ISSUE 1
2025

TRENDS in innovation

from the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology

Mobile solar-dish gas turbine hybrid

Green energy
FROM WATER HYACINTH CARBON BIOMASS

FROM THE LABORATORY TO THE market

Immersive learning
FOR FUTURE-FOCUSED TEACHING

UNIVERSITEIT VAN PRETORIA
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Faculty of Engineering, Built Environment and Information Technology

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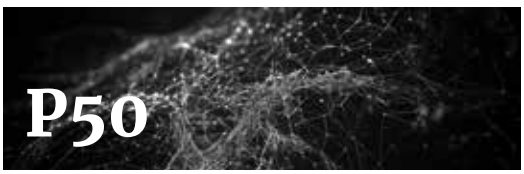

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EDITOR'S note

Higher education institutions have no choice but to stay relevant. The future is unpredictable and no one can say, with any certainty, what tomorrow could hold. Our challenge is to teach students the skills required to manage change and master critical thinking.

At its core, innovation necessitates a critical look at social norms and the trends around us. This enables higher education institutions to strive towards building a sustainable world as our legacy. The research featured in *Trends in Innovation* places humans at the centre. It is our responsibility to understand emerging technology and prepare our students to pick up the mantle for impacting the future. Trends should not be followed blindly, but used to drive impactful research.

Happy reading!

Prof Wynand JvdM Steyn
Dean: Faculty of Engineering, Built Environment and Information Technology, University of Pretoria

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TRENDS in innovation

Impacting global challenges through research in engineering, built environment and information technology at the University of Pretoria

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Balancing fundamental education and future needs to prepare graduates for lifelong careers

In today's fast-changing higher education landscape, universities face the dual challenge of providing foundational knowledge in specific disciplines, while also integrating developing trends driven by industry needs. As the pace of technological advancement accelerates and societal expectations evolve, it becomes essential for institutions to develop graduates who are not only knowledgeable in their fields, but also adaptable to a fluctuating job market.

Foundational knowledge serves as the cornerstone of any academic discipline. A firm grasp of fundamental theories is vital in areas such as engineering, the built environment and information technology. This foundational education equips students with critical thinking skills, problem-solving abilities and the capacity for innovation – essential tools for professional life.

However, universities must also recognise that the world is increasingly shaped by emerging technologies and evolving market demands that require graduates to apply their knowledge in real-world contexts.

Prof Wynand JvdM Steyn

For example, students entering engineering programmes today will graduate into a workforce transformed by technologies like Generative Artificial Intelligence (GAI). The rapid growth of such technologies can create gaps in students' education, as they may begin their studies without exposure to the very tools that will dominate their industries by the time they graduate. This situation presents a significant challenge for educators, who must ensure that curricula remain relevant and aligned with evolving industry expectations.

To address this challenge, universities can adopt several strategies. Firstly, educators should continuously emphasise the significance of foundational knowledge, while also being open to integrating contemporary developments into their teaching. Foundational concepts and emerging trends should be taught as mutually complementary, including discussions of fundamental principles alongside current events that enhance students' understanding and engagement with the material.

Additionally, adopting an agile curriculum framework is vital, allowing for appropriate adjustments in response to industry shifts. Regular curriculum reviews and collaborations with industry professionals can help keep course content relevant.

Involving students in conversations about emerging trends can also encourage critical thinking and highlight the relevance of their studies within the context of their foundational knowledge.

Furthermore, effective communication skills remain crucial in a world of information overload. Universities should emphasise instruction on communication strategies, enabling students to analyse, synthesise and present their ideas articulately through various formats, such as writing, delivering presentations and engaging in discussions.

Collaboration and interdisciplinary approaches should be emphasised, as working in diverse teams prepares students to tackle complex problems, while fostering adaptability – an essential trait for navigating unpredictable futures.

Ultimately, academia should aim to cultivate future influencers by blending foundational capabilities with agile execution skills. By teaching students to navigate uncertainty, we prepare them for the jobs of today and their future careers, ensuring they can thrive in dynamic and evolving environments. T

BY PROF WYNAND JVDM STEYN

Prof Wynand JvdM Steyn is the Dean of the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria. His research interests relate to vehicle-pavement interaction, accelerated pavement testing, pavement engineering, pavement materials and instrumentation. He is a Fellow of both the South African Institution of Civil Engineers and the South African Academy of Engineering and has a B3 rating from the National Research Foundation (NRF).

"Involving students in conversations about emerging trends can encourage critical thinking and highlight the relevance of their studies within the context of their foundational knowledge."

Driving innovation and shaping the future through postgraduate studies

In an era of unprecedented challenges, such as climate change, rapid urbanisation and pandemics, the need for advanced knowledge and innovative solutions has never been greater. Addressing these complexities demands a workforce with specialised skills and the capacity for critical and creative thinking. Postgraduate education in such fields as engineering, the built environment and information technology has emerged as a critical pathway to cultivating this essential talent pool, driving innovation and shaping a sustainable future.

The University of Pretoria (UP) is a leading research-intensive institution in Africa. It plays a pivotal role in fostering academic excellence. With a strong emphasis on interdisciplinary research and a commitment to addressing real-world challenges, UP provides fertile ground for groundbreaking discoveries. Its Faculty of Engineering, Built Environment and Information Technology (EBIT) stands at the forefront of this pursuit, conducting cutting-edge research on renewable energy, sustainable infrastructure, artificial intelligence and cybersecurity. Such research advances scientific knowledge, translating into tangible solutions that benefit society.

While undergraduate programmes provide a foundational understanding of core principles, the complex challenges of the modern world necessitate a deeper level of expertise through postgraduate studies.

Prof James Maina

BY PROF JAMES MAINA

Prof James Maina is the Deputy Dean: Research and Postgraduate Education of the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria. His research interests relate to pavement engineering, mathematical, physical and numerical modelling, full-scale testing and instrumentation of road pavements and the characterisation of road building materials. He is a member of both the Engineering Council of South Africa and the South African Institution of Civil Engineers, Fellow of the South African Academy of Engineering, and has a B3 rating from the National Research Foundation (NRF).

POSTGRADUATE STUDIES OFFER SEVERAL KEY ADVANTAGES:

- **Advanced skill development:** Postgraduate programmes equip students with advanced research methodologies and technical expertise, nurturing critical thinking and problem-solving skills. Postgraduate students learn to conduct independent research, analyse complex data and effectively communicate their findings.
- **Specialised knowledge:** Postgraduate students gain in-depth knowledge and specialised skills by focusing on specific areas within their chosen field. For example, the focus for engineering students may include nanotechnology, biomedical engineering or transportation engineering. Students may specialise in sustainable urban planning, green building design or disaster resilience in the built environment. Specialisations within information technology (IT) may include artificial intelligence, cybersecurity, data science or informatics.
- **Research-driven innovation:** Postgraduate research fosters a culture of inquiry and innovation. By engaging in original research projects, students contribute to advancing knowledge in their field, pushing the boundaries of what is possible and developing novel solutions to pressing global challenges.

Engineering: Driving technological advancements

Postgraduate programmes in engineering play a crucial role in addressing critical global issues. Research in areas like bioengineering is leading to the development of life-saving medical devices and therapies. Advancements in renewable energy technologies, such as solar and wind power, are crucial for mitigating climate change and ensuring a sustainable energy future. Furthermore, research in materials science and nanotechnology is paving the way for innovative materials with enhanced properties, leading to advancements in various sectors, including construction, aerospace, electronics and healthcare.

Built environment: Shaping sustainable cities and communities

The built environment significantly impacts our quality of life. Postgraduate programmes in this field focus on creating sustainable and resilient cities. Research in urban planning explores strategies for optimising land use, improving transportation systems and enhancing social equity. Green building design focuses on minimising environmental impact through energy-efficient buildings, sustainable materials and innovative technologies. Disaster resilience research aims to develop infrastructure and communities to withstand natural disasters and recover quickly.

Information technology: Powering the digital age

In the digital age, IT plays a pervasive role in all aspects of society. Postgraduate programmes in IT equip students with the knowledge and skills to navigate the rapidly evolving technological landscape. Research in artificial intelligence (AI) is driving advancements in areas such as healthcare, finance and transportation, leading to more efficient and personalised services. Cybersecurity research is crucial for protecting critical infrastructure and personal data from cyber threats. Data science and analytics are transforming how we understand and utilise information, enabling data-driven decision making in various fields.

Entrepreneurial success and societal impact

Postgraduate education not only enhances academic and professional prospects, but also fosters entrepreneurial spirit. The advanced knowledge and research skills gained through postgraduate studies equip individuals to do the following:

- **Launch innovative startups:** Translate research findings into novel products and services, driving economic growth and job creation.
- **Lead innovation within organisations**: Develop and implement innovative solutions within established companies, enhancing their competitiveness and adaptability.
- **Address societal challenges:** Apply their expertise and knowledge to develop sustainable solutions to social, economic and environmental problems, such as poverty, inequality and climate change.

Investing in the future

Investing in postgraduate education in engineering, the built environment and IT is not merely an academic endeavour. It is an investment in the future. By nurturing a new generation of highly skilled and innovative professionals, UP, in general, and EBIT, in particular, hope to address the pressing challenges of our time, drive economic growth and create a more sustainable and equitable world. The contributions of postgraduate researchers to scientific discovery, technological advancement and societal progress underscore the critical importance of this undertaking. T

Delivering professionals for the future: *25 years of excellence*

The University of Pretoria's Faculty of Engineering, Built Environment and Information Technology (EBIT) is a source of locally relevant and internationally competitive programmes, and is home to some of the University's exceptional researchers. It is one of the few academic faculties in Africa to feature among the top 650 in the world in five subject areas in the 2024 QS World University Rankings by Subject in the field of engineering and technology. It offers the unique combination of the fields of engineering, built environment and information technology. This places it in a position to conduct exceptional multidisciplinary research to address relevant challenges in society.

IN ITS CURRENT FORM, EBIT WAS ESTABLISHED 25 YEARS AGO WHEN THE UNIVERSITY EMBARKED ON A PROCESS OF RESTRUCTURING ITS ACADEMIC FACULTIES AT THE TURN OF THE CENTURY. ITS FOUR INDIVIDUAL SCHOOLS, HOWEVER, HAVE A LONGER HISTORY.

Prior to the restructuring of the University's faculties, the departments and schools that today make up its largest faculty were located in different faculties and departments. The School of Engineering was a faculty in its own right (the Faculty of Engineering), which originated in 1956. The School for the Built Environment was formed from three departments of the former Faculty of Natural Sciences: Architecture and Landscape Architecture, Quantity Surveying and Construction Management, and Town and Regional Planning. The School of Information Technology was formed from the Department of Computer Science (formerly in the Faculty of Natural Sciences), the Department of Information Science (formerly in the Faculty of Arts) and the Department of Informatics (formerly in the Faculty of Economic and Management Sciences). The Graduate School for Technology Management (GSTM) was added in 2007 as the new home for the postgraduate programmes in engineering management, project management and related fields that had previously resided in the University's Graduate School of Management. In 2025, the Faculty celebrates a quarter of a century of excellence in engineering, built environment and information technology.

A milestone in the positioning of the Faculty as a leader in delivering professionals for the future took place in 2006, when government recognised the need to address the country's mounting demand for scarce skills. This gave rise to the national Accelerated and Shared Growth Initiative of South Africa (AsgiSA) and its associated Joint Initiative for Priority Skills Acquisition (JIPSA). The Department of Education provided an allocation of R170 million to support the University in its aim of significantly increasing its number of engineering graduates.

The University supplemented this allocation from its own funds for capital projects, as well as fundraising income, bringing the total budget for the expansion and upgrading of its engineering facilities to R420 million. These funds were used to construct the Engineering III complex in 2010, which included six new lecture halls with a total seating capacity of 1 800, a drawing hall that could seat 475 students, an interactive group study area for 91 students and four new laboratories, as well as offices and a new parking garage for approximately 1 000 vehicles.

These facilities not only made it possible for the University to accommodate the envisaged growth of its School of Engineering over the subsequent years in line with national needs, but contributed to the delivery of engineers to the market who are innovative thinkers.

Other milestones followed, including the construction of the Mining Industry Study Centre in 2013, the Kumba Virtual Reality Centre for Mine Design in 2015 and the state-of-the-art Engineering 4.0 Facility in 2020, which houses several laboratories, and research and training facilities dedicated to smart, sustainable transportation and infrastructure. Today, the Faculty boasts 90 laboratories across three of the University's campuses to address the needs of students in each of its four schools.

EBIT is organised into four schools

SCHOOL OF ENGINEERING

The School of Engineering presents programmes in all the major engineering disciplines, with many specialisations offered at postgraduate level. It is ranked 334TH out of more than 10 000 engineering schools in the field of engineering and technology.

SCHOOL FOR THE BUILT ENVIRONMENT

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. The School places a particular emphasis on the equitable and sustainable development of people.

SCHOOL OF INFORMATION TECHNOLOGY

The School of Information Technology is a forerunner in the South African IT environment with its unique integration of the fields of computer science, informatics and information science. The School is also a proud member of the international iSchools Organization.

GRADUATE SCHOOL OF TECHNOLOGY MANAGEMENT

The GSTM 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 (GAC) of the Project Management Institute, USA.

Prof Nelishia Pillay

Leading research in artificial intelligence for sustainable development

Prof Nelishia Pillay is a recognised expert on emerging topics in artificial intelligence with a focus on machine learning and optimisation. As Head of Department of the University of Pretoria (UP)'s Department of Computer Science in 2019, she was selected for the Professional Academic Leaders (PAL) programme and was project leader of the winning team. She currently holds the South African Research Chairs Initiative (SARChI) Chair in Artificial Intelligence for Sustainable Development, as well as the MultiChoice Joint Chair in Machine Learning, in the University's Faculty of Engineering, Built Environment and Information Technology.

She is well regarded in the academic community, and chaired the Institute of Electrical and Electronic Engineers (IEEE) Computational Intelligence Society (CIS) Subcommittee on Diversity, Equity and Inclusion, the IEEE CIS Mentoring Subcommittee, the IEEE CIS Outstanding Dissertation Subcommittee and the IEEE Women in Computation Subcommittee. She was the Technical Co-chair for the IEEE 2024 World Congress on Computational Intelligence, and is the General Co-chair for the IEEE 2026 Congress on Evolutionary Computation. Furthermore, she serves as an elected member of the IEEE CIS Administrative Committee. She has also served as Student Affairs Co-chair for the American Computing Machinery (ACM)'s international Genetic and Evolutionary Computation Conference (GECCO) and is currently serving as co-chair for the Genetic Programming track for GECCO 2025.

She is the Associate Editor of the *IEEE Computational Intelligence Magazine, IEEE Transactions on Emerging Technologies*, the *ACM Transactions on Evolutionary Learning and Optimization* and is on the editorial board of *Genetic Programming and Evolvable Machines*. She has previously served as associate editor for *Swarm and Evolutionary Computation* and the *Journal of Scheduling*.

Her research involves using artificial intelligence to solve problems related to the United Nations' Sustainable Development Goals. This has led to advancements in artificial intelligence, specifically in the areas of hyper-heuristics, the automated design of machine learning and search techniques, transfer learning, combinational optimisation, genetic programming, genetic algorithms, and machine learning and optimisation for sustainable development.

In 2024, she received UP's Exceptional Academic Achievers Award, which recognises senior academics who are highly regarded by their peers, and who have consistently excelled in teaching and learning, research, community service and administration. She has a B2 rating from the National Research Foundation (NRF).

She established the Nature-inspired Computing Optimisation Group (NICOG) in the Department of Computer Science, which focuses on creating new and extending existing artificial intelligence (AI) techniques to solve problems related to the United Nations' Sustainable Development Goals (SDGs). This includes innovation in industry, health and wellbeing, lifelong learning and renewable energy. Research conducted under her supervision has contributed to the automated diagnosis of various diseases, including COVID-19, diabetes, heart disease and depression, as well as plant diseases. T

Attaining the United Nations' Sustainable Development Goals by learning from nature

Since its inception in the 1950s, artificial intelligence (AI) has had a major impact on various sectors of the economy, such as health, finance, industry, agriculture and food security, ultimately leading to improved economic growth. Prof Nelishia Pillay explains that the Nature-inspired Computing Optimisation Group (NICOG) in the University of Pretoria's Department of Computer Science, which she established, is using machine learning and optimisation techniques that take analogies from nature, such as genetic algorithms and neural networks, to develop solutions to real-world problems.

Search formed the foundation of early AI systems. This was followed by expert systems, which aimed to emulate experts, such as medical doctors. 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. This led to the introduction of machine learning approaches. These can be categorised into supervised, unsupervised and reinforcement learning. As the field matured, a further development was the evolution of search into robust optimisation techniques, including multipoint search.

These machine learning and optimisation techniques often take an analogy from nature to provide scalable solutions to complex real-world problems. Genetic algorithms are an optimisation technique that takes their inspiration from Darwin's theory of evolution. Similarly, ant colony optimisation and particle swarm optimisation take their analogy from the ant colony and flocking behaviour in nature, respectively.

Neural networks, a machine learning technique, emulate the way the human brain functions and are therefore very effective for solving low-level processing tasks for which humans use their five senses, such as image and sound recognition.

The synergistic relationship between machine learning and optimisation is rapidly growing, with machine learning being used in optimisation, and optimisation being used in machine learning to find solutions to complex optimisation problems. This has led the use of AI to design AI approaches that reduce the workload for experts and make the design of AI systems more accessible to non-experts.

These are the techniques the NICOG is developing and improving to solve complex problems related to the United Nations' Sustainable Development Goals (SDGs), with a focus on health and wellbeing, lifelong learning and innovation in industry.

In the area of health and wellbeing, the NICOG has used these approaches in various areas, like diabetes, heart disease, depression and COVID-19 diagnosis, as well as the detection of oral lesions and various cancers, including, myeloma, brain tumours and lung cancer.

Intelligent tutoring systems is another area the NICOG is focusing on to promote lifelong learning. These systems achieve lifelong learning by providing individualised tutoring, which enables the learner to learn at any place and time. In 2021 and 2022, the NICOG was involved in a project to pilot an intelligent tutoring system prototype for students studying speech therapy at different universities in Africa. Another area related to lifelong learning that the group investigated is learning analytics to predict potential poor performance of learning and put remedial measures in place to prevent failure. The main aim of the research is to support Education 4.0 and reskilling when and where needed.

One of the major impacts of the research conducted by the NICOG is innovation in industry. Together with the MultiChoice Group, the NICOG has solved various problems in the broadcasting industry, including automated video multimethod assessment fusion (VMAF) configuration, viewer recommendations, video shorts creation, movie scene scheduling and automated thumbnail selection. The NICOG has also developed state-of-the-art solutions for routing and packing problems.

More recently, the NICOG has developed multimodal learning approaches, namely learning from more than one type of data, e.g. audio and image, to find better quality solutions to complex problems related to the SDGs.

The research conducted by the group has resulted in advancements in academia in the areas of hyper-heuristics, genetic programming, transfer learning for evolutionary algorithms, multi-space search, multimodal learning, machine learning for optimisation, and optimisation for machine learning.

Prof Vukosi Marivate

Harnessing the power of AI and data science to create positive societal impact

Prof Vukosi Marivate holds the Absa-UP Chair of Data Science in the University of Pretoria (UP)'s Department of Computer Science. He is a researcher in artificial intelligence (AI) and natural language processing (NLP), focusing on local and low-resourced languages. He leads the Data Science for Social Impact (DSFSI) research group in the Faculty of Engineering, Built Environment and Information Technology, which explores data science methodologies to address societal challenges, especially in Africa. He is passionate about training the next generation of data scientists in Africa.

He co-founded Lelapa AI, a socially grounded Africa-centric AI start-up, and the Masakhane Research Foundation, an open and collaborative research initiative, focused on improving NLP for African languages. Prof Marivate is also one of the founding members of the Deep Learning Indaba, an initiative dedicated to strengthening machine learning and AI research across Africa by fostering collaboration, education and innovation on the continent.

Prof Marivate's research and leadership in AI have earned him several prestigious awards and grants, including the Google Research Scholar Award, the JP Morgan Chase AI Award, the International Development Research Centre (IDRC)'s Artificial Intelligence for Development (AI4D) awards, Meta/Facebook awards, National Research Foundation (NRF) awards, and funding from the Bill and Melinda Gates Foundation.

He has also been recognised twice as a finalist for the National Science and Technology Forum (NSTF) awards in the Emerging Researcher and Data for Research categories, respectively. In 2024, he received UP's Exceptional Young Researcher Award, which recognises exceptional young achievers in the field of research, as seen against the University's strategic goals of achieving academic excellence, international competitiveness and local relevance.

The machine learning interface that was developed for low-resourced languages was focused on developing an electronic translation application for languages that are not catered for by systems developed in North America and Europe. It 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.

Machine learning and AI have been responsible for a number of NLP breakthroughs that are in popular use, such as a cell phone's virtual assistant, text-to-speech applications and chat bots. According to Prof Marivate, such advances in NLP have largely benefitted well-represented languages. This has necessitated research into lesser-known global languages. This is, in part, due to the availability of curated data and research resources in well-represented languages, 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 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.

"Language presents a rich interface with which to share information and interact with machines," says Prof Marivate. For African languages, this challenge coincides with the challenges of shaping the current revolution in AI with the global landscape.

Language without borders: Tired of being lost in translation?

Researchers in the field of computational linguistics and natural language processing believe that we need language models that represent the actual ways in which people use language, and conversational interfaces that give people the feeling they do not have to disregard their own linguistic identities.

Prof Vukosi Marivate sketches the following scenario: Imagine walking down a bustling street in one of Africa's cosmopolitan cities, listening to the echo of voices. What do you hear? Words. Foreign and familiar, a mix of languages, even in one conversation. This phenomenon is known as code-switching – a common linguistic practice in multilingual cultures where people switch between languages in a single discourse.

He explains that, currently, about 40% of the world population is bilingual and almost 20% is multilingual. Africa alone accounts for approximately 2 000 of about 7 000 languages in the world, making code-switching an inevitable occurrence. However, most African languages are low-resourced and under-represented in recent natural language processing (NLP) technologies. The most popular NLP technologies are the large language models (LLMs). "It is therefore imperative to move towards equitable representation of these languages and ensure that everyone has equal access to these technologies."

Current research into code-switching has received increased attention in the past decade, with the most popular being on corpus creation, benchmark development and the evaluation of downstream tasks between English and Spanish, Hindi and Chinese. Very little research or available data exists for African languages.

To address this issue of data scarcity, a research team including PhD student Michelle Terblanche and postdoctoral fellow Dr Kayode Olalaye at the Data Science for Social Impact Lab in the University of Pretoria's Department of Computer Science embarked on utilising LLMs such as ChatGPT to generate code-switched text. Methodologies include linguistic prompting, in-context learning and zero/few-shot fine-tuning. Initial results suggest that the embedded knowledge of high-resourced languages can be useful in closing the gap in low-resource language availability. The goal is to develop sustainable methods for corpus creation and to make these resources available to the larger community to continuously support advancements in this field.

This research opens up possibilities for transdisciplinary collaboration in, but not limited to, three fields: linguistics (understanding the constraints of how and why code-switching occurs), education (allowing for a mixed-language setting to promote both teaching and learning) and speech-language pathology (assisting researchers and practitioners to improve recommended development plans).

"Data quality is at the centre of the research," he explains. One of the doctoral research projects under his supervision is focusing on developing methods to evaluate synthetic data with minimal human intervention and low-cost computational resources. "We can then address a broader range of applications, catering for language diversity," he says.

"Our aim is to position Africans at the forefront of shaping AI for our own benefit."

This research is a step towards preserving a rich culture and focusing attention on developing technologies that serve the ever-growing multilingual population.

Other research in the Department is aimed at enhancing financial inclusion, irrespective of linguistic habits or educational background. "Through breakthroughs in code-switching modelling, we envision financial institutions being able to offer more relevant, accessible and engaging experiences to a wide array of customers." This research can potentially facilitate the provision of bilingual customer service, the creation of multilingual documentation and the crafting of marketing material specifically designed to resonate with the diverse linguistic habits of customers.

Prof Marivate believes that the research of the Absa-UP Chair of Data Science can make a real change to society by enabling speakers of African languages to function optimally in a digitally enabled world.

IMAGINE WALKING DOWN A BUSTLING STREET IN ONE OF AFRICA'S COSMOPOLITAN CITIES, LISTENING TO THE ECHO OF VOICES. WHAT DO YOU HEAR? WORDS. FOREIGN AND FAMILIAR, A MIX OF LANGUAGES, EVEN IN ONE CONVERSATION.

Prof Evans Chirwa

Collaborating regionally and internationally to achieve water security

Prof Evans Chirwa is a recognised leader in water utilisation research. He heads the University of Pretoria's Water Utilisation Division in the Department of Chemical Engineering, and holds the University's Rand Water Chair in Water Utilisation. In 2022, he was the winner of the National Science and Technology Forum (NSTF)–Water Research Commission (WRC) Award for his groundbreaking research in advanced water treatment and water recovery.

Originally from Malawi, Prof Chirwa completed his master's and doctoral qualifications at the University of Kentucky, USA. Since joining the University of Pretoria in 2003, he has raised up to R121.5 million (approximately $8.4 million) in funds for research and laboratory upgrades. He has also been instrumental in increasing the research base of the Department's Water Utilisation and Environmental Focus Group, providing leadership and expanding research capacity, as well as the Department's collaborations with universities in Australia, Austria, China, Kenya, Malawi, Malaysia and the USA.

His personal mission is to pursue innovation in water and environmental research, and achieve critical mass in water and environmental research relevant to South Africa and southern Africa. His research interests include the biological remediation of toxic metals and radionuclides, advanced oxidation and the photocatalytic degradation of taste- and odour-casing compounds, recalcitrant toxic organics and organic micropollutants in water, and *in situ* bioremediation processes.

The research project for which he received the NSTF Award in 2022 was aimed at 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 wastewater reclamation projects that are aimed at "creating water" for household use. This was a major breakthrough for a water-scarce country like South Africa.

His research team's projects on advanced water treatment have yielded several innovative developments that have the potential of being taken up by industry. He 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 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.

Prof Chirwa states that the country's water and energy problems are related. "As energy is required to perform water desalination and wastewater 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.

Converting water hyacinth carbon biomass to green energy

Water, as a precious natural resource, is indispensable for safeguarding human health and ensuring agricultural food production. However, the convergence of climate change, escalating water pollution, unequal resource distribution and the constrained availability of clean water resources have led to over a billion people worldwide having limited access to safe drinking water. To exacerbate the issue, the proliferation of invasive species, often associated with eutrophication, has resulted in a deterioration in the water quality of existing water bodies intended for human consumption.

An invasive species that is particularly problematic in this regard is the water hyacinth. This pervasive aquatic plant has become a formidable challenge in areas of southern Africa and parts of Central and North America. Once this plant takes root in a water body, its eradication becomes an arduous task. Studies in lakes and rivers worldwide have revealed its profound impact on water quality and the loss of biodiversity, while the stagnant water areas under its dense mats create an ideal habitat for disease-carrying vectors such as mosquitoes.

The water hyacinth, *Eichhornia crassipes*, invades aquatic ecosystems across the larger geographic area, resulting in unsightly proliferation in natural water bodies. In South Africa, its impact is particularly severe in strategically important water bodies such as Hartbeespoort Dam in North West and Roodeplaat Dam east of Pretoria. It is also becoming a problem in Lake Victoria, which straddles Tanzania, Uganda and Kenya.

As an invasive aquatic plant, it spreads rapidly and covers water bodies, such as lakes, ponds, rivers and reservoirs. It serves as a long-term reservoir for critical nutrients such as carbon, phosphate and nitrogen.

These nutrients accumulate within the hyacinth plant and are released into the water body upon the plant's decomposition, primarily during winter. This causes a deterioration in the quality of the water, to the detriment of both human and environmental health.

The dense growth prevents sunlight from reaching the water's surface, which inhibits the photosynthesis of the aquatic plants below. This leads to reduced dissolved oxygen levels in the water. This poor water quality negatively affects sources of drinking water, as well as recreational activities.

Finding a sustainable solution

In an attempt to address the global challenges associated with climate change and public health, the World Universities Network Research Development Fund allocated an award to Prof Evans Chirwa. He is the Principal Investigator and Academic Lead in a collaborative, transdisciplinary research project in this area of water utilisation that affects not only Africa and the Global South, but areas of North America, Central America and South East Asia as well.

The project is being conducted in collaboration with a multidisciplinary team of 14 researchers from the University of Pretoria (South Africa), the Technological Institute of Monterrey (Mexico), the University of Leeds (United Kingdom), Makerere University (Uganda) and the University of Technology Sydney (Australia).

The team comprises chemical and electronic engineers, biologists, microbiologists and geneticists. The engineers will develop controls in targeting water hyacinth, while minimising harm to non-target species, and creating efficient, cost-effective, and environmentally safe control and monitoring methods.

The biologists study the water hyacinth's life cycle, growth patterns and reproductive behaviour, and identify possible biological controls. They also monitor and map invasive species and their impact on the native fauna and flora. The microbiologists investigate microbial communities associated with water hyacinth, and explore potential growth inhibition. They also explore microbial-based solutions by introducing beneficial microbes for growth suspension. The geneticists analyse the plant's genetic diversity and factors that contribute to its invasiveness. They also develop genetic modification techniques for less invasive strains, and investigate genetic traits related to herbicide resistance to disease susceptibility.

Prof Chirwa explains that following a multidisciplinary approach offers numerous advantages across the studied regions. "It provides a comprehensive understanding by offering a holistic view to enhance strategy effectiveness, considering the unique challenges in each region." It also enables the researchers to devise holistic solutions, which encompass ecological, social and economic factors, ensuring a comprehensive approach. "Interdisciplinary teamwork furthermore fosters innovative approaches, which would otherwise have been missed."

The proposed solutions are locally relevant, as they are tailored to specific conditions in South Africa, North America and South East Asia. "The resultant sharing of knowledge promotes long-term cooperation and capacity building across these regions," says Prof Chirwa.

"The rigorous testing of control methods in controlled environments is essential to prevent unintended consequences and environmental harm." It is envisaged that the engagement of local communities, government agencies and stakeholders will ensure the sustainable management of the water hyacinth. T

THE CONVERGENCE OF CLIMATE CHANGE, ESCALATING WATER POLLUTION, UNEQUAL RESOURCE DISTRIBUTION AND THE CONSTRAINED AVAILABILITY OF CLEAN WATER RESOURCES HAS LED TO OVER A BILLION PEOPLE WORLDWIDE HAVING LIMITED ACCESS TO SAFE DRINKING WATER. TO EXACERBATE THE ISSUE, THE PROLIFERATION OF INVASIVE SPECIES HAS RESULTED IN A DETERIORATION IN THE WATER QUALITY OF EXISTING WATER BODIES INTENDED FOR HUMAN CONSUMPTION. AN INVASIVE SPECIES THAT IS PARTICULARLY PROBLEMATIC IN THIS REGARD IS THE WATER HYACINTH.

Dr Calayde Davey

Integrating academic learning into professional practice

Dr Calayde Davey is a senior lecturer in the Department of Architecture at the University of Pretoria. She holds a master's degree in Architecture from the University of Pretoria and a PhD in Environmental Design and Planning from Kansas State University, USA, where she was a Fulbright Scholar. She is dedicated to exploring the transformative potential of urbanism, transdisciplinary professional practice and innovation within the African built environment.

She leads the University of Pretoria's Hatfield Digital Twin City initiative and the Department of Architecture's Urban Strategy Studio, where she integrates academic learning with professional practice in transdisciplinary settings. In 2023, she led the South African delegation to The Netherlands, at the invitation of the Economic Department of the Embassy of the Kingdom of The Netherlands, for knowledge exchange on the digitalisation of African cities. The delegation visited the University of Twente, the Eindhoven University of Technology's Urban Design Institute, The Netherlands Organisation for Applied Scientific Research and the City of Rotterdam.

In 2023, Dr Davey received the University of Pretoria's Institutional Teaching and Learning Award, as well as the 2023 Quanser Global Sustainability Award for Engineering Education. In 2024, she received the University of Pretoria's Teaching Excellence Award.

Dr Davey's work seeks to impact the African built environment through her innovative approach to education and practical applications in architecture, design and urban strategy. She considers the professional development of students to be an important part of their academic journey. Since architects need to collaborate with a variety of professionals in the built environment when they enter the workforce, their involvement in transdisciplinary project activities is essential.

She has initiated a number of activities to promote an awareness of transdisciplinarity among her students, while developing close ties with industry. This provides students with professional exposure at an early stage in their careers.

In 2021, she collaborated with BIMcommUNITY Africa to launch an annual two-day industry-academia networking event, the BIM Harambee. It is hosted by the Department of Architecture and provides a means of sharing knowledge, exchanging ideas and fostering collaboration between people who are passionate about building information modelling (BIM) and its transformative potential. The goal is to inspire and equip delegates with the necessary tools and insights to shape the built environment of tomorrow.

Dr Davey explains that BIM is about improving collaboration, as well as the quality and sustainability of building projects through shared digital workflows. "BIM is a fundamental component of virtual, design and construction (VDC) – a digital representation of a building project's physical, functional and process-related characteristics." It provides a platform to create, manage and share the digital representation of a building or infrastructure project, while integrating shared project data and information among diverse team members.

This allows stakeholders to collaborate, make informed decisions and optimise project outcomes. "Compared to traditional project delivery, which is linear and hierarchical, BIM project delivery is collaborative and iterative," she says. BIM project delivery is therefore a multidisciplinary cooperation where each discipline brings its own value contribution, shared perspective and expertise to the holistic BIM development process.

A transdisciplinary classroom leads to dynamic learning

Within the University of Pretoria (UP)'s Faculty of Engineering, Built Environment and Information Technology, students and academics involved in teaching and research that relate to the various stages of a construction project are developing a transdisciplinary mindset. This transformation of traditional practices is leading to a radical shift in higher education that is equipping graduates with the skills they need when they enter the world of work.

Dr Calayde Davey of the Department of Architecture joined forces with Dr Johann van der Merwe, a senior lecturer in the Department of Civil Engineering, to develop an innovative approach to built environment education. This approach achieved international recognition for its impact, scalability and sustainability when it received the Quanser Global Sustainability Award for 2023. It was the only shortlisted project from Africa.

This Award was established in 2022 to address global challenges such as climate change, biodiversity loss, and waste and pollution. It acknowledges exceptional academic and research professionals who are dedicated to investigating and advancing sustainable engineering practices within their specific domains. It also encourages the engineering community to transform its practices to improve every element of our global technological and economic systems. In the process, it challenges engineers and architects to consider how they can design buildings that support the principles of sustainability. The project that was submitted for the award focused on improving circular value chains in construction through transdisciplinary education. It focused on leveraging Building Information Modelling (BIM) for the reuse of building material.

The approach Dr Davey took focused on improving value chains and material reuse in construction through transdisciplinary education. Students from the two partner departments took part in a joint project to establish how building material that originated from the potential demolition of structures could be reused in the construction of new buildings. This resulted in a transdisciplinary training model that employed computer modelling with building information data, following the BIM process. Its success depended on collaboration and teamwork between members of the individual disciplines.

Urban digital twinning

Dr Davey explains that a transdisciplinary classroom follows the pedagogical principles of the broader digital twinning initiatives she spearheaded at the University of Pretoria. With digital twinning principles as a background concept, projections of the real world can be made on a digital model, which, in turn, can be matched to an actual situation on the ground to simulate results based on certain hypothetical decisions or actions.

This approach allowed collaboration to take place between members of diverse disciplines such as architects, civil engineers, landowners and owners of a greenhouse structure on the University's Hillcrest Campus. This project served as a case study to determine how much of the structure's material, once demolished, could be reused. The digital mapping of construction waste allowed for an initial quantification of the construction material in the study area.

The collaborative development of this project stands out for its holistic, transdisciplinary approach, spanning the entire design and development process, with circularity at its core. It investigated innovative methods to integrate circular design-for-reuse principles that extend beyond the typical end-of-life scenarios of disciplinary siloes.

By involving the Faculty's postgraduate students in transdisciplinary projects such as these, students in construction economics, quantity surveying, construction management, architecture and civil engineering are subjected to real-life industry situations. Some projects may even lead to the development of prototypes for off-grid smart cities.

This not only gives students exposure to industry, but by working on real-life projects in a simulated digital work environment, they learn skills from other disciplines that they are then able to apply in their own discipline. This enables them to master content to which they would not necessarily gain access in a single-discipline curriculum.

This approach equips them with new technical skills, but also important social skills like teamwork and self-confidence, which will put them in good stead for their future careers.

The Hatfield Digital Twin City initiative, which Dr Davey initiated, entails an approach where reality and simulation meet in real time, in this case through the development of a comprehensive digital twin city. It provides a fully simulated, mirrored image of Hatfield and its surroundings. By establishing thousands of real-time feedback loops between nature, environments, cities, people and processes, researchers can ask new kinds of curious and innovative questions.

The University's Department of Facilities Management has adopted this approach to develop a comprehensive solid waste management strategy. This initiative includes the creation of a dynamic model that integrates real-time monitoring, optimised collection routes and citizen participation to enhance efficiency and sustainability.

Building on this foundation, the Department of Facilities Management has formally expanded its scope, catalysing a broader digital transformation strategy within the University. This has led to the establishment of the UP Operational Twin, developed through pilot projects applied to the University's diverse asset portfolio – including buildings, processes, landscapes, vehicles, communities and populations. This initiative marks a significant step towards a more data-driven and integrated approach to campus management.

The Hatfield Digital Twin City, together with the UP Facilities Management Operational Twin, is set to evolve into a formal centre, dedicated to advancing digital innovation within the African built environment. Its academic-operations relationship spans critical Fourth Industrial Revolution (4IR) and Fifth Industrial Revolution (5IR) topics, including urban digital twins, integrated curriculum development and transdisciplinary collaboration across diverse disciplines. Additionally, it will explore emerging Sixth Industrial Revolution (6IR) frontiers, such as the integration of additive manufacturing, bio-economies and life systems in urban contexts.

This initiative was driven by both internal partners and external industry partners approaching the University for support in addressing sector-specific challenges through digital twinning concepts. These challenges – ranging from cultural, operational and environmental to exploratory in nature – require varied approaches and tailored solutions.

As the Digital Twin City advances research and innovation in digital urbanism, Dr Davey invites industry leaders, professionals and organisations to collaborate through research partnerships, knowledge exchange and joint initiatives. We welcome your engagement if you are interested in contributing to this work or exploring potential areas of collaboration.

Contact Dr Calayde Davey at calayde.davey@up.ac.za

Engaging in research that *impacts global challenges*

Sustainable development is at the heart of the United Nations' 2030 Agenda for Sustainable Development. It was adopted in 2015 by all United Nations' member countries, and provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. This Agenda includes the 17 Sustainable Development Goals (SDGs). These are an urgent call to action for both developed and developing nations to end poverty and other global challenges. They are accompanied by global strategies to improve health and education, reduce inequalities and achieve economic growth, while tackling climate change and working to preserve our oceans and forests.

The Faculty of Engineering, Built Environment and Information Technology (EBIT) focuses its research on impacting these global challenges. As the only faculty at a South African higher education institution to house a unique combination of schools related to engineering, the built environment, information technology and technology management, EBIT is in the ideal position to pursue research that provides solutions to the societal challenges that face South Africa and the world in general.

Across its four schools, the Faculty's research is concentrated on five research areas, as well as the Fourth Industrial Revolution, that contribute significantly to addressing these societal challenges. They focus on bridging the gap between addressing our current realities and aspiring to a better future.

WATER AND ENVIRONMENTAL ENGINEERING

Research efforts focused on the management of South Africa's water quality and wastewater treatment have been inspired by a desire to improve the quality of life of all South Africans, and to improve their health and wellbeing. Research in the Department of Civil Engineering has led to the invention of a passive leak detection method that makes use of fibre optic cables to prevent water loss. This has the potential to benefit thousands of local residents. In the Department of Chemical Engineering, researchers in the Environmental Engineering Division are making use of plasma technology for the treatment and purification of wastewater.

SMART CITIES AND TRANSPORTATION

Research efforts that serve to revive South Africa's cities and facilitate a better life for its citizens have been inspired by a desire to achieve smart urban and public spaces. The Department of Civil Engineering has developed a smart transportation platform at its Engineering 4.0 Complex to support interdisciplinary research. The Department of Town and Regional Planning has focused on the regenerative potential of public spaces to support enhanced urban development. Collaboration between the Department of Engineering and Technology Management, the Department of Civil Engineering and the Department of Architecture, through the York Timbers Chair in Wood Structural Engineering, is contributing to the stimulation of a sustainable mass engineered timber construction industry in South Africa.

ENERGY

Research efforts on efficient energy systems, renewable energy and the efficient utilisation of energy by end-users have been inspired by the need to provide energy to all the citizens of South Africa to support quality of life. Researchers in the Department of Mechanical and Aeronautical Engineering are developing a system to generate electricity by using a mobile solar-dish gas turbine hybrid. In the Department of Civil Engineering, researchers are recommending the integration of hydropower systems into the country's existing infrastructure. In the Department of Materials Science and Metallurgical Engineering, researchers are investigating the possibility of repurposing existing steel pipelines for green hydrogen, as well as the possibility of using alternative methods of steelmaking to achieve lower carbon emissions. Research in the Department of Engineering and Technology Management is considering the decarbonisation of the global economy with green hydrogen.

At its core, innovation necessitates a critical look at social norms and the trends around us. This enables higher education institutions to strive towards building a sustainable world as our legacy.

BIG DATA SCIENCE, INFORMATION AND COMMUNICATION TECHNOLOGY, AND TECHNOLOGY AND INNOVATION MANAGEMENT

Research efforts that serve to harness innovation, secure growth and sustainability, and introduce new products have been inspired by a desire to continue to make disruptive advances in technology and innovation management. In the Department of Civil Engineering, researchers are reimagining transportation networks for a digital future. Research in the Department of Electrical, Electronic and Computer Engineering is making use of deep learning techniques to support farmers and wildlife managers in the identification of crocodiles from aerial images.

MINERALS AND MATERIALS BENEFICIATION

Research efforts that promote minerals and materials beneficiation have been inspired by a desire to find new ways to source valuable minerals from previously unexploited sources. Researchers in the Department of Chemical Engineering are investigating the recovery of rare earth elements (REEs) and uranium from mined phosphate ore. In the Department of Materials Science and Metallurgical Engineering, researchers are devising environmentally friendly alternatives to materials produced in the refractory industry. They are also investigating ways of extracting minerals from fine particles to increase minerals beneficiation, developing a system to monitor and track particles in a slurry, and exploring ways to increase beneficiation and improve the purity of platinum and other minerals.

CONTRIBUTION TO THE UNITED NATIONS' SUSTAINABLE DEVELOPMENT GOALS

These research areas are closely aligned to several of the United Nations' Sustainable Development Goals (SDGs), including **SDG 6** (Clean water and sanitation), **SDG 7** (Affordable and clean energy), **SDG 9** (Industry, innovation and infrastructure) and **SDG 11** (Sustainable cities and communities). Transdisciplinary research also focuses on impacting on several other global challenges, such as **SDG 4** (Quality education), **SDG 12** (Responsible consumption and production) and **SDG 13** (Climate action).

These research contributions, as well as some contributions in the domain of teaching and learning, demonstrate – through their social, economic and environmental impacts – how the Faculty's outcomes continue to improve people's quality of life, and the performance of industries.

PROVIDING ACCESS TO CLEAN WATER

Targeted research improves access to clean water

In a water-scarce country like South Africa, developing methods to provide clean water to those who need it is paramount. Water is not just important for drinking and hygiene purposes, but also to irrigate agricultural lands for food security. Research conducted in the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology is focused on bridging the gap between the current reality and a future that is characterised by the improved health and wellbeing of people across all sectors of the economy.

Challenges related to the management of South Africa's water quality and wastewater treatment are a top priority in two of the Faculty's departments: Civil Engineering and Chemical Engineering. Researchers in these departments are collaborating with other scientists and stakeholders to come up with groundbreaking, transdisciplinary solutions.

A flagship project in the Department of Civil Engineering has led to the invention of a passive leak detection method that makes use of fibre optic cables to prevent water loss. This has the potential to benefit thousands of local residents.

In another project, researchers are exploring pumped storage scheme opportunities in South Africa. Pumped storage schemes represent a pivotal component in the realm of energy storage and grid stability. With its diverse topography and growing energy needs, South Africa holds significant potential for the development and expansion of such storage schemes.

In collaboration with researchers in the Department of Biochemistry, Genetics and Microbiology in the Faculty of Natural and Agricultural Sciences, researchers in the Department of Civil Engineering are also determining the biological stability of water in community reservoirs. Another research team is optimising pier structures to prevent the blockage and flooding of bridges. This is related to the challenge that arises when flooding occurs due to the accumulation of debris such as tree stumps, branches and plastic bags at the entrance of culverts or bridges. This often results in the failure of the river-crossing structure, erosion of the culvert and destruction of the surrounding infrastructure.

In the Department of Chemical Engineering, researchers in the Environmental Engineering Division are making use of plasma technology for the treatment and purification of wastewater. Postgraduate research is also considering issues such as reducing pollution from industrial effluents, improving the water quality in Africa through an innovative solution for industrial wastewater treatment, and eliminating lead contamination in industrial wastewater. T

Passive leak detection has the potential to benefit thousands of local residents

Research conducted in the University of Pretoria's Department of Civil Engineering has the potential to prevent the loss of almost 40% of the country's household water. A South African patent has been granted to the team of Prof SW Jacobsz for a passive leak detection method that uses fibre optic cables. It measures both ground strain and temperature along a pipeline to detect leaks, and has the potential to benefit thousands of local residents.

Prof Jacobsz explains that, in the City of Tshwane alone, an estimated 35% of the potable water distributed by the municipality is lost due to leakages in the ageing distribution system. This amounts to approximately 75 million m^3 per annum. In towns like Makanda, with its older infrastructure, the percentage loss is even greater. Such losses cannot be afforded in a water-scarce country like South Africa, with its growing population and increasing urbanisation. A similar situation is prevalent in practically all arid countries around the world.

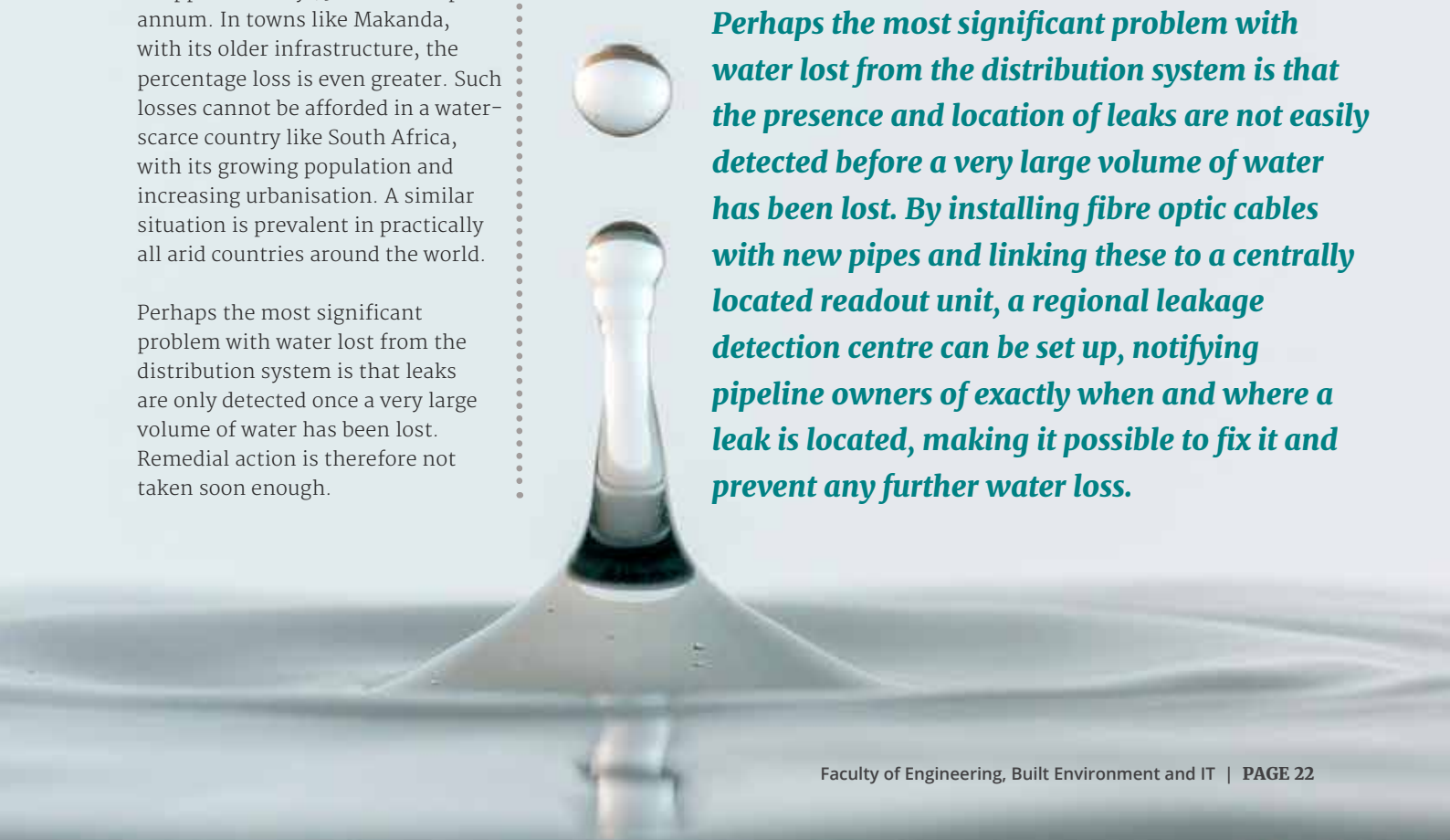
Perhaps the most significant problem with water lost from the distribution system is that leaks are only detected once a very large volume of water has been lost. Remedial action is therefore not taken soon enough.

"Fibre optic instrumentation has been developed over the past 25 years to measure temperature and strain at a high resolution in optic fibres," explains Prof Jacobsz. "Continuous strain and/or temperature readings can be taken along the length of a conventional communication-grade fibre optic cable extending to 50 km or more." A major advantage of such a system is that fibre optic cables are cheap and completely inert, and are therefore not affected by electrical interference.

By installing fibre optic cables with new pipes and linking these to a centrally located readout unit, a regional leakage detection centre can be set up. This will enable the municipality or other pipeline owner to be notified of exactly when and where a leak is located, making it possible to fix it and prevent any further water loss.

The system can also be monitored remotely via the internet, using software to automatically scan the fibre-optic instrumented pipelines for leaks, providing warning messages whenever a leak is detected.

This will enable early remedial measures to be taken to repair the pipe to minimise water loss. This provides a passive means of leak detection, saving on the need to recruit additional service providers to locate such leaks. T



Perhaps the most significant problem with water lost from the distribution system is that the presence and location of leaks are not easily detected before a very large volume of water has been lost. By installing fibre optic cables with new pipes and linking these to a centrally located readout unit, a regional leakage detection centre can be set up, notifying pipeline owners of exactly when and where a leak is located, making it possible to fix it and prevent any further water loss.

Plasma technology proves its success for water purification

The Department of Chemical Engineering's Plasma Technology Laboratory is conducting groundbreaking work in terms of water purification and contaminant removal from wastewater. Prof Samuel Iwarere, who leads this research team at the University of Pretoria, explains that plasma technology has various research applications in addition to water treatment, including hydrogen fuel cell research, sterilising food, disinfecting wounds and treating cancer.

The increased production and consumption of analgesics and antibiotics over the past two decades has led to an increase in contaminants in wastewater that are hard to remove using a conventional treatment approach. The residual pharmaceuticals in wastewater are due to the fact that the entire prescribed dosage of these products is not absorbed in the body, leaving the remaining portion to be excreted as waste. These emerging contaminants pose risks to both aquatic life and human health.

Two recent studies from the Plasma Technology Laboratory have demonstrated the successful use of plasma technology in the removal of residual pharmaceuticals from wastewater. The first investigated the removal of the analgesic Tramadol™ in deionised water and final wastewater effluent using a novel continuous flow dielectric barrier discharge reactor, while the second examined the degradation of the antibiotic Cefixime™ with an atmospheric air dielectric barrier discharge.

This technology has also found application in the removal of organic and inorganic material, as well as microorganisms, from water. As an outcome of this work, an easily operated, small-scale, solar-powered plasma ozonation system that works without chemicals has been developed for the purification of water.

Our vision is to see a healthy and productive Africa.

It combines plasma technology with renewable energy options to provide clean drinking water to rural, off-grid communities.

Since many villages in South Africa and the rest of Africa do not have clean running water or access to electricity, the addition of a solar energy unit to the prototype's design is very important.

The laboratory-scale purification unit has already been successfully tested. It includes a plasma reactor in which water is purified to drinking standards and stored in tanks. The current laboratory prototype, which is being piloted in a local community within the City of Tshwane, can provide 120 ℓ of water every four hours in off-grid situations, which is sufficient to provide water to at least eight rural households.

Prof Iwarere hopes that the Laboratory's research will ultimately help people in many countries in sub-Saharan Africa who struggle with access to clean, drinkable water. "Many lives are lost through water-related diseases. Our vision is to see a healthy and productive Africa, and to address some of the United Nations' Sustainable Development Goals (SDGs), as well as the targets of the African Union's Agenda 2063."

Prof Samuel Iwarere

SUSTAINABLE CITIES AND SMART TRANSPORTATION

Sustainable cities
improve citizens' quality of life

In an increasingly developing world, the global challenge is to improve urban citizens' quality of life, while reducing environmental impact and resource use. The aim is to make cities and human settlements more inclusive, safe, resilient and sustainable. Specific goals include access to transportation, access to green spaces, and the provision of housing that does not generate waste that cannot contribute to a circular economy.

Challenges related to the urban environment are an important consideration in the School for the Built Environment, with notable transdisciplinary collaboration with the Department of Civil Engineering and the Department of Technology Management, as well as the construction industry and practitioners who are focused on exploiting the regenerative potential of public spaces in terms of both architecture, and town and regional planning.

In an effort to support a multitude of interdisciplinary projects at the University of Pretoria, the Department of Civil Engineering has established a series of smart transformation platforms, located on its Engineering 4.0 Complex. One of these platforms, a long-range wide-area network, was initially installed to monitor environmental and road-related conditions associated with smart cities and transportation. It is now completely reinventing the collection, processing and analysis of data in alignment with the research objectives of the University's transdisciplinary research platforms.

Another transdisciplinary project that has been launched at the University of Pretoria is the Regenerative Public Spaces project, located in the Department of Town and Regional Planning. The intention of this project is to recognise the true value of public spaces in cities, especially in South Africa, and to contribute to uplifting changes in these places. Regenerative development is not a fixed-term endeavour, but an ongoing and iterative process of transformation, adaptation and evolution, in collaboration with the communities utilising the public spaces.

Collaboration, as a cornerstone of transdisciplinary research, extends to establishing partnerships with the design and construction industry to ensure a sustainable built environment. This finds expression in the combined efforts of researchers in the Department of Engineering and Technology Management, the Department of Civil Engineering and the Department of Architecture, through the York Timbers Chair in Wood Structural Engineering, to grow industry collaboration in timber design and construction. This has culminated in the presentation of an annual conference that brings together industry professionals and academia in forestry, architecture, structural engineering, construction and built project management to share their experiences in timber design and construction.

Smart transportation platforms support environmental sustainability

The state-of-the-art Engineering 4.0 Facility is positioning the University of Pretoria (UP) as a centre of excellence in smart transportation. Through its focus on the development of integrated transportation systems, its research is concentrating on the reduction of energy consumption levels in transportation, maximising productivity in industry and creating an improved quality of life for the country's citizens.

This unique world-class African facility is a place where novel ideas, scientific research, global expertise, students, academics, entrepreneurs and industry partners can converge to generate new thought leadership, innovation and training opportunities through collaborative partnerships. It was established as a collaborative venture with the South African National Roads Agency Limited (SANRAL) and the Council for Scientific and Industrial Research (CSIR) to establish an integrated education, certification, reference and research facility.

It is located on UP's Hillcrest Campus, in close proximity to the Future Africa Institute, a hub for inter- and transdisciplinary research networks within UP and the global research community.

A series of smart transformation platforms has been developed at the Engineering 4.0 Facility. This includes a long-range wide-area network with its associated antennae and sensors to monitor environmental, road- and railway track-related conditions, and a four-legged terrestrial robot, which 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 series of smart transformation platforms have been developed at the Engineering 4.0 Facility. This is positioning UP as a centre of excellence in smart transportation.

Long-range wide-area network

The long-range wide-area network (LoRaWAN) is in the process of completely reinventing the collection, processing and analysis of data in alignment with the research objectives of UP's transdisciplinary research platforms. With base stations installed on the roofs of both the Engineering 4.0 Building on the Hillcrest Campus and the Agricultural Sciences Building on the Hatfield Campus, it provides signal coverage spanning the University's entire Hillcrest and Hatfield precincts. This is enabling the adoption of Internet of Things (IoT) devices across multiple research disciplines. Through interdisciplinary collaboration, research is supported across all the University's faculties and research institutes without unnecessary duplication.

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

While most of the sensors that support multiple research projects are industrial-grade sensors, the expertise of the microelectronics specialists in UP's Carl and Emily Fuchs Institute for Microelectronics (CEFIM) are at hand to support researchers who require specialised sensors for highly technical measurements. This is further evidence of the interdisciplinary collaboration that is at the centre of this initiative. An institution-wide project that has made use of the live data of the LoRaWAN system is the Hatfield Digital Twin City initiative, which relies on data simulations to mirror the real-life conditions of a city precinct to test hypothetical scenarios that can improve the services, environments, infrastructure, performance, and social and health objectives of cities.

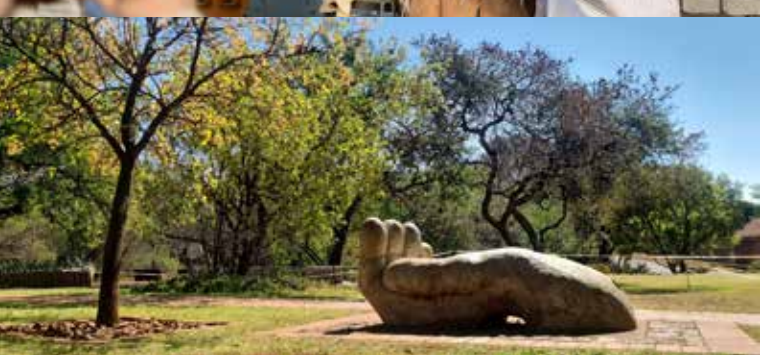
The rapid advancements in technology related to smart infrastructure networks, IoT architectures and big data analysis systems suggest that wireless sensors such as those used in this initiative can be expanded even further in the future as novel systems that make use of robotics, artificial intelligence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

Terrestrial robot

The Faculty of Engineering, Built Environment and Information Technology's four-legged terrestrial robot is a smart alternative transportation platform that was instituted in response to the Department of Civil Engineering's desire to move beyond the laboratory and traditional methods of data collection in the field. This Smart Woef – or "smWoef" – 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, air quality measurements and images at a range of wavelengths) that can form the basis of infrastructure maintenance, rehabilitation and risk management decisions.

Although primarily utilised for transportation research, the digital repository 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) and the Department of Forensic Medicine in the Faculty of Health Sciences.



The regenerative potential of public spaces supports enhanced urban development

A regenerative public space serves as a catalyst to create positive change in the larger urban environment through the reorganisation and transformation of the micro system (site) to create new possibilities that ripple out into the neighbourhood and beyond. Regenerative development and design are just as much about the process of transformation as the outcome or product. It is a co-creative process that enables the emergence of health and wellbeing at scales from the local to the global.

Prof Karina Landman, Head of the Department of Town and Regional Planning and Principal Investigator of the transdisciplinary Regenerative Public Spaces project, explains that thinking about regenerative public space requires the consideration of a number of starting principles to establish a common foundation to further action and engagement. She emphasises that public spaces are not only public parks, but any space that is accessible to the public, generally owned by a public institution and/or co-created by the people that use it.

In an attempt to illustrate the breadth and variability of regenerative public space projects, research teams from the University of Pretoria reviewed four projects in the city, which served as case studies.

These included **Moja Gabedi**, a community garden located in the densely populated neighbourhood of Hatfield; **Muckleneuk Commons**, a small community park developed on a piece of leftover land that has been neglected for several years; **Burgers Park**, one of the first parks to be established in Pretoria, which, although still used extensively by the surrounding residents and the unhoused community, is in a state of disrepair; and two public spaces in the Melusi informal settlement on the western periphery of the City of Tshwane: the **Melusi Clinic** and the headquarters of the **Melusi Youth Development Organisation**.

The project's objective was to recognise the true value of public space in cities, especially in South Africa, and to contribute to uplifting changes in these spaces. It received funding from the National Research Foundation (NRF).

Prof Landman explains that, to achieve this objective, public spaces need to be able to adapt and transform to address the challenges of rapid urbanisation, densification, climate change, social conflict, exclusion and disconnection to nature.

"Through transdisciplinary cooperation and various interactive methods aimed at understanding and working with spatial transformation, the project took the United Nations' Sustainable Development Goals (SDGs) forward through an exploration of the regenerative potential of public space," she says. It enabled members from various disciplines to work together to develop a common conceptual framework and methods, fused together from various disciplines, including architecture, planning and theology, and emerging from ongoing discussions at community workshops. The project furthermore involved members with various backgrounds from academia, private practice and communities.

The research team succeeded in incorporating all three phases of transdisciplinarity in the research process: collaborative framing, co-producing solution-orientated and transferrable knowledge through collaborative research, and the (re)integration and application of produced knowledge.

The research project also drove the development of a digital tool to support enhanced urban development. "The conceptualisation of the tool encompassed the consideration of existing regenerative public spaces in the City of Tshwane," says Prof Landman. The development of the digital platform followed the establishment of a common understanding of regenerative public space to start connecting various existing and potential future stakeholders.

It takes the form of a Web GIS platform, which can support the project's objectives by explaining the concept of regenerative public space, and showcasing the project's case studies. It also provides access to a toolkit of useful resources, and includes a registration platform for projects, practitioners and partners who support the development of regenerative public space. It symbolises new modes of collaborative project planning and research potential between multidisciplinary teams, with technology as the medium and the internet as a catalyst.

This offers a stimulating way of engaging technology to build connections between people and place to enable regenerative public space in practice.

EXPLORE THE RPS PORTAL

Industry collaboration contributes to a sustainable construction industry

Internationally, there is a growing trend in timber construction. The same trend is being observed in South Africa. This is largely due to the contributions of role players like the Department of Trade, Industry and Competition, Green Building Council South Africa, the important forestry research institutions, the large timber mills, architects, and the project and construction management professions.

At the University of Pretoria (UP), the York Timbers Chair in Wood Structural Engineering is making strides in stimulating the development of a sustainable mass engineered timber construction industry in South Africa and the African continent. It is also promoting cross-disciplinary research through its representation within three academic disciplines in the Faculty of Engineering, Built Environment and Information Technology. The Chairholder, Prof Schalk Grobbelaar, is also a professor and researcher in the Graduate School of Technology Management (GSTM)'s Department of Engineering and Technology Management. Research collaborators include Dr Johann van der Merwe, a structural engineer and senior lecturer in the Department of Civil Engineering, and Christo van der Hoven, who represents the University's Department of Architecture.

The built environment currently contributes approximately 40% of global greenhouse gas emissions. About a third of this percentage is emitted during the construction phase of buildings. "By developing better designs and using bio-based materials like wood in construction, we can meet the demand for new buildings, while conserving the environment, drive job creation and economic growth, and ensure that our graduates are skilled for the current and future world of work," says Prof Grobbelaar.

"Throughout the world, mass timber is leading the charge, and South Africa needs to be part of this." This can only be achieved by training good structural and chemical engineers, architects, data scientists, geneticists, breeders and forest scientists who can lead the development of a new, sustainable, wood-based bioeconomy.

He says that, in South Africa, unlike Europe, North America, Canada and parts of South America, forestry plantations did not originate as natural forests. Trees were planted to respond to a need for timber structures and housing in the mining industry. Grasslands were therefore strategically converted into plantations that were populated with trees that could rapidly grow tall and straight to meet the demand for lumber. Pine was imported from South America and North America, and eucalyptus from Australia for this purpose.

He describes the belief that harvesting trees for timber will lead to deforestation as a misconception, since South Africa's structural timber species comprise exotic, cultivated trees that are actively managed, with new saplings planted to replace the trees that are cut down.

"York Timbers, for example, owns 90 000 ha of land, of which only 60 000 ha is under cultivation. It is therefore responsible for the upkeep of the uncultivated land, contributing to the conservation of the country's natural forests."

Although the Forestry Stewardship Council (FSC) prohibits the genetic manipulation of trees, forestry managers can intervene naturally in the propagation of species to obtain trees with improved characteristics, such as trees that grow faster and deliver wood of a better quality and strength for the construction industry.

Several disciplines interact with each other within the timber value chain, explains Prof Grobbelaar. This enables the optimisation of the timber processing industry. "As a complex ecosystem, each contributing role player needs to understand the timber industry. This can only be done by focusing on one's specific core area and then expanding upon it systematically."

"By developing better designs and using bio-based materials like wood in construction, we can meet the demand for new buildings, while conserving the environment, drive job creation and economic growth, and ensure that our graduates are skilled for the current and future world of work."

Timber Construction Conference

Industry collaboration in timber design and construction is supported through the presentation of the annual Timber Construction Conference, which emanates from the partnership between UP and York Timbers. The second annual conference, which was held at UP's Future Africa Campus on 10 September 2024, was presented with the support of the Pretoria Institute of Architecture, and the Department of Trade, Industry and Competition. The event proved to be an enlightening and collaborative gathering of industry experts, academics, government officials and thought leaders, who shared their knowledge, insights and experiences through engaging presentations, panel discussions and exciting exhibitions. It also provided a valuable platform for networking, knowledge exchange and exploring the latest innovations in timber construction.

As an architect, Christo van der Hoven reflects that the conference succeeded in illustrating the renewed interest in timber construction, in which architects are following global trends that reflect their desire to be internationally relevant.

The viewpoint of structural engineering lecturer, Dr Johann van der Merwe, was that the conference's illustration of ways to design and build with timber not only showed delegates what was possible, but demonstrated that local projects are comparable to those implemented internationally, and that South African structural engineers are able to meet global standards.

A valuable contribution of the conference was its focus on the entire timber value chain. It took delegates through the entire process, from the planting and growth of a tree to its processing into a mass timber product for inclusion in architectural designs and use as building material by a construction management professional. In the process, it illustrated the impact of the University's contribution to stimulating South Africa's wood-based bioeconomy.

AFFORDABLE CLEAN ENERGY

Promoting energy efficiency through the use of renewable sources

Energy is a key priority area for development in South Africa and the broader African continent. From a world-class energy infrastructure in the 1980s, South Africa's electrical grid has been deteriorating due to insufficient maintenance of the grid and the power stations that generate electricity, coupled with ageing infrastructure.

With the advent of renewable energy generation, new solutions to producing electricity have become feasible, particularly photovoltaic (PV) or solar, and wind energy. Green energy in the form of hydrogen is also showing great promise to reduce reliance on fossil fuels. However, integrating these new technologies into an old, decaying grid is a significant challenge – one for which South Africa is not fully prepared. Beyond the national electricity system, efficiency in electrical systems could be improved in residential, commercial and industrial sectors by reducing wastage, and integrating alternative sources of energy for specific tasks.

Research efforts in the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology are focused on efficient energy systems, renewable energy and the efficient utilisation of energy by end-users. These efforts have been inspired by the need to provide energy to all the citizens of South Africa to support quality of life.

In the Department of Chemical Engineering, researchers are developing a sustainable solution to the problem of the proliferation of invasive species in the country's water bodies by converting the carbon biomass of the water hyacinth into green energy. In the Department of Materials Science and Metallurgical Engineering, researchers are investigating the possibility of repurposing existing steel pipelines for green hydrogen transportation, as well as the possibility of using alternative methods of steelmaking to achieve lower carbon emissions.

Research in the Department of Engineering and Technology Management is considering the decarbonisation of the global economy with green hydrogen, as well as the development of investment planning models for wind and solar fleets, and the commercialisation potential of bio-based chemicals from waste to be used in transport fuel, and as a feedstock for power generation.

In the Department of Mechanical and Aeronautical Engineering, researchers are generating electricity by using a mobile solar-dish gas turbine hybrid. Finally, researchers in the Department of Civil Engineering are working on methods to integrate hydropower into existing water infrastructure to support municipalities' energy generation objectives.

The all-encompassing aim of research initiatives such as these is to ensure access to clean and affordable energy, which is key to the development of agriculture, business, communication, education, healthcare and transportation.

Decarbonising the global economy with green hydrogen

Green hydrogen offers great potential for the decarbonisation of the global economy. It is also an important alternative to coal-fired sources of power given the country's current energy crisis. Researchers in the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology are evaluating the possibilities of green hydrogen from various angles that support government's Hydrogen South Africa Strategy (HySA) and the Department of Science, Technology and Innovation's Hydrogen Society Roadmap for South Africa.

Prof Roelf Mostert, an Associate Professor in the Department of Materials Science and Metallurgical Engineering, considers green hydrogen to be the most environmentally friendly means of providing energy to fulfil society's needs.

It does not produce any greenhouse gas (GHG) emissions, and releases only water vapour into the atmosphere. He believes that green hydrogen can play an important role in the decarbonisation of the mining, heavy-duty transport and petrochemical sectors, in particular.

The mining sector is currently experimenting with zero-emission hydrogen-powered heavy-duty haul trucks to transport ore on its mines. However, the hydrogen must be stored there in steel pressure vessels at high pressure, and is transported from the source to the pressure vessels via pressurised steel pipelines. Pipelines are also a central element of government's plans to transport hydrogen to ports such as Richards Bay for export purposes. Research by Prof Mostert's team is evaluating to what extent the transportation and storage of hydrogen at high pressure will affect the integrity of steel pipelines and pressure vessels.

The researchers are also focusing on quantifying to what extent the hydrogen atoms will degrade the steel through processes like hydrogen-assisted cracking, and accelerated metal fatigue. Due to the costs involved in laying new pipelines for hydrogen transportation and storage, an important consideration is whether existing steel pipelines can be repurposed for the transportation of hydrogen.

In other research in the Department, Prof Charles Siyasiya is examining the impact of alternative methods of steelmaking on steel properties to achieve lower carbon emissions. As about 10% of global CO_2 emissions come from traditional steelmaking, it makes a significant contribution to the global carbon footprint.

Steel is one of the four materials with the highest global consumption, making up an estimated 2 billion tons per annum. The other materials are cement, plastic and ammonia (as compounds for fertilizers). Steel is traditionally produced using coal.

Prof Siyasiya's team is evaluating the impact of using hydrogen to reduce iron ore into iron on the properties of steel. This will make a tangible contribution towards the transition to green steel in order to curb increases in global temperature. However, it will come at a price in terms of energy input, as more energy will be required to produce green steel compared to traditional steelmaking processes.

From another perspective, Prof David Walwyn, a researcher in the Graduate School for Technology Management, has made use of a techno-economic approach to compare the costs of green hydrogen in six different use cases: as transport fuel, energy storage, gas reforming, electricity, high-temperature energy and minerals processing.

The results of this study indicate that, as a chemical feedstock, high-temperature furnace fuel or reductant in minerals processing, green hydrogen is not competitive, nor will it be competitive in the foreseeable future.

In these applications, the cost of green hydrogen is up to 20 times higher than its comparator (coal or grey hydrogen). Further improvements in the production technology will be essential before its prospects improve.

However, as a transport fuel (to replace petrol, diesel and kerosene) and as a storage means for electricity generation, green hydrogen is close to feasibility, particularly in the case of transport, for long distance rail and truck haulage. In its application within the electricity sector, green hydrogen could be an important technology for the storage of intermittent renewable energy, and to replace natural gas as a back-up for utility-scale electricity supply.

Generating electricity and heat with a mobile solar-dish gas turbine hybrid

South Africa receives an average of over 2 500 hours of sunlight a year, placing it among the countries with the most potential for solar electricity and heat generation in the world. Several innovative means of power generation have been developed that tap into the sun's abundant energy using concentrated solar power (CSP) systems. These systems redirect the sun's rays towards a focal point to enable thermal energy capture.

A research team in the University of Pretoria's Department of Mechanical and Aeronautical Engineering, led by Prof Willem le Roux, has developed a mobile solar-dish gas turbine hybrid for small-scale power and heat generation. Its effectiveness relates to the turbine's high inlet temperature and low emissions.

Mobile energy systems can provide access to electricity and heat where grid access is limited, especially in rural areas. A prototype is being developed, which can be transported to rural areas when the need for electricity and heat arises.

Prof Le Roux explains that micro turbines are versatile, as they can operate on various fuels, from diesel to natural gas or liquid petroleum gas (LPG). They can have a low noise output and are relatively vibration-free. The turbine and compressor are usually attached to a single shaft through a single-stage, radial flow application. Micro turbines can also utilise solar thermal energy in a hybrid configuration, and its high-temperature exhaust can be used for co-generation.

"A solar dish can supplement or replace the heat added by the fuel to further reduce the micro turbine's emissions," he says. Electricity is generated from the output shaft of the micro turbine, while high-temperature exhaust gases are used for metal melting (or recycling) and water heating purposes.

"Small-scale co-generation CSP plants can be compact," says Prof Le Roux, "and can improve the accessibility to heat and power in off-grid rural environments." A hybrid solar-dish Brayton cycle combines heat and power generation, where heat is sourced from combustion, as well as through the focal point (the cavity receiver) of a solar dish, while high-temperature exhaust gases and electricity are acquired from the micro turbine. "A Brayton cycle is a power conversion cycle that uses a gas as the working fluid for compression and heating and, finally, expansion through a turbine to generate power," he explains.

The initial testing of such a system was done on the roof of the University of Pretoria's Engineering II
Building, using a state-of-the-art solar dish with multiple facets. The solar dish has a 21 m^2 reflective surface area. The dish concentrates the sunlight into an aperture of 0.25 × 0.25 m, upon which a coiled pipe receiver is mounted.

The 42 individual elliptical vacuum-membrane solar-dish facets each have a variable membrane depth, and therefore also a variable focal length. Membrane displacement affects system performance throughout an operating day due to changing environmental conditions, especially ambient temperature.

The research team therefore implemented a cost-effective focus control system with low power consumption. The focus control systems were mounted to the 42 facets to maintain the membrane depth to within ±2 mm to achieve a theoretical minimum intercept factor of 90%.

A mobile system has also been developed for demonstrations outside of campus. A control drive can lower the solar dish into a stow position to protect the dish from the elements.

Due to geometric constraints and legislation restrictions, the system is disassembled and transported in sections. Subsequently, the system is erected on a mobile platform (also the trailer) at the demonstration site. Once erected, an automated control system enables the solar dish to follow the sun's path to ensure optimal usage of the available solar energy.

During the initial testing of the state-of-the-art micro gas turbine with an air bearing, experimental results showed that it can produce up to 1 480 W of electricity when operated at a turbine inlet temperature of 1 088 K.

A reduction in the cost of micro turbines could help hybrid solar-dish Brayton cycles access more target markets and improve repayment periods.

The cost of micro turbines can be reduced by using off-the-shelf automotive turbochargers. Such turbochargers have been used extensively in the automotive industry to enhance the performance of an internal combustion engine.

While an automotive turbocharger might not be as efficient as a commercial micro turbine in generating shaft power, it is readily available and relatively cheap. "This may be an attractive solution in combination with a solar dish in industries that require large amounts of heat, such as smelters, bakeries, small businesses or apartment blocks," says Prof Le Roux.

The current project is funded through the Renewable Energy Hub and Spokes Programme of the Department of Science, Technology and Innovation (DSTI). For more information, contact Prof Willem le Roux at willem.leroux@up.ac.za.

Hydropower development provides a pathway to energy security

South Africa faces a unique challenge in balancing its energy demands with sustainable development and environmental stewardship. The integration of hydropower development with existing water infrastructure represents a fundamental strategy to achieve a just energy transition, ensuring sustainable energy generation, while optimising water resource utilisation. It offers a sustainable pathway to enhance energy security and reduce greenhouse gas emissions.

By leveraging existing infrastructure, South Africa can minimise the environmental impacts of constructing new hydropower systems and maximise socio-economic benefits.

However, this approach requires supportive policies, technological innovations and active community involvement. An extremely positive development in this regard is the Department of Water and Sanitation (DWS)'s allocation of water use licences to developers, which enables them to utilise the country's existing water infrastructure to retrofit turbines and generate hydro-electricity. Prof Marco van Dijk, who leads the Department of Civil Engineering's Hydropower Research Group, explains that South Africa's reliance on coal for approximately 80% of its electricity generation contributes significantly to greenhouse gas emissions, making the transition to renewable energy sources a pressing need. At the same time, the country's water-stressed condition, with uneven water resource distribution and frequent droughts, impacts various sectors. The integration of hydropower into the existing water infrastructure offers a practical and relevant solution to these challenges.

Hydropower projects have low operational emissions and can be designed to minimise environmental impacts.

Integrating hydropower into the existing water infrastructure aligns with sustainable energy-generation principles. Hydropower projects have low operational emissions and can be designed to minimise environmental impacts. Utilising existing infrastructure reduces the need for new construction, which can be resource-intensive and disruptive to ecosystems. Additionally, small-scale and distributed hydropower projects can bring clean energy to remote and underserved areas, supporting local development.

By generating electricity from water flows that are already being managed for other purposes, hydropower projects can contribute to more efficient water use. This is particularly important in a water-scarce country like South Africa. The socioeconomic benefits of integrating hydropower into the country's existing water infrastructure include job creation, skills development and economic opportunities in rural and marginalised communities. Local hydropower projects can stimulate economic activity, improve energy access and alleviate poverty.

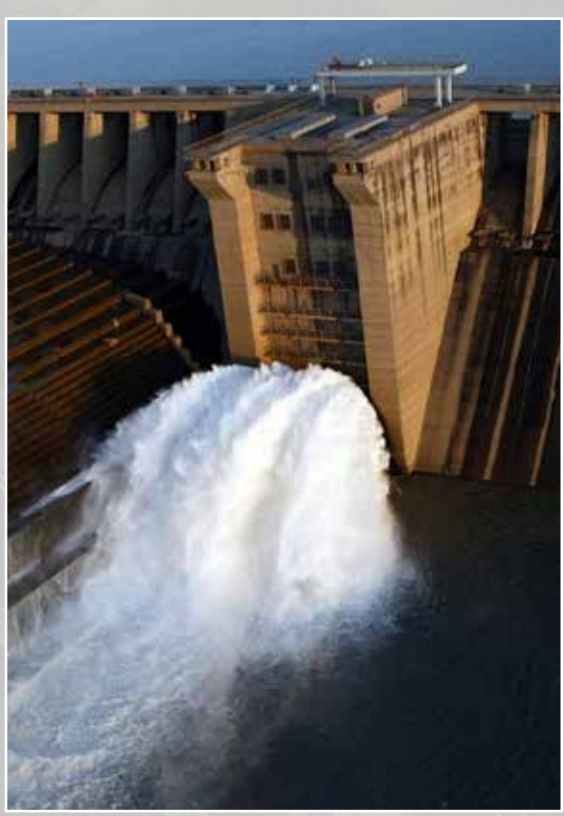
As a source of renewable energy, Prof Van Dijk describes hydropower as a key player in diversifying South Africa's energy mix. "It offers reliable, flexible and low-carbon electricity." Only 20% of the world's large dams are currently being used for hydro-electric power generation. South Africa has over 4 450 dams (of which 1 269 are classified as large dams with a wall height of 30 m or more). Many of these dams were constructed primarily for water supply, irrigation and flood control. Integrating hydropower into these structures and utilising the existing flows (ecological reserve or irrigation releases) can optimise water resource utilisation, enhance infrastructure value and provide additional revenue streams. "This provides ample opportunities for hydropower development," explains Prof Van Dijk.

Small hydropower and pumped storage schemes are particularly relevant in this context. "Small hydropower systems can be integrated into existing water infrastructure by retrofitting non-hydropower dams and weirs, and exploring unconventional hydropower avenues such as conduit hydropower and turbine installations at wastewater treatment works (WWTWs) outlets and potable water systems."

He explains that energy recovery at WWTWs is often overlooked, with a very limited number of WWTW pilot plants having been developed. "Electricity generated at WWTW outlets can be directly utilised in the WWTW, offsetting some of the operational costs associated with the water treatment process."

A supportive policy and regulatory framework are essential for integrating hydropower into existing water infrastructure. Prof Van Dijk believes that South Africa's energy and water policies must be further aligned to facilitate the development of multipurpose projects. Advancements in hydropower technology can further enhance the feasibility and efficiency of integrating hydropower into existing water infrastructure.

Research and development efforts by the University of Pretoria's Hydropower Research Group are focusing on technologies that are suitable for South Africa's unique environmental and infrastructural conditions. This includes innovations such as modular hydropower systems, low-head turbines and advanced control systems, which can enable more flexible and cost-effective projects.

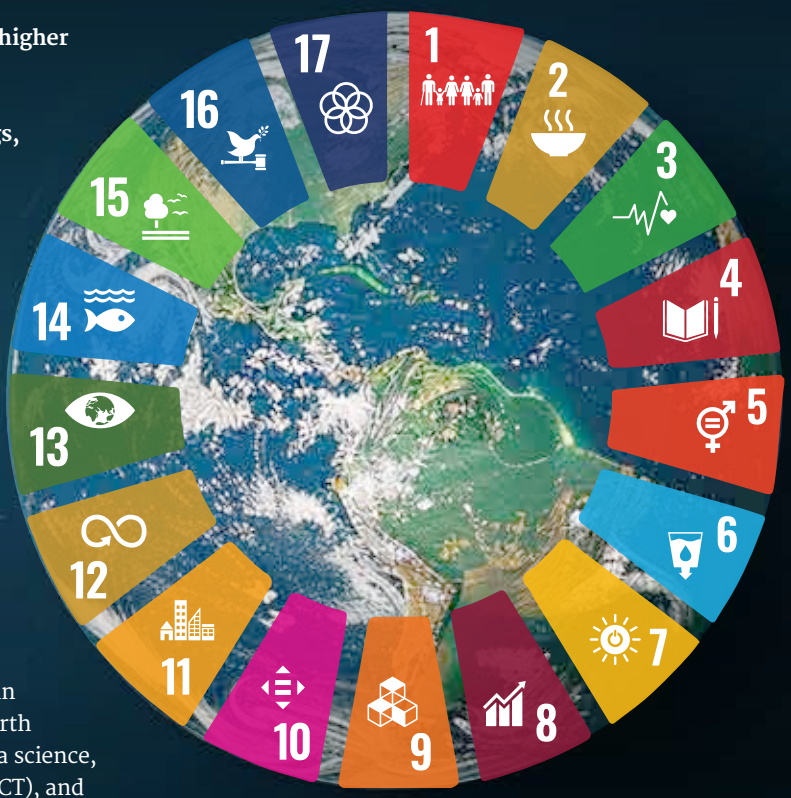


INDUSTRY INNOVATION

Technological advancements foster innovation for increased impact

In June 2024, the University of Pretoria (UP) entered the Top 50 higher education institutions in the global Times Higher Education Impact Rankings. It leapt from 69th position in 2023 to 42nd position in the world in 2024.

These global rankings measure actions taken by higher education institutions around the world towards achieving the United Nations' Sustainable Development Goals (SDGs). In the latest rankings, UP was also placed second in South Africa and second in Africa, out of a record number of 2 152 higher education institutions from 125 countries and regions ranked in 2024.



An audit of the research conducted in the Faculty of Engineering, Built Environment and Information Technology revealed that it addresses 15 of the United Nations' 17 SDGs across its research focus areas:

- **SDG 1 – No poverty:** Research in water and environmental engineering, and smart cities and transportation
- **SDG 2 – Zero hunger:** Research in energy
- **SDG 3 – Good health and wellbeing:** Research in water and environmental engineering, the Fourth Industrial Revolution, smart cities, and big data science, information and communication technology (ICT), and technology and innovation management
- **SDG 4 – Quality education:** Research in smart cities and transportation, and big data science, ICT, and technology and innovation management
- **SDG 6 – Clean water and sanitation:** Research in water and environmental engineering, the Fourth Industrial Revolution, smart cities, and energy
- **SDG 7 – Affordable and clean energy:** Research in water and environmental engineering, minerals and materials beneficiation, the Fourth Industrial Revolution and energy
- **SDG 8 – Decent work and economic growth:** Research in minerals and materials beneficiation, the Fourth Industrial Revolution and energy
- **SDG 9 – Industry innovation and infrastructure:** Research in water and environmental engineering, minerals and materials beneficiation, the Fourth Industrial Revolution, smart cities and transportation, big data science, ICT, technology and innovation management, and energy
- **SDG 10 – Reduced inequalities:** Research in water and environmental engineering, and smart cities and transportation
- **SDG 11 – Sustainable cities and communities:** Research in water and environmental engineering, the Fourth Industrial Revolution, smart cities and transportation, big data science, ICT, technology and innovation management, and energy
- **SDG 12 – Responsible consumption and production:** Research in water and environmental engineering, minerals and materials beneficiation, smart cities and transportation, big data science, ICT, and technology and innovation management

- **SDG 13: – Climate action:** Research in water and environmental engineering, the Fourth Industrial Revolution, smart cities and transportation, big data science, ICT, and technology and innovation management
- **SDG 15 – Life on land:** Research in water and environmental engineering, minerals and materials beneficiation, the Fourth Industrial Revolution, smart cities and transportation, big data science, ICT, technology and innovation management, and energy
- **SDG 16 – Peace, justice and strong institutions:** Research in the Fourth Industrial Revolution, and smart cities and transportation
- **SDG 17– Partnerships for the goals:** Research in water and environmental engineering, minerals and materials beneficiation, the Fourth Industrial Revolution, smart cities and transportation, big data science, ICT, technology and innovation management, and energy

Within the research conducted at the University of Pretoria, the Faculty of Engineering, Built Environment and Information Technology contributes strongly to SDG 9: Industry, innovation and infrastructure. Research projects that respond to this SDG include those related to big data science, ICT and technology innovation management. UP was ranked in the Top 200 universities in the world for this SDG.

The global challenges for sustainable development that are encompassed in SDG 9 include the development of reliable, sustainable and resilient infrastructure, and the promotion of inclusive and sustainable industrialisation.

Engineered solutions enhance agricultural exports

Ensuring that agricultural products intended for the export market arrive at their destination unblemished and suitable for further distribution and sale is a challenge experienced by producers in South Africa. Due to its reputation in smart transportation, researchers in the University of Pretoria's Department of Civil Engineering were approached to devise an innovative solution.

The development of a concept known as "civiltronics" played an important role in finding an innovative solution. This entails the combination of traditional civil engineering with electronics, the Internet of Things (IoT), programming, computer science and additive manufacturing (3D printing).

The flagship project involved monitoring the transportation by cargo ship of a consignment of **avocados** destined for Rotterdam in The Netherlands, from where it would be further distributed throughout the European Union. The team made use of the Department's unique **smAvo** and **smaTo** sensor platforms, which are used to monitor the entire value chain, from farm to fork.

To optimise the data recorded during the transportation of the avocados, the team developed a measuring instrument with microsensors embedded in 3D-printed avocados with a soft water-resistant outer covering that would be exposed to the same conditions as the real produce surrounding them. This instrument was programmed and customised for the objectives of the project so that live, real-time data could be collected and stored for analysis. Real-time data on the ship's location in the Atlantic Ocean, as well as weather conditions throughout the trip, was sent to the researchers in Pretoria to be captured on the Department's central platform.

The microsensors with which the "smart avos" were fitted measured variables such as accelerations in speed, rotational movements of the ship and temperature to determine whether this impacted on the produce itself and the condition in which it arrived at its destination. It also determined whether the cold chain was preserved along the route. This information is not just of value to producers to ensure that they can obtain top prices for their products, but also to avoid additional costs related to transporting damaged products or products that are no longer suitable for trade in the export market back to South Africa.

According to Prof Wynand Steyn, Dean of the Faculty of Engineering, Built Environment and Information Technology, the University's world-class research footprint entails focusing on digital information across a transdisciplinary platform. The success of this project will not be restricted to a single product or engineering discipline. Inherent in this innovative technology is the potential to apply it to other fields as well.

Reimagining transportation networks for a digital future

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

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

Condition monitoring

Condition monitoring traditionally utilises a dedicated instrumentation vehicle to measure track geometry. These vehicles are specialised and are frequently unavailable for the entire network of track that carries regular traffic. This limitation gave rise to the development of an innovative system that makes use of 4IR technology to obtain geometric measurements.

These include techniques such as simultaneous localisation and mapping (SLAM) and photogrammetry, which produces high-resolution three-dimensional (3D) reconstructions that incorporate and combine state-of-the-art neural network architectures. By fusing AI approaches with traditional research methods, a new type of condition monitoring allows the rail industry to improve the safety, efficiency and cost-effectiveness of its rail and train control systems.

Machine learning

A project that formed part of the doctoral research of Dr André Broekman illustrates the use of an optical system to reconstruct the rail in 3D with the required accuracy to measure miniscule deviations, similar to those measured with sophisticated instruments. A challenge in the development of such a solution lies in the fact that the railway environment is difficult to monitor photographically because the railway lines often reflect light as the trains travel over them. As a result, powerful neural networks and machine learning techniques were used to "teach" the instruments to accommodate the reflective characteristics of the railway line.

As neural networks require large datasets from which to "learn", and such available datasets are not suitable for the reflective characteristics of the rail or the accuracy required for this purpose, a virtual railway was created to make photorealistic renderings of the rail environment, as well as depth maps of the camera's viewpoint. The dataset could then be used to optimise the system and "teach" the neural networks to design 3D reconstructions that could be used for digital condition monitoring.

An additional aspect of the project was to ensure the accurate positioning of the camaras. Traditional GPS technology was not deemed sufficient, as the cameras were required to take photographs of the rails at intervals of 150 mm, as one moves along the rail. An innovative feature of the system that was developed was the incorporation of a neural network-based multi-view stereopsis reconstruction pipeline with a millimetre-accurate, real-time kinematics (RTK) geolocation service.

The Internet of Railway Things

As a relatively new development in GPS technology, RTK is a low-cost mobile geolocation service deployed at UP. It entails a GPS sensor and a stationary antenna installed at the University's Data House at Engineering 4.0. This is a dedicated research facility for the deployment of state-of-the-art computer vision systems and the provision of RTK services. It has been constructed adjacent to the N4 freeway and is ideally situated to study the distribution and composition of vehicles, in addition to providing a clear line-of-sight RTK geolocation service. It serves as a centralised data acquisition and transmission platform for transdisciplinary research projects.

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

Following the analysis of the data obtained, real-world testing takes place on the road-rail infrastructure monitoring system and test track near Engineering 4.0. An added advantage of the advancements in sensory capabilities and alternative geolocation services that form part of this system is its potential to act as a catalyst for digital twinning, where a computer-aided model, similar to a real-life structure, can be used to solve complex problems using 4IR technologies. This not only improves railway safety and the sustained good upkeep of railway assets, but opens the way for an automated, digital system that will play an important role in the transportation of products of economic importance. T

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

Automated crocodile detection using deep learning and synthetic data

The use of artificial intelligence (AI) to create a more efficient and inclusive society is gaining momentum and will soon not only transform business, education and health care in Africa, but also farming and wildlife management. A research project conducted in the University of Pretoria's Smart Sensing and Intelligent Systems Research Group is making use of synthetic data to develop a machine learning (ML) model to identify crocodiles from aerial images.

In recognition of the problem encountered by wildlife managers who need to perform population counts or locate crocodiles in dangerous environments, an ML model was developed to locate these reptiles using unmanned aerial vehicles (UAVs) or drones.

The advent of advanced image processing techniques has revolutionised various fields, including nature surveying and agricultural practices. Among these techniques, the image object detector has emerged as a powerful tool that allows researchers and farmers to automatically detect and analyse animals in aerial images. While this technology reduces the cost and time required to perform animal surveys, a major challenge encountered by analysts is the large amount of data required to train the network. This can become problematic if the target animal is scarce, and there is no available data on which to train the model. This was the case with the current project, as only ten crocodiles could be located in the river that had been identified to obtain data to populate the artificial neural network.

Capturing data for the purpose of this research presented multiple challenges. Firstly, logistical constraints during data collection make it difficult to gather sufficient samples of the animal species. Secondly, after obtaining enough data, the annotation process becomes labour-intensive and time-consuming for specialists, which makes it susceptible to human error. Insufficient data can also limit the model's generalisability and accuracy. The researchers therefore decided to make use of synthetic data as an alternative method of data generation.

Synthetic images were generated through computer-based tools such as those used for game development to create realistic-looking environments for the purpose of training the image models. The research aimed to determine whether this approach would deliver a similar object detection model as one developed with live animals, and whether it would still be able to successfully perform the task of identifying the reptiles for management purposes. If this proved to be the case, researchers, veterinarians and wildlife managers would no longer have to go into dangerous rivers to find the crocodiles and count them manually. They could send UAVs into the area that could be automated to find the crocodiles. The ML model could also be used to extract information on specific features like body measurements and the crocodiles' body condition score, and perform comparative analysis on whether the crocodiles' conditions are improving or deteriorating. This data can then be used to identify ecological problems affecting the animals' health.

The utilisation of UAVs in wildlife research has escalated recently due to the increased frequency and improved data quality they offer over manned aircraft and satellites. This has the advantage of enabling comprehensive surveys without disrupting animal behaviour or endangering researchers by exposing them to potentially dangerous situations.

The research study subsequently explored the generation and use of synthetic data to train an object detector to identify crocodiles from aerial images. A virtual environment was set up to generate virtual images using domain randomisation. The images were then used to train the network. The researchers also explored methods to improve the detector's performance.

For the real-world images, aerial images of crocodiles were collected at a commercial crocodile farm. A UAV was set to survey an entire area using a predetermined flight plan. The drone captured 243 images at a high resolution. An orthophoto was then generated from these images. This is a single photograph constructed from multiple photographs of the same area and then geometrically corrected so that the image has an orthographic projection. This normalises the distances of all the objects in the images, allowing for constant measurements, which can be translated to real-world measurements.

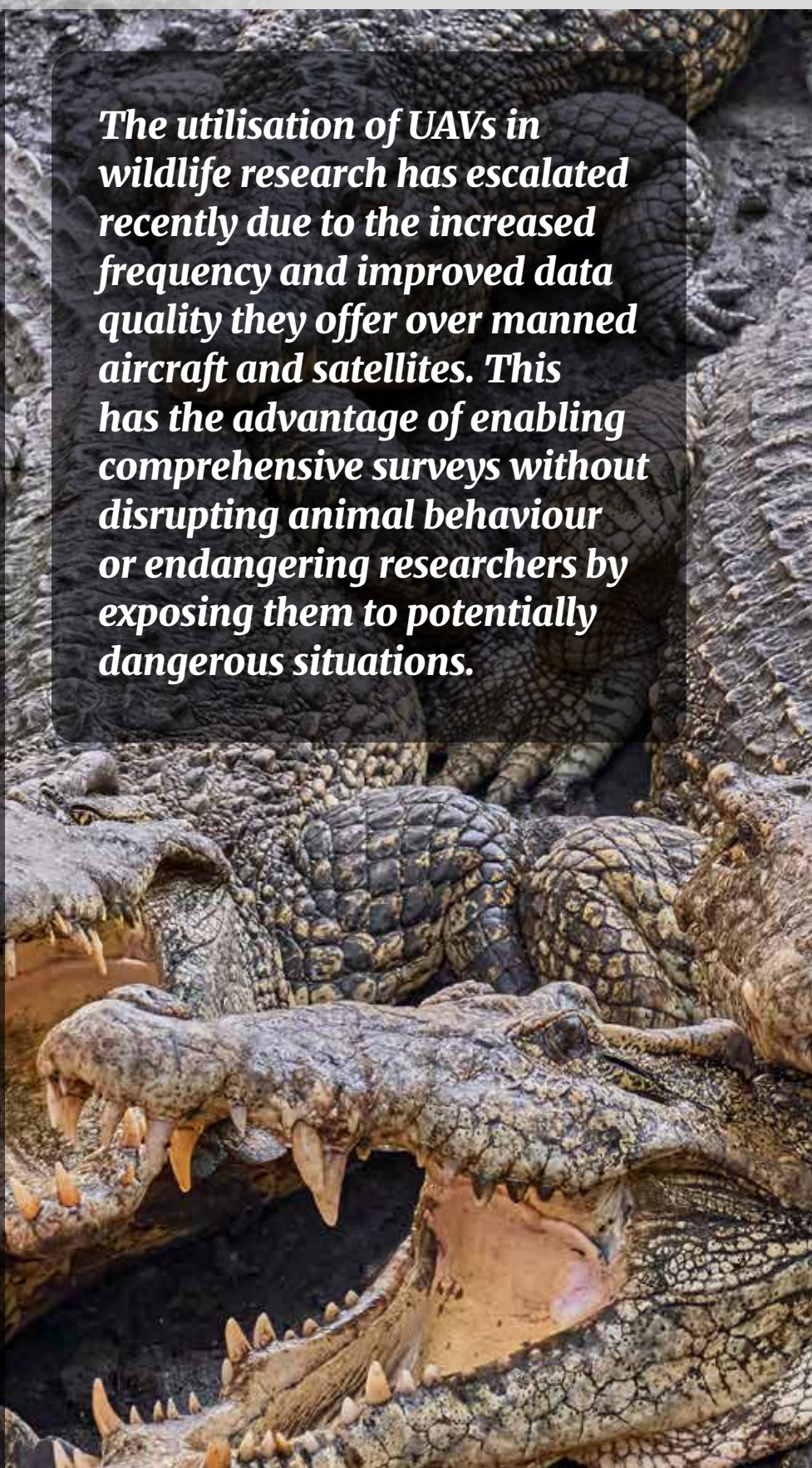
This also ensures that only one version of each crocodile is present in the single image so that different angles of the same crocodile are not present in the training and validation set separately while training.

A virtual camera was then set up above the surface looking downward to generate the synthetic images. It captured three images of each iteration. The annotation of the synthetic image could then be done automatically since the pixel positions corresponded between the images. A bounding box was marked around each of the individual crocodiles to fit the pixels that could be observed in the synthetic image.

The results obtained from the training of the object detection model demonstrated an improvement in the accuracy of the models when the backbone layers were frozen during training on a large real-world dataset. It was found that training on only synthetic images is possible, but training on a small number of real-world images outperformed the synthetic data.

However, integrating the same small amounts of real-world data into the model through fine-tuning or by using mixed datasets that include synthetic and a small number of real-world images, together with image augmentation and transfer learning, significantly enhanced the model's object detection capabilities from aerial images and improved the performance of the model trained only on a small amount of real-world data. This approach is particularly effective when addressing data scarcity challenges in the detection of animals. T

The utilisation of UAVs in wildlife research has escalated recently due to the increased frequency and improved data quality they offer over manned aircraft and satellites. This has the advantage of enabling comprehensive surveys without disrupting animal behaviour or endangering researchers by exposing them to potentially dangerous situations.



Highly mobile platform ensures the safety of underground workers

Mining is a very important sector of the South African economy. Since 2008, the South African mining industry has faced significant challenges. A decrease in commodity prices has severely constrained funding available for expanding and maintaining the essential supporting infrastructure as mines expand further underground. This situation has resulted in a significant portion of mining operations being carried out at greater distances from the shaft infrastructure. Consequently, workers have less time at the face, leading to reduced production and increased safety concerns.

As part of a collaborative project to extend the operational life of these mines, the University of Pretoria's Vehicle Dynamics Group (VDG) in the Department of Mechanical and Aeronautical Engineering and the Mandela Mining Precinct have developed a remote-controlled, mobile platform to charge blast holes with emulsion explosives in the unsupported face area. Its overarching objective is to enhance safety by reducing the need for personnel to work directly within these hazardous zones.

The platform of the mobile unit was designed to withstand the harsh underground environments and effectively navigate the various obstacles commonly found in underground areas. Equipped with a robust 4x4 drive system, differential steering and large all-terrain tyres, the unit offers exceptional mobility, is highly manoeuvrable and boasts a tight turning circle. It can easily negotiate rocks, mud and inclines of up to 20 degrees.

To allow safe remote operation, the platform is equipped with a pair of cameras that captures video feed. This is then transmitted wirelessly to the control console. This setup enables the operator to operate the platform remotely while standing securely in a well-supported area, as long as there is a maintained line of sight between the console and the unit.

To fulfil its primary function of charging blast holes, the mobile platform base has a detachable two-joint arm mounted on top of it. The robotic arm can be controlled to charge blast holes in a range between 150 and 1 500 mm above the stope floor. The arm's positioning is driven by two linear actuators. At the end of the arm, a rotational joint allows the charging lance to be angled upward or downward. The lance, which consists of a reinforced tube and a flexible pipe, is inserted into the blast hole using a dual-friction drive system. One of the cameras is positioned so as to view the rock face where the blast holes are drilled, allowing the operator to accurately locate the holes that need charging.

Apart from the blast hole charging application, the platform is suitable for many other operations such as inspection and surveying. The platform can carry many types of sensors and instrumentation that can aid in safe inspection, as well as the mapping of freshly blasted areas. Although it is currently remote controlled, it can be further developed to be autonomous so that it can operate independently for routine tasks.

New technology such as this mobile underground platform promises to make mining safer and more efficient in the future, extending the life of current mines and creating more economic value for the country.

MINERALS AND MATERIALS BENEFICIATION

Beneficiating the minerals and materials industry

Minerals and materials beneficiation has become one of the key drivers in advancing the empowerment of historically disadvantaged communities in South Africa. It also creates opportunities for the development of new entrepreneurs in both small and large mining industries.

The concept of beneficiation is not new in South Africa, but took major steps forward during the 1990s when the South African mining sector changed from being predominantly an exporter of primary commodities to becoming a world exporter of processed materials. Despite these developments, South Africa still has the potential to further raise the level of beneficiated mineral output, particularly in the production of finished goods.

At the University of Pretoria (UP), research efforts that promote minerals beneficiation have been inspired by a desire to find new ways to source valuable minerals from previously unexploited sources.

In the Department of Materials Science and Metallurgical Engineering, researchers are devising environmentally friendly alternatives to materials produced in the refractory industry. They are also investigating ways of extracting minerals from fine particles to increase minerals beneficiation, developing a system to monitor and track particles in a slurry, and exploring ways to increase beneficiation and improve the purity of platinum and other minerals.

Researchers in the Department of Chemical Engineering, on the other hand, are investigating the recovery of rare earth elements (REEs) and uranium from mined phosphate ore.

In the Department of Mining Engineering, researchers are finding homegrown solutions for South Africa's unique challenges in the mining industry, with a particular emphasis on mechanisation and automation, and the development of techniques to simulate the rock mass behaviour in South Africa's deep-level gold mines.

A three-year public-private partnership, funded by the Department of Science, Technology and Innovation's Mandela Mining Precinct and the Minerals Council South Africa, has given rise to a collaborative research initiative to benefit the country's mining sector. This initiative, a research programme under the South African Mining, Extraction, Research, Development and Innovation (SAMERDI) strategy, has been jointly allocated to the country's four universities with mining schools: the University of Pretoria, the University of the Witwatersrand, the University of Johannesburg and the University of the Free State. Each institution was allocated specific research activities, with UP focusing on mechanised mining systems. This research activity has been jointly allocated to the Department of Mining Engineering and the Department of Mechanical and Aeronautical Engineering.

Finding homegrown solutions for South Africa's unique challenges in the mining industry

Despite South Africa's prevailing electricity shortages, logistical problems and low commodity prices, the mining industry remains a key contributor to economic prosperity. The University of Pretoria's Department of Mining Engineering focuses on conducting world-class research to meet the unique challenges of the South African mining industry.

Prof Francois Malan, Head of the Department of Mining Engineering, remarks that this is not the first time that the South African mining industry has had to survive exceptionally difficult periods. "With ingenuity, and a bit of luck, we always seem to pull through."

In the 1960s, for instance, the gold price was artificially low due to the actions of the London Gold Pool to defend the price of US$35 per ounce. Many of South Africa's marginal gold mining operations had to close. The strong mining units survived, however, and did exceptionally well during the gold boom that followed in the 1970s.

RANKED TOP 36

FOR MINERALS AND MINING ENGINEERING WORLDWIDE IN THE LATEST QS UNIVERSITY RANKINGS BY SUBJECT

South Africa is currently ranked first in the world for chromium, manganese and Platinum Group Metals (PGM) reserves; fourth for gold reserves; and sixth for coal reserves. These commodities will always be in demand and the South African industry needs to develop economically viable mines. Part of building this resilience, explains Prof Malan, is to ensure that we conduct the necessary research to improve our productivity and lower our production costs. In its 1995 report, the Leon Commission of Inquiry into safety in the mining industry stated:

...as no other region of economic significance has similar geometry, no mining industry outside South Africa pursues the solution to this problem.... The solution must therefore be found in South Africa.

Now, three decades later, the solution still lies in conducting world-class research to solve South Africa's mining challenges. This is accompanied by a need to establish and maintain research groups to contribute to the generation of new knowledge. With the demise of the historically important mining research centres in South Africa (the Chamber of Mines Research Organisation and the Council for Scientific and Industrial Research (CSIR)'s Miningtek), the University's Department of Mining Engineering has become a key player to rebuild and grow the country's mining research capacity and find solutions to its problems. Its research therefore endeavours to increase the productivity and safety of the country's mines. "The focus must be on homegrown solutions for South Africa's unique challenges," explains Prof Malan.

The Department has four key research areas:

- Mechanisation and automation
- Management and leadership
- Rock engineering
- Extended reality technology

Through the support of Harmony Gold in the form of a Research Chair in Rock Engineering, the Department is recognised as a leader in rock engineering. The Research Chair investigates techniques to simulate the rock mass behaviour in South African deep-level gold mines. It is the only research programme currently conducted in South Africa to develop the rock engineering tools to improve safety in and the profitability of the deep tabular gold mining industry. Important aspects related to this research include locally developed numerical modelling software, enhanced design criteria to improve layouts, better tools to study which pillars and remnants can be mined safely, and better simulation of closure rates for enhanced support design in seismic conditions.

The Department furthermore engages in cross-disciplinary research, which is facilitated by its Mining Resilience Research Centre (MRRC). The activities of this research centre are aimed at revitalising mining research, development and innovation in South Africa to ensure the sustainability of the industry. Through research initiatives such as these, the Department is enthusiastic about developing the next generation of mining engineering researchers to benefit the South African mining industry.

Adding value to raw materials to generate an income in local and international markets

South Africa is not only blessed with the world's largest deposits of platinum, chromium, vanadium and manganese. It also has extensive reserves of gold, iron, lead, zinc, copper, nickel, coal and diamonds. The minerals industry contributes 50% of South Africa's exports and is one of the largest employers in the country.

Metallurgical engineers play a key role in the production of minerals and metals, and help to process metals into final products with added value. In this way, the maximum income is generated in local and international markets. "Components made from metals and other materials are designed to perform optimally in all aspects of modern life," says Prof Natasia Naudé, Head of the University's Department of Materials Science and Metallurgical Engineering.

"The Department is unique in South Africa as it is the only academic department entirely dedicated to metallurgical engineering," she says. It has been ranked as the best metallurgical engineering department at a South African university for several consecutive years by the Minerals Education Trust Fund (METF). It was also ranked 36th in the world for minerals and mining engineering in the latest QS University Rankings by Subject. This acknowledges the Department's valuable impact on the field. Its commitment to providing advanced education and state-of-the-art facilities ensures that its graduates are well prepared to meet the challenges of the modern world.

The Department focuses on six key areas related to the processing, refinement and application of minerals and metals: minerals processing, pyrometallurgy, hydrometallurgy, physical metallurgy, welding engineering and corrosion engineering. "Collaboration with industry partners enhances the relevance of our research programme," explains Prof Naudé. "This enables us to serve as a technical resource for industry, providing information and expertise." The Department's research programme is therefore focused on industrial problems faced by the metallurgical industry in South Africa and the rest of the world.

Devising environmentally friendly alternatives to refractory materials

Research in the Department's Centre for Pyrometallurgy is investigating alternatives to materials produced in the refractory industry. One such material is taphole clay, which is used to form a semi-permanent seal in a smelting vessel until it is opened to tap the molten liquid from the smelter or furnace. Taphole clay must be able to withstand the hydrostatic pressure from inside the furnace, resist chemical interactions between the clay and the charge, maintain a secure seal, protect and preserve the tap hole and its surrounding area, and ensure that no gases escape through the tap hole. For the past 50 years, high-temperature coal tar and coal tar pitch have been used as binders in taphole clays. However, their use is under scrutiny as they contain polycyclic aromatic hydrocarbons (PAHs), which are carcinogenic, mutagenic and harmful to reproduction. Research to devise environmentally friendly alternatives has provided much-needed information that is currently lacking in the literature. Prof Andrie Garbers-Craig, under whose supervision this research is taking place, reveals that industry has already expressed interest in alternatives to coal tar as a taphole clay binder to ensure safer and healthier options to the material currently being used in the refractory industry.

Extracting minerals from fine particles to increase minerals beneficiation

With the important role that the mining industry plays in South Africa's economy, it is essential that as much of the mineral ore as possible is extracted and processed. This includes the recovery of valuable minerals from smaller pieces of ore, known as fine particle beneficiation. As the high-grade ore that is relatively easy to extract becomes depleted, it is becoming increasingly necessary to develop techniques to extract the finer ore that is left behind. The research of Wynand Roux is investigating the use of an advanced fine-particle, gravity-based separator to separate fine particles based on the difference in their density or particle size. This is particularly useful in extracting fine particles from coal, chrome and iron ore to increase the volume of mineral ore that can enter the market.

Developing a system to monitor and track particles in a slurry

In collaboration with the Department of Electrical, Electronic and Computer Engineering, researchers have developed novel methods to monitor and track mineral particles in mineral slurries using a spiral concentrator. This gravity-separating equipment is used widely in the minerals processing industry to separate high- and low-density minerals. The operations efficiency of spiral concentrator plants can currently only be inspected visually. The researchers therefore sought to develop a novel system that uses magnetic particle tracking to track tracer particles in a slurry. These tracer particles had the same properties as those of real mineral particles. With this novel system, the tracer particles' position and velocity could be determined in the muddy slurry on the surface of the spiral concentrator.

Increasing beneficiation and improving the purity of platinum and other minerals

South Africa is the world's largest producer of platinum, holding approximately 70% of the world's platinum reserves. Such minerals require concentration through froth flotation. Research by Mfesane Tshazi in the Department of Materials Science and Metallurgical Engineering is responding to some of the challenges experienced in the flotation industry by evaluating the effect of particle size and hydrodynamics on mineral recovery. In his research, he compared the performance of laboratory batch scale cells and highlighted the importance of cell design in flotation efficiency. Additionally, his research emphasises that particle size plays a critical role in optimising flotation recovery.

Metallurgical engineers play a key role in the production of minerals and metals, and help to process metals into final products with added value.

CLIMATE ACTION

Protecting humankind from the impacts of climate change

The University of Pretoria's Faculty of Engineering, Built Environment and Information Technology focuses its research on making a significant contribution to society, particularly on the most pressing challenges of the developing world. It encourages research and innovation that is not restricted to finding solutions to challenges within a single discipline, but to developing initiatives that will have an interdisciplinary impact that can be applied locally, regionally and globally.

Its research strategy is aligned with the University of Pretoria's overall research strategy, in which it aims to be a leading research-intensive university in Africa. At the same time, it seeks to be recognised internationally for its quality, relevance and impact, and for developing people, creating knowledge and making a difference locally and globally. Accordingly, the Faculty encourages its researchers to take cognisance of national, regional and global commitments.

Its focus on global challenges is not restricted to those that are traditionally associated with industry innovation and communities, responsible consumption and production, affordable and clean energy, and sustainable cities and communities, but also those related to challenges that affect citizens on a broader level, such as climate change.

In the School for the Built Environment, researchers in the Department of Architecture are involved in an interdisciplinary research project to lower heat stress exposure in our cities and improve the health and wellbeing of our urban residents.

On another level, researchers in the School for Information Technology's Department of Informatics are focusing on a phenomenon known as digital decarbonisation. The rapid evolution of information and communication technologies, coupled with globalisation and digitalisation, has led to a vast network of interconnected devices, which contribute to the exponential growth of data.

As organisations store more data without effective management, dark data grows, leading to increased storage needs and inefficiencies. The implications for carbon emissions are significant, as storing and managing large volumes of dark data require substantial energy consumption, contributing to higher carbon footprints, with its associated impact on climate change.

Dark data management as a catalyst for digital decarbonisation

While big data offers organisations valuable insights and transformative opportunities, such as enhanced customer engagement and business model optimisation, it also presents significant challenges.

One pressing concern is the environmental impact of data storage, with data centres contributing to 2% of global greenhouse gas emissions. They are also projected to consume up to 4% of global electricity by 2030. The concept of digital decarbonisation has emerged as a critical focus, with the aim to reduce the carbon footprint associated with digital storage and processing. A key aspect of this effort lies in the management of dark data – unused information that, if effectively leveraged through knowledge management practices, artificial intelligence (AI) capability and machine learning (ML) models, could support sustainability goals.

Prof Hanlie Smuts, Head of the University's Department of Informatics, explains that dark data refers to the information that organisations collect, process and store, but do not actively use or analyse. This often includes unstructured data from sources like emails, old documents and logs, which remain hidden or unused. The accumulation of dark data is typically caused by factors such as poor data management practices, inadequate data governance and the failure to implement systematic data archiving processes. The inefficient use of resources associated with dark data can also hinder sustainability efforts and inflate operational costs.

She says that organisations need to unlock dark data's hidden value by applying technologies such as AI and ML to derive insights from dark data. However, relying solely on technology is insufficient. "Organisations need comprehensive strategies to discover dark data, map its contents, establish policies for its retention and destruction, develop the necessary data science skills and integrate dark data analytics into their business processes."

From a knowledge management practice focus, organisations should invest adequately in the development of human and social capital. This investment ensures that the organisation has the necessary tools and skilled personnel to handle, analyse and derive value from dark data. By applying advanced technology, organisations can enable substantial and targeted knowledge sharing across geographical barriers, ensuring that insights derived from dark data are accessible to all relevant stakeholders. "This approach not only enhances the organisation's ability to manage and utilise dark data," concludes Prof Smuts, "but fosters collaboration and innovation across different regions and teams, driving overall organisational growth and resilience".

Learning from complex living environments to beat the heat

According to the Paris Agreement of the United Nations Framework Convention on Climate Change, the goal of the signatories was to limit the global temperature increase to 1.5 °C above pre-industrial temperatures by 2025. This was necessary to mitigate the worst impacts of climate change, However, experts have confirmed that we have already been living in these climatic conditions since May 2023. In fact, Monday, 22 July 2024, marked the hottest average global temperature measured in earth's modern history.

While this temperature increase seems small, the past few years have also been marked by several extreme weather events resulting from these higher temperatures. These events have affected many African countries, and ranged from flooding in Libya and cyclones in the eastern regions of southern Africa to significant droughts over the central southern African regions. Although extreme weather events are widely documented, the increase in heat stress and extreme heat days that affect marginal communities in our society often go undetected.

At the University of Pretoria (UP), the Department of Architecture is working on solutions to lower heat stress exposure in our cities and improve the health and wellbeing of our urban residents. Understanding the extent of heat stress exposure and how it can be addressed in the built environment, specifically in vulnerable environments such as informal settlements, has been the research focus of an interdisciplinary research team from the Department of Architecture, the Department of Chemical Engineering and the School of Public Health and Health Systems at UP, together with researchers from the University of the Witwatersrand's Reproductive Health Institute (RHI) and the Centre for Sexual Health and HIV AIDS Research (CeSSHAR) Zimbabwe. Through a series of research projects, located in the City of Tshwane, South Africa, and Mount Darwin in Zimbabwe, the research team has been documenting the built environment of dwellings and early childhood development centres in informal and rural settlements, and monitoring heat exposure in these contexts. The latest research project, Heat Adaptation for Pregnant Women and Infants (HAPI), funded by the Wellcome Trust, extends the project's focus to consider multilevel interventions that include health practitioners, policy makers and residents in defining heat health solutions.

Climate crisis and heat stress

Heat stress can be defined as the increased stress on the human body to regulate its internal temperature when exposed to high thermal conditions. As a result, the body is put under strain to cool itself. Heat stress can have multiple impacts on individuals, ranging from irritability and discomfort to heat stroke and death. It has also been noted to affect communities financially due to lower labour efficiencies, and socially with a marked increase in violence and violent behaviour.

Dr Jan Hugo, a researcher in the Department of Architecture, indicates that the team's research has also shown that, while the built environment is highly effective in lowering exposure to climate-driven crises, the inverse occurs where poorly constructed built environments increase our exposure to extreme weather conditions such as heat waves and extreme heat. This is especially evident in marginalised and poor communities that have little resources to address this and often have little to no access to formal cooling technologies such as air-conditioners.

Researchers from the City of Tshwane and the Council for Scientific and Industrial Research (CSIR) have suggested that we will experience an increase in extreme heat days. Large portions of South Africa's urban population that live in informal settlements run the risk of being increasingly negatively affected. As a result, the Department's research projects have been implemented in the Melusi informal community in Pretoria West. The Department also recently expanded its focus to include Itireleng and Mooiplaas, close to Laudium, and further into Africa to more rural settings in Mount Darwin in northern Zimbabwe. All these communities live in informal, self-built settlements with limited infrastructure.

Developing solutions

Researchers have argued that solutions to address heat stress typically take place on three levels: personal practices, technical solutions and social/cultural adjustments. This highlights the importance of understanding that heat stress solutions cannot be developed by a single discipline, but need to involve multiple stakeholders.

Subsequently, the HAPI study aims to define response strategies that can be developed, tested and implemented synergistically. The focus is on multiple levels, ranging from dwellings (at the household level), health facilities and community, to the national policy level. "We envision that the work will result in strategies that affect national health policies, considerations to adapting the built environment, strategies to improve the capacity of residents to undertake climate change adaptation measures, and guidelines to develop heat health practices in clinics," says Dr Hugo.

The research team in the Department of Architecture has furthermore been actively documenting and monitoring various buildings and informal dwellings. This immersive process of visiting, observing and working with communities allows the team to better understand the environments that individuals inhabit, and helps researchers formulate typical buildings and building practices. Once back in the "lab", the data is utilised to develop digital models of these dwellings, allowing for further simulations and analyses that consider both current and future climate change-affected conditions.

QUALITY EDUCATION

Producing work-ready graduates through quality education

The University of Pretoria's Faculty of Engineering, Built Environment and Information Technology prides itself on embracing innovation in the teaching and learning space so as to produce work-ready graduates. Its use of cutting-edge immersive technology tools, among others, is a testament to this. Innovating our tomorrow starts with adopting innovation today. At the same time, it is important to keep abreast of the latest developments that may affect students' performance, such as Generative AI and its associated challenges.

An example of the Faculty's commitment to teaching innovation is the application of virtual and augmented reality in its teaching. It has adopted the concept of immersive learning as an innovative approach to provide its students with a deep experience of reality. This exposes them to real-world projects, where they can test multiple solutions in a fail-safe environment, preparing them for the world of work.

Furthermore, the Faculty is preparing for an intensive revision of its first-year engineering curriculum and integrated project stream across all seven engineering departments, which will be launched in 2026, with initial changes starting in 2025. This is based on international collaboration and trends regarding the transformation of engineering education. It will bring the Faculty's curriculum in line with global best practices. These initiatives are aimed at ensuring that our students will make a meaningful impact on the world once they graduate.

This reinforces the University's reputation as an institution that is recognised internationally for its quality, relevance and impact.

Redefining the South African Engineering curricula

Engineering schools around the world have an important role to play in equipping a new generation of innovators with the skills they need to address global challenges. This will contribute to a sustainable future for both mankind and the planet, while improving graduates' employability and readiness for the world of work.

South African higher education institutions are committed to delivering engineering graduates of distinction. An important element of curricular reform is the integration of technical and non-technical competencies (often called soft skills or generic competencies) into engineering curricula. This drive for change was captured in a study commissioned by the Massachusetts Institute of Technology (MIT) in 2018, which highlighted key institutions across the world that are implementing innovative strategies in their engineering curriculum.

An integrated curriculum carefully interconnects the content with the appropriate facilitation skills for learning and assessment practices to ensure a student-centric experience. In a generation where information is readily available, and workspaces are dynamic, academics need to cultivate a new skill set in their students. Besides technical knowledge and critical thinking, this entails developing a mindset of growth and continuous self-improvement, valuing and seeking out a diversity of backgrounds, skills and perspectives, and promoting flexibility and adaptability when solving problems rather than working towards a fixed goal. This approach also encourages students to find solutions that are linked to the United Nations' Sustainable Development Goals (SDGs).

South African tertiary engineering institutions have found inspiration and guidance from the University College London (UCL) in their endeavour to transition to integrated engineering curricula. This leading engineering institution in the UK has successfully implemented such an integrated engineering curriculum over the last 10 years, and is mentoring other institutions to follow suit.

At the University of Pretoria, Prof Lelanie Smith is spearheading an exciting engineering education transformation project, with the focus on developing innovative engineering curricula. The initiative, funded by the Royal Academy of Engineering and the University Capacity Development Programme, is displaying pioneering efforts and international collaboration. It is coordinated and funded by a national team representing 11 of South Africa's 16 engineering schools, the UCL and Aalborg University in Denmark as formal partners. Its primary objective is to redefine how engineering curricula are developed and delivered across South Africa. It integrates expertise from academia, industry and accreditation bodies. The programme focuses on developing a cohesive understanding of an integrative curriculum in the South African context, and preparing students and staff for innovative and creative engineering education. T

Immersive learning provides innovative ways of engaging with academic content

With the establishment of the Virtual Reality (VR) Centre for Mine Design in the University of Pretoria's Department of Mining Engineering in 2015, the training of mining engineers in South Africa entered a new era. The centre was the first of its kind in Africa to be hosted at a university, and only the second in the southern hemisphere. It has since been used for other virtual learning applications within the University, together with the Department of Information Science's new Immersive Technology Laboratory, which was launched in 2024.

VR Centre for Mine Design

The VR Centre for Mine Design was based on the premise of providing safe training to students and mine staff on mine safety and other related issues in a simulated mining environment. The equipment could realistically simulate a range of mining functions, from accident reconstruction and risk analysis, to responding to potential hazards and testing evacuation procedures – all in a low-risk, high-impact learning environment.

The facility consists of three sections, each designed and developed to provide students with a realistic and an immersive experience. The first section comprises a computer-assisted lecture hall where students learn about mine design and apply their newly acquired skills to their own mine design projects. The second section comprises a wall-to-wall 3D theatre, where presentations and other teaching resources can be showcased so that students can learn through a visual process. The final section provides an immersive experience, and comprises a theatre with 360° floor-to-ceiling screens inside which the VR simulator casts images against the dark surrounding panels with cinematic clarity and highly realistic sound effects.

The immersive learning opportunities that are presented in the VR Centre provide students with a deep experience of reality. Through VR tools, it is not just possible to take the classroom to a remote and unsafe environment, such as an underground mine, but students can potentially be taught to operate equipment in the virtual space before they are exposed to the actual machinery in the laboratory. This not only reduces the chance of accidents, but increases accessibility.

A further application of VR in the Department of Mining Engineering is its use of a VR blast training wall, which teaches students and industry practitioners to implement safe and efficient blasting practices in an environment that virtually simulates an underground mining environment. This contributes to safer working conditions and increased productivity. It also enables learners to plan and execute the blasting of a rock face in a controlled and safe environment.

They are able to design the blast, mark the blast holes and blast hole timing sequence activities, and actually execute the blast, and experience the "explosion" on an interactive screen. This has the advantage over teaching in a traditional classroom environment, as the learners are able to visualise and fully comprehend the concepts being taught, while gaining practical experience in a user-friendly, safe and erasable environment, where mistakes can be made without any consequences.

Immersive Technology Laboratory

In recognition of the role that immersive technology plays in allowing students to experience complex concepts and scenarios that would otherwise have been difficult to simulate in traditional learning settings, the Department of information Science has launched its Immersive Technology Laboratory.

This cutting-edge facility was designed to immerse both students and staff in the dynamic world of virtual and mixed-reality technologies. It serves as an open-access space where students can explore various applications for learning and entertainment. At the same time, staff members can utilise the lab to enhance teaching and conduct pioneering research on user interactions with these advanced technologies.

The new lab boasts three "play areas" and four development pods. The development pods are equipped with high-performance computers and HTC Vive and Valve Index headsets, allowing students to hone their development skills and create new virtual experiences.

It not only enhances students' familiarity with immersive technology, but broadens their understanding of its potential applications. Students can experiment with virtual simulations that make abstract concepts more tangible and accessible, helping them grasp complex theories through interactive experiences. The lab also offers relaxation tools, such as virtual meditation sessions during high-stress periods like exams, providing students with innovative ways to manage their wellbeing.

It furthermore equips students with the skills and experiences necessary to navigate and excel in a technology-driven world. Simultaneously, it strengthens research capabilities, enabling institutions to contribute to cutting-edge developments and remain at the forefront of scientific and technological progress. According to Prof Marlene Holmner, Head of the Department of Information Science, this investment in immersive technology enhances educational outcomes and drives forward the frontiers of research, ensuring that universities play a pivotal role in shaping the future.

Developing professionals through *vertical integration* and *immersive theatre*

The ability of students to operate in complex and multicultural environments when they graduate is strengthened by their participation in community-based projects. The University of Pretoria's Faculty of Engineering, Built Environment and Information Technology is therefore committed to ensuring that it produces well-rounded graduates – one project at a time.

This takes place through students' involvement in the compulsory Joint Community Project (JCP) module, which is presented to all 1 600 second-year students in the Faculty's 18 degree programmes. It caters to students of varying abilities and backgrounds, fostering their growth as responsible, engaged individuals. It builds social awareness, teamwork and civic responsibility, which enables graduates to function in diverse environments when they enter the world of work.

As the JCP Coordinator, Prof Lelanie Smith uses service learning as a pedagogical approach that provides students with the opportunity for hands-on skills development with a community partner of their choice. Each student devotes 40 hours to preparation and 40 hours to fieldwork in the community. During 2024, the students were involved in 346 projects with more than 50 community partners across Gauteng. Two strategies are used to support this learning agenda: vertically integrated mentorship and an immersive theatre experience.

Vertically integrated mentorship

The vertically integrated mentorship team comprises 15 fourth-year students (senior mentors) and 35 third-year students (junior mentors) who have already completed the JCP programme. The mentors' training and development takes place in collaboration with success coaches from Curiosity Campus. The senior mentors complete two days of interactive sessions to develop skills in supporting and listening, giving and receiving feedback, asking clarifying questions and caring responsibly. In the second year, they complete a second round of training, which includes negotiation and spheres of control. These skills equip them to guide the students in their engagement with the community and their team-mates, as well as in their self-discovery.

Each senior mentor supports three junior mentors, and each junior mentor supports approximately 40 JCP students in eight to ten groups. The structure simulates the workplace, in which the project is framed as a "company", with the JCP Coordinator as the CEO. The community partners are the clients, the senior and junior mentors are the members of the company's respective management levels, and the JCP students are the new employees. All the learning exercises and casual engagements are framed within this context so that the students can contextualise their learning.

The immersive theatre experience

The immersive theatre experience was designed around the development of the necessary skills for the JCP module. These include responsibility (negotiation), team cohesion and team dynamics, levels of listening (growth mindset and empathy), giving answers and asking questions (problem solving), conflict and tension resolution, and giving and receiving feedback.

Eight activities were designed that took place in sequence, with a variable starting point at different locations on campus. This learning experience offered the kind of real-world, embodied, relational situations to which the taught skills would be applied. It included spatial mapping, walking and interactive exercises. Students were constantly asked to reflect and decide on means of adaptation to support their connection with the material.

A narrative was conceptualised that tied the learning objectives together in a story format. It centred around a fictitious character, "Trinity", a world-famous transdisciplinary researcher in computational biology and organic architecture in the year 2123. She required the students' assistance to collect information and clues, and to complete activities that would restore a distorted timeline to ensure that she receives a funding grant to develop a significant hallmark to curb climate change.

The theatre immersion took approximately two hours to complete, and was repeated four times with seven subgroups. The subgroups were supported by a mentor, and were added to a WhatsApp group. Each subgroup was directed to a different starting location on campus by a message on the WhatsApp group, through which they received instructions in the form of text messages or short videos of Trinity. These messages supported movement between locations, and built the story. When the students arrived at each location, senior mentors engaged them in the activity, or served as "actors", who appeared as part of the storyline to act out certain scenes.

The immersion was designed to serve key objectives in the students' learning experience. It linked the exercise and experience to a specific space on campus, grounding the learning spatially. It also engaged the students' imagination and curiosity in terms of the storyline that was unfolding. Finally, the activities supported an embodied experience of the learning material that had been covered online. Prof Smith explains that students' understanding of sustainability, personal and professional growth, and civic responsibility is at the core of their development through the JCP programme. It is centred on the pivotal role that engineering, built environment and information technology professionals play in finding solutions to complex global challenges.

Prof Lelanie Smith

Embedding a culture of responsible and collaborative *urban citizenship*

Rapid urbanisation in South Africa is exacerbating the socio-spatial inequities of apartheid planning. According to Prof Carin Combrinck, Head of the University of Pretoria (UP)'s Department of Architecture, and Director of its Unit for Urban Citizenship, this has resulted in the emergence of numerous informal settlements across the urban landscape. "Although national policies have been established to assist the process of urbanisation, many of them have not been successfully implemented."

She considers the most concerning impact of rapid urbanisation to be on women and children growing up in informal settlements, where pending citizenship status and economic migration intersect with inadequate essential primary care, including maternal and child health, dietetic and sanitation facilities, and a lack of education facilities. This is resulting in the perpetuation of the cycle of poverty and despair. "These daily frustrations and survivalist strategies undermine social cohesion and agency, which contribute to a decrease in governance and accountability," she says.

This has encouraged postgraduate students in the University's School for the Built Environment to see how they can make a difference in the informal settlements within the City of Tshwane. Since 2016, the activities of the Unit for Urban Citizenship have not only been addressing the residents of the informal settlements of Plastic View and Melusi's need for a sustainable built environment, but also for basic services and infrastructure.

Image: Dario Schoulund

Prof Combrinck explains that the Unit's activities are driven by a desire to embed a culture of participation to achieve collaborative urban citizenship. A current postgraduate research project in the Unit, under the supervision of Prof Combrinck and lecturer Jason Oberholster, forms part of a three-year transdisciplinary study on co-creating wellness and human dignity in urban settlements, which was initiated in 2023. It entails the facilitation of community-based research and science engagement.

During the first year, the researchers documented and mapped the community services and the built environment structures in the two informal settlements. This enabled stakeholders to understand the living conditions of these communities, and how they affect the residents' wellbeing. In 2024, a needs analysis was conducted in collaboration with community partners. The final year will entail the development of community action plans based on the previous two years' work to enable the community to move forward independently.

According to Prof Combrinck, the intended impact of the research is to empower the resident communities through the co-production of knowledge. Working with the communities in an engaged manner, spatial proposals can be co-designed with the community members.

The project reflects the dedication of UP's School for the Built Environment to community upliftment as it seeks to enable the residents of the informal settlements to co-create action plans for the implementation of micro-scale interventions aimed at alleviating their most imminent needs. In the process, the research will contribute to the growing body of postgraduate, governmental and other institutional research, which has started to formalise participation and communication structures between the residents of informal settlements and the external stakeholders working with these communities.

The research has already increased the City of Tshwane's awareness of and interest in participatory action research methods as an alternative to its current eviction and relocation strategies. It is also expected to contribute to the necessary reconsideration of long-term urban upgrading policies.

Prof Combrinck states that the self-organisation that is hoped to result from the research and planning process furthermore aims to empower leadership structures in their negotiations with municipal authorities to implement appropriate upgrading policies. Additional intermediate and long-term outcomes are the strengthening of social capital and improved access to economic opportunities, thereby improving livelihoods and socio-spatial agency. T

Mitigating train-wildlife collisions in *Greater Kruger*

Transnet Freight Rail operates a railway line through the Balule Game Reserve, a connected Big Five reserve bordering the Kruger National Park. The railway connects the phosphor mine at Phalaborwa with the town of Hoedspruit. The length of the track through the reserve is approximately 41 km and the single, currently non-electrified line crosses the Olifants River in the north.

The train schedule through the reserve comprises roughly seven loaded and seven empty trains per day. As the railway line is unfenced, collisions between trains and wild animals (ranging in size from rodents to elephants) frequently occur and are a source of the unnatural removal of animals from the reserve. This has negative impacts on the conservation of species.

At the beginning of 2023, the University of Pretoria (UP)'s Chair in Railway Engineering, in collaboration with the Balule Game Reserve and Transfrontier Africa, embarked on a research project with a cross-disciplinary focus that included aspects of railway engineering and ecology. The train-wildlife collisions have negative consequences from a wildlife conservation perspective, as well as financial implications for the train operator. The aim of the research was to investigate the problem, identify the contributing factors and provide guidelines as to how it could be managed to reduce future occurrences.

Prof Hannes Gräbe, Head of the Department of Civil Engineering and Chairholder of the Transnet Freight Rail Chair in Railway Engineering and the Railway Safety Regulator Chair for Railway Safety, explains that the investigation had three primary objectives. "Firstly, it aimed to create a digital infrastructure inventory of the railway line and adjacent area." This would include topography, track geometry and a mapping of all railway assets. "Secondly, the study would identify contributing factors to the collisions taking place on the railway line." The initial phase of the investigation would focus on "hot spots" where animal crossings are prevalent. "Finally, the study would investigate other related railway engineering aspects with the focus on train and track condition monitoring."

The University's road-rail vehicle, acquired through the National Research Foundation (NRF)'s National Equipment Programme, was used to map the rail reserve and infrastructure assets in conjunction with UP's light detection and ranging (LiDAR) system. This system was mounted to the front of the road-rail vehicle to conduct a survey along the entire length of the railway line in the game reserve.

Prof Gräbe explains that the LiDAR system creates a 3D point cloud by acquiring over 300 000 points per second. "The LiDAR survey was done at a slow speed, below 10 km/h, to ensure a dense point cloud." The resultant point cloud covered the railway assets (mast poles, ballast, sleepers, rails and fasteners) for 20 to 50 m on both sides of the railway line. It could therefore be used to take measurements, calculate volumes and areas, and draw cross-sections along the railway line. "In this project, advanced point cloud manipulation was used to extract the sleeper elevation and ballast profile along the track." Areas or crossing points where the ballast had been disturbed by animals could then be identified and marked for comparisons with ground truth and other data.

In conjunction with the LiDAR mapping, a KRAB™ geometry trolley was utilised with the road-rail vehicle to obtain high-resolution track geometry data of the line. "Track geometry is useful for maintenance planning and to ensure that corrective maintenance is done at priority locations."

In addition to the track geometry measurements, a drone was used to create orthographic maps of specific hot-spot locations on the railway line. By taking multiple photographs along the railway line, a 3D image of the track could be created. Another drone was used to record detailed LiDAR data of specific track sections and fixed infrastructure, such as the Olifants River steel bridge, and concrete culverts and bridges in the game reserve. All drone surveys were carried out by licensed remotely piloted aircraft system pilots, who conducted the flights in accordance with South African Civil Aviation Authority regulations.

The investigation identified critical collision hot spots along the railway line, while providing valuable data for planning and mitigation strategies. The LiDAR-generated digital infrastructure inventory and track geometry measurements will also aid in predictive maintenance planning and future intervention calculations. "The findings and recommendations from this investigation lay the foundation to implement effective measures to manage and mitigate future occurrences of train-wildlife collisions," he concludes.

Prof Hannes Gräbe

Innovating our *tomorrow*

The University of Pretoria (UP)'s Faculty of Engineering, Built Environment and Information Technology is committed to fostering and promoting a climate of innovation in the belief that innovation is a significant contributor to competitiveness, growth and prosperity. Integral to its research agenda is the commercialisation of inventions that are the outcome of research activities, following the protection of intellectual property and conclusion of licensing agreements. Several such outcomes have emanated from the Faculty over the years.

Researchers in the Institute of Applied Materials developed a slow-release, longer lasting mosquito repellent to contribute to the fight against malaria. This technology has since found other applications as well, including an insect-repellent mosquito net, insect-repellent hiking socks and an innovative anti-bedbug mattress cover.

Researchers in the Department of Electrical, Electronic and Computer Engineering joined forces with the Department of Speech-Language Pathology and Audiology in the Faculty of Humanities to develop an innovative mobile hearing screening application, marketed as hearScreen. The spin-out company that was established to commercialise this technology has since expanded its product portfolio to address the global hearing loss pandemic, and currently includes the No 1-selling hearing aid brand in the USA. It completed the full cycle of commercialisation when the company purchased the IP from UP to continue as an independent company.

Research in the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) gave rise to the development of low-cost, efficient and fast-switching silicon light-emitting devices in photonic integrated circuits using the injection-enhanced silicon in avalanche (INSiAVA) technology. A UP spin-out company was founded to serve as a vehicle to commercialise the novel silicon light-emitting technology. This company is still going strong 20 years later, and has branched out into the design of customised integrated circuits for clients, and the development of a range of smart sensors for motion detection.

The support the University provides to its inventors is illustrated in the success story of Khutso Bapela. As a young computer science graduate, he invented anti-cyber bullying software, which attracted attention globally. He went from strength to strength, adding more inventions to his portfolio, and establishing two companies that provide services and develop products in the field of artificial intelligence, digitisation strategies and app development. He is currently involved in developing AI systems for healthcare services, and is committed to bridging the digital divide. These inventions all contribute to making a difference to the world we live in.

New applications for long-lasting insecticide treatments

Dr Mthokozisi Sibanda, a former member of the University of Pretoria (UP)'s Institute of Applied Materials (IAM), has gained recognition for an invention that reduces the evaporation of expensive insect repellents. This invention, which emanated from research conducted in UP's Faculty of Engineering, Built Environment and Information Technology, was subsequently licensed. This led to the development of a spin-out biotechnology company of UP, known as African Applied Chemical (AAC).

This innovation led to the manufacture of an insect-repellent mosquito net and insect-repellent hiking socks. Its latest application is the development of an innovative anti-bedbug mattress cover, which is being marketed as NoBugs Nobites™. The effectiveness of the product has undergone independent evaluation by Clinvet International, a global veterinary contract research organisation.

The evaluation entailed the testing of both untreated textile samples and samples that had been treated with the product. The samples that had been treated with the product were divided into several groups prior to testing, including those that were not washed after treatment, those that were washed 10 times after treatment, and those that were washed 20 times after treatment. All the samples were exposed to the common bedbug, *Cimex lectularius*, for 240 minutes before testing. After initial exposure, the insect was removed from the treated and untreated material, and knock-down (alive, but paralysed) was recorded at various time intervals, ranging from five minutes to four hours.

Dr Mthokozisi Sibanda

Five minutes after exposure, the treated nets that had been washed 10 times produced the highest knock-down. After 60 minutes of initial exposure, the samples that had not been washed after application of the product achieved 100% knock-down. The samples that had been washed 20 times after application of the product achieved 100% knock-down after 120 minutes. After 24 hours of initial exposure, the samples that had not been washed after application of the product recorded 85% of dead bedbugs, while the samples that had been washed 20 times after application of the product recorded 72% of dead bedbugs. All remaining bedbugs were still in a knock-down state and never recovered. None of the untreated samples induced more than 10% mortality.

Dr Sibanda describes bedbugs as a persistent nuisance pest of humans. They also opportunistically feed on other mammals, including household pets. "Bedbugs do not remain on the host, but only feed at night. They live in shelters such as bedding when not feeding."

This has led to insecticide treatment being ineffective and the development of insecticide resistance, as contact with insecticides is limited or chemical control is applied when the bedbugs are not present on the host. The chemical control of bedbug populations should therefore be focused on treating the bedbug's environment to ensure sufficient contact with the insecticide treatment.

Beta cyfluthrin, an active ingredient of the product's formulation, which is infused into the fibre of the mattress cover, is a contact insecticide that is released by the mattress cover over an extended period of time, says Dr Sibanda.

Commenting on the results of the experimental evaluation of the product, Dr Sibanda explains that it is important to note that, in a knock-down state, the bedbugs are in a comatose state and cannot actively feed on their victims. "In real-life conditions of application, the knocked down bedbugs will be continuously exposed to the treated material instead of for only 240 minutes as in the laboratory test, and will all die in less than a day." This result proves that the insecticide-infused mattress covers can be washed at least 20 times before they lose their effectiveness.

He stresses that the innovative technology used to manufacture this product allows for the infusion of a piperonyl butoxide active that deactivates any ability of the bedbugs to resist insecticidal action. "The innovative NoBugs Nobites™ anti-bedbug mattress cover is designed to be effective, even on insecticide-resistant bedbugs."

UP spin-out company completes the full cycle of commercialisation

Prof De Wet Swanepoel and Nic Klopper

The University of Pretoria (UP)'s spin-out company, hearScreen (Pty) Ltd has completed the full cycle of a university-licensed invention that has followed the commercialisation route. On 18 November 2024, representatives of UP's Innovation and Contracts Management Division signed an agreement to transfer the invention's Intellectual Property (IP) to the hearX Group. This was a milestone event, which marked UP's first sale of its IP to an independent company.

The invention that led to the company's establishment in 2016 – a novel mobile hearing screening application (app) – was developed as a transdisciplinary venture in UP's laboratories. It was the outcome of the combined intellectual prowess of Prof Herman Myburgh, a researcher in the Faculty of Engineering, Built Environment and Information Technology's Department of Electrical, Electronic and Computer Engineering, and Prof De Wet Swanepoel, a researcher in the Faculty of Humanities' Department of Speech-Language Pathology and Audiology.

Prof Swanepoel explains that the idea came to him while he was looking for a way to provide accessible audiology services to people in underserved rural areas. He approached Prof Myburgh in 2013 to assist him with creating a cell phone application that could perform hearing screening tests on children and adults.

This was a new field at the time. Prof Myburgh and his students set about developing an Android app for the Samsung Galaxy Pocket Plus. At the time, this was an inexpensive phone with a retail price of approximately R500.

They performed numerous tests to ensure the signal frequencies and intensities were correctly generated and adhered to rigorous calibration requirements. In contrast to traditional equipment, the patented hearScreen app could detect background noise and indicate this to the person conducting the test. The test could then be taken at a later stage or in another venue. A huge benefit and novel development of the technology was that the data of every screening could be uploaded to a central, secure database. The users, whether they were school nurses or community health workers, each had an account on the database and could access and monitor their patients' data. It soon attracted the interest of role-players outside the hearing health industry, including mining houses and companies performing clinical trials, where the monitoring of hearing health is vital to their compliance to standards.

Leveraging mobile phones for hearing health gave rise to a second product, hearZA™, a free app that allowed users to test their hearing on any smart device, which referred them to their nearest hearing healthcare provider if they failed the test. The app could be downloaded onto any Android or iPhone system, and took less than three minutes to complete. The test uses digits presented in background noise to provide a real-world test of hearing performance.

Launched as South Africa's national hearing screening test, hearZA™ has been adapted for the World Health Organisation's global screening app, hearWHO. Based on the same technology, it has provided free hearing screening to almost 500 million individuals in 191 countries.

After the invention had been licensed with the support of UP's Innovation and Contracts Management Division, the next step was its commercialisation and market entry. For this purpose, a spin-out company had to be established. Nic Klopper, a seasoned entrepreneur with extensive experience of taking start-ups on the route to commercialisation, was appointed as the company's Chief Executive Officer (CEO), with members of UP's Executive and the inventors on the Board of Directors.

Expanding the product portfolio

Under the leadership of Klopper, the company expanded its product portfolio to address the global hearing loss pandemic. In addition to the original hearing screening tools, it developed a full diagnostic test for use in the occupational health and safety industry, as well as in neonatal units for newborn hearing testing. This was followed by the development of a platform for the distribution, fitting and support of hearing aids under its Lexie Hearing consumer brand. It was soon able to provide a total solution for hearing-compromised individuals.

The turning point for the company came in 2022 when new legislation in the USA led to the deregulation of the hearing aid industry, allowing the company to market its over-the-counter (OTC) hearing aids to individuals with mild to moderate hearing loss in the USA. This enabled it to pioneer digital hearing solutions to detect, diagnose and treat hearing loss around the globe. Its hearing aids are now available in over 15 000 retail doors across the USA, and its Lexie Hearing brand is currently the No 1-selling OTC hearing aid brand in the USA.

Closing the circle

Celebrating the company's success, Adv. Lawrence Baloyi, Head of UP's Innovation and Contracts Management Division, described the sale of the IP to the company as a significant milestone for both UP and hearScreen. He acknowledged that this would not have been possible without the hard work, vision and perseverance of the entire team, under the leadership of Klopper as CEO.

"Since the licensing of its original invention, the hearX Group has succeeded in turning an idea into something tangible and – more importantly – it is making a real impact in the world of hearing health." Adv. Baloyi noted that the success the company had achieved was not just about the technology. "It is about jobs being created, innovation being nurtured and the contribution to both the local and the global economy. It is about creating a ripple effect that will continue to make waves in the world of healthcare." T

Microelectronics expertise provides the foundation for globally competitive innovation

One of the University of Pretoria's promising spin-out companies, INSiAVA (Pty) Ltd – named after the injection-enhanced silicon in avalanche (INSiAVA) technology that it sought to commercialise, is still going strong 20 years later. Its origin was based on a quest to solve the chip-to-chip and on-chip interconnect problem that is prevalent in microelectronics engineering.

Emanating from research conducted in the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) in 1990 by Prof Monuko du Plessis, the company was founded in 2005 to serve as a vehicle to commercialise the University of Pretoria's novel silicon light-emitting technology.

The company secured private investment in 2007 and embarked on an extensive research and development programme to improve and optimise silicon-light emission and implement its standard complementary metal-oxide semiconductor (CMOS) processing technology. The goal was to produce products based on the company's technology without the need to deviate from the fabrication technologies used for large-scale electronic chip manufacturing.

The company achieved several world-first breakthroughs, and is a leader in the integration of light emission in standard CMOS processing technology.

Dr Jannes Venter, who was appointed as the company's first full-time CEO in 2014, was a lecturer in the Department at the time of the company's establishment, so he has been with INSiAVA (Pty) Ltd right from the start. He explains that the cutting-edge research and development using INSiAVA's silicon light-emission technology led to interesting application areas, including opto-isolation devices, microdisplays, microfluidic sensing and chip-to-chip communication.

INSiAVA owns and actively manages an extensive patent portfolio that covers several inventions that led to more than 65 granted patents in various international jurisdictions, including the USA, Europe, China and Japan. Of these, 11 inventions relate to light emission from indirect band gap semiconductors, two relate to the implementation of silicon light emission in CMOS applications, and three relate to specialised circuits in analogue and mixed-signal applications. In addition, the company has specialised know-how and other forms of intellectual property (IP) for applications in the fields of its ordinary business. Since 2017, it has diversified its business by increasing its IP and product portfolio to include the design and development of specialist integrated circuits targeting the power and sensor markets on the back of new opportunities in the field of the Internet of Things (IoT).

In 2021, the company decided to expand its product range, leveraging the expertise of its team of microelectronics engineers to design smart sensor products for passive infrared (PIR) motion detection and thermopile sensor applications, as well as customised integrated circuits for clients. To distinguish its focus on sensor products from INSiAVA's original light-emitting technology, it established a subsidiary company called INSiAVA Sensor ICs (Pty) Ltd. This enabled it to streamline its sensor product development and sales activities, while maintaining the IP of the silicon light-emission technology in the original company.

Dr Venter explains the company's value proposition, which is to develop and produce innovative, specialised integrated circuit products and technologies that have global competitive advantage.

"We envision being on the forefront of specialised integrated circuit design, providing the competitive edge to customers globally by building and delivering products of a superior quality with best-in-class performance for real-world applications through our array of expertise and years of experience in the field of semiconductor engineering."

Its leading product range entails a range of digital passive infrared smart sensor integrated circuits for motion and presence detection. The range currently includes three devices, each targeting a very specific market segment. They were developed to interface directly with pyroceramic sensors and to directly digitise passive infrared signals, while maintaining high signal fidelity and noise immunity. Dr Venter says that these devices have the lowest operating voltage and power consumption in the industry, while they provide a rich feature set, underpinned by highly innovative designs. They feature a predictable and well-controlled high-impedance input stage, a highly sensitive differential analogue front-end, low power consumption and ultra-low voltage operation. They are used in security, industrial and residential applications, and for smart building management, as well as for human and animal presence detection.

Dr Venter's future plans for INSiAVA include expanding the smart sensor business to achieve a sustainable volume of devices sold in order for the company to be self-sustaining. "We will introduce our new products to our anchor customers, so that we can make a more efficient ingress into our existing customer base, but also to expand our customer base to users that are still reliant on older technologies." Over the medium term, the team plans to use its base technology to expand to other sensor technologies with ultra-low power features through the development of concept products. At the same time, it will be working on the silicon light-emission technology, which still has potential for further development. While several major market players are operating in this field, the challenge for the company lies in the fact that it is a very focused area, where continued innovation is the only key to success. He is confident that, with the robust team supporting its product development, the company has a bright future ahead of it.

INSiAVA achieved several world-first breakthroughs, and is a leader in the integration of light emission in standard CMOS processing technology.

Team members (from left): Nicolaas Fauré, Marius Goosen and Dr Jannes Venter

Alumnus reveals the productive outcomes of an early *innovative spirit*

Khutso Bapela, who graduated with a BSc in Information Technology in 2012, followed by an honours degree in Engineering and Technology Management in 2019, is living proof that the spark of innovation, nurtured early in life, is not easily extinguished. He first came to the attention of his alma mater in 2014 when he developed anti-cyber bullying software, which the University of Pretoria (UP) supported by incubating his fledgling company at the Innovation Hub in Pretoria

This venture, known as the Motswadi System, was not Bapela's first attempt at developing a solution for an identified problem in society. As a schoolboy at Mahwetse High School in rural Limpopo, he participated in the Eskom Expo for Young Scientists. The project he entered entailed an air-conditioning system that incorporates water mist to cool the surrounding air – similar to the one that is in the market today. He was a finalist at district level, and proceeded to both the provincial and national rounds of the competition. Coming from a village school, he experienced difficulty communicating in English, especially as he was competing against learners from private schools in Pretoria and Johannesburg, but considers this to have been a valuable learning experience.

The Motswadi System that he developed was aimed at helping parents of young children in South African communities monitor their children's online activities in an attempt to prevent continuous unsurfaced cyber bullying. It employed an algorithm that wirelessly picked up the specialised SIM card in a child's cellphone. It enabled parents to set up an internet profile, tailored to each particular child's needs and vulnerabilities. He received funding from the Technology Innovation Agency (TIA) for the development of this innovative product. However, with the proclamation of the Protection of Personal Information (POPI) Act in 2020, among other challenges, he had to discontinue this invention, as it contravened its users' privacy.

Not deterred by this unexpected hurdle, he proceeded to investigate other avenues where he could put his enthusiasm and innovative thinking to use to benefit society. "I had acquired valuable skills in entrepreneurship and innovation management." This included participating in the UP Business Incubator programme, and an opportunity provided by the TIA to attend an Executive Education Programme in Business Administration, Management and Operations at Emory University's Goizueta Business School in Atlanta, Georgia, in the USA.

In 2016, he completed a Leaders in Innovation Fellowship with the Royal Academy of Engineering, in collaboration with Imperial College, which brings together the top young engineers in the global innovation community. He also furthered his academic qualifications through an Advanced Diploma in Business Project Management at the University of Cape Town and an honours degree in Business Informatics at the University of South Africa. He then enrolled in the Gordon Institute for Business Science (GIBS)'s Entrepreneurship Programme.

In addition to the Motswadi System, Bapela had a couple of other inventions in his portfolio. Collaborating with UP's Technology Transfer Office, he filed a patent for BSMARD, a smart-card wallet to relieve individuals who carry heavy wallets with multiple cards. It made use of cloud storage with encryption and biometric security for access. He also developed a digital communication platform for the Royal Bafokeng Platinum Mine. It incorporated features such as announcements, safety alerts, production statistics and RBPlat radio on a user-friendly dashboard. Another invention was Cyber Guardian™, an early depression detector cyber-bot built on artificial neural networks. It had a customised dashboard that displayed mental risk levels, personalised advice and recommended activities. In case of an emergency, it used GPS to identify local help centres, such as hospitals, surgeries and social workers.

These inventions earned him recognition in various forms. The Royal Academy of Engineering in the UK recognised him as one of the world's top young engineering and technology experts. In 2017, he received the International Telecommunication Union (ITU)'s Telecom World Award as one of the top innovative small businesses. In 2019, he was a finalist at the South African Innovation Summit's grand finale (the Africa Cup) for his Cyber Guardian™ invention.

In 2020, Bapela established Idigitize, a company that specialises in robotics, app development, digitisation strategies and training. Its aim is to achieve complete artificial intelligence (AI) through cutting-edge algorithms.

He also co-founded Cyruze in 2022, a no-code app development platform built on Web 3.0. It enables people without technical skills to build their own mobile apps, which they can then publish to the various online app stores. He considers it a form of democratising digital technology.

However, what has been keeping him busy for the past two years is an initiative that is set to revolutionise the healthcare industry. He is a creative strategist and national manager of Class Three Medical Solutions, where he leads a team of engineers, sales executives and inventory controllers. His current role entails ensuring that the company's goals are aligned with local market conditions, customer needs and the regulatory requirements.

"The company is dedicated to saving lives by providing state-of-the-art medical equipment that is manufactured to meet current and future industry expectations. Our devices are equipped with central monitoring systems that enable clinical staff to monitor patients' vital signs remotely."

These patient monitors are incorporated into neonatal ICU incubators and infant warmers, as well as ventilators and respiratory devices, ensuring effective patient management and care without clinical staff being present all the time. As these devices are mobile, they bring AI into the hospital setting, reducing risks associated with human error. The equipment is already in use in many hospitals countrywide, including rural hospitals.

Bapela considers these devices to be crucial in bridging the digital divide and ensuring an inclusive economy for healthcare services.

Disrupting the norm
in higher education

Preparing learners for the future entails more than just ensuring that the curriculum content remains up to date and in touch with the latest developments in industry. It means preparing them for the university classroom of the future. The idea of traditional pen and paper, and an overhead projector or presentation screen being augmented by a pair of digital headsets and a pointer, and the classroom space being substituted by an alternate universe may sound like science fiction, but it is the reality – the virtual reality!

The Faculty of Engineering, Built Environment and Information Technology (EBIT) has embraced the concept of immersive learning as an innovative teaching approach to provide learners with a deep experience of reality. Through virtual reality (VR) tools, we are not just able to take the classroom to a remote and unsafe environment, such as an underground mine, but it is hypothetically possible to teach students to operate equipment in the virtual space before they are exposed to the actual machinery in the laboratory. This not only reduces the chance of accidents, but increases accessibility. Dean of the Faculty, Prof Wynand Steyn, believes that exposing students to emerging teaching technologies in a transdisciplinary fashion allows them to make the mindshift towards a future in which their unique talents and experiences will further the development and growth of sustainable communities. XR expert, Koos de Beer, explains that extended reality (XR) technologies allow one to design interfaces that can enable intuitive interaction with virtual environments. It exposes users to real-world projects and enables them to test multiple solutions in a fail-safe environment.

The Faculty continues its work to take the concept of immersive learning further. This starts with getting young people excited about the expansive possibilities that the future holds. EBIT also realises that the future is transdisciplinary. Collaborative recruitment drives featuring the University's Faculty of Health Sciences, Faculty of Natural and Agricultural Sciences, and Faculty of Veterinary Science are exposing prospective students to career opportunities across science, technology, engineering and mathematics (STEM) fields. The Faculty's marketing and recruitment teams are empowering learners from all corners of the country to visualise their future and find a place where they can make a difference. T

Our footprint, our impact

29
undergraduate degree programmes

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postgraduate degree programmes

14 specialised academic departments

QS-rated subjects

- MECHANICAL AND AERONAUTICAL ENGINEERING
- COMPUTER SCIENCE AND INFORMATION SYSTEMS
- CHEMICAL ENGINEERING
- MINERAL AND MINING ENGINEERING
- ELECTRICAL AND ELECTRONIC ENGINEERING
- MATERIALS SCIENCE

4 Schools

- School of Engineering
- School for the Built Environment
- School of Information Technology
- Graduate School of Technology Management

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Academic staff members with a doctorate

100
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EBIT boasts over **90 laboratories** across three of the University's campuses, including:

- UP's state-of-the-art **Engineering 4.0 Complex**
- Africa's first **Virtual Reality Centre for Mine Design**
- **Immersive Technology Laboratory** accessible for all UP students
- **Boukunde Living Laboratory** for architecture and the built environment

Brace for impact

EBIT embraces the concept of interactive immersive technology to provide students with a deep experience of reality. Through virtual reality tools, we immerse students in the learning experience to expose them to the work they will be doing when they enter industry in a fail-safe environment. This allows students to make the mindshift towards a future in which their unique talents and experiences will further the development and growth of sustainable communities. The Faculty of Engineering, Built Environment and IT offers study and research opportunities across these fields – placing us in a position to conduct exceptional multidisciplinary research to address relevant challenges in society.

The School of Engineering is ranked **334TH** out of more than 10 000 engineering schools in the field of engineering & technology.

TOP 400

RANKED GLOBALLY FOR CHEMICAL ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

UP stands out as the premier choice for aspiring chemical engineers due to its unparalleled commitment to excellence, innovation and global impact. Our curriculum is uniquely designed to equip students with the skills and knowledge necessary to address pressing global challenges, particularly in Africa, where sustainable development is paramount. Through cutting-edge research and practical experience, graduates are prepared to tackle issues such as access to clean water, renewable energy solutions and environmental conservation.

The bachelor's programme is fully accredited by the Engineering Council of South Africa (ECSA), which attests to its sustained quality and international reputation. In addition, the 2024 QS World University Subject Rankings placed the Department in the top 400 globally.

The Department takes pride in its distinguished alumni, who have left indelible marks on various industries and sectors. These include notable figures like Honey Mamabolo, a former Managing Director of the South African Mint, and Dr Pulane Molokwane, who served as a Planning Commissioner in the Presidency of South Africa.

Our final-year students have a track record of developing groundbreaking solutions. A recent project focused on the development of a novel wastewater treatment system using plasma technology, showcasing UP's commitment to pushing the boundaries of conventional engineering.

Through strategic partnerships with leading universities and research institutions worldwide, UP fosters a diverse and dynamic learning environment that encourages global perspectives and cross-cultural understanding.

Choosing UP for a degree in chemical engineering offers unparalleled opportunities for personal growth, academic excellence and meaningful contributions to global challenges. With a strong emphasis on innovation, sustainability and international collaboration, you will be equipped with the skills and mindset needed to thrive in an increasingly interconnected world.

DEPARTMENT OF CIVIL ENGINEERING

The Department of Civil Engineering is a renowned hub of excellence in engineering education and research, both locally and internationally. The Department has consistently evolved to meet the demands of the rapidly changing engineering landscape. At the heart of its success lies a robust curriculum that covers a breadth of subjects, from structural engineering and transportation to hydraulics, water resources and geotechnical engineering. This holistic approach ensures that graduates are adept at addressing real-world engineering challenges upon completion of their studies. The Department's crown jewel is the Engineering 4.0 Facility, providing students with cutting-edge laboratory resources for hands-on learning experiences. Under the mentorship of staff members, who are mostly professionally accredited and internationally recognised in their respective fields, students engage in pioneering research that encompasses infrastructure planning, design, construction and maintenance.

A unique characteristic of the Department is that it integrates electronic technologies into civil engineering applications to innovate and advance the profession. Typical applications include structural health monitoring, smart infrastructure, geospatial technologies using drones and robotic platforms, as well as construction automation. Forging strong industry ties, the Department collaborates closely with leading engineering companies and government agencies in Europe and the United Kingdom, the USA, China, Australia and many African countries, enhancing students' learning through exposure to real-world projects and amplifying their employability upon graduation.

DEPARTMENT OF ELECTRICAL, ELECTRONIC AND COMPUTER ENGINEERING

Graduates of the Department of Electrical, Electronic and Computer Engineering become pioneers in global technological innovation and make a tangible impact on the world. The Department offers unique study and research opportunities in its three fields of specialisation.

With courses that cover every aspect of modern technology, students receive a practical education that prepares them for a dynamic career in engineering. Our department does not just teach engineering; we shape the future. Our cutting-edge education is focused on laying the foundations to ensure that our graduates are ready to tackle the tough, but important problems of the day.

Our lecturers are not only renowned researchers, but also industry leaders, providing invaluable insights and mentorship to our students. Students undertake innovative final-year projects, like creating a system for speech enhancement, which makes use of a moving speaker that utilises microphone arrays and beam-forming techniques. Graduates join the ranks of top engineers and entrepreneurs.

Our programmes offer students the hands-on experience necessary to excel in industry by immersing them in real-world challenges. Under lecturers' expert guidance, students learn to apply their knowledge and skills to develop creative solutions under practical constraints. Whether they aspire to lead groundbreaking research, launch their own start-up, or make a positive impact in their community, the Department empowers students to turn their ambitions into reality. Partner with the Department of Electrical, Electronic and Computer Engineering to embrace the opportunity to shape the future and become a part of something extraordinary.

TOP 400

RANKED GLOBALLY FOR ELECTRICAL AND ELECTRONIC ENGINEERING

UP's Department of Electrical, Electronic and Computer Engineering has been ranked **top in South Africa** in the fields of electrical and electronic engineering in the QS World University Rankings by Subject for five years running.

DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

UP's Department of Industrial and Systems Engineering is the premier industrial engineering department in South Africa and Africa. We graduated our first cohort in 1963. Consequently, we have produced the most industrial engineers in South Africa, both practitioners and academics. We have continued to maintain our rich tradition, and to evolve with time to remain relevant and at the cutting edge of industrial engineering globally.

Industrial engineering training involves training across a number of engineering disciplines. Coming to UP is an opportunity to be part of an elite engineering training institution in Africa. Studying industrial engineering at UP guarantees you one of the best training offerings you could have internationally, and our graduates are well sought after, not only in South Africa, but all over the world. Not only will you receive the all-round development in critical thinking that is expected of an industrial engineer. You will also have the opportunity to acquire cutting-edge industry skills and certifications, and learn with some of the most advanced training technologies, like the virtual and augmented reality solutions that are currently being deployed across a large spectrum of our Faculty's training programmes, including industrial engineering.

The age and size of our department means we have a large network of alumni, which you will join when you graduate. This can be one of the biggest prizes you will take with you as you complete your studies with us, as you access a large network of industrial engineering professionals built up over a long time.

The Minerals Engineering Trust Fund (METF) distinguishes the Department of Materials Science and Metallurgical Engineering at the University of Pretoria as the premier metallurgical engineering department in South Africa.

TOP 36

RANKED GLOBALLY FOR MINERAL AND MINING ENGINEERING

DEPARTMENT OF MATERIALS SCIENCE AND METALLURGICAL ENGINEERING

The discipline of metallurgy is one of humanity's oldest professions, with archaeological evidence tracing crude smelting back to the Copper Age (~3500 BC), and the publication of the seminal work, *De Re Metallica* by Georgius Agricola in 1556. Despite its ancient roots, this field, which now encompasses materials science, remains dynamic, and is continuously advancing to address contemporary challenges such as resource sustainability, the circular economy and global environmental concerns. The Department of Materials Science and Metallurgical Engineering at the University of Pretoria boasts a cadre of highly qualified and experienced lecturers and support staff. Our team is committed to enriching the educational experiences of our students.

Established in 1958, the Department has undergone continual evolution to meet the evolving demands of the metallurgical domain. Our curriculum, which is recognised as one of the most comprehensive globally, spans the breadth of metallurgy, and encompasses minerals processing, hydrometallurgy, pyrometallurgy, physical metallurgy and welding. This holistic approach equips our graduates to tackle real-world engineering challenges adeptly.

Housed in the recently refurbished Minerals Science Building, the Department enjoys state-of-the-art laboratories and resources, fostering an environment that is conducive to cutting-edge research and learning. Our strong industrial partnerships ensure that our research and teaching remain relevant and responsive to emerging technologies, such as green processing methods and the circular economy. We are privileged to receive sponsorships from industry partners, which facilitate pioneering research endeavours.

DEPARTMENT OF MINING ENGINEERING

The mining industry is a major force in the world economy, occupying a key position at the beginning of the resource supply chain. Mining engineers from the University of Pretoria are proudly at the forefront of tackling global challenges, growing the economy in South Africa and ensuring a supply of critical minerals to all sectors in the economy. Mining operations have the potential to develop people and communities, and to bring about impressive engineering innovations.

As a student, you will be involved in other interesting projects. Some of our students work on projects using extended reality (XR) and virtual reality (VR) to train mine operators to identify hazards. Some of these students also use state-of-the-art technology, such as numerical modelling programs, to design more productive and safer mines.

Studying at the University of Pretoria will also give you access to our international partners. We collaborate with the University of New South Wales in Sydney, Australia, on methods to design improved mining layouts. As a qualified mining engineer, you will be sought after to work in countries such as Canada and Australia, where there are a shortage of mining engineers.

DEPARTMENT OF MECHANICAL AND AERONAUTICAL ENGINEERING

UP's Department of Mechanical and Aeronautical Engineering is ranked No. 1 in South Africa and is ranked in the top 300 (according to the 2024 QS rankings) and the top 200 (according to the 2023 Shanghai rankings) for mechanical engineering globally.

We have a strong emphasis on excellence in teaching and research. Our committed and knowledgeable team is well equipped to support learning and the development of technical skills, from undergraduate to postgraduate levels. We offer a unique learning environment with opportunities for the practical application of theoretical knowledge in activities like the Tuks Baja team and the AREND flight project.

An exchange programme with the Massachusetts Institute of Technology (MIT) in the USA makes it possible for students to study at MIT for a year, and for MIT students to study at the University of Pretoria for a year.

Our internationally esteemed research groups in the fields of physical asset integrity management, vehicle dynamics and clean energy are generating excellent, state-of-the-art research that has significantly impacted on a number of fields, including concentrated solar power systems, novel and enhanced heat transfer phenomena, off-road tyre parameterisation, vehicle collision management systems, vibration monitoring and turbine conditioning monitoring.

The Department boasts world-class facilities that include many well-equipped experimental laboratories that are designed to assist teaching, learning and research in dynamics, structural mechanics, thermodynamics and fluid mechanics, as well as software laboratories for simulation and data-driven education and research.

TOP 300

RANKED GLOBALLY FOR MECHANICAL AND AERONAUTICAL ENGINEERING

UP's Department of Mechanical and Aeronautical Engineering has been ranked **top in South Africa** in two separate international ranking systems.

GRADUATE SCHOOL OF TECHNOLOGY MANAGEMENT

Engineering, technology and innovation management is a globally evolving discipline. The increasing complexity of engineering projects, systems and activities, the scope and sophistication of resources, as well as advances in technology have all been driving forces in the evolution of this field.

The Graduate School of Technology Management (GSTM) offers internationally recognised postgraduate programmes. These programmes are offered at honours, master's and doctoral level and address different needs in the field of engineering management, technology and innovation management, as well as project management. The GSTM 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 (GAC) of the Project Management Institute, USA.

In addition to its academic programmes, the GSTM is also involved in community activities and offers several certificate programmes and short courses in collaboration with Enterprises University of Pretoria. The goal is to develop individual and organisational skills gained from research-based knowledge offered by experienced lecturers who are leaders in industry.

A strong focus is placed on high-quality research and excellent teaching and education. Research ensures relevance to the market in terms of increased international competitiveness, optimising product life-cycles, technology transfer and the positioning of technological abilities within the international context.

DEPARTMENT OF ARCHITECTURE

The following aspects of the University of Pretoria's undergraduate Architecture programme set it apart from other programmes offered in the country:

- The emphasis on community engagement, wellbeing and environmental responsibility in the curriculum instils an ecosystemic ethos based on principles of regenerative design, which prepares our students for their responsibilities as professionals, who are able to respond to the challenges of the 21st century.
- The vertical integration of the different curriculum streams provides a coherent narrative of engaging with the knowledge that builds from first-year to third-year and beyond into the Department's postgraduate programmes.
- The horizontal integration of the theory explored in the various modules in each year, with design outcomes in each year, ensures that students understand how the theory is applied in practice.
- Students are exposed to a multidisciplinary learning environment where the disciplines of interior architecture, architecture, urban design and landscape architecture are treated as one integrated spatial design continuum.
- The University of Pretoria was ranked 42th globally in the 2024 Times Higher Education Impact Rankings, which measures work towards the United Nations' Sustainable Development Goals.

DEPARTMENT OF CONSTRUCTION ECONOMICS

As the construction industry is a significant contributor to global CO_2 emissions, graduates can contribute to the global challenge by joining the international drive to reduce CO_2 emissions in industry. This can be done, for example, through net positive or green buildings that reduce CO_2 in the atmosphere rather than adding to it. Graduates in Construction Economics can contribute by developing (real estate) and constructing (construction management) net positive buildings, and conducting lifecycle assessments on embodied carbon (quantity surveying).

The Department is accredited by international industry bodies for all its degree programmes, including the Royal Institution of Chartered Surveyors (RICS) and the Chartered Institute of Building (CIOB). It also collaborates with BA ISAGO University (Botswana), Federal Polytechnik University (Nigeria), Kufstein FH Tirol (Austria), the Association of South African Quantity Surveyors, Green Building Council South Africa, Atterbury Properties, York Timbers, the Pacific Association of Quantity Surveyors, RLB (cost benchmarking; Crane Index), CIB (Task Group 124: Net Zero Carbon: Building Design & Construction).

DEPARTMENT OF TOWN AND REGIONAL PLANNING

Cities across the world are changing rapidly. Urban systems and spaces are changing to accommodate moving people and new functions. This is driven by things like population growth, migration, climate change, economic decline in rural areas and political instabilities. Graduates from the Department of Town and Regional Planning can contribute to mitigating and addressing challenges globally and in Africa. They do this through a detailed and well-rounded understanding of the causes and possible solutions to deal with rapid change. This will contribute to more resilient cities, and harvest the potential inherent in cities to create healing and thriving environments.

Our research positions the Department to make an impact in practice with industry-relevant projects related to resilience, green infrastructure, regenerative public space, mining and municipal capacity building, planning interventions for township businesses, informality and transdisciplinarity in planning research. Some of our key research projects include work on municipal governance and capacity building, spatial transformation, housing development trends and regenerative public space. Members of the Department are currently working with the University of Amsterdam (The Netherlands), the Technical University of Berlin (Germany), the Sydney University of Technology (Australia), the University of Cardiff (United Kingdom), the University of Alto (Helsinki, Finland) and the University of New Delhi (India).

The Faculty' School of Information Technology is a forerunner in the South African IT environment, with its unique integration of the fields of computer science, informatics and information science. The School is also a proud member of the international iSchools Organization.

TOP 650

RANKED GLOBALLY FOR COMPUTER SCIENCE AND INFORMATION SYSTEMS

The Department of Computer Science is ranked among the **top 1%** of computer science departments in the world based on citations of its research outputs, according to the Essential Science Indicators.

DEPARTMENT OF INFORMATICS

Studying informatics or information systems at the University of Pretoria is a smart choice if you are interested in technology and its impact on the world. In today's digital age, where technology is crucial for businesses in every industry, this field offers diverse career opportunities.

In the Department of Informatics, you will gain practical skills in areas like system analysis and design, software development, databases, critical thinking and data analytics. With hands-on learning experiences such as our capstone project, you will be able to apply what you learnt to real-world situations. For the capstone project, you will engage with a real-world industry client, document their software solution requirements, design their system by writing the software code, and test the system to ensure that the solution is working according to the industry client's requirements.

Our degrees' international accreditation with the Accreditation Board for Engineering and Technology (ABET) means that you are well prepared for the job market. In addition, the Department's supportive learning environment and dedicated lecturers will ensure that you receive the help you need to succeed.

Informatics is an exciting field with endless possibilities for innovation and growth. If you are therefore passionate about technology and eager to make a difference, studying Informatics at the University of Pretoria is the perfect fit for you!

DEPARTMENT OF COMPUTER SCIENCE

The Department of Computer Science fulfils a vital role within the broader information technology (IT) spectrum in South Africa, as well as internationally. Its main objective is to explore and research the scientific basis of new technologies. It furthermore promotes the proliferation of reliable, robust and innovative computing and information technologies into South Africa's IT industry.

Excellence in computer science education, the development of internationally and nationally recognised research initiatives, and strong industry collaboration are the driving factors that underpin the Department's success. Its researchers work in the areas of artificial intelligence, computer and information security, digital forensics, computer science education didactics and applications, system specifications and formal methods, software engineering and software architecture, and data science. In addition to its bachelor's degree in Computer Science, the Department also offers a cutting-edge undergraduate programme in Information and Knowledge Systems.

The Department has established itself as a very strong research entity, both nationally and internationally. It is ranked among the top 1% of computer science departments in the world based on citations of its research outputs, according to the Essential Science Indicators. It is also ranked in the top 650 in the world for computer science and information systems according to the QS World University Subject Rankings.

DEPARTMENT OF INFORMATION SCIENCE

The Department of Information Science is concerned with how information is generated, organised, circulated and utilised in society. It houses programmes in three unique information-related fields: information science, multimedia and publishing. By leveraging the knowledge gained at UP, graduates can contribute significantly to addressing information access disparities, digital literacy issues and data management challenges that are prevalent in Africa and globally.

- The Information Science programme focuses on the use of information technology and the processing of information products. It is designed to train students in the management, retrieval, organisation, packaging and distribution of information, thereby adding value to it.
- The Multimedia programme is an IT-focused degree that is situated at the intersection of computer science, graphic design and web development. It trains students to work in a team of developers and designers by furthering their understanding of design, animation and game design.
- The Publishing programme teaches publishing theory and skills that enable students to select and develop content based on the needs of the user, and to appropriately package this content through a process of adding value. It offers students access to the full publishing value chain.

UP's affiliation with the iSchools Organization signifies its dedication to advancing research and innovation in information science, providing students with a platform to engage in groundbreaking projects with real-world implications. This partnership opens opportunities for collaboration on projects that have a meaningful impact on information dissemination and management on a global scale.

ENGINEERING FIVE-YEAR PROGRAMME

The five-year programme provides a carefully structured curriculum to help students adjust to university life and cope with its academic demands. It is offered in all engineering disciplines. It is a five-year programme, in which the volume of work is gradually increased, while the support provided is decreased over a period of three years. However, the workload is high from the beginning.

Students take the same first-year modules as students following the four-year degree programme, and attend the same classes, but the modules are spread out over two years. In their third year of study, students take the remaining second-year modules, while they follow the same programme as the four-year degree programme in their last two years of study.

READ MORE ABOUT THE PROGRAMME

a home for entrepreneurs

TuksNovation is a non-profit company for technology incubation and acceleration that is located at the University of Pretoria. It acts as a catalyst for the development of business technology clusters to positively impact on the South African economy.

INNOVATION COMMERCIALISATION

In a knowledge-driven economy, universities play a major role in regional socio-economic development. Innovations arising from a university's intellectual capital can stimulate economies through new product development. Universities are thus highly valued in terms of economic potential. The creation of spin-offs is one of the key mechanisms that universities can leverage to promote socio-economic development.

SUPPORT FOR STUDENTS

TuksNovation provides technology development and entrepreneurship support, from the prototype to the commercialisation growth stages, to ensure that the technology is fully developed, and addresses a relevant market need. A virtual incubation programme focuses on technology and techno-entrepreneurship skills, while an acceleration programme focuses on commercialisation and business growth.

TuksNovation
ACCELERATING INNOVATION

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