORTANT TO UNDERSTAND THE FUNDAMENTALS OF THE PROBLEM AT HAND TO ENSURE THAT THE ALGORITHM CAN BE AS SUCCESSFUL AS POSSIBLE. THIS NEW ABS ALGORITHM IMPROVES EMERGENCY BRAKING ON RURAL ROADS WITHOUT COMPROMISING THE BRAKING PERFORMANCE ON URBAN ROADS.

Publishing project facilitates cultural, social and ideological exchange

Samantha Miller

During a recent book discussion initiative of Zuid-Afrikahuis, the central information point on South Africa in Amsterdam, The Netherlands, the topic of discussion was the Dutch translation of Elsa Joubert's *Ons wag op die kaptein* (1963) as *We wachten op de commandant* (2021).

The discussion included a lecture and was followed by a panel discussion featuring Dutch/Afrikaans translator Rob van der Veer, literary studies expert Martina Vitackova (Ghent University) and Stacey Vorster (University of Amsterdam College), as well as Afrikaans author Kirby van der Merwe. Tycho Maas, a postdoctoral research fellow at North-West University, facilitated the discussions. Samantha Miller, Publishing Studies lecturer in the University of Pretoria's Department of Information Science, presented a South African publisher's perspective, elaborating on the social and political context of the time, which could have influenced the publication decision of this controversial title. The impact of apartheid, the influence of nationalist ideology on publications, as well as the social importance of cultural exchange between countries, were discussed.

HISTORICAL BACKGROUND

Elsa Joubert, perhaps best known for *Die swerfjare van Poppie Nongena* (1978), published her debut novel *Ons wag op die Kaptein* in 1963. An article in *Die Transvaler* (1961), reporting on a violent farm attack on an Angolan farm, inspired the story for this book.

A small group of inhabitants, including Carlos Figueira and his wife Ana-Paula, are taken hostage by black soldiers on their farm. Their fate can only be decided once the captain of the rebels arrives. Continuously juxtaposing black and white, rich and poor, upper and lower class, amidst the background of a lush farm in Angola, using the farm as a symbol of the Boer/the "chosen" Afrikaner, while building tension, their fate is being decided.

The novel, published by Tafelberg, was regarded as revolutionary prose. Reviewers praised the use of strong characterisation, dialogue and analogy to display the harsh racism between black and white people.

In 1963, the apartheid government introduced the Publications and Entertainment Act, a law that prohibits the publication of any books that may be deemed obscene, blasphemous or contradictory to the Nationalist ideology. Due to the restrictions imposed by this Act, some authors' works were banned or censored, and some were even exiled to other countries.

Kennis van die aand and *Labola vir die lewe* (André P. Brink), and *Sewe dae by die Silberteins* (Ettienne le Roux) are some of the titles that were banned. A group of authors, known as the Sestigers, used their writing to express their resistance to the apartheid regime, tried out avant-garde writing styles and addressed taboo topics in their work. Breyten Breytenbach, Ingrid Jonker, Andre P. Brink, Ettienne le Roux, Abraham de Vries, Adam Small and Elsa Joubert were some of the authors in this group. "It was the reclamation of a language, and a people, from an oppressive and monolithic system through literary revolution" (Die Sestigers, n.d.).

Ons wag op die kaptein had several reprints. It was approved as a prescribed text, and was translated into English as *To die at sunset* (1982).

THE REPRINT

In 2005, Tafelberg republished this title under its classic series of books. Harmful speech, politically incorrect descriptions and references that were used to refer to black people in this title were removed and a new cover was conceptualised. The positioning of this book was re-evaluated and published in a way that would be more accessible to the modern reader.

Several other titles authored by members of the Sestigers were published in this classic series. Combining the titles that had previously been deemed controversial, they now appear as part of a series that reflects on time past and adds to the Afrikaans literary memory bank.

WHY PUBLISH THE TITLE?

Why would Tafelberg risk republishing a racially sensitive title like *Ons wag op die kaptein* in post-apartheid South Africa?

The themes of "the other", racial conflict and farm murders were still relevant at the time of republication in 2005. The aim of Joubert's story, which was to reflect inherent racism, was preserved, even with the adaptations to the text.

Joubert was a prize-winning author, who was considered part of Tafelberg's social capital. In 2005, specifically, she was honoured by the Department of Art and Culture for *Die swerfjare van Poppie Nongena*, which won the best prose award. Furthermore, in 2005, Tafelberg published the memoir of Elsa Joubert's life, *Wat 'n wonderlike geweld*. A strong awareness of this author and her work existed at the time, which justified the publisher's decision to publish this controversial title. It is also a publisher's strategy to revive an author's previous publications to create awareness about an author's ouvre.

THE TRANSLATION

When a foreign publisher acquires translation rights to a book, the fit with its editorial philosophy and list, potential for positive reception by its readers, status of the author (in terms of prizes) and subject matter of the book are considered. The publisher was of the opinion that this story is still relevant today in a world where contrasts like "us and them", "similar and different" exist.

In 2021, with the assistance of the PEN Afrikaans Vertaalfonds, this title was translated into Dutch and published by Manuzio. The translator used the filtered 2005 edition as source text for the translation. It would be interesting to assess the reception of this title among a Dutch audience 58 years after the book's original publication.

In conclusion, publishers consider the social and political contexts of the time when considering the republication of books. Translation is not only a publishing act, but facilitates cultural, social and ideological exchange between countries and cultures.

Reference

Die Sestigers, n.d. www.diesestigers.wordpress.com/about/

WATCH
Boeken uit het Huis: Elsa Joubert, 'We wachten op de commandant'

New SARChI Chair for Computer Science

The University of Pretoria has been awarded four new Research Chairs under the South African Research Chairs Initiative (SARChI). One of these, the Chair in Machine Learning for Sustainable Development, was awarded to Artificial Intelligence specialist, Prof Nelishia Pillay, in the Department of Computer Science.

Prof Nelishia Pillay, Chairholder of the SARChI Chair in Machine Learning for Sustainable Development

The other recipients were Prof Zodwa Dlamini in the Department of Health Sciences (the Chair in Precision Oncology and Cancer Prevention), Prof Thulani Makhalanyane in the Department of Natural and Agricultural Sciences (Chair in Marine Microbiomics) and Prof Chris Changwe Nshimbi in the Faculty of Humanities (Chair in the Political Economy of Migration in the SADC Region).

SARChI is a government programme led by the Department of Science and Innovation and the National Research Foundation. It seeks to significantly expand the scientific research base of South Africa in a way that is relevant to national development and in support of making the country a globally competitive knowledge economy.

Prof Pillay is delighted to have this honour bestowed on her. "Being awarded this Chair has given me the privilege to do what I love doing every day," she said. "It feels surreal to use something that I am so passionate about – Artificial Intelligence (AI) – to help improve the quality of life of others."

She explained that the Chair will focus on developing new and extending current machine learning and optimisation techniques, as well as embracing current trends in AI to solve problems related to sustainable development. The sustainable development areas on which the Chair will focus include health and wellbeing, agriculture, education, innovation in industry, and equity, diversity and inclusion.

"The overall aim is for our group to be a leader internationally in AI, while at the same time harnessing the benefits of these approaches to improve quality of life and contribute to sustainable development," Prof Pillay explained.

THE MOST EXCITING PART OF THE JOB IS SUPERVISING POSTGRADUATE AND POSTDOCTORAL STUDENTS, WHICH ALLOWS ME TO WORK WITH YOUNG, VIBRANT MINDS TO REALISE THIS IMPACT AND HELP THEM ACHIEVE THEIR DREAMS.

Championing the rights of under-represented groups in computational intelligence

Prof Nelishia Pillay has been appointed to chair the Women in Computational Intelligence (WCI) subcommittee of the global Institute of Electrical and Electronics Engineers (IEEE) Computational Intelligence Society (CIS). Prof Pillay is a former Head of the Department of Computer Science in the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria and is Chairholder of the South African Research Chairs Initiative (SARChI) Chair in Machine Learning for Sustainable Development in the Faculty.

The commitment to gender diversity is an important feature of the activities of the IEEE CIS. As such, it pledges to work towards gender-diversified panels at all meetings, conferences and events of the CIS. It supports the inclusion of a diverse set of speakers, which could lead to more creative, interesting and representative panels. The WCI subcommittee develops, promotes, organises and runs activities directed at the achievement of gender diversity within the Institute.

According to Prof Pillay, the subcommittee is devoted to meeting the needs of the greater community of women in computational intelligence by sharing ideas and opportunities, answering questions and addressing any other concerns women may have in their professional interactions. "The impact women are making in the field of computational intelligence is on an upward trajectory," says Prof Pillay. "This can be seen in the increasing number of leadership roles played by women, including being invited to deliver keynote presentations and to serve as general conference chairs at computational intelligence conferences."

As Chair of the WCI subcommittee, she is promoting the use of computational intelligence to solve problems related to equity, diversity and inclusion. An IEEE taskforce has been established to promote research in this area. The subcommittee does not just focus on women, but also advocates for the recognition of other under-represented groups in computational intelligence. It therefore promotes the inclusion of people from different cultures and languages, and people with disabilities, among other under-represented communities in the field.

At the WCCI 2022 IEEE World Congress on Computational Intelligence held in Padova, Italy, from 18 to 23 July 2022, she hosted a reception for women in computational intelligence. This is considered to be the world's most influential computational intelligence congress and featured some inspirational speakers. It had a good representation of presenters from all sectors of society, including women.

It included a panel discussion on the role of diversity and inclusion in responsible technological innovation, which Prof Pillay chaired. As a member of the organising committee, she also served as Publication Chair of this congress.

THE SUBCOMMITTEE IS DEVOTED TO MEETING THE NEEDS OF THE GREATER COMMUNITY OF WOMEN IN COMPUTATIONAL INTELLIGENCE BY SHARING IDEAS AND OPPORTUNITIES, ANSWERING QUESTIONS AND ADDRESSING ANY OTHER CONCERNS WOMEN MAY HAVE IN THEIR PROFESSIONAL INTERACTIONS.

Chancellor's Medal for Mining Engineering alumnus

Chris Griffith, a loyal alumnus of the Department of Mining Engineering and CEO of Gold Fields, was awarded the University of Pretoria's Chancellor's Medal for his contribution to society at the University's graduation ceremony on 10 May 2022.

Vice-Chancellor and Principal, Prof Tawana Kupe, presents the Chancellor's Medal to Chris Griffith

"THE MODERN MINE OF TODAY IS A MECHANISED, AUTOMATED AND INCREASINGLY DIGITAL OPERATION, STAFFED BY A SKILLED WORKFORCE THAT CAN BRING A HIGHER LEVEL OF INTELLECTUAL RIGOUR TO THE WORKPLACE."

This award was made in acknowledgement of Griffith's achievements and contributions to society, which have a national and international impact, signify creative spirit and intellect, and are related to the University of Pretoria's vision, mission, values, strategic goals and objectives.

In accepting this honour, Griffith recognised the value of a qualification from the University of Pretoria, which enabled him to gain a foothold in the industry and provided him with the educational foundation to advance as far as he has done in his career. He admits that the skills set in the modern mining sector has changed significantly from when he graduated in 1988. "The modern mine of today is a mechanised, automated and increasingly digital operation, staffed by a skilled workforce that can bring a higher level of intellectual rigour to the workplace."

Along with the changing mining industry, he remarks that society's expectations of companies in general are also changing, but the University of Pretoria is adapting to this change and is providing industry with graduates who are capable of keeping up with and leading this change. "I am proud to serve as an ambassador of this great institution."

Griffith is a member of the University's Mining Engineering Advisory Board. He also played a critical role in his former position as CEO of Kumba Iron Ore in the sponsorship that led to the establishment of the University's Kumba Virtual Reality Centre for Mine Design in 2015. The Faculty acknowledges his support and contribution.

A “Science Oscar” for Prof Evans Chirwa

Prof Evans Chirwa, Chairholder of the Rand Water Chair in Water Utilisation in the Department of Chemical Engineering, is the recipient of the National Science and Technology Forum (NSTF)-Water Research Commission (WRC) Award for his groundbreaking research. He received the award during the 24th NSTF-South32 awards ceremony on 21 July 2022. He was recognised for his work on introducing the use of biological analogues in advanced water treatment and water recovery with applications in metal-halide heterogenous photocatalysis into South Africa.

MY RESEARCH GROUP AND I ARE OVERJOYED BY THIS ACHIEVEMENT. MY POSTGRADUATE STUDENTS WORK VERY HARD EVERY DAY. THEY ARE THE TRUE WINNERS OF THIS AWARD.

The NSTF Awards are the largest, most comprehensive and most sought-after national awards of their kind in the country. They recognise outstanding contributions to science, engineering and technology (SET) and innovation by SET-related professionals, teams and organisations in South Africa. The University of Pretoria had nine finalists for these awards.

Commenting on Prof Chirwa’s achievement, Prof Tawana Kupe, UP Vice-Chancellor and Principal, remarked that the depth, excellence and quality of his research, and the fact that he is training a generation of students who will perform the same level and quality of research, are making an impact on society.

Prof Chirwa said that being nominated for this award has been the greatest recognition he has received since joining the University 20 years ago.

Inaugural addresses

Prof Johan Labuschagne
Department of Chemical Engineering

Clay: From pottery to supercapacitors, and plasticine sculptures to LDH solar panels

Clay is the oldest known ceramic material, with pottery shards dating back as far as 14 000 BC having been discovered. Its applications are vast. There are many different types of "pure", naturally occurring clay minerals that are layered in structure. These layers typically carry an electrical charge, balanced by counterions. Anionic clays make up a small fraction of naturally occurring clay and comprise positively charged layers with anionic (negatively charged) counterions. The most well-known naturally occurring anionic clay mineral is hydrotalcite, a lactate dehydrogenase (LDH) of magnesium and aluminium that typically has carbonate as a counteranion in between the layers. The first synthesis of a synthetic hydrotalcite was described in 1942. Large-scale commercial production commenced in the 1970s due to the use of hydrotalcite for medicinal purposes (antacid) and its potential as a catalyst. Prof Labuschagné's most recent research has shown the potential use of LDH in solar panels and supercapacitors and as a photocatalyst.

Prof Michael Njoroge Gitau
Department of Electrical, Electronic and Computer Engineering

Effects of changes in the energy mix and load types on future power grids

Fossil fuels dominate the present-day energy mix, despite the benefits of a higher share of renewable energy in the energy mix. Renewable power generation utilises power electronic converters and DC power transmission and distribution. With dispersed renewable energy sources, bidirectional power flow becomes inevitable in distribution grids that previously handled only unidirectional power flow. The widespread adoption of electrified transportation will see a marked increase in the number of DC loads. Furthermore, renewables providing additional electricity will compensate for a lower share of fossil fuels in the energy mix. Changes in the energy mix and loads lead to an increase in DC grids, a need to develop bidirectional solid-state/DC protection systems, and a need to develop control strategies for dispersed energy storage to ensure that dispersed renewable energy sources operate efficiently. The electrical grid will also have to be expanded to cater for energy previously transported by other means. These changes create an opportunity for structuring future grids differently for better performance. However, suitable power electronic converters to provide energy management services, bidirectional DC protection, and reduced interactions between the various subsystems will be needed, and converters to interface subsystems will have to be developed.

Prof Christo Venter
Department of Civil Engineering

Transformative transport in African cities – progress and prospects for success

Transport is a key lever in the project to transform cities into more efficient, equitable and environmentally sustainable places. The need for transformation is especially urgent in African cities, given their low infrastructure bases and massive projected increases in population. Transportation planning is evolving from being highway-oriented to embracing the full range of urban mobility problems in their political, social and economic context. However, the transformative impacts of several projects are limited by an over-reliance on narrow technical analysis, in particular, Bus Rapid Transit (BRT) projects that have been planned or introduced in several African cities. In many cases, project implementers under-estimate the importance of engaging with stakeholders, especially the incumbent informal transport industry, and also the complexity of implementing such radical interventions in public spaces. Research at the BRT+ Centre of Excellence has contributed to a better understanding of these problems.

Prof Ndeke Musee
Department of Chemical Engineering

Anthropogenic activities, implications to aquatic ecosystems, and integrated response

Anthropogenic activities are by nature Janus-faced. The societal benefits of such activities include providing water, food, health care and ease of communication. On the other hand, these activities have, for decades, been recognised as impacting negatively on aquatic ecosystems. This is the result of a sharp increase in pollution related to industrial activities and domestic toxic chemicals over recent decades. Deleterious impacts include biodiversity loss in freshwater and marine environments, rapidly diminishing potable water supplies, and high costs related to health-care and restoration of damaged ecosystems. This research details the implications of selected pollutants to the aquatic systems, their occurrence on local and global scales, and the risk assessment approach based on experimental and modelling techniques. It also address the consequences in relation to SDG 3, SDG 6 and SDG 12, with reference to achieving specific targets aimed at improving human and ecological health through the proper management of hazardous chemicals. Recommendations address chemical pollution through a multi-faceted approach.

Industry support

UP AND SANRAL HOST THE MEDIA AT ENGINEERING 4.0

Since the official opening of the University of Pretoria's Engineering 4.0 research facility in November 2020, there has been increased interest from the media and industry in this state-of-the-art facility.

Addressing the media, Prof Tawana Kupe, Vice-Chancellor and Principal of the University of Pretoria, observed that South Africa is ranked 18th in the world in terms of the longest paved roads. "Roads are the world's arteries for people's livelihoods and quality of life," he said. "They connect us to social, economic, commercial and healthcare opportunities, which enable us to function, develop and thrive."

This provides some insight into the importance of teaching and learning, research, planning, design and engineering in pavement engineering, as well as road use, traffic flow, smart transport systems and future developments in the form of hybrid, electrical and autonomous vehicles. "We constantly need to think ahead and work out how to integrate transport and smart transportation systems," he said.

Engineering 4.0 is a research and training hub for smart transportation systems and smart cities, including Africa's latest independent materials testing facility and national reference laboratory. The facilities present a unique physical space to foster and accelerate the adoption of disruptive technologies, Big Data analytics and rapidly evolving research methodologies to test and analyse how different road surfaces and materials perform, how traffic moves on highways, the density and type of traffic at any given time, and emissions testing and air quality monitoring as part of environmental sustainability in line with the requirements of the Sustainable Development Goals (SDGs).

The integrated facility will contribute to an increase in engineers with postgraduate qualifications, who are able to focus on innovative solutions for the transportation industry, to be taken up by government, SANRAL and the industry. This will ultimately enhance South Africa's growth and infrastructure development.

Launch of commemorative publication to celebrate Department's 60th anniversary

In celebration of its diamond jubilee, the Department of Mining Engineering launched a commemorative publication of the Department's development and achievements over the past 60 years. The event took place as part of the celebratory meeting of the Department of Mining Engineering Advisory Board on 3 November 2021.

The launch of this commemorative publication was one of several events planned to celebrate 60 years of excellence in mining engineering education.

During the event, Prof Tawana Kupe, Vice-Chancellor and Principal, shared his message of congratulations on the Department's 60th anniversary. This was followed by messages of congratulations from Prof Con Fauconnier, Honorary President of the Mining Alumni Society of the University of Pretoria (MASUP), on behalf of the Department's alumni, and Chris Griffith, CEO of Gold Fields, on behalf of the mining industry. Prof Ronny Webber-Youngman provided some highlights over the past decade before the book was officially launched by Prof Sunil Maharaj, former Dean of the Faculty of Engineering, Built Environment and Information Technology, and Acting Vice-Principal: Research and Postgraduate Education.

The book takes readers through the history of the Department since its establishment in 1961 and includes recollections of students from among the first classes of Mining Engineering at the University of Pretoria, as well as photographs of all the final-year groups since 1965.

The narrative takes readers through each decade of the Department's existence, culminating in the most recent decade. It covers some of the Department's flagship initiatives, as well as its focus on the future, and its intent to develop mining engineers who are prepared for the challenges of the next decades.

Prof Ronny Webber-Youngman, Head of the Department of Mining Engineering, presents the Department's jubilee publication to Prof Tawana Kupe, Vice-Chancellor and Principal

Bursary initiatives

AFRICAN RAINBOW MINERALS (ARM)

Long-time supporter of the Department of Mining Engineering, ARM, launched a collaborative bursary initiative at the University of Pretoria in April 2022. The beneficiaries of this bursary initiative included undergraduate and postgraduate students in Accounting Sciences, Financial Sciences, Chemical Engineering, Electrical Engineering, Mechanical Engineering, Mining Engineering and Metallurgical Engineering.

Prof Ronny Webber-Youngman, Head of the Department of Mining Engineering, explained that minerals and mining engineering cannot operate in isolation. Many of the challenges faced in industry today require a transdisciplinary solution, which is what makes the inclusion of beneficiaries from other disciplines so relevant in the collaboration initiative.

André Joubert, an alumnus of the Department of Mining Engineering and Chief Executive of ARM's Ferrous

Division, was the driver of this initiative. Busi Mashiane, ARM's Group Executive: Human Resources, who presented the bursaries to the beneficiaries, stated that ARM is focused on developing and attracting the best young talent going forward, which is why the company is so excited to be partnering with the University of Pretoria in this initiative.

"We need people who are future-focused if we are to lead the mining industry into the future."

- Busi Mashiane

"Receiving this bursary means that I am a step closer to achieving my dream of becoming an electronic engineer. This bursary gives me the unique opportunity to meet people in the industry and be inspired by their success stories. It is a deeply encouraging experience."

- Thandeka Biyela

"This bursary is close to my heart and hits home because it is important to me to contribute to innovative solutions. As the world embraces the digital age, technology is becoming essential in many, if not all industries. I am grateful to receive such a bursary to study for a degree that is so lucrative. It is the Fourth Industrial Revolution, and I am at the forefront of change! Thank you for the opportunity!"

- Keitumetse Molefe

SEED ANALYTICS

Seed Analytics has awarded a full annual tuition bursary to two of the Faculty's female students, thereby giving them the opportunity to venture into the field of data analytics. Ms Thandeka Biyela, a student in the Department of Electrical, Electronic and Computer Engineering, and Ms Keitumetse Molefe, a student in the Department of Computer Science, were overwhelmed with joy when they received the news that they were the recipients of these bursaries.

Seed Analytics assists wealth managers and financial advisors in finding solutions for key problems when it comes to consolidated client statements, business intelligence and identifying clients that are at risk. The company is committed to developing young professionals who see data analytics as a career opportunity. The Seed Analytics Bursary Scheme was identified to assist committed and dedicated students who are struggling financially to fund their studies.

CEO and UP alumnus, Tim Vieyra, commented as follows: "The level of experience and skill needed to back up our client promise is hard to come by. That is why we are committed to developing young professionals who may see data analytics and our company as a career opportunity."

Greenovate 2021

The Green Building Council of South Africa (GBCSA) was founded in 2007, and its Green Star SA rating tool was launched in 2009. The Green Star Office tool is the oldest of the GBCSA's tools, with the largest number of Green Building certifications. The updated version 1.1 was launched in 2014. The Office version 1.1 tool (now called the New Built and Major Renovations tool) needed updating to keep abreast of new developments in the Green Building industry. This process started in 2022.

A team of three BSc Hons Quantity Surveying students from 2021, Carmia Venter, Sanchia Lewis and Mckayla McMaster, focused their mini-dissertation to assist this process of the GBCSA. Their study evaluated and described the level of difficulty of achieving the various credits in the Green Star tool, based on recent actual industry case study performance. GBCSA data was used on 87 buildings certified between 2016 and 2019. The study structure replicated a published Australian study from 2016.

The University of Pretoria's team presented its study at the Greenovate Forum in Sandton in November 2021. Some of the judges at the event also serve on the Working Committee of the GBCSA, developing the New Built version 2 tool. The team was also asked to present its findings at the first meeting of the GBCSA version 2 Working Committee. This achievement proves that the University's students can make contributions recognised by industry.

Matthews/IPGIP intervarsity competition

Angelo Rossi, a 2021 final-year student from the Department of Chemical Engineering, was selected to be the University of Pretoria's nominee for the annual Matthews/Integrated Post Graduate Industry Partnership (IPGIP) prize.

Due to COVID-19 restrictions, the judging and prize-giving ceremony could not take place in December 2021. Instead, each of the finalists received a R15 000 share of the total prize money.

Angelo's project investigated the potential performance enhancement of carbon fibre electrochemical capacitor electrodes via heat and chemical activation methods. The effect of layered double hydroxide (LDH) deposition on performance was specifically investigated. A novel and facile LDH ethanol suspension dropwise deposition technique was explored and compared to *in-situ* deposition. Angelo plans to confirm his experimental findings before publishing them in a peer-reviewed journal.

He is exploring further opportunities in the field of energy storage devices and would like to perform industrial/commercial research in this field once he completes his postgraduate studies.

EBIT Week 2022:
Time waits for no one

The Faculty of Engineering, Built Environment and Information Technology (EBIT) hosted the EBIT Week from 10 to 13 July 2022 on the University of Pretoria's Hatfield Campus. EBIT Week is a four-day holiday programme presented biannually for learners in Grade 10, 11 and 12. Prospective students are offered this hands-on opportunity to obtain information regarding all the disciplines offered in the School of Engineering, the School for the Built Environment and the School of Information Technology.

Some 220 learners from Gauteng, KwaZulu-Natal, the Free State and the Western Cape attended EBIT Week. They stayed in the residences, attended lectures and visited the laboratories. A traditional braai night with good music added the needed balance between hard work and relaxation.

The feedback from the learners was extremely positive.

Our slogan, "Innovating our Tomorrow", keeps us on the path of pursuing innovation. We are committed to remaining relevant and addressing the challenges of the Future of Work.

The EBIT Generation is a generation of change-makers. Therefore, we want to offer as many students as possible the opportunity to be part of this exciting faculty, which is driven by our need to be part of the solution for a better world for all our fellow human beings.

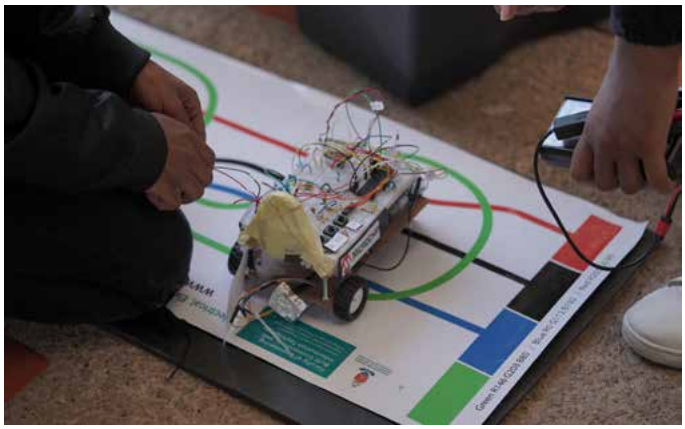
Robots of EEC Engineering

TUKS-EBIT ROBOT RACE

The Department of Electrical, Electronic and Computer (EEC) Engineering was proud to host its ninth Tuks-EBIT Robot Race in 2022. This education-in-action event not only teaches students the fundamentals of embedded design, but also develops skills that are regarded as essential for the Future of Work.

Firstly, cognitive flexibility is developed since students have to consolidate academic success with a public competition. The development of digital literacy and computational thinking goes without saying, given the nature of the educational objectives of an embedded design module. Judgement and decision making are cultivated as students have to navigate their way through a challenging academic load towards eventual success at the Robot Race event.

Since the development of the robots and eventual participation in the event are undertaken in groups, emotional and social intelligence are nurtured. The need to demonstrate accountability towards qualifying as competent engineers is also stressed by the realisation that the community that students will serve upon graduation attends the event as a witness to their progress towards achieving this goal. Finally, a creative and innovative mindset is fostered by encouraging students to explore the boundaries of performance with their robot cars and by allowing them to attend to the aesthetics of their designs.



ROBOT SCHOOL

In 2021, the Robot Race spawned the EECE Robot School, which aims to introduce school learners to science, technology, engineering and mathematics (STEM) in a fun, but focused way. The classes are presented at the University's community garden, Moja Gabedi. The idea is to develop an ecosystem of connected courses to nurture learners into choosing a career in STEM. This year, the EECE Sensor School was also added to the course portfolio. Plans are underway to extend the offering to an online platform to increase accessibility to the learning material.

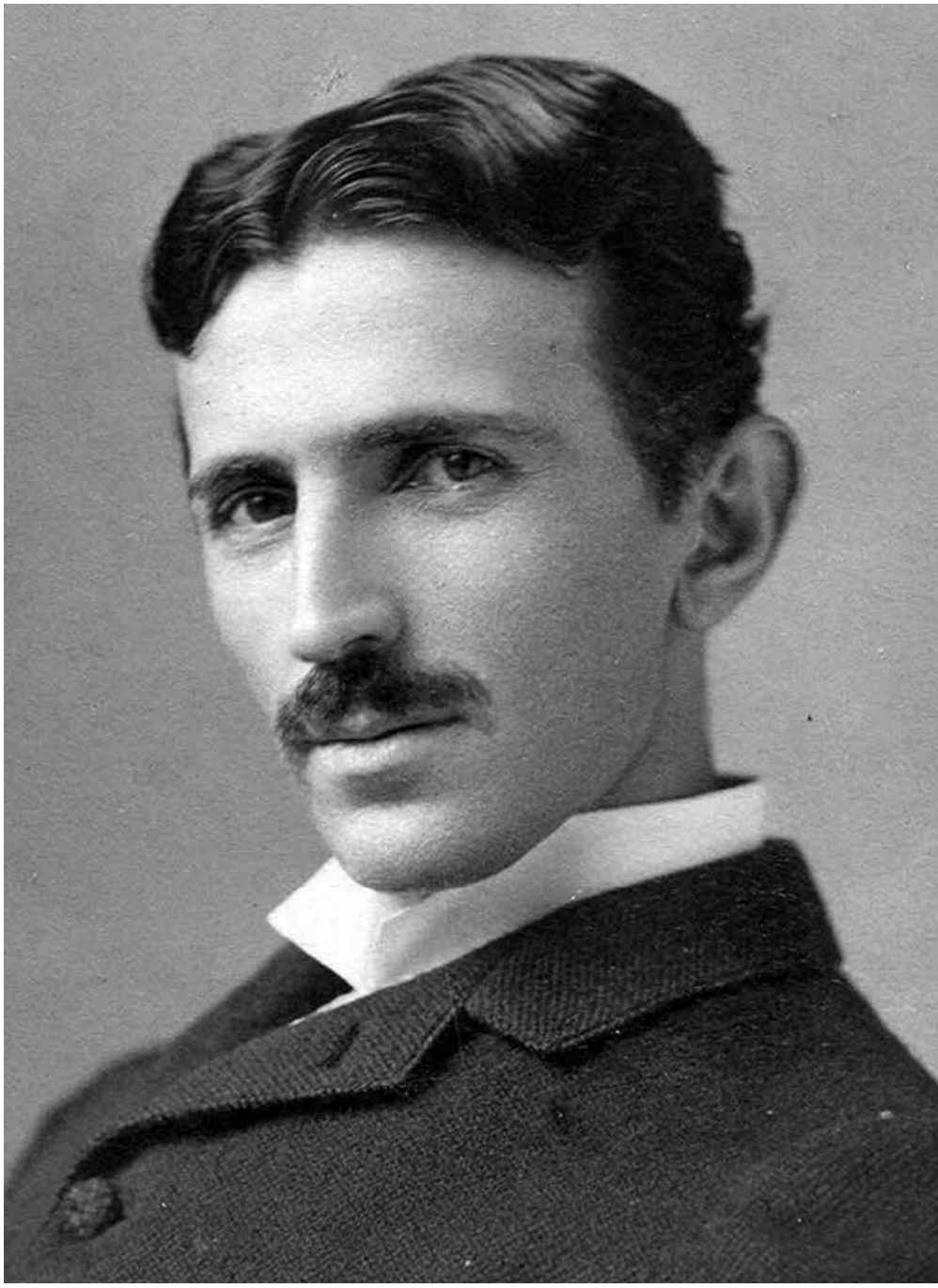
Nikola Tesla:

The brilliant lightning scientist

Nikola Tesla is regarded by many as the most gifted engineer of the late 19th and early 20th centuries. He was a prolific inventor and a major pioneer of radio technology. His inventions include the telephone repeater, the rotating magnetic field principle, the polyphase alternating current (AC) system, the induction motor, AC power transmission, the Tesla coil transformer, wireless communication, radio and fluorescent lights.

HIS LIFE'S WORK

- Tesla devises the method for transmitting alternating current on which modern electrical power systems are based.
- He invents the induction motor in 1883.
- After arriving penniless in the USA in 1884, Westinghouse Electric buys the rights to his AC inventions in 1885.
- He invents the Tesla coil in 1891, which he uses to produce, among other things, some of the first neon fluorescent illuminations, X-ray photographs and wireless energy transfers.
- He builds a hydroelectric plant in the Niagara Falls.
- He showcases a radio-controlled boat in 1898, which he terms a "teleautomation".
- He discovers terrestrial stationary waves in 1899.
- He makes important contributions to the fields of radar and vertical take-off and landing (VTOL) later in his life.
- He is credited with more than 700 patents around the world.



Born in 1856, his early career in the last two decades of the 19th century is a tale of almost unrelenting success. With his powers at their peak, he seemed to be turning out paradigm-shifting inventions almost by the month. This was followed by a long decline, which, although punctuated by odd moments of brilliance, was generally characterised by feuds, failures and increasing eccentricity.

He grew up in Austria-Hungary (now Croatia). His brilliance became apparent from a young age. Although he did not come from an academic family, there was a history of inventors in his ancestry. His father worked hard on developing Tesla's mental abilities. Despite interruptions to his childhood education due to frequent sickness and the severe trauma caused by the death of his older brother, he went on to study at the Austrian Polytechnic in Graz and the Charles Ferdinand University in Prague.

While at university, Tesla was exposed to demonstrations of existing generators and electric motors, and started pondering better ways of creating and transporting electricity. He later came up with an idea that involved a rotating magnetic field in an induction motor, which would generate alternating current (known as AC). Most of the electricity that was generated at the time for use in homes, offices and factories was direct current (DC), which had its limitations, particularly in terms of the cost involved in generating it, the difficulty of transporting it over long distances and its need for a commutator. Tesla would go on to prove that AC could travel safely, efficiently and cheaply over long distances.

In 1880, he moved to Budapest to become the chief electrician of the National Telephone Company, where he invented his induction motor, a type of AC motor that would revolutionise the industrial world. This was in line with his earlier ideas, and was the first big step in that direction. His next move was to sell it. However, he could not find anyone in Europe willing to invest in it.

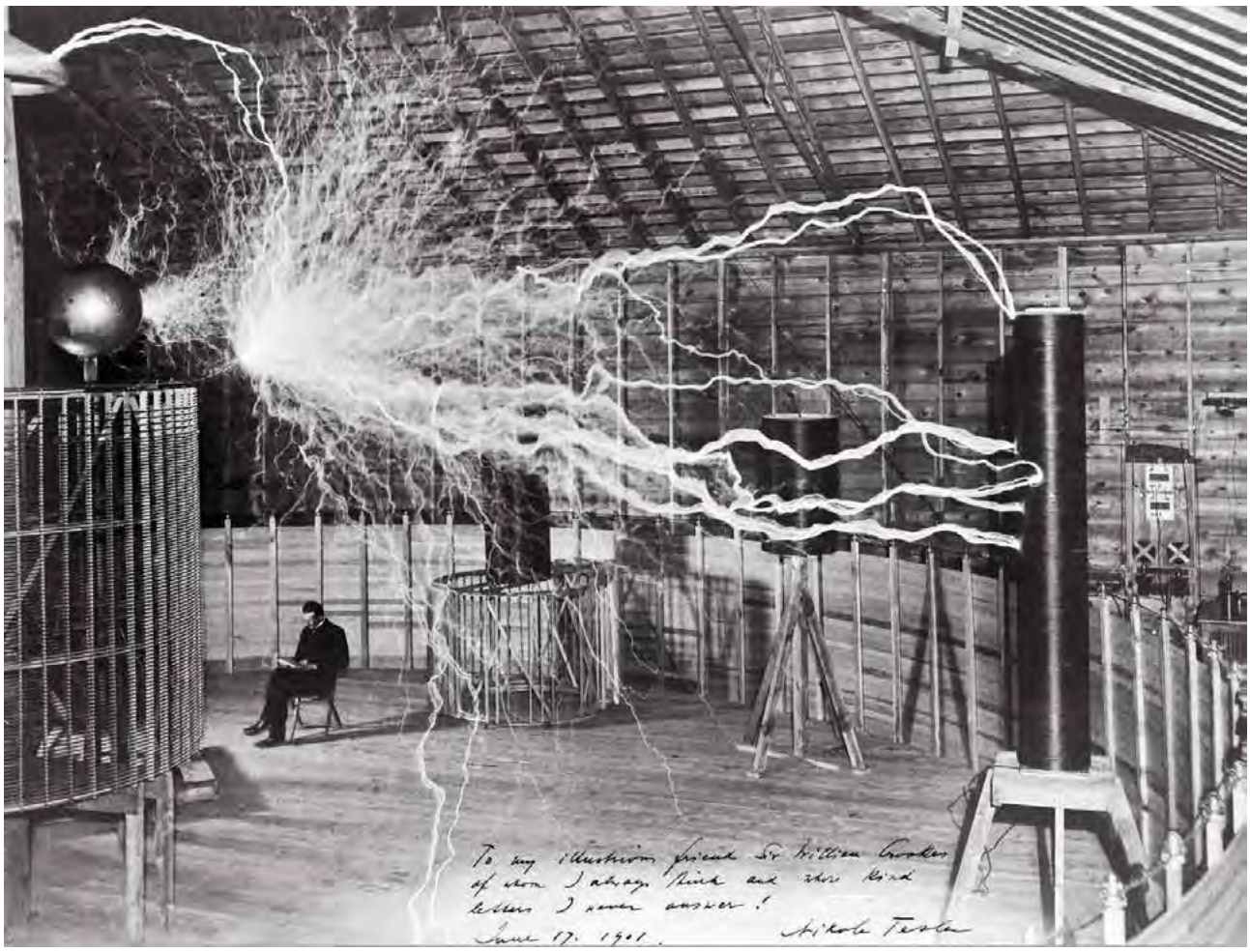
By 1882, he was working in Paris at Thomas Edison's European outpost. Edison was the one man Tesla was sure would "get" his ideas, if only he could find a way to show them to him. Tesla travelled to the USA in 1884 to meet Edison, armed with a letter of recommendation from Charles Batchelor, Tesla's boss at the Continental Edison Company, which reputedly stated: "I know two great men and you are one of them; the other is this young man."

Unfortunately, Tesla's faith in Edison's insight proved to be somewhat misplaced. Tesla used his brilliant intellect and academic rigour to conceptualise a solution, while Edison relied on simple trial and error. Unable to conceive the theoretical possibilities of Tesla's AC motor, Edison was quite uninspired, He was, however, impressed by Tesla, offering him a job and a reward of a staggering US$50 000 (more than US$1 million today) if he could improve the efficiency of his DC generation plants, which were struggling to maintain the supply for his burgeoning electric light industry.

Tesla then decided to emigrate to America, arriving penniless, but soon finding work by making use of his electrical engineering skills, while working on Edison's challenge. However, when he succeeded in improving the efficiency of Edison's DC generation plants, Edison allegedly refused to pay him, upon which Tesla resigned.

However, Edison's rival, George Westinghouse, bought the rights to Tesla's AC inventions and the War of the Currents began.

WHILE AT UNIVERSITY, TESLA WAS EXPOSED TO DEMONSTRATIONS OF EXISTING GENERATORS AND ELECTRIC MOTORS, AND STARTED PONDERING BETTER WAYS OF CREATING AND TRANSPORTING ELECTRICITY. HE LATER CAME UP WITH AN IDEA THAT INVOLVED A ROTATING MAGNETIC FIELD IN AN INDUCTION MOTOR, WHICH WOULD GENERATE ALTERNATING CURRENT (KNOWN AS AC). HIS INVENTION OF THE INDUCTION MOTOR WOULD REVOLUTIONISE THE INDUSTRIAL WORLD.



THE WAR OF THE CURRENTS

Tesla spent the next few years of his career perfecting his system for AC power transmission. His system provided a direct challenge to the DC system developed and patented by Edison, which had become the standard for electrical distribution in the USA. This gave rise to the so-called "War of the Currents" in the 1880s and 1890s, which grew into a worldwide battle for electrical supremacy.

Although Edison's economic might and reputation warded off competition for a while, AC eventually won, principally because it was the better system – it could be transmitted over longer distances at higher voltages than if one used a lower current; and had greater transmission efficiency. With the subsequent invention of better transformers to transport electricity, AC became the standard, with DC increasingly being confined to only specialist applications. The trend continues to this day.

WIRELESS ENERGY TRANSMISSION

While Tesla was busy convincing the world of the benefits of AC, he was also growing increasingly interested in the wireless transmission of energy. His first major breakthrough was the development of the Tesla coil in 1891, a type of transformer that could produce pulses of high-frequency, high-voltage alternating current. It had many applications and is still widely used today in radio, television and electrical machinery. He also used this invention to explore other scientific avenues, including fluorescent lighting and X-ray photography.

However, Tesla believed his device's greatest application would be in the wireless transmission of electrical energy, both through the ground and through the air. He had a vision of a network of devices spanning the globe to form a giant communication system with messages being sent and received in an instant.

Using the Tesla coil and his turn-of-the-century discovery of terrestrial stationary waves, which basically meant that Planet Earth could be employed as an electrical conductor, he produced some spectacular demonstrations. He generated self-made "lightning strikes" over 100 feet long, and once lit 200 lamps, unconnected by wires, stretched over 25 miles.

The idea of the widespread transmission of electricity without wires became a particular area of interest for Tesla in his later years. The "tesla", the SI unit of magnetic flux density, is named in his honour.

RADIO-WAVE TECHNOLOGY

In 1902, Tesla entered into a public feud with Guglielmo Marconi, who would prove to be an even more fearsome adversary than Edison. By the mid-1890s, Tesla had become firmly established as the leading figure in radio-wave technology, having filed his first patent for radio in 1897. However, a fire destroyed much of this research and his place at the forefront of innovation was taken by the young Marconi. In 1899, Marconi had transmitted the first international radio signals across the English Channel. However, the similarity between his equipment and that devised earlier by Tesla led the US patent office to turn down Marconi's patent application in 1900. But Marconi's stock was rising, as his wireless telegraph company began to receive significant financial backing from Andrew Carnegie and Thomas Edison.

In 1901, Marconi increased the stakes, transmitting radio signals across the Atlantic. Tesla, however, remained unfazed, commenting: "Marconi is a good fellow. Let him continue. He is using 17 of my patents."

His attitude would be considerably more relaxed in 1904, however, when the US patent office (probably under pressure from powerful vested interests) sensationally reversed its earlier decision and awarded Marconi the patent for the invention of the radio.

Financial difficulties caused by the "War of the Currents" meant that Tesla was unable to challenge the decision. He also lost the royalties for his European patents at the outbreak of World War I.

He continued to work in a range of fields, including radar and vertical take-off and landing (VTOL), but increasingly became a marginalised figure. When he died in the New Yorker Hotel in 1943, he left behind significant debts, but one of the greatest inventing legacies of all time – amounting to more than 700 patents worldwide – and a revered, if slightly unusual place in popular culture.

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