Innovate:

Issue 18 2023

IMPACT TOMORROW

The transdisciplinary classroom

Immersive learning

Transforming circular construction

Improving the daily commute

AI and machine learning

Ethics of ChatGPT

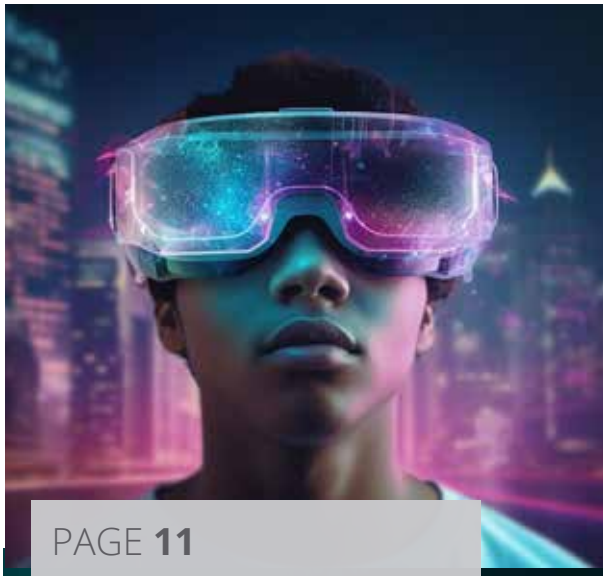
UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology

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

Make today matter

Inside



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





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FACULTY NEWS

Innovate:

Issue 18 2023

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

Editorial note: *As a South African publication,* Innovate *uses the term "faculty" to refer to an academic structure within a university, used generally to denote a faculty such as the Faculty of Engineering, Built Environment and Information Technology. It does not denote academic staff members, in the sense that "faculty" is used in some other countries.*

ON THE COVER

IMPACT TOMORROW

The research and academic activities in the various departments of the Faculty of Engineering, Built Environment and Information Technology are making an impact on the global challenges contained in the United Nations' Sustainable Development Goals. Their outputs impact tomorrow beyond the traditional disciplines of engineering, the built environment and information technology.

PUBLISHER

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Impacting on 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 focuses on six research areas that contribute significantly to addressing these societal challenges. These comprise the following:

- Smart cities and transportation
- The Fourth Industrial Revolution
- Energy
- Big Data Science, Information and Communication Technology, and Technology and Innovation Management
- Water and Environmental Engineering
- Minerals and Materials Beneficiation

In a recent evaluation of the research outputs of its four schools, scientifically quantified using artificial intelligence (AI) tools based on machine learning and deep learning, more than 4 000 publications disseminated between 2005 and 2022 were considered to determine their contributions to the SDGs. The schools were collectively found to have contributed significantly to quality education, affordable and clean energy, industry innovation and infrastructure, sustainable cities and communities, responsible consumption and production, climate action, and partnerships for the goals.

In this edition of *Innovate*, you will once again find a selection of exciting contributions to the research and educational activities of the Faculty, which illustrate the impact of its research, and its teaching and learning activities.

They 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.

Embedded in these articles is the contributors' commitment to maintaining the Faculty's research-intensive, transdisciplinary focus, which is aimed at developing holistic, cross-cutting solutions that transcend traditional disciplinary boundaries. These articles furthermore reflect the Faculty's cutting-edge research, which makes a difference to society through its impact.

Happy reading!

Prof James Maina
Editor

RESEARCH IN THE FACULTY IS FOCUSED ON IMPACTING GLOBAL CHALLENGES

MESSAGE FROM THE DEAN

Prof Wynand JvdM Steyn
Dean: Engineering, Built Environment and Information Technology

The Faculty of Engineering, Built Environment and Information Technology (EBIT) is home to a generation of leaders and innovators dedicated to making a difference – in their communities and cities, the country and the world.
It is a source of internationally competitive programmes, and harbours some of the University's exceptional researchers.

The heartbeat of the Faculty is innovation: finding novel solutions that lead to real-world change. Its students and researchers are therefore ensuring that they can contribute to society at large by focusing on topics that will solve global challenges and change the world for the better, to the benefit of both the people that inhabit it, and the planet that provides it with its source of sustenance.

In this way, the Faculty supports its students and researchers to positively impact the lives of their families, their country and the world. The ultimate goal of the academic and research staff in its 14 departments is for their students to be the change they want to see in the world through innovative and cutting-edge research, and collaborative community engagement.

From their first year of study until they graduate and enter the world of work or enrol for postgraduate studies, our students are encouraged to do more than qualify for a given profession. They are urged to recognise that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability. They are therefore nurtured to become engineers who solve engineering challenges for future generations, built environment practitioners who create sustainable solutions for society, and information technology specialists who use the disruptive technologies of the Fourth Industrial Revolution to the utmost benefit of the human race.

Our students and researchers are increasingly concerned about the future of humanity, particularly in terms of global challenges such as energy security, food security, infrastructure security and data security. Their understanding of the consequences of not addressing these challenges drives them to seek solutions that extend beyond the traditional disciplines of engineering, the built environment and information technology.

A contributing element is that the boundaries between disciplines are becoming increasingly vague, which causes professionals to seek solutions for challenges that are not in their expected field of expertise.

This has also brought about an expansion of the traditional roles covered by the Faculty's fields of study so that graduates can predict future challenges and make a difference by developing global solutions that support life within every discipline – the health sciences, the natural and agricultural sciences, the social sciences, and the economic and management sciences.

The **engineer** is therefore focused on designing things to support life beyond traditional engineering concepts, such as enhancing water security by improving the country's dams and sewerage works, and designing sensors to determine water quality. The **built environment professional** focuses on designing and planning locations to support life, such as clinics and schools that are easily accessible to people in rural areas, houses close to job opportunities and infrastructure that provides efficient transportation.

THE HEARTBEAT OF THE FACULTY IS INNOVATION: FINDING NOVEL SOLUTIONS THAT LEAD TO REAL-WORLD CHANGE. WE STRIVE TO CONTRIBUTE TO SOCIETY AT LARGE BY FOCUSING ON TOPICS THAT WILL SOLVE GLOBAL CHALLENGES AND CHANGE THE WORLD FOR THE BETTER, TO THE BENEFIT OF BOTH THE PEOPLE THAT INHABIT IT, AND THE PLANET THAT PROVIDES IT WITH ITS SOURCE OF SUSTENANCE.

The **specialist in information technology** is focused on data to support life, ensuring access to data, the security of data, and information and communication technologies that support health, education and food security, including the application of elements such as Big Data and Artificial Intelligence (AI). The **technology and innovation manager** is focused on ensuring that management processes can support life using effective innovation and technology management systems.

The Faculty's strategic vision is to develop critical mass and synergies that can contribute to solving the global challenges that form part of the United Nations' Sustainable Development Goals (SDGs). Its research focuses on impact: making a difference to society and the world by heeding the global call to action to end poverty, protect the earth's environment and climate, and ensure that people everywhere can enjoy peace and prosperity.

Against this background, its research activities are concentrated on building resilient infrastructure, promoting inclusive and sustainable industrialisation, and fostering innovation, making cities and human settlements inclusive, safe, resilient and sustainable, ensuring access to affordable, reliable, sustainable and modern energy for all, and ensuring sustainable consumption and production patterns. At the same time, it does not disregard the importance of the other sustainability objectives related to alleviating poverty and hunger, promoting good health and well-being, quality education, gender equality, clean water and sanitation, decent work and economic growth, and reduced inequalities.

Keeping our eyes fixed on the future, we will continue to pursue innovation, while maintaining relevance for present challenges. At the same time, we will embrace the digital transformation process to ensure that its impact on individuals and organisations will improve the well-being of both people and the planet. We will continue to "innovate our tomorrow", ensuring that the difference we make will be felt by all the generations to come.

Message from the Deputy Dean:

Research and Postgraduate Education

Prof James Maina

The Faculty of Engineering, Built Environment and Information Technology (EBIT) focuses its research on making a significant contribution to society, particularly on the most pressing challenges of the developing world. The Faculty 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 or transdisciplinary impact that can be applied locally, regionally and globally.

The Faculty is one of the few academic faculties in Africa to feature among the top 550 in the world in six subject areas in the 2023 QS World University Rankings by Subject in the field of engineering and technology. These are architecture, computer science, chemical engineering, electrical and electronic engineering, mechanical engineering, and mineral and mining engineering. These rankings are based on academic and employer reputation, staff-to-student and international staff-to-student ratios, and citations. This reinforces EBIT's recognition as a faculty that is comparable to the best in the world.

The Faculty's 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.

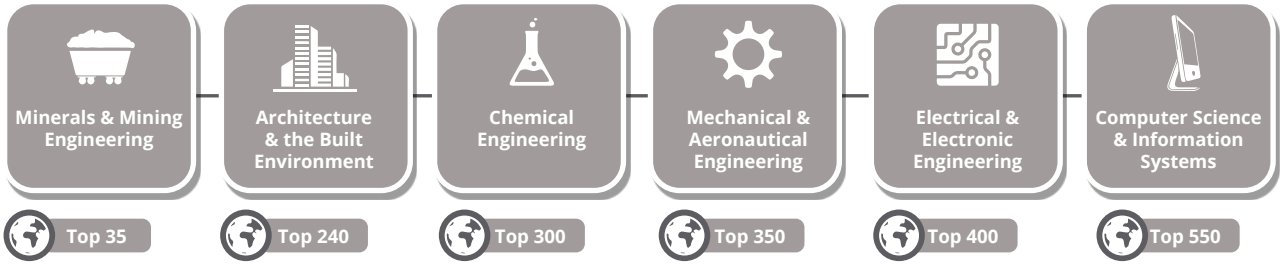
According to the International Alliance of Research Universities (IARU), the purpose of a research-intensive university is to make groundbreaking discoveries, and to seek and transmit knowledge and new understanding in its own right, and to the benefit of society. Academics from such universities are expected to assume a technology transfer role, and to focus on economic development in collaboration with the public and private sectors. This is at the top of the Faculty's quest for research-intensivity.

The Faculty's research strategy further acknowledges the call for action contained in the University's Strategic Plan for 2025, which recognises that "business as usual" is not an option. New and innovative ways of thinking are required for its continued existence, relevance, competitiveness and sustainability. As a public university, the University of Pretoria – and by extension, each of its nine faculties – is responsive to national priorities and global challenges.

Accordingly, the Faculty encourages its researchers to take cognisance of national, regional and global commitments such as those contained in South Africa's National Development Plan, its National Infrastructure Plan and the Human Resource Development Strategy for South Africa, as well as the African Union's Agenda 2063 and the United Nations' Sustainable Development Goals (SDGs).

To achieve this, the Faculty strives to strengthen the University's research profile, international reputation, global engagement, and social responsiveness and impact on society. Against this background, the Faculty is developing a research, development and innovation strategy that will improve collaboration across its departments and schools, as well as among different faculties within the University and with other institutions, both locally and internationally. This entails performing basic and applied research, which culminates in developing new or improved products and processes to bring research into the realm of the man in the street.

QS World University Rankings by Subject



This will be done, among other things, by expanding the existing relationships and trust among researchers, and developing new ones. At the same time, it plans to incentivise multidisciplinary and long-term collaborations by developing interdisciplinary teams for multiyear flagship projects. These could be supported through bilateral or multilateral collaborations with alumni, government, industry and other institutions.

The guiding principle in the Faculty's research strategy going forward is to ensure it remains responsive to national priorities and global challenges. This requires the continued development and implementation of innovative research and postgraduate strategy, as well as the support of an enabling environment for departments to achieve their targets in research, and postgraduate supervision and throughput. Finally, it will encourage and enable interdisciplinary and transdisciplinary research and the forging of international academic links.

Through the collective expertise that is housed within the Faculty's 14 independent and complementary departments, its researchers have the potential to develop innovative solutions to South Africa's social and economic challenges. These can, in turn, address global challenges, as many of these problems are not unique to the developing world. The secret lies in cultivating our researchers' curiosity and imagination as they search for innovative solutions, and our postgraduate students' willingness and joy of working with and learning from others.

As a vibrant faculty, characterised by innovative and transdisciplinary collaborative interdisciplinary projects, EBIT can succeed in contributing to socioeconomic and environmental sustainability in alignment with the objectives of both the African Union and the United Nations. This will ensure our continued commitment to making a difference in every sphere in which our researchers and academics encounter a challenge with a potential solution that can improve quality of life.

EXCEPTIONAL FEATURES OF THE FACULTY

100
NRF-rated researchers

16
Externally funded research chairs

13
Research centres and institutes

72%
Academic staff members with a doctorate

28%
Estimated supply of South African engineers

IN A NUTSHELL

EBIT aims to be a leading research-intensive entity; making groundbreaking discoveries, while seeking and transmitting knowledge and new understanding in its own right, and to the benefit of society. Our academics are expected to assume a technology transfer role, and to focus on economic development in collaboration with government and industry. We aim to be responsive to national priorities and global challenges by encouraging collaboration across our departments and schools, as well as among different faculties within the University and with other institutions both locally and internationally. This entails performing not only basic and applied research, but developing new or improved products and processes that can bring research into the realm of the man in the street.

Message from the Deputy Dean:
Teaching and Learning

Prof Alta van der Merwe

The 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.

This year marked the first full year of face-to-face teaching following the online and hybrid approaches to teaching and learning that had to be put in place due to the COVID-19 pandemic. Despite the challenges posed over this time, the Faculty's teaching staff continued to come up with innovative solutions to overcome the limitations brought about by the lockdown restrictions.

This propelled the Faculty into a space where it can truly embrace teaching innovation. One such example is the application of virtual and augmented reality in its teaching. The Faculty 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.

However, this year also introduced us to a new technological development that has the potential to impact on the higher education environment in a hitherto unknown manner. This was the introduction of Artificial Intelligence (AI) and machine learning in the generation of content in the form of the Generative AI application ChatGPT.

The fundamental principle behind Generative AI is that these models can learn patterns in data and use this understanding to produce new content similar to the input data, but distinct and unique in its own right. It is set to change the way students and researchers search for information on the web, and is causing us to rethink traditional forms of teaching and learning.

Among the important matters that need to be considered from an academic point of view relate to ensuring data privacy and confidentiality, and upholding academic integrity.

Safeguarding the integrity of assessment and assignments, while ensuring the credibility of qualifications is a significant concern for universities, particularly those with large undergraduate classes like the University of Pretoria. Since the value of its qualifications depends on the integrity of its teaching and learning, it is essential for the Faculty to ensure that technological advancements that enter the public domain are used ethically and responsibly.

It is important to make students aware of the inherent risks associated with the technology. It is based on the application of large language models that do not truly comprehend semantic content. Instead, they generate text based on patterns and relationships between words identified during their training phase. They should thus serve as a tool to support learning, rather than a means to replace human creativity and critical thinking. They can therefore inadvertently produce inaccurate information.

However, the application can also be leveraged to enhance teaching, learning, assessment and student support. With its effective use, lecturers can enhance students' comprehension, foster critical thinking skills and aid them in their planning. Lecturers can also leverage Generative AI as a tool for planning and preparation and for various assessment-related purposes.

Students can use Generative AI to gain a deeper understanding of various subjects. In this way, they can use it as an effective tool to improve academic performance. However, its ethical and appropriate use is essential.

The Faculty's lecturers have already attended several workshops on exploring ways to maximise the benefits and ethical use of this disruptive technology, and the Faculty will continue to provide the necessary guidance in this regard.

The University's Department for Education Innovation has developed a guideline for lecturers to assist them in managing the minefield that this technology represents, and an official policy is being developed. The underlying principle is that it should be used ethically, and that lecturers and students should understand how to use it effectively for the utmost academic benefit.

One of the foundational steps is to educate students about the University's plagiarism policies. A comprehensive understanding of official policies, including the implications of using AI, can help students maintain a high standard of academic honesty.

To further reinforce these principles, implementing a rigorous honour code can be a constant reminder of the importance of academic integrity and the potential consequences of violating these principles.

As responsible users, students should prioritise ethical considerations, such as respecting privacy, avoiding discrimination, acknowledging the source of information, and critically evaluating the advice provided to ensure that their use of the technology benefits themselves and society as a whole.

EBIT PRIDES ITSELF ON EMBRACING INNOVATION IN THE TEACHING AND LEARNING SPACE IN ORDER 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 FOR US TO ENSURE THAT THE FACULTY KEEPS ABREAST OF THE LATEST TECHNOLOGICAL DEVELOPMENTS THAT MAY AFFECT STUDENTS' PERFORMANCE, SUCH AS GENERATIVE AI.

A **REIMAGINED** FACULTY

aims to make an **impact**

With the appointment of Prof Wynand JvdM Steyn as the new Dean of the Faculty of Engineering, Built Environment and Information Technology (EBIT) on 1 December 2022, and Prof James Maina as the Faculty's new Deputy Dean: Research and Postgraduate Studies on 1 March 2023, the Faculty is entering an exciting new era. They are supported by Prof Alta van der Merwe, the Faculty's Deputy Dean: Teaching and Learning.

THE FACULTY'S SLOGAN, "INNOVATING OUR TOMORROW" WILL KEEP IT ON THE PATH OF PURSUING INNOVATION THAT LEADS TO REAL-WORLD CHANGE ON THE OUTSIDE FOR THE GOOD OF HUMANITY AND THE PLANET, AND INNOVATION FROM WITHIN.

EBIT is the only faculty at a higher education institution in South Africa that offers a unique combination of four schools (for Engineering, the Built Environment, Information Technology, and Technology Management) in one place. This positions EBIT to conduct excellent transdisciplinary research that can address pertinent challenges in a global society. Its exceptional students and staff contribute actively to society and industries in their fields of specialisation. They possess highly technical skills, and are critical thinkers and problem solvers.

As such, EBIT's work relates to fields as diverse as artificial intelligence, Big Data science, robotics, machine learning, the planning and construction of green buildings, urban citizenship, technological innovation, water and environmental engineering, green energy, minerals and materials beneficiation, smart cities and intelligent transportation. These fields are all tied together through a common association with EBIT's four schools.

EBIT's strategic vision is to develop critical mass and synergies at the intersection of its research focus areas. It strives for excellence in the four schools that fall within its scope by ensuring that its researchers do not work in silos, but contribute to solutions to the global challenges that form part of the United Nations' Sustainable Development Goals (SDGs).

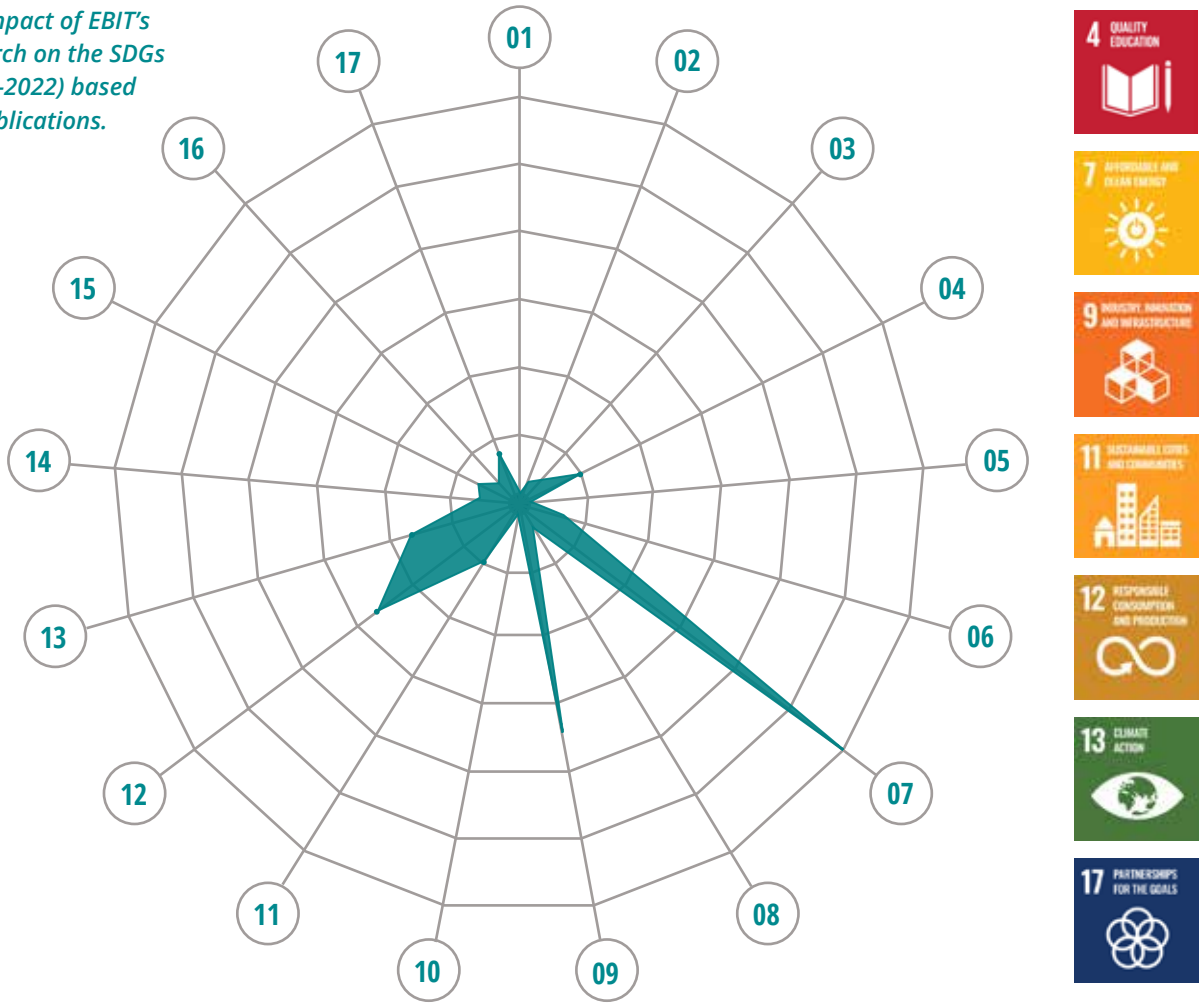
According to Prof Steyn, a priority is to develop and implement innovative research and postgraduate strategies, and promote a conducive environment where academics, researchers and students can make a difference and achieve their targets. This will be achieved by encouraging transdisciplinary research, establishing close ties with industry partners and supporting the forging of international academic collaborations.

In support of this, Prof Maina sees the Faculty increasingly engaging in innovative interdisciplinary research projects across departments and schools, as well as across faculties at the University of Pretoria and in partnership with other institutions, locally and internationally. In this way, he sees the Faculty contributing to South Africa's socioeconomic and environmental development, as well as that of the continent, supporting the solution of global challenges.

RESEARCH AND DEVELOPMENT

Prof Maina believes that research and development covers three activities. "Basic research is experimental or theoretical work undertaken primarily to expand and generate new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view." It is an original and planned investigation to obtain new knowledge and superior understanding in the scientific

The impact of EBIT's research on the SDGs (2015–2022) based on publications.



and technological field. The main outputs are publications. "Applied research," on the other hand, "is an original investigation that seeks to solve practical problems." It is directed primarily towards a specific practical aim or objective to obtain a sample, model or prototype to test and evaluate a concept or process. The main outputs are technology demonstrators.

However, innovative research is the ultimate research activity performed in EBIT. This is defined as experimental development that draws on existing knowledge. It is directed at producing new materials, products or devices, obtaining new processes, systems and services, or improving substantially on those already developed or installed. The main outputs at the heart of transdisciplinary research and development in engineering, the built environment, information technology and technology management are services and applications.

TRANSDISCIPLINARY RESEARCH

Research generally takes place within different disciplinarities: within a single discipline (intradisciplinary), viewing one discipline from the perspective of another (cross-disciplinary), working together with people from different disciplines (multidisciplinary), integrating knowledge and methods from different disciplines (interdisciplinary) and creating a unity of intellectual frameworks beyond disciplinary perspectives (transdisciplinary). "Transdisciplinary research is what the Faculty is striving for to improve its global ranking and impact," says Prof Maina. This will be achieved by participating in impactful, interdisciplinary flagship research projects, which will include bilateral and multilateral collaboration.

Prof Steyn believes that the Faculty's reputation will furthermore be enhanced by the visibility of its research impact, both on the continent and internationally.

FUTURE-FOCUSED RESEARCH

Prof Maina recognises the fact that impactful research in the Faculty's four schools is strongly linked to advancements in information and communication technology.

Such research is aligned with the evidence-based impact of artificial intelligence (AI) and machine learning (ML) tools. This has already started to pave the way for the Faculty's researchers to be recognised as leaders in their field.

However, the use of such tools for research and postgraduate education has certain practical implications. Their use should thus be guided by ethical considerations.

TEACHING AND LEARNING

Prof Steyn states that EBIT's undergraduate recruitment drive, focusing on prospective students who want to make the world a better place, should bear fruit, not in the distant future. These students will contribute to addressing global challenges by developing solutions that support life in every conceivable discipline. They are focused on the bigger picture: contributing to the world economy and job creation, food security, energy security and sustainable development.

He emphasises the importance of solid student support systems to ensure students can complete their qualifications in the minimum prescribed time. They should also receive effective academic support, assuring them of a firm foundation from which to launch their postgraduate studies, while nurturing an awareness of the importance of contributing their time and skills to communities that do not have the same advantages as they do.

At the postgraduate level, students are focused on making an impact through transdisciplinary, specialised research that addresses the global societal challenges contained in the United Nations' Sustainable Development Goals (SDGs). Collaboration with researchers at other institutions, locally and internationally, provides greater impetus to the impact of the Faculty's research outputs.

EBIT's teaching staff are supported by a dynamic teaching and learning strategy, which encourages them to develop creative approaches to transferring knowledge, thereby achieving improved academic performance. The focus on preparing students for the Future of Work forms an important part of this strategy. In this way, the Faculty ensures that its graduates are not just exceptionally qualified professionals, but can make a meaningful contribution in the workplaces they enter by being equipped with empathy and people skills.

According to Prof Van der Merwe, an important focus of the Faculty's Teaching and Learning portfolio is to embrace innovative teaching methodologies. This can be seen in its use of cutting-edge immersive technology tools, among others. It also keeps abreast of the latest technological developments that may affect students' performance. "We are closely monitoring the challenges associated with Generative AI, such as ChatGPT," she says. Lecturers have already attended several workshops on leveraging Generative AI to enhance teaching and learning, and maximise the benefits and ethical use of this disruptive technology. The Faculty will continue to provide the necessary guidance in this regard.

IMPACTING THE FUTURE

The Faculty's slogan, "Innovating our tomorrow" will keep it on the path of pursuing innovation that leads to real-world change on the outside for the good of humanity and the planet, and innovation from within. "We will strive to remain relevant by embracing change to create a peaceful and more sustainable planet," concludes Prof Steyn.

About the Dean

Prof Wynand JvdM Steyn is a qualified and registered civil engineer, who spearheaded the development of the Engineering 4.0 facility at the University of Pretoria. He is the former Head of the Department of Civil Engineering and Chair of the School of Engineering. His research interests include pavement engineering, structural design, and construction and rehabilitation of road pavements and instrumentation.

About the Deputy Dean: Research and Postgraduate Education

Prof James Maina is a qualified and registered civil engineer who continues to develop and build skills in his research areas of interest by supervising master's and doctoral students. His research interests include pavement engineering, mathematical, physical and numerical modelling, full-scale testing and instrumentation of road pavements and the characterisation of road building materials.

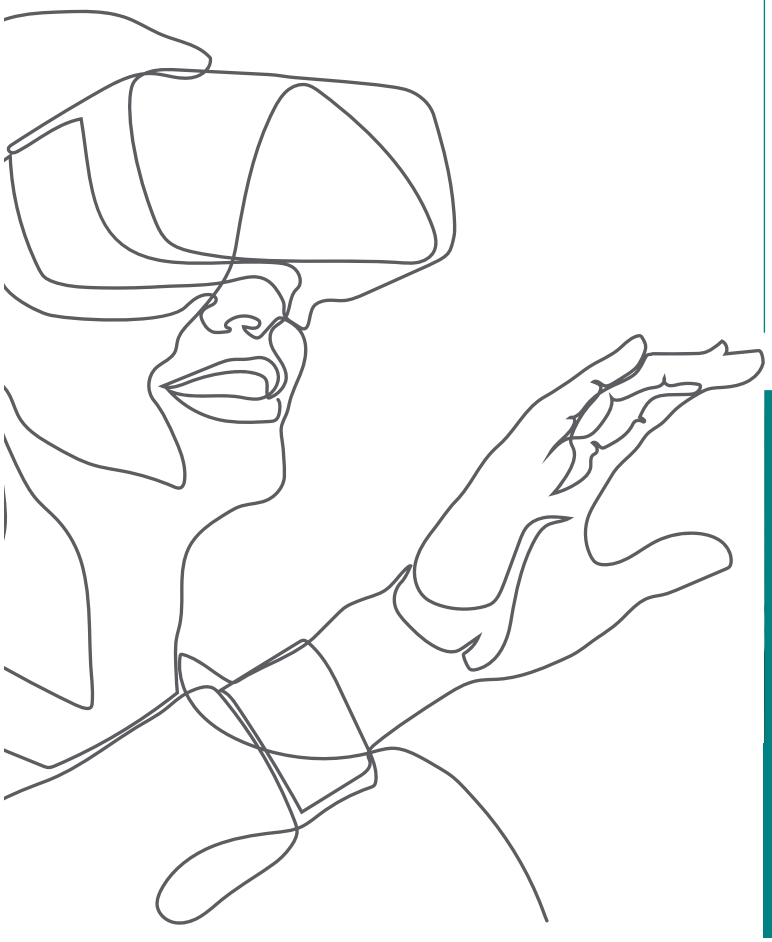
About the Deputy Dean: Teaching and Learning

Prof Alta van der Merwe is a qualified computer scientist. She is a former Head of the Department of Informatics, and still serves as a professor in this department. Her research interests include enterprise architecture, Society 5.0, design science research and theories supporting the successful use of technology organisations.

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.

Making use of virtual reality as a teaching tool is not a new initiative in the Faculty. A trailblazer in this space is the Department of Mining Engineering, which established a virtual reality training centre for its students in 2015. This facility comprises floor-to-ceiling screens on which 360° 3D images are displayed with cinematic clarity and highly realistic sound effects. When it was inaugurated, it was the first centre of its kind to be housed at an African university – and only the second in the southern hemisphere – to provide safe training to students and mine staff in a simulated mining environment.

Innovative teaching and learning methods leave no one behind; Calvin Nel helps a learner to experience VR

IMMERSIVE LEARNING PROVIDES STUDENTS WITH A DEEP EXPERIENCE OF REALITY. THIS EXPOSURE 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.

The immersive learning opportunities that are presented in the VR training centre allow students to participate in the learning event and influence the outcomes. It also provides the opportunity for instantaneous evaluation. According to senior lecturer Jannie Maritz, who heads the VR centre, it can be used to easily explain various mining methods before taking students on mine visits. This allows for discussion in a "teaching friendly" environment over the noisy and dusty mining faces.

A further development in the Faculty, also spearheaded by the Department of Mining Engineering, is the Exxaro Chair in XR Technology, established in 2021 and formally housed in the Department of Information Science. As XR expert and researcher in the Chair, 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 is now poised to take the concept of immersive learning a step further through collaboration with the University's Faculty of Health Sciences. Ms Estie Powell, the Faculty's Chief Marketing and Communication Officer, describes immersive learning as the teaching method of the future. "It provides learners with a deep experience, in which they are immersed in the situation, and become part of the learning experience. It takes the concept of experiential education to the next level."

Another example of immersive learning that the Faculty is interested in duplicating, is the XR Toybox of the Faculty of Health Sciences. This is an incubator for immersive learning, which exposes students and staff to XR technology. As an interactive training facility,

students can use extended reality to practice using sensitive equipment, so that when they do their practical training, they have already been exposed to a situation in the virtual realm that represents an actual operating theatre.

Prof Tiaan de Jager, Dean of the Faculty of Health Sciences, believes that the University's transdisciplinary immersive learning initiatives are transforming the education landscape, preparing learners for a future where technology and innovation will be integral.

Clearly, we cannot continue to teach as we did in the past. If we want to educate a new generation of learners for the future, we need to do things differently. Immersive learning enables us to prepare learners for the industry they will enter as graduates by making them part of the experience before they even encounter it in the real world.

Team members from left: Mpho Makhuvha, Nontuthuzelo Sono, Similo Siyenga, Estie Powell, Calvin Nel and Thabo Masenamela

The innovative teaching and learning initiatives at EBIT and the Faculty of Health Sciences were recently exhibited to prospective students at the 21st Sasol Techno X Science, Maths, Engineering and Technology Exhibition, held in Sasolburg from 14 to 18 August 2023. This exhibition, which targeted learners from marginalised communities in Grade 8 to Grade 12, focused on exposing them to the infinite possibilities of a career in science, technology, engineering and mathematics. **The University's immersive learning exhibition received the Innovation Excellence Award at this event.**

WATCH
SmWoef – University of Pretoria's Robo-Dog

Smart technology enables immersive learning

A smart alternative platform is providing the opportunity for students and researchers to go into high-risk environments that are difficult to access or that require repetitive data collection that may lead to a lack of attention to detail. This platform, located in the Department of Civil Engineering, takes the form of a four-legged terrestrial robot, "smWoef" – the Smart Woef.

It 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 an autonomous robotic platform such as this with sensor networks, an infrastructure data collection methodology has been developed that provides for a safe, sustainable, continuous process of collecting current digital infrastructure data (including ambient environmental conditions and images at a range of wavelengths) that can form the basis of infrastructure maintenance, rehabilitation and risk management decisions.

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 platform's access to unsafe, inaccessible environments aid in novel data collection and research support.

AS A WEB-BASED APPLICATION, MAGNIFYUP ALLOWS LECTURERS TO SHARE NON-TRADITIONAL CONTENT WITH STUDENTS. THIS INCLUDES 3D MODELS THAT CAN BE VIEWED ON A DESKTOP OR LAPTOP COMPUTER, TABLET OR SMART PHONE.

Magnifying UP for enhanced learning

In collaboration with the Faculty of Health Sciences, the Department of Mining Engineering has developed and rolled out a teaching aid, known as **MagnifyUP**, to enhance learning. Built as a web platform, the application is device agnostic, so the content can be accessed via any mobile device, as well as through a browser on a personal computer.

Using a 360° camera, it allows lecturers to capture unobstructed photographs or video content. The application was initially developed in the Department of Mining Engineering to teach abstract engineering concepts. However, its application institution-wide was soon realised. As a web-based application, it allows lecturers to share non-traditional content with students. This includes 3D models that can be viewed on a desktop or laptop computer, tablet or smart phone. However, the VR assessments need to be done using a VR headset. Departments involved in the pilot project include Taxation (in the Faculty of Economic and Management Sciences), Anatomy (in the Faculty of Health Sciences), Civil Engineering and Mining Engineering (in the Faculty of Engineering, Built Environment and Information Technology), as well as the faculties of Veterinary Science, and Theology and Religion.

The platform has four basic functionalities:

- A virtual reality (VR) and augmented reality (AR) viewer: This allows learners to view 3D models using any device connected to the internet and can be viewed using mobile AR by simply switching modes on compatible smart phones. On a mobile phone, a visual tag viewed through the device's camera links the learner to 3D-AR contents related to the hard copy notes. This visual tag uses a QR code embedded in notes or on a screen that the student can scan with their phone. They are then taken to the browser where they can log in and view the content.

- 360° in-video assessment: By uploading 360° images or videos on the platform, the facilitator can set up a quiz for the students to complete. This uses VR technology to immerse the learner.

- Embedded 360° YouTube videos: The platform allows 360° YouTube videos to be linked for viewing through VR. Users can also view the content on their mobile devices and on a PC as it uses the YouTube video player.

- Scenario training: A scenario with various decision points is created with various outcomes, depending on the chosen option. In the case of a positive choice, the story continues. In the case of a negative choice, the reason for the incorrect choice is explained, after which the student is taken back one step to change their decision. This employs the learn-unlearn-relearn principle. As this is also a VR-only component, it needs a set of VR headsets.

This creates a truly immersive learning experience.

Dr Johann van der Merwe and Dr Calayde Davey

The transdisciplinary classroom leads to dynamic learning

Within the Faculty of Engineering, Built Environment and Information Technology, students and academics who are 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.

WATCH

Members of the departments of Architecture and Civil Engineering have embarked on 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. This annual accolade 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 re-use of building material.

According to Dr Johann van der Merwe, a senior lecturer in the Department of Civil Engineering, the global construction industry contributes significantly to the emission of greenhouse gases and depletion of resources. "This is exacerbated by substantial wastage during both construction and demolition processes." Adopting a circular value chain for building materials presents a compelling opportunity to address these challenges, while reducing embodied carbon, dependency on raw materials and wasteful practices. Since so much building waste ends up in the country's landfill sites, this has both a financial and an environmental impact.

In the domain of construction and sustainability, many initiatives place a significant emphasis on addressing the fate of products and materials once they reach the end of their useful lifespan. This effort primarily focuses on the critical task of drastically reducing the physical waste generated when a building reaches the end of its life cycle. However, in the construction sector, the process of deconstruction can be exceptionally challenging, particularly when the building was not originally designed with these aspects in mind.

Unfortunately, current design and procurement practices often overlook the essential considerations of deconstruction and demolition as key drivers of the circular design process. Consequently, achieving circularity at the end of a traditional building's life presents formidable challenges.

"While the traditional approach to teaching circularity is useful in addressing immediate concerns of waste in the construction industry, it falls short of fostering a fundamental paradigm shift among practitioners, explains Dr Calayde Davey, a senior lecturer in the Department of Architecture. This shift is necessary not only to address the symptoms of wastage, but also to delve into the root causes, all within a broader, long-term ecological perspective. Dr Davey believes that the concept of waste must be redefined altogether. Instead of viewing waste as "valueless", she advocates for a transformation in perspective where waste is recognised as a fundamental and valuable part of our urban-ecological world.

In nature, waste is an alien concept. Within an ecological mindset, waste simply does not exist at all.

"To bring about systemic change in our industry," says Dr Davey, "we must begin by cultivating an ecological mindset in our practical education for the built environment." The journey to eliminating waste from our physical world commences with the elimination of waste from our minds, echoing the wisdom of nature. "Embracing this approach is the only path towards genuine progress in advancing the circular economy within our buildings, infrastructure and city landscapes," she says. "To do so, we need to learn how to work together as professionals, and we need to practice in school *how* to work together."

As a structural engineer, Dr Van der Merwe has experienced the need in industry to collaborate more closely with architects at a much earlier stage in a construction project, as this would make a big difference to the success of the project.

"Collaboration among architects, engineers, landowners, consultants and users is crucial from the start of a project's life cycle," he explains. As a supervisor of structural engineering research projects at postgraduate level, he therefore noted the contribution that the Department of Architecture's **digital twinning initiative** could make in supporting research into circular construction and the reuse of building material.

Dr Davey, who is also the research lead for the Hatfield Digital Twin City Initiative, explains that digital twinning provides a collaborative, data-driven learning environment that allows for a multitude of research and experimentation opportunities. "Using digital twinning as a vehicle for collaboration among diverse disciplines is particularly useful, especially when teaching co-design at a strategic level." The collaboration of students and researchers from the departments of Architecture and Civil Engineering on this project therefore made perfect sense.

Traditionally, built environment education takes place within disciplinary siloes. This results in fragmented and very diverse perspectives on complex topics such as circularity. Drs Van der Merwe and Davey therefore realised that a new, systemic and collaborative approach needed to be adopted that transcends individual disciplines and cultivates cooperative problem-solving behaviour. "Empowering practitioners with scalable circularity skills such as transdisciplinary teamwork and unlocking shared realities is vital to effectively address challenges related to circularity," explains Dr Davey.

The success of the transdisciplinary training model that was co-created by Drs Van der Merwe and Davey lies in the fact that existing resources were leveraged to overhaul traditional built environment education.

Existing modules in Architecture, Civil Engineering and Construction Economics were used to instil a circularity and transdisciplinary mindset in students and researchers without disrupting the core pedagogy. The initiative furthermore focused on the students' professional development. It entailed transcending disciplinary boundaries so that students can fully comprehend the significance of collaboration and learning by doing.

"This innovative setting accentuates students' recognition of the immediate and long-term value of collaboration," says Dr Davey. "It fosters novel insights, shared impacts and diverse perspectives through collective learning." As students from different disciplines exchange methods, skills and diverse viewpoints, a dynamic learning environment emerges that mirrors the intricacies of real-world projects.

While formally focused on Architecture and Civil Engineering students, the initiative attracted interest from students from other departments as well.

"As the original group struggled to quantify their models for varying detail levels," explains Dr Van der Merwe, "Quantity Surveying (QS) students from the Department of Construction Economics voluntarily joined to help them."

The QS students prepared presentations on QS methodologies that had a significant impact on the team's understanding and outcomes of the core concepts of circularity.

"This sensitised the entire student cohort to the QS discourse, an experience the original students would not encounter in a traditional education setting," explains Dr Davey.

Furthermore, while the structural engineering students delved into their individual research on structural life-cycle assessment (LCA), the QS students swiftly offered their disciplinary perspective on LCA.

This significantly enriched the comprehension and intricacy of LCA for all involved, intensifying the team's inquiry, and kindling heightened enthusiasm for broader circularity concerns.

In the process, the transdisciplinary classroom organically transitioned into a flipped classroom, in which students mutually instructed each other in core disciplinary skills using shared BIM models. Dr Davey explains that cross-skilling within a shared digital ecosystem not only reshapes perspectives on the subject matter, but fosters collaboration, critical thinking and creative, complex problem-solving skills.

The impact of this approach is that it is scalable beyond the classroom. When they enter industry, graduate architects and structural engineers will already be aware of the benefit of collaborating with professionals from other disciplines at an earlier stage in the construction process, with benefits to all concerned. From an academic point of view, the scalability of the approach is evident in its application across different themes, as complex problems can be better solved by working together.

This transdisciplinary initiative is furthermore aligned with the United Nations' Sustainable Development Goals (SDGs) as it addresses multiple facets of responsible consumption and resource use, which fosters sustainable urbanisation.

As a pilot initiative, this project served as an experiment, paving the way for further transdisciplinary collaboration at the University of Pretoria. Dr Davey explains that the expansion of this initiative could continue as informal collaborations or evolve into structured transdisciplinary teams within the Faculty of Engineering, Built Environment and Information Technology, all the while safeguarding the development of core disciplinary competencies.

The ultimate vision of the academics involved is the creation of transdisciplinary classrooms that can serve as a catalyst for significant, far-reaching transformation within the built environment.

By nurturing well-rounded professionals, who are adept at navigating complexity and who can seamlessly collaborate across disciplines, this approach strives to foster substantial and enduring change.

The research team acknowledges the valuable contribution of HP Architects and UP Facilities Management for allowing the students to experiment on a real-life project.

RESEARCH FOCUS

From waste to wisdom: Transforming circular construction

Dr Calayde Davey and
Dr Johann van der Merwe

Researchers in the departments of Architecture and Civil Engineering have co-created a groundbreaking transdisciplinary initiative, empowered by cutting-edge digital tools and techniques. This led to postgraduate students from the two departments engaging in a collaborative project to explore novel methods to capture material and structural information within Building Information Modelling (BIM) and digital twinning models and workflows to explore the potential reuse of building material in South Africa. Such digital models could play a pivotal role in constructing comprehensive material inventories, paving the way for the future "mining" of reusable resources in the vast ecosystem of the built environment.

Research focused on adopting a circular value chain for building materials is exploring the use of the transdisciplinary classroom to foster innovation and cross-disciplinary cooperation to transform construction practices and tackle the challenges related to wasteful, unsustainable building practices that have a negative impact on the environment. This will pave the way for a more sustainable and regenerative built environment that will benefit both the present and future generations.

This research aims to determine the viability, cost-effectiveness and environmental benefit of reusing building material from disassembled buildings – as opposed to demolishing the built structures and adding even more building waste to burgeoning landfill sites. Two heritage greenhouses located on the premises of the University of Pretoria are considered as case study structures for the research. The project considers the hypothetical deconstruction of these structures for selective material reuse. Costs and embodied carbon associated with this process will be compared with the cost and embodied carbon associated with an equivalent inventory of new building material.

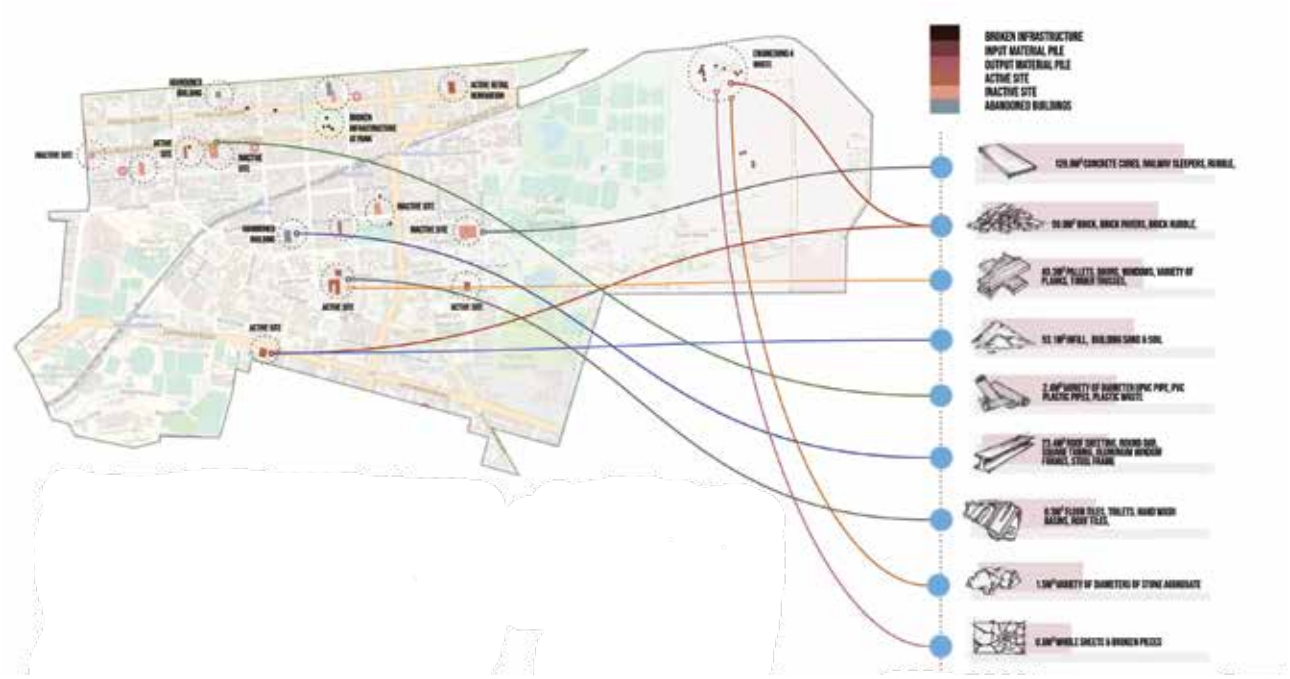
The research project was initiated after Architecture students had engaged in a systems-thinking design studio and fieldwork.

While this studio had primarily honed evidence-based design-thinking skills, it sensitised students to a comprehensive understanding of waste issues in the construction sector and potential avenues for repurposing construction waste.

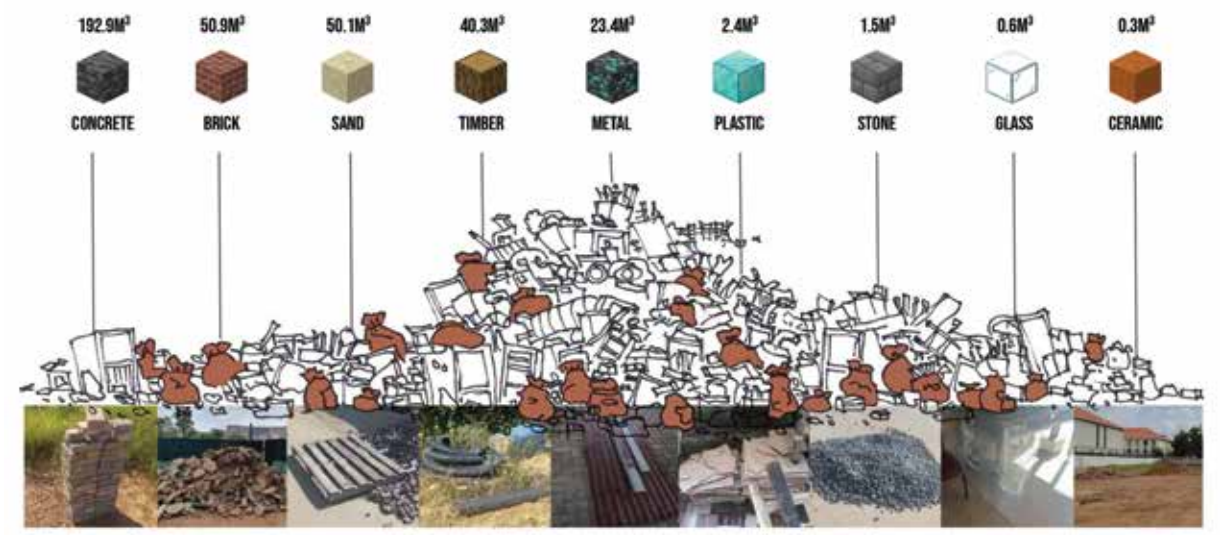
Noteworthy student studies emerged from this studio, such as a comprehensive mapping of construction waste in Pretoria to elucidate material types and quantities. Over the course or one academic quarter, an area of 25 km^2 in the Hatfield business district was mapped to quantify the different types of construction material waste.

Follow-up studies will build on this pilot study to gain a more holistic understanding of construction waste types and material flows in and around Pretoria. This will help to better understand which material types require the greatest focus for potential studies on their reuse.

This exposure furthermore sensitised students to the broader global waste challenge. They were driven by a deep desire to cultivate practical and technical proficiencies to solve the global challenge and develop methodologies and tools to address this overarching issue.



Digital mapping of construction waste types identified over the study area during the first quarter of 2023.



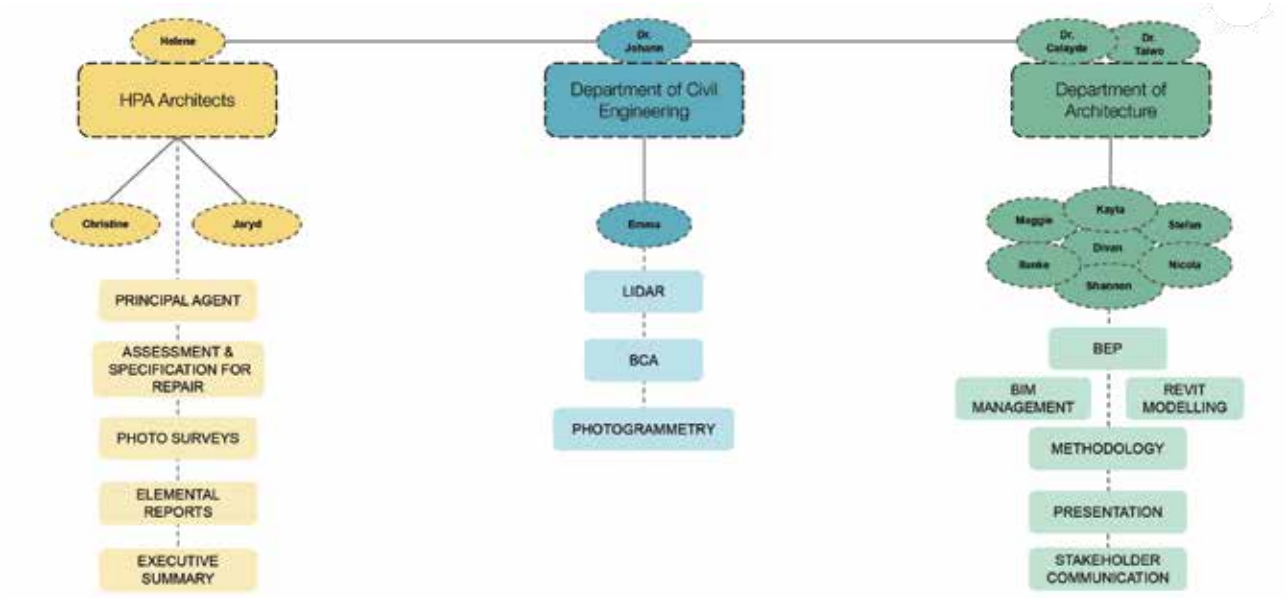
The digital mapping of construction waste allowed for an initial quantification of construction waste in the study area.

The unique advantage of the transdisciplinary classroom setting allowed them to gain hands-on experience within a safe-to-fail experiential environment, while preserving the core disciplinary competencies that were essential to their respective professional degrees.

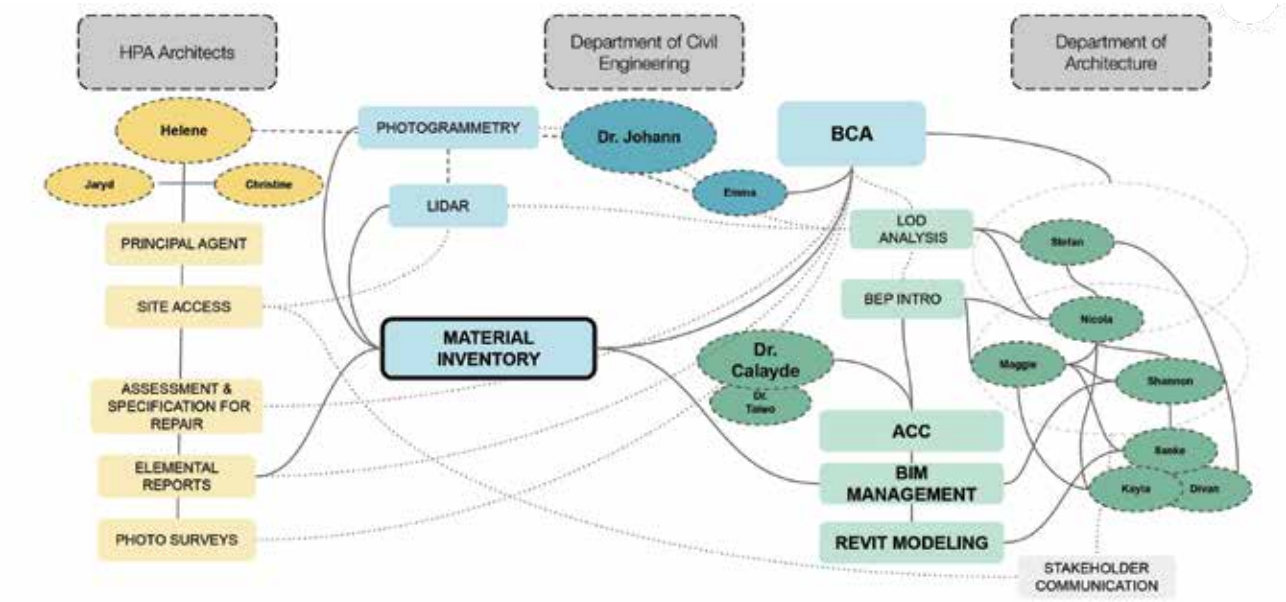
The members of the project team initially crafted an organisational framework outlining roles and responsibilities. This initial representation underscored disciplinary boundaries, each confined to its designated domain. However, after just seven weeks, they came to realise the value of a transdisciplinary approach, and decided to refine the flow chart by dismantling the traditional disciplinary siloes. This mirrored the emergence of an interactive, value-driven and skill-sharing transdisciplinary project environment.

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

★ *Two greenhouse structures on the University's Hillcrest Campus were the focus of the transdisciplinary study.*



The project team's initial task and role allocation network, which underscored disciplinary boundaries.

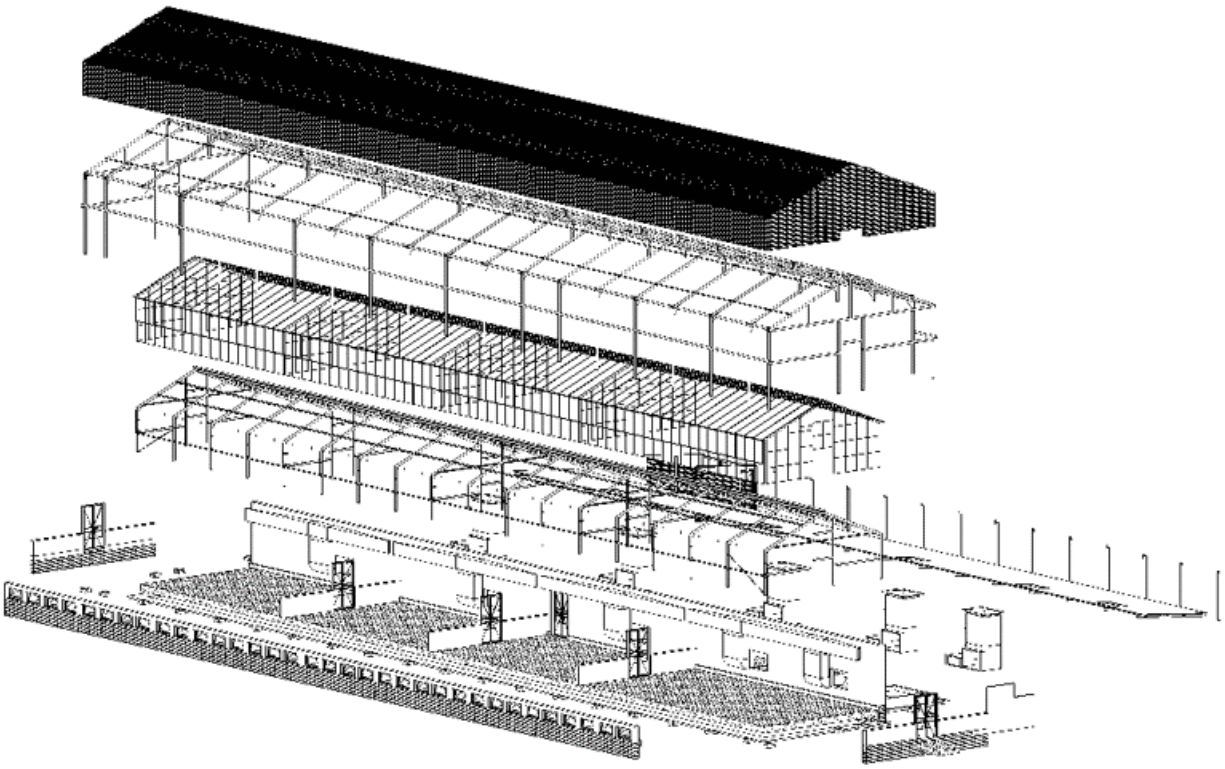


The project team's revised transdisciplinary task and role allocation network.

This project would not have been possible without the permission granted by HP Architects and UP Facilities Management, whose open-mindedness allowed the students to experiment on an actual project. As owner and principal architect of the heritage architecture firm that had been appointed to oversee the restoration of the two heritage greenhouses, Helene Potgieter explains the reason for their involvement: "We need to change our mindset regarding design and build." She explains that our planet, earth, is a finite resource. The quantum of building rubble that ends up on refuse sites as part of demolition activities can no longer be ignored. In the USA alone, demolition rubble from construction projects pushed to refuse dumps measures 50% the area of the Kruger National Park. "HP Architects' collaboration in this project serves to alert and sensitise students on this burning issue."

In collaboration with the heritage architecture firm, the transdisciplinary student team made use of drone-operated light detection and ranging (LiDAR), iPhone-embedded LiDAR and photogrammetry to scan the buildings on the research site. Together with hand-held LiDAR scanners and physical measurements, a digital twin of the structures was developed.

A circularity-oriented BIM workflow was developed, articulating appropriate levels of modelling detail to systematically capture relevant information to support decisions related to the material's deconstruction and selective reuse potential.



Digital twin models were developed that captured all relevant structural information to serve as a material inventory for elemental reuse identification.

In addition to BIM workflow development, the study included the development of a novel structural condition assessment rating system specifically developed with selective reuse potential in mind, and aligned with typical BIM workflow levels of detail.

The use of a hands-on, transdisciplinary approach underscores the significance of choosing appropriate physical and digital tools for specific tasks, which emphasise the effectiveness of even basic tools, such as pick-axes and shovels, for gathering essential information to inform digital models and workflows.

The students had the opportunity to showcase their work at the BIM Harambee Conference, coordinated by Dr Davey and hosted at the University of Pretoria in July 2023. The teaching team's presentation highlighted the transdisciplinary classroom as a case study for built environment education, featuring collaborative learning via BIM workflows within the African context.

The integration of transdisciplinary exposure within the core curriculum, as illustrated at this industry conference, gained recognition from both industry and academia. The feedback received from the Acting Vice-Dean of Teaching and Learning at the University of Johannesburg's Faculty of Art, Design and Architecture commended the conference as "an exemplary example of education-industry collaboration that involved preparing young designers, engineering and construction students for the challenging and rapidly changing technological environment."

The project team discuss aspects related to an evaluation of the structure's selective reuse potential.

Unique integral bridge construction reduces maintenance costs

Prof Elsabé Kearsley and Dr Sarah Skorpen

In the Department of Civil Engineering, researchers in structural engineering are joining forces with their colleagues who specialise in building materials to make an impact on South Africa's roads infrastructure. They are developing tools for designing reinforced concrete bridge decks without expansion joints or bearings, known as integral bridges.

The objective is to ensure that these structures can withstand the loads caused by environmental forces. A structure of this type requires limited maintenance and can help ensure the longevity and structural health of our country's road network bridges.

As part of her PhD research conducted in 2017, Dr Sarah Skorpen of the Department of Civil Engineering instrumented and monitored an integral bridge built on the N1 near Trompsburg in the Free State.

The Van Zylspruit bridge is the longest integral bridge in the country, being approximately 90 m in length. The location of this bridge was specifically selected due to the area's harsh, dry climate, which is characterised by both high and low temperatures. The instrumentation included strain gauges to measure strains in the bridge deck, as well as temperature sensors, tilt-meters and earth pressure sensors behind the bridge abutments. The data obtained from this project has been enabling designers to compare real and assumed effective bridge deck temperatures, earth pressures and the tilting or movement of the supporting structure. This has been one of the largest bridge structural health monitoring systems implemented in South Africa.

Structural health monitoring can be used for the following:

- Continuous conditions assessment, which can help lengthen the design life of the structures
- Calibrating theoretical models, which will assist in the design of more durable structures
- Refining design assumptions and improving structural behaviour understanding, which will promote more economic designs
- Highlighting guideline updates for design and construction, which will keep the industry current with new materials, construction methods and climatic conditions.

Building on the success of the Van Zylspruit bridge, researchers in the Department of Civil Engineering, under the supervision of Prof Elsabé Kearsley and Dr Sarah Skorpen, are making use of facilities in the University of Pretoria's Concrete Laboratory in the state-of-the-art Engineering 4.0 Building to build and monitor a number of scaled models of various bridge deck profiles. These models were built as part of the South African National Roads Agency Limited (SANRAL)'s research project on integral bridges, and are being used to assess environmental effects on the behaviour of integral bridge decks, with the aim of optimising the deck shape and reinforcement to minimise cracking of the deck and movement of the abutment wall.

Changes in solar radiation and ambient shade temperature result in changes to the temperature of the bridge deck, causing it to expand and contract. This expansion and contraction result in curvature in the concrete structure as it pushes into or away from the soil fill. These secondary thermal effects can cause cracking of the integral bridge deck and affect the structure's durability.

Another important parameter to consider when studying the heat flow and temperature change of a concrete bridge deck is the concrete conductivity, specific heat and coefficient of thermal expansion. These parameters are affected by the concrete mix design and aggregate type, in particular.

In the experiments that Prof Kearsley and Dr Skorpen are conducting at the Concrete Laboratory, variables include aggregated type, concrete thickness, reinforcement percentage, and daily and seasonal temperature changes. Understanding the effect that these parameters have on integral bridge

deck behaviour will help designers design better for crack control, and predict the thermal movement of the integral bridge abutment. The abutment movement results in changes to the earth pressure behind the abutment, which influences the load effects on the abutment.

The seasonal change in temperature, which caused the deck and abutment of the Van Zylspruit bridge to extend outwards in the hotter summer months and inwards in the colder winter months, is reflected in the earth pressures measured.

The earth pressure in summer was found to increase towards the base of the abutment wall. However, in winter, the earth pressure reduced significantly. This seasonal change in earth pressure has also been observed in other integral bridges where earth pressure has been monitored.

Using structural health monitoring, small-scale models and extensive materials testing, this research aims to give civil engineers the tools to not only design longer integral bridges, but ensure that these bridges are economical, requiring very little maintenance.

UNDERSTANDING THE EFFECT OF PARAMETERS ON INTEGRAL BRIDGE DECK BEHAVIOUR WILL HELP DESIGNERS DESIGN BETTER FOR CRACK CONTROL, AND PREDICT THE THERMAL MOVEMENT OF THE INTEGRAL BRIDGE ABUTMENT. THIS RESULTS IN CHANGES TO THE EARTH PRESSURE BEHIND THE ABUTMENT, WHICH INFLUENCES THE LOAD EFFECTS ON THE ABUTMENT.

Dr Sarah Skorpen – Structures

Prof Elsabé Kearsley – Materials

Researchers use small-scale models to test the behaviour of different material strengths.

The Van Zylspruit bridge near Trompsburg in the Free State.

Optimising drainage structures with physical and CFD modelling

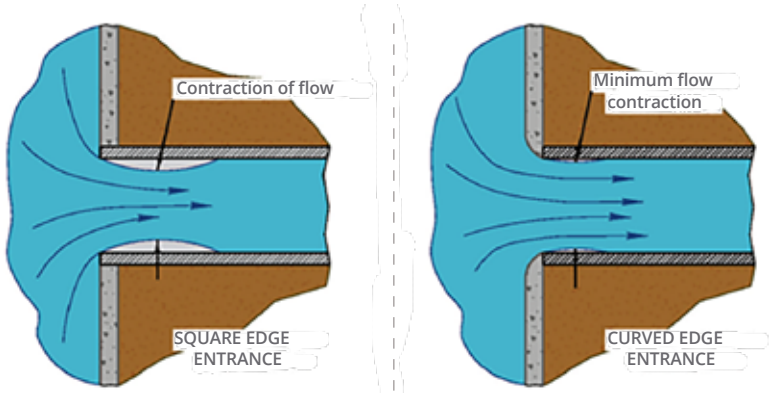
Marco van Dijk, Louis Coetzee and Ione Loots

The hydraulic capacity of a culvert – a structure designed to convey water underneath roads, railways or other obstructions – can be improved by altering its inlet configuration. The inlet configuration plays a crucial role in determining the flow efficiency and capacity of the culvert. Several modifications can be made to enhance its hydraulic performance.

One common approach is to use an improved inlet design, such as a flared or bevelled inlet. These designs involve widening the entrance of the culvert, allowing for a smoother flow transition, and reducing the potential for flow separation (the detachment of a boundary layer from a surface into a wake). By providing a more gradual and streamlined path for the water to enter the culvert, these inlet configurations minimise energy loss, reduce turbulence, promote a more uniform flow distribution and result in increased flow capacity.

Straub et al. (1953) stated that inlet structures like wing walls, head walls, slope-metered inlets and bevelled edges would have a significant bearing on culvert capacity. Harrison et al. (1972) noted that tapered inlets could result in full, or nearly full flow, thereby increasing culvert capacity significantly. Schall et al. (2012) found that bevelled inlets also improved culvert performance. Several studies (Ashour et al., 2014; Graziano et al., 2001; Jones et al., 2006) found culvert capacity improvements for certain wing wall, end wall or headwall configurations.

The utilisation of bevelled edges at the entrance of the culvert is another method that can be used to increase inlet performance. Bevelled edges reduce the contraction of flow by effectively enlarging the face of the culvert.



Bevelled edges at the entrance of the culvert (James et al., 2012).

The South African National Roads Agency Limited (SANRAL) is increasingly incorporating provincial roads into its national road network to meet the country's medium to long-term developmental needs. In many instances, the roads being incorporated do not meet the design criteria for the class of road as described in SANRAL's Drainage Manual (SANRAL, 2013). During upgrading of its own road network, drainage systems are re-evaluated and, in certain cases, found to be under-capacity. As the costs for upgrading drainage structures could be significant, SANRAL appointed the University of Pretoria to evaluate the hydraulic efficacy of improving culverts' inlet characteristics.

In some cases, modifications to existing culverts may improve the culvert's hydraulic performance to such an extent that it can meet the requirements of the class of road it serves. The cost associated with these enhancements is typically only a fraction of the cost of alternatives such as replacing or adding a culvert. In addition, modifications could be applied to culverts that frequently overtop, damaging the roadways and posing a risk to road users. Improving the hydraulic performance of culverts during the design stage of various projects could also reduce project budgets during the construction phase.

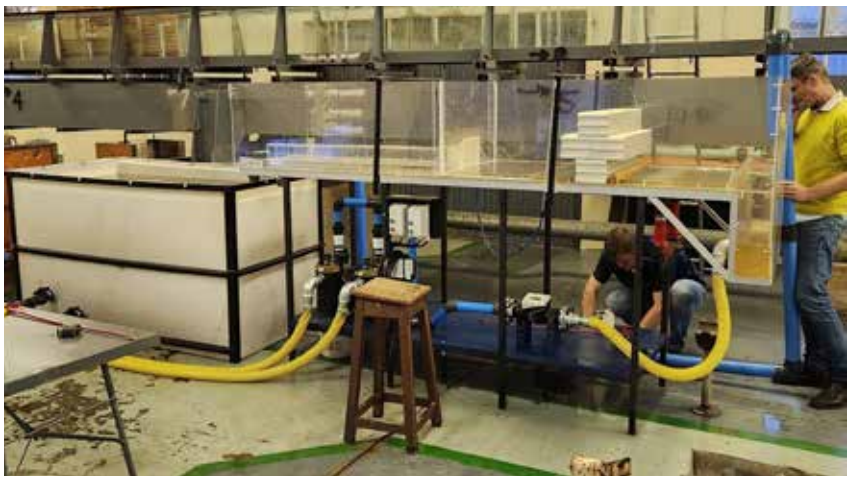
The Federal Highway Administration (FHWA) (2006) states that: 'The most widely

recognised manual on culvert hydraulics is the FHWA Hydraulic Design Series No. 5 (HDS-5), Hydraulic Design of Highway Culverts, published in 1985, but based on research conducted in the 1960s and 1970s." This statement suggests that there is scope for further research into the optimisation of culverts in general. Similarly, SANRAL's Drainage Manual (SANRAL, 2013) only contains a short section on the improvement of the inlet capacity of culverts by introducing dimensional and slope variations at the entrance. There is therefore also scope for the inclusion of innovative techniques to improve the hydraulic performance of culverts under inlet control conditions through the optimisation of the inlet characteristics in this design manual, which is widely used by South African engineers for the design of culverts.

A physical model was constructed at the University of Pretoria's Water Laboratory and a number of inlet configurations are being tested and compared to the equations used in practice. The test results look promising, with the hydraulic capacity improving by more than 12% compared to standard designs when the drainage structure operates at a typical design submergence level of head-to-diameter (H/D) = 1.2. The results of these tests are now being used to validate the computational fluid dynamic (CFD) modelling.

A CFD model is a numerical model that is used to represent the discharge through the culvert by solving a set of complex equations over time. The equations include the conservation of mass, momentum and energy that can capture complex flow phenomena such as turbulence, vortexes and eddies that may form in the fluid volume as a result of sudden flow directional changes.

One of the software packages used to analyse these complex flows is OpenFOAM (Open Field Operation and Manipulation). OpenFOAM is popular open-source CFD modelling software. It is used after validation of the physical model to test more configurations of the culvert inlets. The software utilises a finite volume method to discretise the aforementioned governing equations, allowing researchers to accurately simulate complex fluid flows and explore various physical phenomena from a desktop setting.



Physical model: the flume with culvert model

It is anticipated that incorporating different culvert layouts, including side and sloped tapered inlets, as well as chamfers and transition sections, could enhance hydraulic efficiency and thereby increase the culvert's capacity. By utilising CFD modelling, many more iterations of improvements can be evaluated across different flow rates and variations, surpassing what is practically feasible with physical modelling.

Once the validation of the numerical model is complete, a number of different culvert layout configurations will be tested for box, portal and round culverts, as well as multiple barrel installations. Alterations can then be made to existing culverts to improve their intake capacity, enabling a cost-effective solution to improve road safety and reducing the risk of potential flooding during a storm event without reconstructing the road and culvert.

SCAN TO WATCH: ***CFD modelling of culvert inlet***

Acknowledgements

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Mitigating train-wildlife collisions in Greater Kruger: A cross-disciplinary investigation and infrastructure inventory

Prof Hannes Gräbe and Dr Albert Myburgh

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.

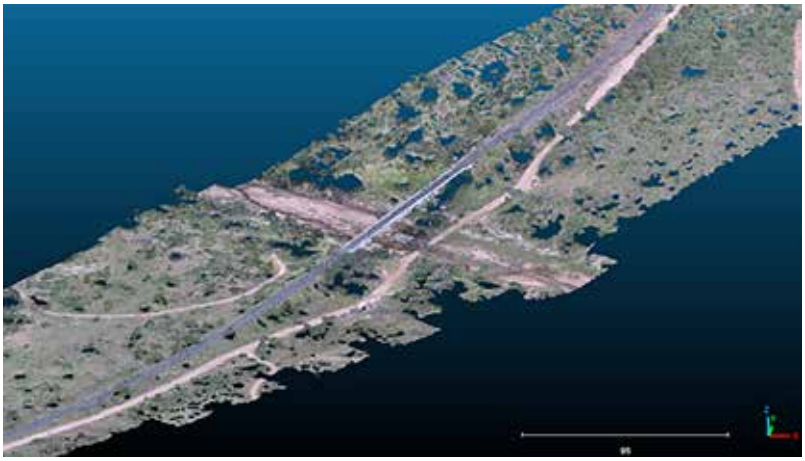
The train schedule through the reserve comprises roughly seven loaded and seven empty trains per day. As the railway line is unfenced, collisions between trains and wild animals (ranging in size from rodents to elephants) frequently occur and are a source of the unnatural removal of animals from the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

At the beginning of 2023, the University of Pretoria'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 is to investigate the problem, identify the contributing factors and provide guidelines as to how it can be managed to reduce future occurrences.

The objectives of the investigation include the following:

- Create a digital infrastructure inventory of the railway line and adjacent area. This would include topography, track geometry and the mapping of all railway assets.
- Identify contributing factors to the collisions taking place on the railway line. The initial phase of the investigation focuses on "hot spots" where animal crossings are prevalent.
- Investigate other related railway engineering aspects with the focus on train and track condition monitoring.

The field measurements were carried out in two phases over a period of two weeks. General mapping and measurements were carried out during the first week. Following the reduction and interpretation of the data, a second investigation phase of measurements was conducted at selected locations along the railway line.



LiDAR MAPPING OF THE RAIL RESERVE

The University of Pretoria's road-rail vehicle (RRV), acquired through the National Research Foundation (NRF)'s National Equipment Programme, was used to map the rail reserve and infrastructure assets in conjunction with the University's Hovermap light detection and ranging (LiDAR) system. The Hovermap LiDAR system, manufactured by Emesent in Australia, was mounted to the front of the RRV to conduct a survey along the entire length of the railway line in the game reserve. Hovermap creates a 3D point cloud by acquiring over 300 000 points per second. The LiDAR survey was done at a slow speed, i.e. 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.

The point cloud can 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.

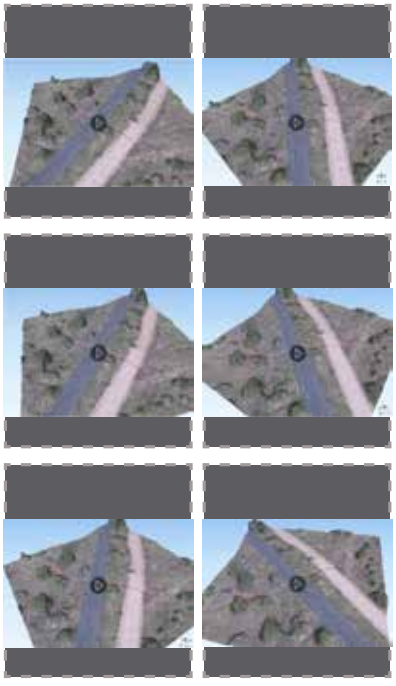
Track geometry measurements

In conjunction with the LiDAR mapping, a KRAB™ geometry trolley was utilised with the RRV to obtain high-resolution track geometry data of the line. Parameters recorded by the KRAB include profile (vertical alignment) left and right, versine (horizontal alignment) left and right, track gauge, twist and cant/superelevation. Data is recorded for post-processing and can be referenced to specific features along the length of the track. Track geometry is useful for maintenance planning and to ensure that corrective maintenance is done at priority locations. This initial track geometry data can also be used as a datum for comparison to future measurements. This will enable maintenance staff to calculate degradation trends, and predict and plan future maintenance interventions.

Photographic mapping

A Mavic 2 Enterprise drone was used to create orthographic maps of specific hot-spot locations on the railway line. Multiple photos with sufficient overlap were taken along the railway line to create this map. The creation of a 3D image of the railway was also possible following this exercise.

A DJI Matrice 300 drone was used to record detailed LiDAR data of specific track sections and fixed infrastructure, e.g. the Olifants River steel bridge and concrete culverts and bridges in the game reserve. It should be noted that all drone surveys were carried out by licensed remotely piloted aircraft systems pilots, who conducted the flights in accordance with South African Civil Aviation Authority regulations.



Rail track investigations

In addition to ecological research, final-year Civil Engineering students were responsible for detailed surveys and measurements, following the first phase of investigations.

Their research projects included the following:

- Wheel load measurements along the railway line to obtain accurate loading profiles of the trains. Novel pre-installed strain gauges were utilised for this purpose and compared to traditional wheel load strain gauging.
- Condition monitoring of track infrastructure (e.g. bridges and culverts) with wireless accelerometers (Kli-pi) at selected locations.
- Rail profile measurements with line lasers on tangent and a curved railway track to investigate rail wear and fatigue.

CONCLUSION

This collaborative research project, undertaken by the University of Pretoria and other role players, offers significant potential to reduce train-wildlife collisions, while enhancing wildlife conservation efforts and ensuring financial benefits for Transnet Freight Rail.

The investigation identified critical collision hotspots along the railway line, providing valuable data for planning mitigation strategies. The LiDAR-generated digital infrastructure inventory and track geometry measurements will aid in predictive maintenance planning and future intervention calculations. The research carried out by Civil Engineering students adds valuable insights to address specific railway engineering challenges.

The findings and recommendations from this investigation lay the foundation for implementing effective measures to manage and mitigate future occurrences of train-wildlife collisions.

Research team: Hannes Gräbe, Albert Myburgh, Johan Scholtz, Paul Allin, Stehan Bouwer, Paul Hume and Christiaan Mol

Showcasing research in railway engineering

Rail transport is an indispensable element of South Africa's transport infrastructure. All the major South African cities are connected by rail, and our railway system is recognised as the most advanced in Africa. The Department of Civil Engineering's links with the rail industry span more than 25 years.

The first industry-sponsored research chair in railway engineering was established at the University of Pretoria (UP) in 1996 with the initiation of a partnership between UP and Spoornet (now Transnet Freight Rail). This led to the establishment of the Chair in Railway Engineering in 2008.

The collaboration of the railway engineering programme with industry continued, with the establishment of the Railway Safety Regulator (RSR) Chair in Railway Safety in 2013. Partnerships were concluded with other rail industry partners over the years, such as with the Gautrain Management Agency and other rail industry partners. This support revolves around three major aspects: graduate training, continuing education courses for industry, and railway research.

At the International Rail Safety Council Conference, held at the Century City Conference Centre in Cape Town from 2 to 6 October 2023, members of the railway engineering programme had the opportunity of showcasing various research initiatives in railway engineering. This conference, hosted by the Railway Safety Regulator, brought together railway safety professionals from all over the world to exchange information and provide experiences and share lessons learnt to improve railway safety. The theme of the conference was: Reshaping railways in an uncertain world.

Members of the Faculty's technical team at the International Rail Safety Council Conference: from left (front): Jordan Mostert, Similo Siyenga and Prof Hannes Gräbe; (back): Estie Powell, Thabo Masenamela, Paul Hume and Christiaan Mol.

Prof Hannes Gräbe, Head of the Department of Civil Engineering, and Chairholder of the Railway Safety Regulator Chair in Railway Safety at UP, also received the Best Presenter Award at the conference. The title of his presentation was: "Technological advancements and digital mapping for a safer rail network".

A technical tour formed part of the conference activities. This event included scaled experiments and demonstrations of innovative responses to rail safety, as even the smallest event, incident or issue can have major implications.

Delegates visited the Winelands Light Railway in Stellenbosch, where researchers from both UP and Stellenbosch University showcased some of the technical aspects related to their research.

Through three simulated incidents, researchers Jordan Mostert, Paul Hume and Christiaan Mol from the University's Chair in Railway Safety demonstrated their current research and innovative solutions in railway safety.

This illustrated how the equipment and technologies that have been developed in the Chair can assist in measuring the condition of railway tracks, as well as in the investigation of railway incidents. The main aim of the demonstration was to raise rail safety awareness, thereby saving lives and making railways safer.

The first experiment focused on rail incident investigations using the Department of Civil Engineering's four-legged, terrestrial robot, smWoef, in combination with drones. The researchers illustrated how they make use of light detection and ranging (LiDAR) to map incident scenes for post-incident investigations. The LiDAR scanner is mounted onto the drone or terrestrial robot, and the scans are analysed to determine factors that contributed to a derailment, for example. Measures can then be implemented to prevent a repetition of such a disaster.

The second experiment demonstrated infrastructure monitoring and condition measurement using smart track components. Over the years, the University's researchers have developed smart ballast, smart rail pads and smart deflection sensors to assist them to measure the structural health of a railway track. These measurements can be used as part of rail incident investigations. They also make use of a road-rail vehicle that can digitally map the layout and geometry of the track.

The third experiment illustrated the use of virtual reality (VR) in rail safety training. The University uses reconstructed incidents, projected in its VR facility on the Hatfield Campus, to train rail safety inspectors. In the stereoscopic cinema, typical derailments can be viewed as part of safety training. Future developments in this area include the development of a Rail Safety Inspector Qualification and the use of VR headsets for immersive training.

Prof Gräbe emphasised the fact that basics are important: "by addressing the small issues, we can build a safety culture and establish awareness."

The research conducted at the University of Pretoria is accompanied by a sense of urgency, as people's wellbeing and future depends on the work of its researchers, as well as their investigations and findings. Prof Gräbe also stressed the importance of training, skills development and sustainability in the rail sector. "In the technologies and innovations that form part of our research, we strive to inspire and give hope to a nation of rail commuters."

He believes that the impact of the University's research in railway safety will continue to save lives and make rail safer for all sectors of the economy.

RAILWAY ENGINEERING RESEARCH TECHNICAL TOUR

Prof Hannes Gräbe and his Stellenbosch University counterpart, Pieter Conradie, exploring EBIT's VR applications.

Improving the daily commute by empowering passengers

The experience of commuting between home and work has an important impact on the daily lives of marginalised communities who make use of minibus taxis as a form of informal public transport. It influences their financial stability, the time they have to spend with their families and their safety. The availability of sufficient and accurate information about public transport is therefore essential.

The Centre for Transport Development in the Department of Civil Engineering has been conducting research on the preferences of informal public transport users for several years. Research into the options available to commuters, and how these options affect their travel choices, plays an important role in improving the daily commute. This research recently gained added impetus through collaboration with the discipline of information science.

Prof Ina Fourie, Head of the Department of Information Science, explains that information science is increasingly focusing on giving a voice to marginalised communities, improving their daily lives and contributing to the Sustainable Development Goals (SDGs), as well as equity, diversity and inclusion. "The use of everyday life information behaviour as a research lens can reveal information activities, influencing factors, information sources and contexts that apply to informal transportation use by poorer socioeconomic groups."

Recognising the value of adequate information about public transport to empower the users of informal public transportation, Prof Christo Venter of the Centre for Transport Development realised that understanding information behaviour contexts, and how to bridge the digital divide, while promoting networking and information sharing in marginalised populations, can help tailor interventions to improve their lives. "As one of the key dimensions of mobility, information is emerging as an important lever through which sustainable access can be promoted in sub-Saharan African cities."

Information acts as an enabler of transport by allowing travellers to make informed decisions on whether, when and how they should travel. In contrast, the absence of information can act as a barrier to accessing the desired services, with consequences for the attainment of equity and human development goals.

"As settlements expand and become more complex," explains Prof Venter, "transport systems typically evolve from single-mode, direct routes to more multimodal, complex networks. To navigate this increasing complexity, users' needs for accurate information is increasing." Understanding the provision of public transport information is especially pertinent for informal public transport, which has grown into the largest provider of public mobility in sub-Saharan Africa (SSA).

Despite this market dominance, informal public transport services like minibus taxis in South Africa and boda-boda motorcycle taxis in Uganda do not provide any systematic source of information about their operation. This is, in part, because their ecosystems are made up of many individual operators. Outside the cities and communities in which they operate, little is known about how their passengers need, find and use information.

The growing interest in information on informal modes of transport is underscored by several recent developments. There have been growing efforts to collect better data on informal transport services. These efforts have resulted in growing databases on routes and services, and have been used to support resilience planning, and analyse service and accessibility patterns. Despite this effort, the uses of this data are still limited, and questions remain about how users can directly benefit from this data.

Mobile applications (apps) for public transport are being developed for emerging market contexts that incorporate informal transport data. An example is Rumbo, an Android application developed by WhereIsMyTransport, a public transport platform based in South Africa.

Yet, these are not yet widely adopted, and questions exist about their efficacy and suitability in the SSA context. In addition, differential access to technology (especially smartphones) may create a barrier to segments of the population.

Researchers in the Department of Civil Engineering and the Department of Information Science conducted a collaborative exploratory study to discover the information needs, practices and behaviour of the passengers of minibus taxis in Tshwane, South Africa, while collaborators at Makerere University in Kampala, Uganda, conducted a similar investigation on the passengers of boda-boda motorcycle taxis in this city.

They made use of concepts from the field of information behaviour, a sub-discipline of information science, which focuses on activities such as seeking information, defining information needs, sharing information, and using and encountering information. The intersection between travel behaviour and information behaviour led to several specific research questions. These included questions like which information-seeking strategies passengers employ when they need information on public transport; and how information – or the lack of it – affects travel choices and the ability to access destinations.

The information needs of passengers is determined by its accessibility, usability, accuracy and timeliness. Passengers of informal transport seem to depend on informal and social communication channels to access this kind of information. This includes direct observation, oral communication, the use of hand signals and print media. Digital sources include real-time information systems such as variable message signs, SMSs, websites, mobile apps and social media, as well as verbal announcements used to relay information about delays.

According to Prof Venter, information sources vary significantly across modes: the more informal and decentralised a mode's operations, the more passengers depend on informal and socially transmitted sources of information.

Despite recent attempts to provide web-based information portals that cover multiple modes, there is wide variation in the scope and quality of information. There are also information gaps that are not adequately addressed by current sources, including custom journey planning and information about service delays. Many contextual and personal factors furthermore mediate a user's ability to access and apply information. In addition, the information people provide when asked about their information needs does not always fully reflect the information they require to cope with situations such as commuting.

For this study, researchers relied on methods common to information behaviour research for the collection of data that could delve deeper into the personal experiences and daily challenges of the users of informal transport. Three methods of data collection were used: paper-based travel diaries, photovoice (photographs or video clips and voice messages) and information horizon interviews (drawings showing information sources and recorded interviews). "The data was very rich in terms of the range of experiences captured," says Prof Venter. "It revealed the importance of information in the travel experience, the social nature of information seeking, information poverty (evidence of unmet needs) and the use of digital technology."

People need information to find solutions to the mobility challenges they face in their everyday lives. These challenges stem, in part, from the complexity of the transport environment that users must navigate. This is reflected in the large number of individual actions, decisions and considerations that collectively make up the travel experience. Furthermore, by their nature, informal modes are flexible and adaptive, with routes, departure times, stop locations, and sometimes even fares changing according to conditions. Information helps deal with this fluidity, even during regular or daily trips.

Since most minibus taxi environments are poorly signed, taxi users are heavily dependent on other people to provide them with the correct information. This immediately raises issues of trust. This social nature of information seeking also brings about questions of inclusion on the basis of language, culture and verbal ability. The system of hand signals, used to flag down taxis going to specific destinations, is a form of non-verbal language that has developed within the taxi industry in South Africa. These signals have been learnt from childhood, and learning the correct signals as a new user may be a barrier to travelling to new destinations or using taxis in new areas. Many passengers closely watch what others do – evidence of the importance of situational awareness in successfully navigating the system.

Overall, there was strong evidence of information poverty; subgroups are persistently excluded and isolated due to their lower ability to access, process and use information to their benefit. Informal passengers tend to have a very small circle of friends on whom to rely for help. Formal sources of information are almost non-existent, so that seeking and sharing information is almost entirely based on oral communication. This raises questions of agency. What happens when people are unable or unwilling to access the information they need to make a trip?

Limited evidence was found of the use of digital technology to address information gaps. Not many passengers made use of the online information provided by formal systems. This could be due to ignorance, preference and a lack of trust in these sources. It was, however, noted that social media provided a way for some respondents to combine their need for up-to-date information with their need to triangulate it with other sources, especially other passengers.

Within the minibus taxi industry, what little information is provided is concentrated at formal ranks and terminals, although even here the informal exchange of information by drivers and queue marshalls is very important. As marshalls and taxi officials are generally seen as authoritative and trustworthy sources of information, they could potentially be better resourced to fill passengers' immediate information gaps.

INFORMAL PASSENGERS TEND TO HAVE A VERY SMALL CIRCLE OF FRIENDS ON WHOM THEY CAN RELY ON FOR HELP. FORMAL SOURCES OF INFORMATION ARE ALMOST NON-EXISTENT, SO THAT SEEKING AND SHARING INFORMATION IS ALMOST ENTIRELY BASED ON VERBAL COMMUNICATION. THIS RAISES QUESTIONS OF AGENCY. WHAT HAPPENS WHEN PEOPLE ARE UNABLE OR UNWILLING TO ACCESS THE INFORMATION THEY NEED TO MAKE A TRIP?

Safeboda motorcycles in Uganda, by Ndahiro Derrick (Wikimedia Commons)

Based on the findings of this research, it is suggested that researchers in the transport field should pay greater attention to the emotional landscape of the public transport experience if they are to understand how to promote its use as a choice, and not just as a mode of force. Although there are many needs for information that cannot be fixed through the provision of information, such as the infrequency of transportation on isolated roads, it was evident from data showing how participants used their mobile phones for directions on Google Maps and relied on signage at taxi ranks that there is scope for industry involvement in meeting information challenges. However, a grey digital divide was evident: relatively older people who lacked digital skills.

The Department of Information Science, under the guidance of Prof Ina Fourie, has initiated a project on an intergenerational approach to bridge the grey digital divide. This will culminate in an interdisciplinary project in different contexts such as health and mobility.

These findings on the potential use of mobile phones to provide trip-relevant data, coupled with the importance of social networks as a trustworthy source of information, led the researchers to consider whether socially triangulated digital sources can be useful in addressing some information gaps in informal transport.

This gave rise to a spinoff project to explore, prototype and test such an approach with the involvement of potential users in a co-design setting. It involved the technology development company, WhereIsMyTransport, as well as information designers from the University of Pretoria's School of the Arts.

The focus of this project was to increase the impact of information behaviour research to provide better information to the users of informal transportation. The ultimate outcome is to develop more empowered commuters, who have more time to spend with their families, and are ensured of a safer, more streamlined public transportation experience.

It will test ways to develop useful and accurate information channels, including apps and digital maps of minibus routes by working closely with passengers in a co-design laboratory setting.

UP specialist weighs in on Turkey's devastating earthquakes

The earthquakes that hit Turkey on 6 February 2023, as well as the aftershocks during the course of the following month, leading to the loss of life and damage to buildings and other structures in the aftermath, left the world in shock. During a public lecture on 9 March 2023, Prof George Markou of the Department of Civil Engineering shared his thoughts on what went wrong.

Prof Markou is a specialist in structural engineering with a particular interest in earthquakes. During his professional career as a civil engineer in Cyprus, he designed numerous structural engineering projects, which mainly involved seismically resistant residential and commercial reinforced concrete buildings with the use of the Cyprus, New Greek Earthquake Design Code and Eurocodes.
In addition to that, Prof Markou developed a finite element analysis software, Reconan FEA, for the seismic assessment of structures such as bridges, wind turbine towers, nuclear reactor buildings and foundation systems through advanced numerical modelling, a software that he used to seismically evaluate different types of structures around the world. He is thus pre-eminently qualified to voice an opinion on the devastating earthquakes in Turkey and what could have been done to prevent the extensive damage to Turkey's concrete structures.

He started his lecture by explaining what earthquakes are and how they occur. He then went on to provide the facts about the two main seismic events that took place. The first earthquake, which took place on 6 February, had a moment magnitude of 7.8 and struck southern and central Turkey, and northern and western Syria. The epicentre was 37 km from Gaziantep.

This was followed by a second earthquake with a magnitude of 7.5 that occurred in Kahramanmaraş, 95 km from the primary event. More than 3 500 aftershocks followed the two main seismic events.

These natural disasters, together with their aftershocks, caused widespread damage over an area of 350 000 km^2, which resulted in more than 50 000 fatalities.

An estimated 14 million people (16% of Turkey's population) were affected, and four million buildings in Turkey and Syria were damaged or collapsed entirely.

The cause of the seismic sequence of events was determined to be shallow strike-slip faulting in the underlying geomorphology, which occurred at the juncture of three tectonic plates: the Anatolian, the African and the Arabian tectonic plates.

Following the events, the Turkish Ministry of Environment, Urbanisation and Climate Change inspected 763 000 buildings for damage. It revealed that more than 41 000 buildings collapsed and at least 60 000 buildings would have to be demolished. The direct physical damage amounted to $34.2 billion (4% of Turkey's GDP).

According to Prof Markou, the question that inevitably arises is what could have been done differently to prevent the structural damage that left about 1.5 million people homeless.

Working with data from the Engineering Strong Motion (ESM) database of Italy's National Institute of Geophysics and Vulcanology, researchers were able to extract accelerograms and compile a response spectrum diagram of the main event, which could be used to illustrate the reinforced concrete behaviour of structures under seismic excitation.

What researchers sought to determine with this data was how structures could be expected to behave under different seismic loads.

They first compared the behaviour of tall buildings between four and 15 storeys to those with only one to three storeys to determine whether one could expect to experience more failures in tall or short buildings. The resulting elastic spectrum diagrams were then compared to the expected behaviour of these structures according to the Eurocode standards for the reinforced concrete earthquake-resistant design of structures.

Another question that was considered related to the overall safety factor that derives from the design of a structure through Eurocode 8 (the European Union's standard for the design of structures for earthquake resistance) and the Turkish design code. By means of a modelling exercise, varying loads were computed according to Eurocode 8, specifically to determine the behaviour of reinforced concrete buildings. The results of this exercise revealed that the maximum strength of a reinforced concrete building should have been able to withstand a force three times larger than the design seismic load, a phenomenon attributed to the partial safety factors that are used during the design of structures. Through the use of the developed spectrum acceleration diagram, it was found that shorter buildings were more likely to develop damages than taller buildings with a larger number of storeys as the shorter buildings were expected to develop a larger spectrum acceleration during the main earthquake event.

Following the earthquakes, some experts claimed that the quakes were so massive that no building code could have prevented the collapses that were witnessed during the events. However, upon examining the collapsed buildings, it was noted that there were isolated buildings that remained standing, despite the surrounding buildings crumbling to the ground.

Contrary to the results of the modelling exercise, some of the buildings that remained standing were buildings with only a few storeys, while buildings of eight and more storeys directly behind them collapsed.

Upon further investigation, several disturbing factors came to light. One report determined that shop-owners had removed some of the structural columns in buildings to create more space for their wares, thus weakening the structural strength of the buildings.

An examination of the debris also determined that high-rise buildings that were purported to be constructed with reinforced concrete had, in fact, been constructed using sub-standard material that did not adhere to the building codes, while reinforcement was absent or not very prominently used. It appears that this was the result of a desire by the authorities to build low-cost housing to solve the housing problem in the cities of Kahramanmaraş and Hatay. Contractors profited from an arrangement such as this, which entailed no official site inspection or proper design code implementation.

An interesting case that came to light, which might prove the suspicions created following the examination of the debris in Kahramanmaraş, was the case of **Ezrin City**. This has become known as the "city that did not collapse", and many consider it to be a miracle. Located only 80 km from the epicentre of the main earthquake event, it suffered no fatalities and no buildings collapsed, despite experiencing a quake with a magnitude of 7.8. Officials and residents attribute this to the city's long-standing determination not to allow construction that violated the country's building codes. In fact, when officials encountered buildings that had been built illegally, they were summarily demolished. This seems to be what saved Ezrin from destruction.

Destruction in Turkey

WHY DID SOME BUILDINGS REMAIN STANDING?

Concluding his lecture, Prof Markou acknowledged the fact that Turkey's main seismic event, with a magnitude of 7.8, giving rise to a second event with a magnitude of 7.5 and more than 3 500 aftershocks, could not have been anticipated by any design code in the world. "Nevertheless, our current knowledge of designing earthquake-resistant structures allows civil engineers to prevent any failure, even for extreme events of this kind."

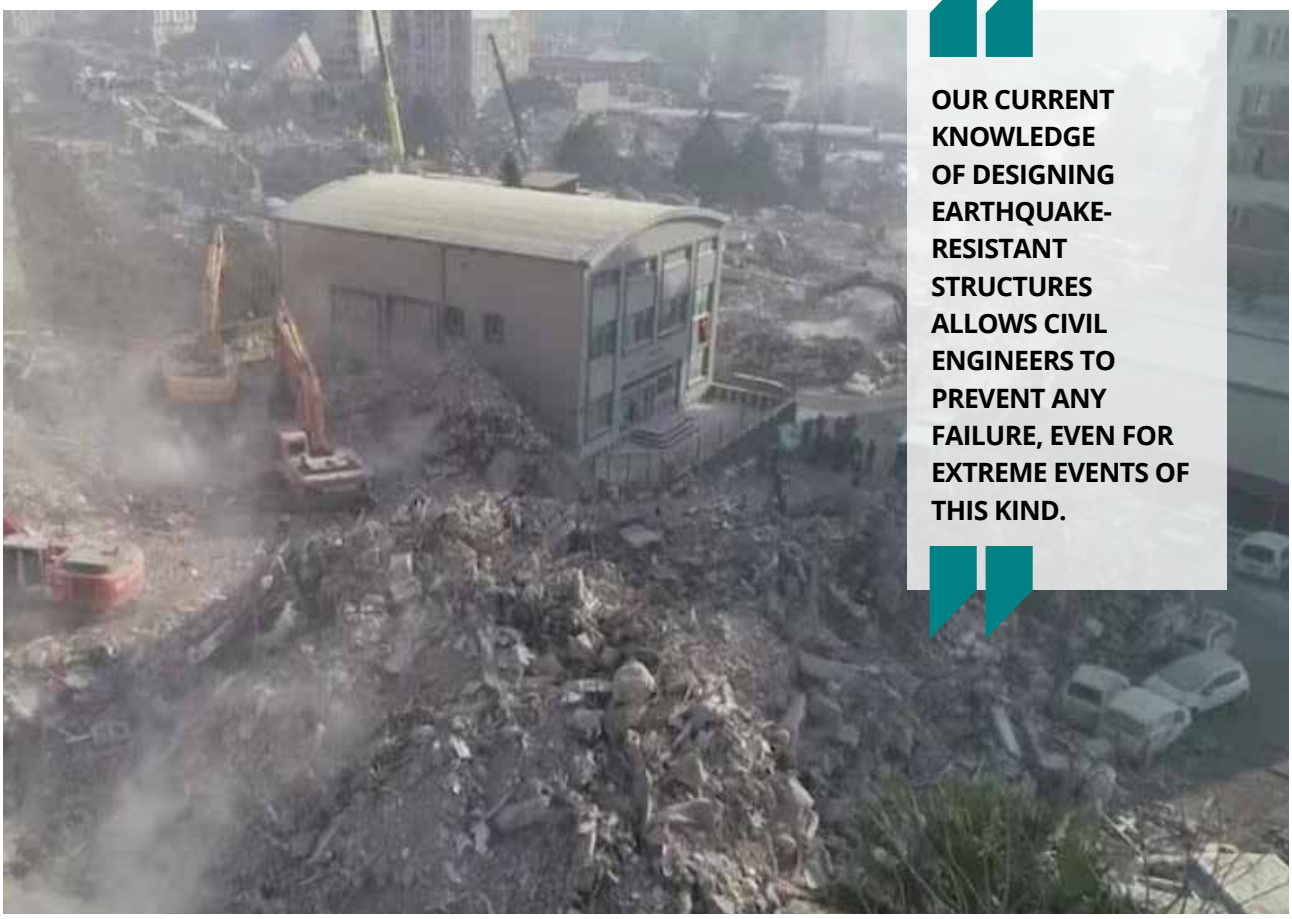
The question of why the events of 6 February led to so many building collapses in Gaziantep and Kahramanmaraş points to building amnesties, construction companies not complying with the country's building codes, illegal interventions to existing structures and poor-quality construction materials. In some cases, designers had inadequate know-how and a lack of fundamental earthquake-resistant design knowledge.

"If the design codes had been properly implemented, the destruction of infrastructure and loss of life could have been significantly reduced."

Reflecting on the latest trends in structural engineering research internationally, which is what Prof Markou and his research team are engaged in at the University of Pretoria's Department of Civil Engineering, he emphasises that the design of buildings and other city infrastructure should be motivated first and foremost by a desire to create a safe built environment for the world's urban population.

His work is focused on making use of artificial intelligence (AI) and machine learning to predict the strength of structural members and full-scale structures under different actions, including that of seismic loads. From data modelling to the design of algorithms to test the strength of concrete structures mathematically, and the smart monitoring of the built environment, the latest developments in the discipline of structural engineering can contribute to the solution of several emerging problems by describing the complex interactions among various input variables and their corresponding responses.

With this innovative approach, actual physical experimentation will soon be completely replaced by detailed 3D state-of-the-art mathematical simulations that can be used to generate millions of results for different types of reinforced concrete structures, assuming different material properties, while considering various geometries and reinforcement configurations. This will revolutionise the way civil engineers design their structures, given that new advanced AI-generated predictive models will be made available for the design of civil engineering structures, ensuring that they can withstand even the strongest forces of nature.



OUR CURRENT KNOWLEDGE OF DESIGNING EARTHQUAKE-RESISTANT STRUCTURES ALLOWS CIVIL ENGINEERS TO PREVENT ANY FAILURE, EVEN FOR EXTREME EVENTS OF THIS KIND.

Breaking traditional boundaries in civil engineering with machine learning and high-performance computing

Prof George Markou and Dr Nikolaos P. Bakas

Machine learning (ML) has become ingrained in our daily life, our society and our decision making. Digital assistants, social networking platforms and online search engines are just a few of the everyday tools that rely on this technology. ML algorithms are used to process enormous volumes of data, identify patterns, and generate precise and trustworthy predictions.

They have also been utilised in society to identify ailments and develop individualised treatment strategies in healthcare, finance and transportation by improving routes and relieving traffic. Businesses now have more options since ML can streamline procedures, increase productivity and stimulate innovation. Overall, it is impossible to estimate how important ML is and how it will continue to influence the way we live, work and interact with technology in the future.

THE PROBLEM WITH THE CURRENT DESIGN CODES

Developing new technologies for the design of safe structures is of the utmost importance to ensure a sustainable and secure built environment. Engineering relies heavily on the accuracy of design equations since they direct the development of structures that are both efficient and safe. To guarantee the security of structures and infrastructure, these design equations must be impartial, precise and current.

Technology improvements have given engineers new tools and methods to develop and assess structures, leading to designs that are more durable, effective and sustainable. Engineers may advance the design and construction process, and encourage the building of secure, long-lasting facilities that will benefit local communities for many years to come. They do this by investing in the development of innovative technology. This was the essence of a research project initiated in the Department of Civil Engineering, which foresaw the use of ML and artificial intelligence (AI) algorithms to develop accurate and reliable predictive models for the safe design of structures.

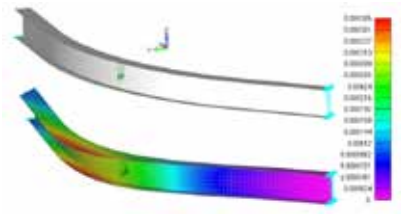
The disaster in Turkey on 6 February 2023 serves to highlight the importance of this research project with its main objective to develop ML-based design tools for safer structures. In the aftermath of the earthquake, some of the observed failures in the many buildings that collapsed were attributed to insufficient building design codes. The fact that over a million people have lost their lives due to earthquakes worldwide since 2000 is heartbreaking, especially as our buildings and infrastructure should be designed to withstand such events.

These facts encouraged the authors, who specialise in the earthquake-resistant design of structures, to work even harder to develop innovative ideas to aid the international engineering community to minimise the destructive effects of earthquakes.

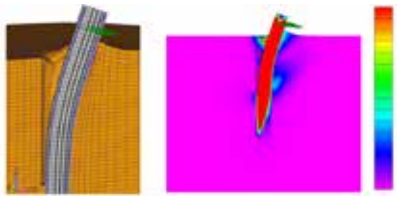
This research amalgamates knowledge and methodologies from disciplines such as engineering, computer science and statistics, where the utilisation of ML improves structural design and assessment processes. This interdisciplinary endeavour strives to bridge the gap between different scientific fields and represents an innovative approach that combines traditional engineering knowledge with modern data-driven methods to tackle diverse quandaries.

The ML software that resulted from this research constitutes a versatile tool that can be deployed by scientists across the globe to solve problems related to any discipline.

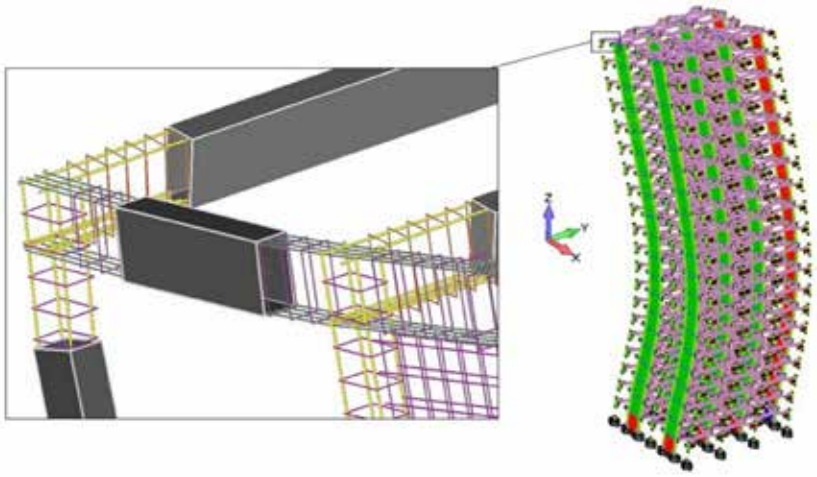
It is important to note that the landscape of structural design for safe and sustainable structures is formed using empirical and semi-empirical knowledge to develop design formulae. However, there is inherent uncertainty and a chance of incorrectness due to limited data used to develop these formulae. This contributes to the necessity of using high-safety factors during design. The inability to produce a plethora of experimentally obtained data results in the development of less accurate and objective design formulae. Additionally, some design codes do not propose formulae to predict mechanical responses in certain cases. This requires the use of new methods to develop practical and safe solutions.



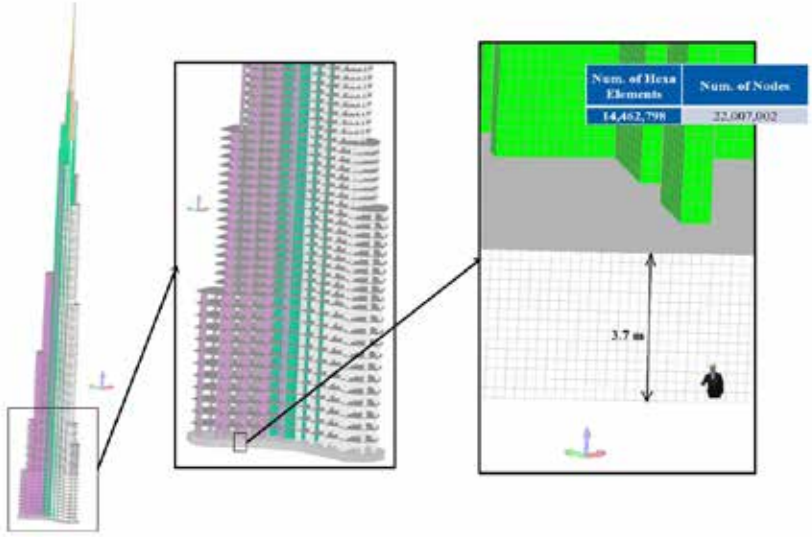
Steel I-beam model. Undeformed and deformed shape with displacement contour after loading.



Deformed shape and strain contour of a reinforced concrete pile prior to failure.



Modal shape of a fixed-base 20-storey reinforced concrete building with shear walls, together with the deformed shape of the 368 773 embedded rebar elements.



3D detailed modelling of super-tall buildings. Burj Khalifa, with a height of 828 m.

A NEW IDEA

To overcome these limitations, a pilot research project was initiated in 2018 that aimed to combine state-of-the-art 3D detailed modelling with AI and ML algorithms for the development of predictive models to compute the strength of reinforced concrete beams without stirrups. The main idea behind this research was to replace the actual physical experiment with a numerical experiment, decreasing the cost of performing an actual test by 100%. Reconan FEA software was successfully used to perform this demanding task, in which numerous datasets were developed.

Since then, the research team has managed to advance the proposed methodology through the use of high-performance computers to develop the large datasets used to train predictive models with superior accuracy and objectivity compared to existing design equations. Supercomputing is an important field that can significantly accelerate the computational time required to obtain these predictive models.

The authors have managed to successfully use in-parallel 64 Tesla GPUs for the training of their ML predictive models. They are now using Meluxina, one of the largest supercomputers in Europe, under a EuroCC research project, to develop datasets for the further training and testing of more advanced and accurate predictive models.

AN IMPORTANT MILESTONE

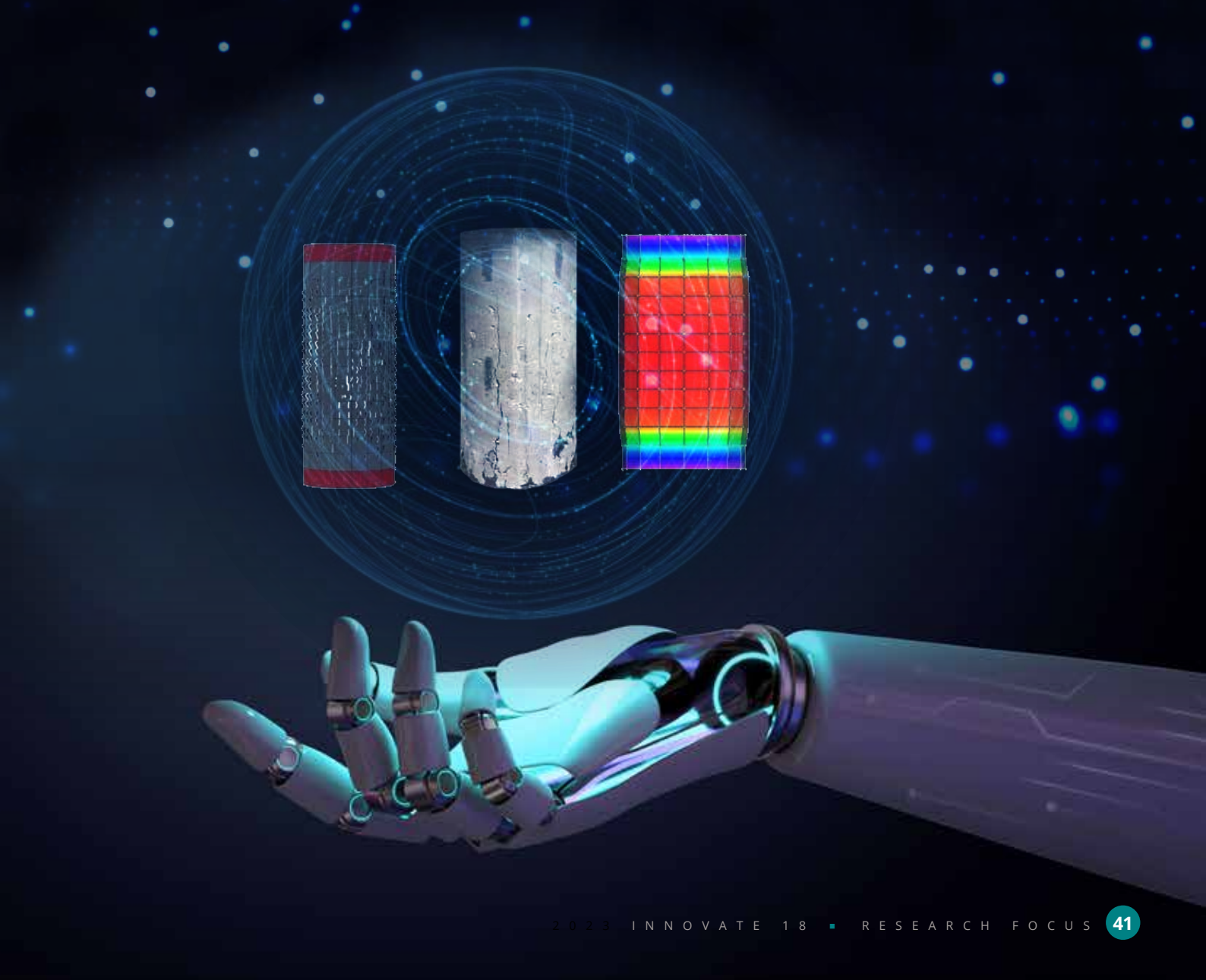
The development of ML tools represented an important milestone under the umbrella of this research project. Computer codes are provided in Python that are capable of analysing any dataset to train predictive models in any engineering field or discipline, thus breaking the barriers of civil engineering.

Some of the engineering problems that are being investigated through the use of the algorithms developed based on high-performance computing, physical experiments and advanced finite element modelling through Reconan FEA are given below:

- The development of predictive models to estimate the mechanical response of reinforced concrete structures under seismic loading
- The development of predictive models to estimate the mechanical response of sand soil-structure interaction problems under monotonic and cyclic loading
- Computing the shear capacity of concrete deep beams without stirrups reinforced with fibre-reinforced polymer bars
- Predicting the fundamental period of reinforced concrete and steel structures with and without accounting for the soil-structure interaction effect
- Predicting the deflection and rotation of curved steel I-beams for specific boundary conditions
- Estimating the maximum capacity of reinforced concrete piles embedded in clay loaded horizontally
- Predicting the maximum shear capacity of reinforced concrete columns

CONCLUSION

This research project, which endeavours to harness the power of ML and predictive modelling to enhance the safety and reliability of structures, is an endeavour of immense significance. Not only does it hold the potential to revolutionise the field of structural engineering, but it promises to make a meaningful impact in mitigating the devastating consequences of natural disasters. Furthermore, the collective nature of this project, which involves the collaboration of multiple scientific disciplines, ensures that the resulting technology will be informed by a broad spectrum of knowledge and expertise. The provision of such technology will further democratise knowledge, creating a safer and more sustainable world for all.



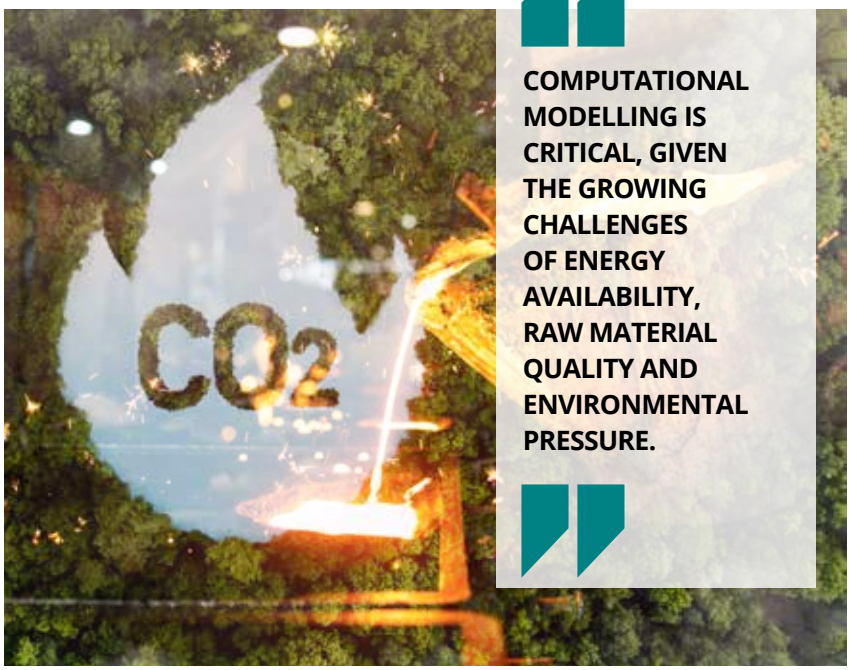
Greener metals through cross-disciplinary innovation in pyrometallurgy

A doctoral study by mechanical engineer Willem Roos, under the supervision of Dr Johan Zietsman, an honorary lecturer in the Department of Materials Science and Metallurgical Engineering, has transcended the boundaries between engineering disciplines. It has made great strides in solving what may be considered an insurmountable problem in the computational modelling of pyrometallurgical processes, which are used for the production of most of the metals used in our modern society.

Through his involvement in the Department's former Glencore Chair for Pyrometallurgical Modelling, Dr Zietsman had established the importance of computational modelling and the valuable insight it provides into pyrometallurgical processes and equipment, and the challenges that the industry is facing. "Modelling, as part of the rapid and reliable development of new production technologies, is critical, given the growing challenges of energy availability, raw material quality and environmental pressure." Dr Zietsman pointed out how computational modelling is aiding the improvement of existing operations in the mining and metallurgical industry, and how it is employed to develop new and more sustainable production technologies.

An important advantage of computational modelling is that it can enable industry to progress faster, with greater certainty and lower risk. However, according to Dr Zietsman, "our current ability to accurately and efficiently calculate thermochemical and thermophysical properties of process materials is limiting how well we can describe high-temperature processes with computational models".

Thermochemical equilibrium calculations, along with the composition- and temperature-dependent thermophysical properties of materials like slags, alloys and mattes, can improve the accuracy of computational models. However, they are mostly omitted due to the complexity and computational expense of these calculations.



COMPUTATIONAL MODELLING IS CRITICAL, GIVEN THE GROWING CHALLENGES OF ENERGY AVAILABILITY, RAW MATERIAL QUALITY AND ENVIRONMENTAL PRESSURE.

According to Roos, "the equilibrium state of a thermochemical system is determined through the computationally expensive process of minimising the Gibbs energy for a given set of chemical element concentrations, temperature and pressure, which becomes impractical when large numbers of these complex calculations have to be performed." This makes the direct integration of thermochemical equilibrium calculations into computational models infeasible, since it would take months or years to compute ... even on powerful supercomputers.

The essential problem that this research addressed was the development of an acceleration method that can be used to efficiently include thermochemical equilibrium calculations into computational models. Roos explains that several similar attempts have been made by other researchers.

Lessons learnt from such prior methods, together with high-dimensional vector algebra and fundamental thermochemical theory, were used to conceptualise, develop, and implement a new accelerator algorithm.

The algorithm uses a system's phase diagram and the Gibbs phase rule to map the thermochemical system to geometric space by calculating physical and thermochemical properties *in-situ* for later recall and interpolation.

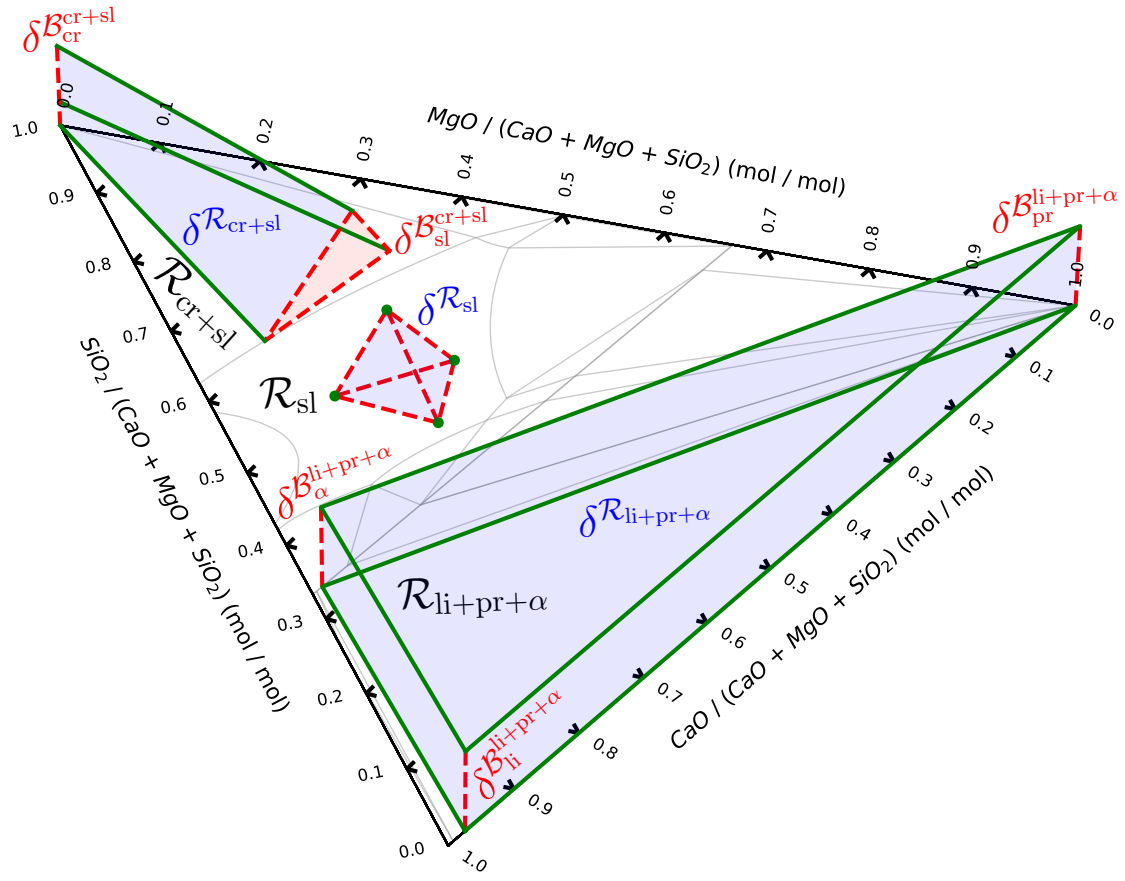
Roos believes that linear interpolation, together with the lever rule in geometric space, is orders of magnitude faster than Gibbs energy minimisation. The generality of vector algebra and the fundamental thermochemical theory on which the algorithm is based allow the accelerator to be used in any system, regardless of the number of chemical elements.

The performance of the accelerator algorithm was tested on a number of two- and three-element systems, as well as on two industry-related processes: a simplified four-element ilmenite smelting system and a simplified five-element iron- and steelmaking system. The algorithm was hundreds, and in some cases even thousands, of times faster, while maintaining acceptable levels of accuracy. The performance of the accelerator is being improved by transferring it to a more computationally efficient compiled programming language and utilising a more performant database system.

As a member of the Multiphysics team at Ex Mente Technologies, a global metallurgical engineering consulting company founded by Dr Zietsman in 2001, Roos is applying the acceleration method he developed during his research to practical industry problems by creating models of pyrometallurgical processes that are now more realistic than ever before.

This allows the company to develop deeper insight into these complex processes, assisting clients to improve their operations, reduce environmental impact and develop new production technologies.

A specific area of focus has been "green steelmaking", which develops new iron- and steelmaking technologies for more sustainable production, lowering CO_2 emissions and combatting climate change.



A conceptual illustration of the accelerator algorithm developed by Willem Roos.

Contributing to international research into the thermal management of microprocessors

Dr Marilize Everts, a senior lecturer in the Department of Mechanical and Aeronautical Engineering, has been leading the University of Pretoria's participation in an international five-year programme focusing on the smart thermal management of high-power microprocessors using phase change. This European Commission Horizon 2020 Research and Innovation Staff Exchange (RISE) programme, ThermaSMART, brought together researchers from 18 universities across five continents, and included three industry partners. The project came to an end in September 2023.

The programme developed into an international network of organisations working on joint research into the phase-change cooling of microprocessors and high-power electronic devices. It was established to gain a competitive advantage through the exposure of researchers to new research environments in academia and industry to enable the exchange of crucial skills and knowledge in this increasingly important field.

The partners, who hail from Europe, Asia, Africa, North America and South America, were committed to promoting intersectoral collaboration through research and innovation staff exchanges, and the sharing of knowledge and ideas from research to market, and vice versa. The project offered a unique opportunity to train 41 early-stage researchers over 285 exchange months in state-of-the-art experimental and modelling techniques for phase-change and microfabrication at participating universities and industries.

In addition to regular consortium meetings, technical workshops and research publications, the programme held workshops, summer schools and co-hosted events alongside major conferences in Tianjin, China; Dublin, Ireland; Kyushu, Japan; Toronto, Canada; and Edinburgh, Scotland. It also presented several exchange programmes to sustain a long-term interaction between the partners.

The project's concluding workshop was held in Cape Town on 10 and 11 August 2023, hosted by the University of Pretoria. It was followed by the 17th International Heat Transfer Conference from 14 to 18 August. According to Dr Everts, the project was a major success, with many publications, theses and successful graduates. This would not have been possible without the contribution of the partners who hosted students, and trained and upskilled them on specialist expertise.

During the course of the project, four staff members from the Department of Mechanical and Aeronautical Engineering had the opportunity to conduct research on the thermal management of microprocessors internationally and to work closely with members from the partner universities. In addition to Dr Everts, these included Prof Ken Craig, Prof Jaco Dirker and Dr Mohammed Moghimi Ardekani.

Together with a postdoctoral fellow and two master's students, Dr Everts worked on the bubble dynamics of nucleate pool boiling. Their experimental research focused on bubble dynamics on nanocoated wires in collaboration with Prof Khellil Sefiane from the University of Edinburgh, Scotland. The numerical research was conducted in collaboration with Dr-hab Panagiotis Theodorakis from the Institute of Physics, Poland.

They investigated the effects of various cavity geometries on pool boiling and bubble formation, as well as the bubble behaviour on mechanically roughened surfaces. The aim of these projects was to increase the understanding of nucleate pool boiling to unlock the potential of phase-change for ever-more demanding computational cooling requirements. They used the OpenFOAM software package, a powerful, modular, open-source computational fluid dynamics (CFD) package, to accomplish this.

The research conducted by Prof Craig included a team of five master's students, who worked on the simulation of jet impingement boiling using CFD. The students were co-supervised by Prof Prashant Valluri from the University of Edinburgh, Scotland. The aim of the research was to enhance heat transfer in the cooling of power electronics.

Four enhancement techniques were investigated: jet impingement, phase-change latent heat transfer, surface enhancement using pin fins and/or surface curvature, and vortex generators.

For jet impingement boiling on a flat surface, validation was performed against experimental data from literature for single jet and multi-jet arrays. For the case of pin-fins, various parameters of the pin-fin layout were investigated to eliminate dry-out regions that could lead to hot spots when cooling the electronic heat load. Surface curvature allows for an acceleration of the jet flow after impingement and an increase in heat transfer area. Research was also focused on finding the optimum relation of geometrical and subcooling parameters. Finally, the use of vortex generators was investigated for their ability to enhance mixing and aid rewetting through spent vapour removal.

Research into flow boiling in high aspect ratio rectangular microchannels for electronic cooling applications was performed by three master's students of Prof Dirker and two master's students of Dr Ardekani. This research was conducted in collaboration with Prof Khellill Sefiane and Prof Prashant Valluri from the University of Edinburgh in Scotland.

They investigated one-sided uniform heat flux with fluids, including FC72, water, butanol, butanol-water mixtures, ethanol and ethanol-water mixtures at mass fluxes from 10 to 40 kg/m^{2}s at various heat fluxes at atmospheric pressure.

Special attention was given to the influence of flow channel orientation to cover horizontal flow, as well as different flow inclinations from vertical upward flow to vertical downward flow.

Researchers from the University of Edinburgh, Scotland, with their South African counterparts during their time at the University of Pretoria for the ThermaSMART programme.

The effect of channel rotation was also checked by altering the azimuth angle to include cases such as heating from below, heating from the side, and heating from above within a gravity field. Of interest was the thermal and fluid response, which was monitored via infrared thermography and high-speed flow visualisation recording. Experimentally obtained data was processed and complemented with numerical simulations to describe and characterise the heat transfer performance, flow stability and bubble dynamics. Finally, the ideal operating conditions and fluid combination were identified.

Reflecting on the programme, Dr Everts observed that the smart thermal management of high-power microprocessors using phase change is becoming increasingly challenging across the globe. The benefit of a programme such as this is that it is an effective way of launching a collaborative international research endeavour to find a solution to the global problem of effective heat transfer.

The programme provided researchers from the collaborating universities the opportunity to spend a period of time ranging from a minimum of one month to a maximum of 12 months at one of the partner universities, supervised by specialists at these universities. The researchers from the University of Pretoria were partnered with researchers from the University of Edinburgh in Scotland and the Institute of Physics in Warsaw, Poland.

This collaborative endeavour was of immeasurable value, remarked Dr Everts, as it provided the opportunity for researchers to learn from each other. The researchers from each country were specialists in their own field, but by incorporating insights from another field, the ability to solve global problems was enhanced exponentially.

"The researchers included physicists, engineers and mathematicians, so they were able to supplement each other's knowledge domains through a kind of cross-pollination of ideas." It also presented an opportunity to share the equipment and resources of other institutions, instead of each institution being required to procure expensive equipment of its own to perform research.

The programme also provided an opportunity for researchers from the University of Edinburgh in Scotland to spend time at the University of Pretoria to learn from the heat transfer experts in the Department of Mechanical and Aeronautical Engineering. It was therefore mutually beneficial for all parties concerned.

Dr Everts is confident that the research partnerships that have been established will continue in the form of follow-up projects to contribute to solving the global challenge related to affordable and clean energy.

Improving mining safety with collision prevention systems

On 21 December 2022, a significant development took place in the South African mining industry. Mr Gwede Mantashe, Minister of Mineral Resources and Energy, announced that long-awaited collision prevention measures within the Mine Health and Safety Act had been activated with immediate effect.

This unique regulatory requirement, unlike any other in the world, mandates the use of collision prevention systems (CPS) to safeguard pedestrians and machine operators from accidents involving trackless mobile machines (TMMs) in underground and surface mines.

The introduction of these clauses implies that any mine at risk of such accidents without CPS installed on their TMMs may receive a section 54 instruction from an inspector. A section 54 instruction is issued when unsafe conditions, practices or occurrences jeopardise mine personnel's health and safety. Typically, it results in the temporary suspension of part or all of a mine's operations, leading to production and financial losses.

The University of Pretoria's Vehicle Dynamics Group (VDG) in the Department of Mechanical and Aeronautical Engineering has been pivotal in advising the South African mining industry on CPS since 2016. According to Dr Herman Hamersma, a senior researcher in the VDG, CPS products have been available for several years, with some of the earliest versions dating back to the mid-2000s. However, initial adopters experienced production losses of up to 30%.

This additional pressure was unwelcome, given the industry's existing challenges, including power shortages, rising production costs and fluctuating commodity prices. The key technological challenge for CPS developers is not just to slow and stop machines, but to do so only when necessary, allowing production to continue as far as possible.

Hamersma elaborates: "Our focus has been on the technology behind CPS, contributing to its maturity in the market by applying systems engineering principles to this complex technological challenge."

In collaboration with stakeholders and experts, notably the Minerals Council South Africa's Mining Occupational Health and Safety (MOSH) Learning Hub, the research team defined CPS user requirements based on common mining processes. This was followed by establishing functional and technical performance requirements, each with measurable acceptance criteria. Subsequently, a comprehensive test specification was developed to evaluate commercial products against these criteria. "This allows mines to easily compare CPS products with each other when choosing one for their operation," concludes Hamersma.

To meet the requirements of the MOSH CPS specification, the VDG Laboratory significantly expanded its testing capabilities with the support of the Minerals Council South Africa. CPS technology is essentially an application of automatic emergency braking (AEB), a technology common in commercial and heavy vehicles. However, AEB systems are primarily designed for urban or highway environments in developed countries, not for the demanding conditions of mining operations. Unlike road vehicles, large mining trucks are less stable, and the unpredictable mine environment poses unique challenges.

Consequently, the research team had to create a mine-specific test specification and adapt commercial vehicle testing instruments and test procedures to the demands of mining product testing. The MOSH CPS test specification follows a stage-gate approach, explains Hamersma, aligning with the well-established Technology Readiness levels. This ensures highly repeatable, scientific testing in a controlled environment during the early stages of product development, followed by safe testing in a representative mining environment before a product is considered mature.

THE VEHICLE DYNAMICS GROUP IN THE DEPARTMENT OF MECHANICAL AND AERONAUTICAL ENGINEERING HAS BEEN PIVOTAL IN ADVISING THE SOUTH AFRICAN MINING INDUSTRY ON COLLISION PREVENTION SYSTEMS.

When asked about the road ahead for CPS adoption, Hamersma emphasises: "Solving the technological challenge is only one piece of the CPS puzzle. Our immediate focus has been on maturing the first CPS products for widespread implementation." CPS technology is modern and intricate, requiring specialised skills for installation, maintenance and repair. "We are collaborating with various educational institutions to train more technicians and artisans to support the CPS ecosystem."

CPS is a good example of the Fourth Industrial Revolution in action. Installing CPS on machines and equipping pedestrian cap lamps with CPS sensors gives the mine management access to previously unavailable information. The dissemination and analysis of this information may lead to significant advances in mine safety, production and efficiency.

However, technology is not the only aspect that requires attention. "CPS represents a critical human-machine interface. Non-technical factors such as ergonomic design, change management, stakeholder management and updates to a mine's way of doing things are equally vital," explains Hamersma. "We are in the early stages of CPS technology development, and expect new technologies to emerge rapidly." There are currently only a limited number of applicable technical standards, and some of them are outdated. "We anticipate the need for new and updated standards to persist in the foreseeable future. Our challenge is to stay ahead of the curve."

The shortage of mature CPS products in the market not only opens doors for new entrants, but presents innovative research opportunities for academics and postgraduate students within the VDG.

Several master's students in the VDG are tackling CPS-related challenges and more opportunities are available for interested students.

This is an exciting time for the VDG. "We possess a unique set of instruments, and likely have the best-equipped vehicle laboratory on the continent and in the southern hemisphere," boasts Hamersma. "Our current research encompasses developing a virtual proving ground where CPS products, equipped with modern sensors like light detection and ranging (LiDAR), cameras and radar, can undergo simulation testing, hopefully speeding up development."

Such an environment will allow the VDG to simulate dangerous interactions, providing confidence that the product can be tested safely. Additionally, researchers are actively working on CPS algorithms that are tailored to handle the congested working environments commonly found in mines. "It is immensely satisfying to address real-world challenges faced by the local industry, bridging the gap between academia and practical applications," concludes Hamersma.

Remote controlled underground mining platform

Glenn Guthrie

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 proof-of-concept, remotely operated mobile unit to charge blast holes with emulsion explosives in the unsupported face area. The overarching objective of this project 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 unit 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 unit 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, similar to that found on excavators, 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, depending on how the blast hole was drilled. 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.

The unit was tested extensively above ground in the VDG Laboratories to quantify its mobility and performance in controlled conditions. After exceeding all design specifications, a further testing stage was performed to test the unit in a representative underground mining environment at the Maseve test mine outside Rustenburg. To mitigate risk, no actual explosives were charged during this testing phase. Instead, the unit's mobility and capability to locate blast holes was tested under real conditions. The Maseve mine prides itself on care and maintenance, so testing the unit did not interfere with production. The rock faces that would be used for simulated charging were supported and are safe for normal operations.

The testing was very successful and pointed out a few minor design issues that can be easily fixed. Overall, the unit was extremely mobile, never getting stuck, despite moving the operator trying to find challenging terrain.

New technology such as this remote-controlled underground platform promises to make future mining safer and more efficient, extend the life of current mines and create more economic value for the country.

THE DEPARTMENT OF MECHANICAL AND AERONAUTICAL ENGINEERING'S VEHICLE DYNAMICS GROUP AND THE MANDELA MINING PRECINCT HAVE DEVELOPED A PROOF-OF-CONCEPT, REMOTELY OPERATED MOBILE UNIT TO CHARGE BLAST HOLES WITH EMULSION EXPLOSIVES IN THE UNSUPPORTED FACE AREA. THE OVERARCHING OBJECTIVE OF THIS PROJECT IS TO ENHANCE SAFETY BY REDUCING THE NEED FOR PERSONNEL TO WORK DIRECTLY WITHIN THESE HAZARDOUS ZONES.

State-of-the-art mobile soils laboratory for tailings engineering

Prof SW Jacobsz

A number of very prominent tailings dam failures have occurred around the world in recent years. This has focused the attention of the mining industry and society on the risk that tailings dams could pose to the safety of nearby communities, mine workers, the economy and the environment.

Arguably the worst tailings dam failure in recent years occurred when a large iron ore tailings dam failed near the town of Brumadinho in Brazil on 25 January 2019, resulting in the loss of 270 lives, widespread environmental impact and massive economic consequences. The dramatic failure was captured on high-definition video and vividly brought the dangers potentially posed by these structures to the attention of the public.

Tailings dams are some of the largest structures made by man, often measuring kilometres in cross section. They are constructed to contain waste products from the mining process, comprising ground-up rock particles of sand-, silt- and clay-sized fractions, mixed with water and transported to the dam by pumping. After deposition on the dam, the solids settle out and excess water is decanted, usually by means of a penstock pipe or floating barge near the centre of the dam.

In the case of the so-called "upstream" construction method, the tailings itself is used to raise the outer walls of the dam to accommodate more tailings within. This results in the raised sections of the embankment being constructed on top of previously placed material. This method of construction is popular because it offers significant economic advantages over other methods. It is by far the most common tailings dam construction method in South Africa.

When constructing tailings dams using the upstream method, it is essential that material is allowed to consolidate and desiccate to develop enough strength to ensure the stability of the walls as new material is continuously placed on top of previously placed tailings. When tailings dams are raised too rapidly, not enough time is allowed for this strength gain and weak layers of low density may be incorporated into the walls. Problems associated with such layers may only become apparent in a number of years, after the dam has gained significantly more height.

The strength of tailings and soils in general arises from interparticle friction and particle interlock. Friction is simply the result of normal forces between particles, while interlock develops during over-consolidation, which takes place during the drying and desiccation processes. As tailings dries after the excess water has decanted, negative water pressures or suctions develop in the pore spaces between the tailings particles. This draws particles closer together, increasing the density of the tailings. The strength of tailings is closely linked to density, which plays an important role in the behaviour of tailings when subjected to shear loading.

Because it is essentially constructed from a rock flour slurry, most of the material in a tailings dam is saturated with water. Generally, only a relatively limited outer zone of the dam wall finds itself in an unsaturated state. This unsaturated outer zone is responsible for much of the stability of the dam walls.

Certain loading situations can occur where a tailings body is loaded in such a way that positive pressures develop in the pore water between particles. These positive pore pressures lower the effective stress between particles and reduce the frictional strength between them. It can also dramatically weaken the material, leading to dramatic and sudden failure. This is known as undrained loading. The strength of soil under such conditions is referred to as its undrained strength. The undrained strength of soil is very strongly dependent on the void ratio (density) of the soil. Depending on the loading, liquefaction of tailings is possible, resulting in dramatic flow failures.

To best measure the strength of the soil, one needs to be able to control the mean stress between the

A view inside the mobile laboratory with the two triazial rigs in the foreground.

From left: Opeyemi Fajire and Ruan Murison (postgraduate students), Prof SW Jacobsz, Vian Venter (the technician responsible for the mobile laboratory) and Faith Abimaje

The UP-Anglo-American mobile soils laboratory.

soil grains (referred to as effective stress) and the pressure in the water between the grains. This means that one needs to have control over the total stress acting on the sample and the drainage of the pore water in the soil sample. This is routinely achieved in the triaxial apparatus, which is standard equipment in soil laboratories. To determine the strength of tailings, undisturbed samples are collected from dams and are transported to triaxial laboratories where triaxial shear tests are carried out on the samples.

Many mines around the world are located in remote areas, far from urban centres where modern soils laboratories are available. This means that soil samples need to be transported long distances from where they are recovered to where they can be tested. This often results in the samples being transported by road, rail and air, with all the associated vibration. The most critical samples are typically the ones with the lowest density, which means that these samples are extremely sensitive to disturbance. It is therefore very difficult and often impossible to deliver such samples to laboratories in an undisturbed state.

Vibration associated with transport typically results in the material densifying, changing its state and undrained strength, which is a crucial parameter in the assessment of tailings dam stability. Sufficient densification can completely change the response of a tailings sample to shear loading, causing the sample to change from a contractive state to a dilatant state, resulting in an unconservative assessment of shear strength. (Contractive behaviour implies that the sample increased in density during shearing, which is associated with increased pore pressure and lower strength, while denser samples tend to dilate during shearing, with negative pore pressures developing, and hence increased shear strength.)

The renewed awareness of tailings dam stability in recent years led to the implementation of the Global Industry Standard for Tailings Management (GISTM), with strict new requirements for the management of tailings storage facilities, placing the burden on tailings dam owners to prove the stability of their tailings deposits.

With this burden in mind, Anglo American, in collaboration with the University of Pretoria, established a state-of-the-art mobile soils laboratory, which will enable sensitive tailings samples to be tested very close to the point where they are recovered, possibly even on the tailings dam itself, access permitting.

The laboratory is housed in an 8-ton truck, sourced from Hino South Africa. The truck body measures 9 m in length with a width of 2.5 m and a height of 2.45 m. It is fitted with two hydraulic stabilisers to provide lateral stability against wind when the laboratory is in use.

The laboratory houses four triaxial test frames, two dynamic cyclic simple shear (DCSS) apparatus, an automated oedometer and a dewpoint hygrometer for measuring soil suctions. It is equipped with an 80-litre drying oven, a freezer for freezing samples to allow accurate void ratio measurement and a number of electronic balances.

It is furthermore fitted with a 200-litre water storage tank and a vacuum deaerator to produce the deaired water necessary for triaxial testing.

Ample storage space is provided in the form of numerous lockable cupboards and drawers. Desk space and a mobile internet router is provided for the two technicians who will man the laboratory.

The truck freight space is lined with thermal insulation panels and it is fitted with an inverter air-conditioning system to maintain a constant temperature. The air conditioner's compressor unit is housed in a purpose-built lockable enclosure under the truck.

The mobile laboratory is powered with a solar power system, comprising a tiltable array of solar panels covering the entire roof of the freight space, a 25.5 kWh battery and a 12 kW power inverter, providing an uninterrupted 220 V of power supply, sufficient to power all equipment.

The power system includes 30 m-long three-phase and single-phase extension cables to allow the laboratory to run on mains power where available. For emergencies and overcast weather, a 6.5 kWA generator is housed under the truck's body.

A security system comprising an alarm system, all-round lighting, cameras, motion detection sensors and tracking units has been fitted. The system can be controlled and monitored remotely using a computer or cellphone.

The specialised soil test equipment housed in the laboratory was sourced from GDS in the United Kingdom. Two triaxial presses are intended to be used for critical state line testing and are standard triaxial systems. Two additional triaxial presses are equipped with piezo-ceramic bender elements to allow shear wave velocity measurement during testing, and include on-sample local strain measurement. They are intended to be used for brittleness studies. Brittleness is a crucial property of tailings.

The two DCSS systems represent GDS's state-of-the-art simple shear system which, in addition to imposing simple shear conditions, allows the confining stress in samples to be controlled. A simple shear apparatus allows near-perfect pure shear strain to be imposed on soil samples. It is primarily used for the assessment of cyclic soil behaviour and constant volume (undrained) behaviour.

The triaxial systems with bender elements and the DCSS equipment are the first of their type in South Africa. The automated oedometer system allows convenient oedometer testing to determine the compression and consolidation properties of soils. The dewpoint potentiometer allows pore water suctions of up to 300 MPa to be measured conveniently and accurately. Assessment of suction is important in the determination of the stress state of soil, and is also used in the determination of the soil water retention properties of soils.

The laboratory will be staffed by Mr Vian Venter, a highly experienced soil laboratory technician appointed for the project, and an assistant who is currently being recruited. Mr Venter will be responsible for the day-to-day operation of the facility under the management of Prof SW Jacobsz of the Department of Civil Engineering. The laboratory will be based at the Department of Civil Engineering's Engineering 4 complex on the University's Hillcrest Campus, where it will be used for geotechnical research in the Department, as well as the characterisation of tailings at the request of Anglo American.

The laboratory will travel to Anglo American mines for on-site testing at the request of Anglo American. It will also be available for other site work subject to availability and approval. The contract with the University is for five years with the option to be extended upon expiry.

The availability of the new state-of-the-art equipment and the unique feature of being able to carry out sophisticated soil tests very close to where the samples are recovered opens up new research opportunities in terms of the accurate determination of tailings properties. Not only will this provide the most accurate soil properties to assess the true state of the stability of tailings dams. It will also provide new insights into tailings behaviour as much of our understanding in terms of tailings behaviour in laboratory tests has been gained from samples at least partly disturbed during transport. To our knowledge, this mobile soils laboratory is the only one of its kind in the world.

As in the case of the partnership between the South African National Roads Agency Limited (SANRAL) and the University of Pretoria, which led to the establishment of the Engineering 4 complex, the Department of Civil Engineering looks forward to a mutually beneficial relationship with Anglo American, who is supporting the mobile soils laboratory initiative.

Mechanised mining systems benefit from collaborative research

Prof Stephan Heyns and Prof Francois Malan

A three-year public-private partnership funded by the Department of Science 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 mining schools: the University of Pretoria (UP), the University of the Witwatersrand (Wits), the University of Johannesburg (UJ) and the University of the Free State (UFS).

The purpose of the larger SAMERDI project is to revitalise mining research, development and innovation in South Africa to ensure the sustainability of the industry for economic growth. Each institution was allocated specific research activities. UP would focus on mechanised mining systems, Wits on real-time information management systems, and the successful application of technologies centred around people, UJ on the longevity of current mines, and UFS on advanced ore body knowledge.

The focus of the overall research project is on research and capacity building, together with fundamental research: the basic and pure research that creates new knowledge about mining, technology and data, systems and processes, and the people associated with the sector. The outputs from this fundamental research will be aligned with and will inform the applied research of the Mandela Mining Precinct.

UP's research activity was jointly allocated to the Department of Mining Engineering, and the Department of Mechanical and Aeronautical Engineering.

The inclusion of the latter department in this mining engineering research activity was based on the fact that mechanisation is an acknowledged strength of the Department of Mechanical and Aeronautical Engineering, and adds value to the research activity.

The specific research objectives of UP's Research Activity in Mechanised Mining Systems (RAMMS) are to establish research expertise to assist in the fundamental understanding of mining equipment used in mechanised mining processes, the interaction of mining equipment with the rock on which it acts, the interaction of mining machines between themselves, and the interactions with the network and communications infrastructure.

The research programme currently has three specific research thrusts. These comprise the following:

1. **The cutting and drilling of hard rock**
2. **The productivity and maintenance optimisation of mining equipment**
3. **The monitoring and interpretation of utilisation, performance and condition monitoring information measured on mining equipment**

To accomplish these goals, RAMMS focuses on the development of digital twins, which rely, on the one hand, on physics-based models of mining equipment and processes, and on the other, on data-driven models based on process and other parameters that are continuously measured during mining operations. An interesting feature of the research that is currently being conducted is the use of so-called transfer learning methods, which allow researchers to use physics-based models, together with data-driven models, to get the best of both worlds.

Research into the efficient and safe mining of narrow-reef hard rock is particularly important to South Africa. Two of the world's greatest mineral deposits are found in South Africa: the gold deposits of the Witwatersrand Basin and the platinum and chrome reefs in the Bushveld Complex. These ore bodies are tabular in nature and a large fraction of the reefs worked by these mines is less than 2 m in width. The limited mining height of these excavations and the lateral persistence of the reefs prevents the application of mining techniques used successfully elsewhere in the world. These tabular mining geometries may thus lead to exceptionally high stress concentrations at the edges of the excavations. No other mining region of economic significance has these stoping geometries and more efficient mining methods must be found in South Africa.

The RAMMS research is supervised by Prof Stephan Heyns from the Department of Mechanical and Aeronautical Engineering, and Prof Francois Malan from the Department of Mining Engineering. Prof Heyns is Director of the University of Pretoria's Centre for Asset Integrity Management. He has research interests in machine and structural health diagnostics and prognostics, based on vibration measurement and analysis. Prof Malan is Director of the University's Mining Resilience Research Centre. His research interests include the inelastic numerical modelling of tabular excavations, and simulating pillar behaviour and pillar strength. Both Prof Heyns and Prof Malan are B-rated researchers with the National Research Foundation (NRF), and are able to provide the necessary research competency support.

An important task of the RAMMS was the appointment of a staff complement to provide administrative and research support. Thobeka Masango was appointed as administrative officer for the duration of the contract, while Luke van Eyk was appointed as a full-time researcher. Prof Johann Wannenburg was appointed as a senior researcher on a part-time basis. Van Eyk has a master's degree in mechanical engineering and is currently registered for his PhD, which aligns very well with the responsibilities of the research activity. Prof Wannenburg is a senior engineer with vast experience in the mining industry and in academia. He has a PhD in mechanical engineering.

A key condition of the RAMMS was the involvement of students from historically disadvantaged universities in the research work. During 2022, the University of Limpopo and the University of Venda were identified as partners for collaboration. Both these universities could offer relevant expertise, which would enhance the research programme at UP in meaningful ways. It was therefore decided to involve both universities, and a formal Memorandum of Understanding was signed with each of them. A student with a supervisor from each of these universities is currently participating in the RAMMS.

Nine postgraduate students are conducting their studies through the RAMMS. Seven of these students are working towards completing their master's degrees in engineering. The remaining two are master's degree students in geology at the University of Limpopo and the University of Venda, respectively.

Current student projects focus on the following:

- The development of an optimised insourcing/outsourcing maintenance model for mechanised mining
- Productivity improvement of mechanised underground mining processes through simulation
- The modelling of rock cutting for mining in deep hard-rock environments
- The optimal extraction of key performance indicators for a load-haul dumper from limited sensor measurements on actual mining equipment
- A quantitative study of reliability, availability and maintainability to enhance plant productivity
- Predictive maintenance and digitalisation in the mining industry
- The optimisation of underground hard-rock mining equipment maintenance strategies
- The mineralogical characterisation of the brittleness indices of platinum-bearing reefs located in the eastern limb of the Bushveld Igneous Complex
- Investigation of rock properties on the selection of drilling equipment in mechanised mining

In a very interesting project, RAMMS is developing numerical models of load-haul dumpers (LHDs), which will ultimately be used for the optimisation of various aspects of LHD utilisation, performance and condition monitoring. Rham Equipment, a South African developer of specialised mining equipment, has liberally assisted UP in this endeavour by making test facilities and experimental data available to do this development in a way that would enable the University to make meaningful research contributions in this field.

The SAMERDI contract amounts to R9.9 million over a four-year period from January 2022 to December 2025. The bulk of this funding will be used to fund the newly appointed staff members, as well as postgraduate students. Some of the funding will also be used to develop specialised research facilities.

The first of these was the development of a linear rock-cutting test facility, which has already been used to conduct interesting research on the modelling of rock-cutting processes using finite element models, which are calibrated against experimental results.

Current initiatives are focused on developing stronger research relationships with industry, as well as significant international research relationships. RAMMS hopes to use this as a basis for continued industry support after December 2025 when the current SAMERDI funding cycle comes to an end.

Developing a missing person locator system for underground mines

Larrance Ngwenyama

Underground mines are often regarded as one of the most dangerous areas in which people are expected to work. This can be attributed to the continuing accidents and disasters that often result in fatalities and serious injuries to people. Fortunately, mineworkers and visitors are not always fatally injured in an accident. Some miners can survive the initial accident, but may remain trapped or lost in unknown and life-threatening locations underground.

At this point, emergency response is highly desired for any chance to save or even rescue the missing persons and sometimes recover bodies. The emergency response in terms of search-and-rescue operations becomes ineffective when the location of the missing persons is unknown. The rescuers are then forced to search random or presumed areas. This becomes time wasted and limits the chances of survival.

This was observed from an investigation and analysis of accidents from different mines that resulted in trapped or lost miners being deceased and, in some cases, surviving. These accidents occur every year, and search and rescue can take as long as 14 days due to the locations being unknown. One such example is the Lily mine tragedy, in which three mineworkers became trapped in a container on 5 February 2016. Despite rescue attempts, their bodies have still not been recovered.

At the heart of this problem is the wide range of systems that are commercially available to determine the location of the missing persons. This includes tagging-and-tracking, locator and two-way communication systems. A postgraduate research project in the Department of Mining Engineering entailed evaluating the capabilities and limitations of these systems to determine fit-for-purpose or failproof systems that can be operated efficiently in harsh underground environments.

Tagging-and-tracking systems provide the position of personnel in real time and can provide their last detected locations in the case of the system being damaged. The disadvantage of these systems is the requirement for extensive infrastructure, which is susceptible to damage during an accident. This means that the location of the missing persons after the accident may not be accurate.

Locator systems are used to determine the location of persons trapped behind a fall of ground, buried in a fall of ground or trapped in cavities. Rescue teams need to be between 20 and 40 m from the trapped persons to scan for signals emitted by active tags carried by the trapped persons or mounted on cap lamps.

Two-way communication can be provided by means of handheld radios, through leaky feeder or ethernet infrastructure or station-based wireless, through-the-earth mechanisms. Two-way communication via handheld radios is also infrastructure based, while no major infrastructure is required for through-the-earth communication systems. Through-the-earth communication systems are capable of surviving an accident and can remain operational after the accident.

Through the Mine Health and Safety Council (MHSC), the Department of Mineral Resources and Energy has initiated a process to put regulations in place regarding missing person locator systems in underground mines. The proposed amendments seem to be based on a locator system for detecting persons trapped 30 m behind rock.

The interest of PhD researcher Larrance Ngwenyama in this topic dates back to 2016 when he was involved in research to develop a missing person locator system for the MHSC through Enterprises University of Pretoria. He has continued research on this topic for his master's study as he recognised its relevance and the need for further study on this topic.

The impact of the outcomes of this study are indisputable in terms of safeguarding the lives of mineworkers and any other visitors to the mine. The ultimate goal of this research pertains to saving survivors who have become trapped or lost underground following a mine accident.

Under the supervision of Prof Ronny Webber-Youngman, and in collaboration with the Department of Electrical, Electronic and Computer Engineering, Ngwenyama's PhD study aims to integrate the capabilities of the available systems to develop a total system. This is intended to mitigate the limitations of each of the systems, and thus increase the effectiveness of the total system.

The total system will comprise three stages in order of increasing effectiveness, while also taking a strategic implementation plan into consideration. The first stage is based on a through-rock locator system, which makes use of active tags and very-low frequency signal scanners. Field tests will be conducted on the propagation of signals through solid and collapsed ground at a very low frequency.

The second stage is based on tagging and tracking, which can determine locations in real time using radio-frequency protocols such as wi-fi or bluetooth. The simulation and modelling of high-frequency signals is being conducted to improve communications between active tags and signal readers.

The third stage is based on the post-accident, through-the-earth communication. This entails the simulation and modelling of electromagnetic wave propagation through rock at an ultra-low to extremely low frequency spectrum, generally narrowband below 10 kHz. The electromagnetic waves can only be propagated to a limited depth of 600 to 1 000 m based on magnetic waves or electric fields.

In addition, a seismic wave detector system for trapped miners is being considered as a backup due to its simplicity and lower dependency on infrastructure. Collectively, all these stages can be integrated and interoperated as a single, total system.

Ngwenyama explains that this work is still ongoing at the University of Pretoria. He envisages the development of a prototype of the total system from the proof-of-concept.

THE ULTIMATE GOAL OF THIS RESEARCH PERTAINS TO SAVING SURVIVORS WHO HAVE BECOME TRAPPED OR LOST UNDERGROUND FOLLOWING A MINE ACCIDENT.

Research into pillar strength benefits the mining industry

Prof Francois Malan

The South African mining industry faces several engineering challenges. One of these is the need to improve pillar strength and pillar design methodologies for hard rock mines. South Africa's shallow chrome, platinum and manganese mines typically use mechanised bord-and-pillar mining layouts. As older operations are vital to the South African economy, it is critical to ensure that the ore bodies contained in these reefs are optimally exploited.

It may be somewhat surprising to note that many of the mine layout designs in use today are still mostly based on the Hedley and Grant pillar strength formula, which was originally developed for Canadian uranium mines in the early 1970s. Since then, very little research has been conducted to develop specific reef-type pillar strength formulae for South Africa's hard rock mines.

This reinforces the importance of developing new mine design models for South Africa, and was the driving force behind the Department of Mining Engineering's focus on rock engineering. A key aspect of its research, which is widely acknowledged for its excellence, is the development of new design criteria and layouts for hard rock mines to ensure their sustainability. Some of the studies that have been undertaken include investigations into the use of a limit equilibrium pillar model in a boundary element code, laboratory studies to calibrate these models, underground observations of pillar behaviour, the effect of confinement on pillar strength, and the effect of pillar shape.

In recognition of its work in this regard, one of the country's leading gold mining companies, Harmony Gold, committed its support to the Department's rock engineering research with the establishment of a Chair in Rock Engineering, which has been running since 2013. Research in this Chair is focused specifically on techniques to simulate rock mass behaviour in South African deep-level gold mines. It is currently the only research programme in the country to develop the rock engineering tools that are needed to improve safety and profitability in the deep tabular gold mining industry. Close collaboration has also been established with other mines, such as Northam Platinum and Impala Platinum.

Over the past year, the Department has showcased its research on various platforms. A research colloquium, held on 18 November 2022, provided researchers the opportunity to share the findings of a selection of its rock engineering projects with industry. This was followed by a special edition of the *Journal of the South African Institute of Mining and Metallurgy* in May 2023, focused specifically on hard rock pillar research in South Africa. The articles in this edition predominantly featured research conducted in the Department. This issue is recognised as a welcome addition to the available research literature on hard rock pillar strength.

A SELECTION OF THE DEPARTMENT'S RESEARCH CONTRIBUTIONS TO HARD-ROCK PILLAR DESIGN

Numerical simulation of large-scale pillar layouts

A number of shallow coal or hard rock mines employ pillar mining systems as a strategy for roof failure control. In certain platinum mine layouts, pillars are designed so that they can "crush" in a stable manner as they become loaded in the panel back area. The correct sizing of pillars demands some knowledge of the pillar strength and the overall layout stress distribution.

An important design strategy is to model relatively detailed layout configurations that include a precise representation of the local pillar layout geometry and to analyse multiple mining scenarios and extraction sequences to select optimal pillar sizes and barrier pillar spacing. Although the proposed computational solution technique for tabular stopes is impressive in terms of run-time efficiency, a major difficulty is encountered in assigning suitable material properties to the pillars and devising an effective material description of the layered rock strata overlying the mine excavations.

Research conducted by Prof John Napier and Prof Francois Malan outlined a novel numerical modelling strategy that can be used to assess large-scale pillar layout performance, while retaining the ability to modify individual pillar constitutive behaviour. The proposed method was applied to selected mine layouts to compare estimated average pillar stress values against values determined by detailed modelling and against observed behaviour.

The effect of pillar shape on pillar strength

Pillar strength is affected by pillar shape, but past research studies have largely ignored this. Bord-and-pillar layouts are typically designed using empirical strength equations developed for square pillars.

Owing to the poor quality of pillar cutting, many hard-rock pillars have an irregular shape. It is not clear how this affects pillar strength. Furthermore, the strength of rectangular pillars is difficult to quantify.

The "perimeter rule" is widely adopted for rectangular pillars, but its applicability to pillars with irregular shapes has never been tested. A study by Jannie Maritz used numerical modelling to investigate the effect of pillar shape on strength. An analytical limit equilibrium model of a square and a strip pillar also provided useful insights. For slender pillars, the strength of a long rib pillar is essentially similar to that of a square pillar.

In contrast, for rib pillars with a large width-to-height ratio, there is a substantial increase in strength. The study found that the perimeter rule should not be used for irregularly shaped pillars. Displacement discontinuity modelling, using a limit equilibrium approach, is proposed as an alternative to determine the strength of these pillars.

Simulating time-dependent pillar scaling in hard-rock bord-and-pillar mines

Danél Wessels used a limit equilibrium model to simulate the time-dependent scaling of hard-rock pillars. In manganese bord-and-pillar mines, extensive scaling was observed for pillars characterised by a high joint density.

The scaling appeared to occur in a time-dependent fashion. Selected pillars were monitored in an attempt to quantify the rate of time-dependent scaling. The scaling distance for pillars of different ages could be measured and most of the scaling seemed to occur soon after the pillars were formed. Numerical modelling of the time-dependent scaling was conducted using a displacement discontinuity code and a limit equilibrium constitutive model.

The postulated exponential decay of the failed rock mass strength at the edges of the pillars resulted in simulated behaviour that was qualitatively similar to the underground observations. This method can be used to investigate the long-term stability of bord-and-pillar excavations.

A study of UG2 pillar strength using a new pillar database

A recent experimental pillar extraction project at a UG2 bord-and-pillar mine presented Thomas Oates with a unique opportunity to compile a new pillar database. Currently, the South African hard-rock bord-and-pillar mines are designed using the Hedley and Grant formula with a modified K-value. This empirically derived formula was developed for uranium mines in the Elliot Lake district of Canada. The use of this formula for the design of pillars in South Africa is questionable. Very few pillar failures have nevertheless been observed and its current calibrations for the various reef types are possibly too conservative.

Oates compiled a new UG2 pillar database of 66 pillars, of which seven are classified as failed.

This enabled a revised "first-order" calibration of the K-value for the Hedley and Grant formula. The new estimated value for the UG2 mine gives a pillar strength that is more conservative than the PlatMine formula. This work should be seen as a preliminary calibration as the database was small. Further work is required to determine whether the exponents in the formula for the width and height parameters are appropriate for UG2 pillars.

Simulating pillar reinforcement with a displacement discontinuity boundary element code

A study by Johann Esterhuyse explored the use of a novel numerical modelling approach to study the effect of pillar reinforcement on pillar stability. Case studies in the literature indicate that tendons, strapping of the pillars and shotcrete or thin spray-on liners are commonly used to reinforce pillars. No clear methodology exists to select the type of support or design the capacity of the support required.

This has led to ongoing collapses in some mines despite heavy support being used to reinforce unstable pillars. A limit equilibrium model with confinement on the edge of the pillar was used to simulate the interaction of the support with the failing pillar.

The model correctly predicts that an increase in confinement will lead to a decrease in the extent of pillar failure. As the displacement discontinuity boundary element method allows for the efficient solution of large-scale bord-and-pillar layouts, the effect of pillar confinement can now be studied on a mine-wide scale. Accurate calibration of the limit equilibrium model is, however, required before this method can be used for the design of effective pillar support.

Bord-and-pillar design for the UG2 reef containing weak alteration layers

A study by Paul Couto proposed a layout design for the UG2 reef where weak geological alteration layers are present. The collapse of the Everest platinum mine in South Africa indicated that these layers substantially weaken the pillars. The popular Hedley and Grant pillar strength formula cannot be used where these alteration layers are present. Underground investigations at Everest mine and numerical modelling of the layout were conducted using the TEXAN code and a limit equilibrium model. Simulations of a collapsed and an intact area allowed for a preliminary calibration of the model.

This was subsequently used to explore modified layouts for these ground conditions. An alternative is to compartmentalise the blocks of ore using barrier pillars. The numerical modelling predicted that the barrier pillars appear to remain stable, even in the case of large-scale collapses, provided their width exceeds 25 m. Main access routes into the mine can be protected by a double row of pillars at least 15 m wide to provide a safe travelling way. Calibration of the limit equilibrium model remains a challenge due to the large number of parameters involved.

Calibration of the limit equilibrium pillar failure model using physical models

The limit equilibrium model used in displacement discontinuity codes is a popular method to simulate pillar failure. A study by Ruan Els investigated the use of physical modelling to calibrate this model. For the experiments, an artificial pillar material was prepared and cubes were poured using the standard 100 mm × 100 mm civil engineering concrete moulds. The friction angle between the cubes and the platens of the testing machine was varied by using soap and sandpaper. Different modes of failure were observed depending on the friction angle. Of interest is that significant loadshedding was recorded for some specimens, which visually remained mostly intact. This highlights the difficulty of classifying pillars as failed or intact in underground stopes where spalling is observed. The laboratory models enabled a more precise calibration of the limit equilibrium model compared to previous attempts.

The use of backfill confinement to reinforce pillars in bord-and-pillar layouts

A study by Divine Ile explored the use of backfill in hard-rock bord-and-pillar mines to increase the pillar strength and extraction ratio at depth. The use of backfill will also minimise the requirement for tailings storage on the surface and the risk of environmental damage. A literature survey indicated that backfill is extensively used in coal mines, but rarely in hard-rock bord-and-pillar mines. To simulate the effect of backfill confinement on pillar strength, an extension of the limit equilibrium model was proposed. The numerical modelling of an actual platinum mine layout was used to illustrate the beneficial effect of backfill on pillar stability at greater depths. The magnitude of confinement exerted by the backfill on the pillar sidewalls is unknown, however. This needs to be quantified using experimental backfill mining sections equipped with suitable instrumentation.

Innovative slow-release technology finds additional applications

Dr Mthokozisi Sibanda

A patented technology that originated in the University's Institute of Applied Materials (IAM) has found an additional application, which has led to the development of a low-cost transdermal drug-dosing patch. The initial invention, known as the Bi-Ko™, enabled insect repellents to last longer by reducing their evaporation. It was applied to mosquito nets and hiking socks, thereby playing an important role in the fight against malaria.

This invention was developed by Dr Mthokozisi Sibanda, in collaboration with Prof Walter Focke, Director of the IAM. Its licensing led to the development of a spin-off company of the University of Pretoria, a biotechnology company known as African Applied Chemical (AAC) (Pty) Ltd, of which Dr Sibanda is the founder.

The company manufactures advanced textile fibres, which are designed to store and slowly release high-value organic actives. The aim is to extend the residual effectiveness of these actives and reduce evaporative losses in the case of volatile actives. The latest application of this technology is the development of a slow-release cannabis patch, known as the CBDpatch™. This patch has been designed to slowly release controlled doses of Cannabidiol (CBD) under the skin.

Transdermal drug dosage is a useful way of introducing small amounts of drug actives into the body at a sustained rate. This increases the efficacy of the drug by directly introducing the active at the target site where action is required to bring rapid relief. Furthermore, bypassing the oral route reduces the loss of actives due to digestive processes, and ensures that all the actives are taken up in the bloodstream. The transdermal dosing of CBD also saves on the costs associated with using CBD for medical purposes.

Cannabidiol is an upcoming active that is touted as being useful against chronic inflammation. Several cannabis products are currently being proliferated commercially in the market. Almost all of them are ingested orally. High-purity CBD is commercially expensive, which puts it out of the reach of many consumers who need it. Government regulations limit the intake of CBD to only 20 mg a day.

MANUFACTURE OF THE SLOW-RELEASE PATCH

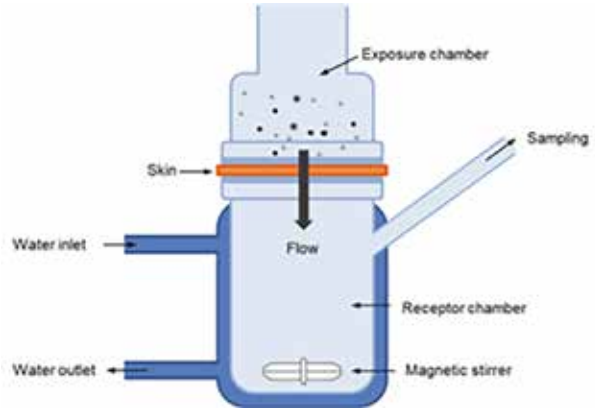
Proprietary Bi-Ko™ slow-release fibres were manufactured by infusing a blend of 10% of CBD dissolved in a penetration enhancer into the fibres at a loading level of 5%. The fibres were then cut into staples and processed into a non-woven textile measuring approximately 200 g/m^2 using the needle-punching technology. This non-woven textile formed the final CBDpatch™ product.

The aim of this study was to determine the release of CBD from a substrate CBDpatch™ impregnated with a 5% CBD blend formulation. Although it was difficult for the patch to adhere directly to the membrane used, measurements showed some release of the active ingredient from the patch, which could be detected by ultraviolet-visible (UV-Vis) analysis.

Permeation experiments were performed using vertical Franz diffusion cells. A skin-mimicking membrane (Strat M® Merck, South Africa) was placed between a donor and a receptor compartment of the diffusion cell. The receptor compartment was filled with ethanol and was continuously stirred at 600 rpm and kept at a temperature of 32 °C. A weighed sample of the CBDpatch™ (approximately 60 mg) cut into a circular shape to fit the diffusion cell was placed onto the membrane.

Sample aliquots (3 mℓ) were withdrawn at pre-determined intervals (from one to six hours) from the receptor compartment,

and replenished with an equal volume of the fresh receptor medium. The sample aliquots were analysed using a UV-Vis spectrometer (Perkin Elmer Lambda 70s, USA). All experiments were performed in triplicate and average values are reported.



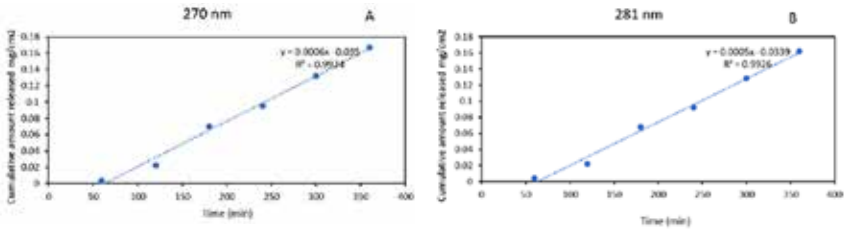
A sketch of a Franz diffusion cell (adapted from the Karolinska Institute, University of Helsinki)

RESULTS

The permeation parameters – average cumulative release after six hours and average flux of the sample – were determined by performing transdermal diffusion experiments using Franz diffusion cells and skin-mimicking membranes.

Average percentage released, average cumulative amount per area released after six hours, average flux and the coefficient of determination (r^2) of CBD from a transdermal patch.

Measuring wavelength (nm)	Average percentage release of active after six hours (%)	Average cumulative amount released per area after six hours (µg/cm²)	Average flux (µg/cm² per hour)	Coefficient of determination (r^2)
270	9.84 ±0.82	166.9 ±14	60	0.992
281	9.56 ±0.81	162.0 ±13	50	0.992



Cumulative amount per area (µg/cm²) as a function of time to illustrate the average flux value for CBD released from the patch.

Samples collected at pre-determined intervals were analysed for the concentrations of CBD using UV-Vis spectroscopy. Two characteristic UV peaks of CBD (270 and 281 nm) were used for calibration and quantitative determination. The Franz diffusion cells give an indication of the amount of CBD permeated through the membrane at different time intervals. The result showed a release of around 9 to 10% of the active component from the patch after six hours of measurement. An average amount of 162 to 166 µg/cm² of CBD was released after six hours, indicating a slow release from the patch. Plots of the cumulative amount of CBD permeated through the membrane against time were used to determine the parameter's flux (µg/cm² per hour). The slope of the plots of the cumulative amount permeated against time gave the value of average flux, which was 50 to 60 µg/cm² per hour.

CONCLUSION

This proof-of-concept study was carried out to demonstrate the use of a low-cost slow-release fibre technology (Bi-Ko™) to store and slowly release a 5% CBD formulation transdermally in a patch form (CBDpatch™). The study indicated that the patch releases 60 µg/cm² per hour through an artificial model skin in a Franz diffusion cell setup. A 20 cm² patch can dose approximately the maximum government-sanctioned rate of 20 mg per day.

However, there are still questions that need to be answered. Most concerning of all is the lack of quantitative scientific studies that clearly prove that CBD is of medical benefit. This is despite massive hype generated around CBD locally and internationally on the health benefits of CBD and the aggressive commercial proliferation of various CBD-based products.

The questions that need to be answered are whether it is possible to show quantitatively that CBD is anti-inflammatory. If so, what is the minimum dosage level that will give adequate anti-inflammatory action for acute and chronic conditions? A comprehensive search of commercial products infused with CBD indicated that there are very few products on the market. The reason for this may be that the CBD industry is still in its nascent stages.

AAC is perfectly positioned to claim market lead for a transdermal CBD slow-release patch.

Energy security depends on the development of South Africa's hydrogen economy

Given the country's current energy crisis and the increasing problems related to the supply of coal-fired sources of electricity, the time has come to consider expanding South Africa's current alternative energy sources. As an institution committed to pursuing research that addresses complex societal challenges, the University of Pretoria has identified energy as one of its core institutional research themes.

In the Faculty of Engineering, Built Environment and Information Technology, research focused on optimising and developing new approaches to the country's energy and power systems is located, among others, in its Department of Electrical, Electronic and Computer Engineering (EECE). A particular focus of this Department is building capacity to support the development of South Africa's hydrogen potential and the creation of a South African hydrogen economy for energy security and sustainability.

While fossil fuels such as coal, oil and natural gas have long proven their effectiveness in producing heat and providing power for domestic and industrial use, they are becoming harder to extract in a cost-effective manner. Their effect on the environment and human health in terms of their carbon emissions is becoming an increasing source of concern globally.

The drive to find alternative sources of energy finds its origin in the Paris Agreement, signed by 196 parties at the United Nations Climate Change Conference in 2015. This agreement seeks to limit the global increase in temperature to less than 2 °C by the end of the century. Achieving this target depends on reducing our dependence on fossil fuels and realising carbon-neutrality.

Although South Africa has made huge strides to enter the renewable energy sector through the introduction of solar, wind and hydropower over recent years, there are many arguments in favour of adding hydrogen to the list of alternatives. At the same time, this will contribute to establishing South Africa's hydrogen economy. Most of the challenges facing the large-scale adoption of renewable energy relate to the efficient storage and transportation of clean energy.

Hydrogen – particularly green hydrogen – is exceptionally energy dense per unit of weight compared to other fuels. This facilitates its storage and transportation. Through its direct combustion, coupled with its use in fuel cells and as an industrial feedstock, it can be produced cost effectively to support decarbonisation, and presents enormous opportunities for South Africa in the global carbon economy.

Green hydrogen, as an alternative fuel source, is produced in a sustainable manner with zero emission of carbon. It is mainly produced through the electrolysis of water. Since South Africa is a water-scarce country, use is increasingly being made of desalinated water for this purpose. An additional contribution to the economy is the beneficiation of the country's platinum group metals (PGMs) that are used in the manufacture of the hydrogen fuel cells.

The South African National Energy Development Institute (SANEDI) has identified the University of Pretoria as a leader in research into energy efficiency and the integration of renewable energy into the national energy grid.

In partnership with Bambili Energy, one of the country's leading manufacturers of hydrogen fuel cells and their subcomponents, the Department of EECE is building capacity to safely install, operate, maintain and refuel the hydrogen fuel cell systems on which the creation of a hydrogen economy depends. This training is aimed at developing competent, capable and work-ready technicians for the deployment, installation and maintenance of hydrogen fuel cell systems.

According to Prof Raj Naidoo, Head of the Department of EECE, training such as this will contribute to positioning South Africa in the emerging global hydrogen economy. Not only is it aligned with the University's commitment to ensure a safer, more sustainable way of life for the next generation, but also forms part of Cabinet's long-term strategy to participate in international hydrogen and fuel cell technology platforms.

Expertise in machine learning leads to mutually beneficial collaboration

Recent advances in Artificial Intelligence (AI) and Machine Learning (ML) continue to highlight the advantages of a digital society. These include the development of large language models as applied in the ChatGPT chatbot. Increased online activity has demonstrated how large volumes of data travel all over the world every second of the day. AI and ML are two elements of the digital future that assist humans to perform tasks where underlying patterns in and insights into large volumes of data are not obvious.

In recognition of the key role that AI – and specifically machine and deep learning – will play in unlocking a truly digital future, MultiChoice South Africa partnered with the University of Pretoria (UP) to sponsor the MultiChoice Chair in Machine Learning in 2018. This research chair strives to address the global skills shortage in ML development, thereby helping to bridge the digital divide. This will enable Africa to excel, given its unique challenges and opportunities.

The Chair is jointly located in the School of Information Technology and the School of Engineering. Acting as co-chairholders, Prof Nelishia Pillay represents the Department of Computer Science, and Prof Pieter de Villiers represents the Department of Electrical, Electronic and Computer Engineering. Prof Pillay heads her Department's Nature-inspired Computation Optimisation Group, while Prof De Villiers heads his Department's Signals, Information Fusion and Communications Research Group.

The initial five-year agreement entered into between UP and MultiChoice South Africa in 2018 was aimed at the pursuit of joint collaboration and research for their mutual benefit.

Given its past success, the agreement has now been renewed for a second five-year term until 2028.

The Chair undertakes academic and applied research, as well as human resource development in the field of machine learning, which is applied to several advanced topics of interest to MultiChoice.

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

During the course of the first five years of the partnership, MultiChoice funded 13 students across various levels of under-graduate and postgraduate study: eight in the Department of Computer Science and five in the Department of Electrical, Electronic and Computer Engineering.

The opportunities and projects identified by MultiChoice are addressed through master's and PhD projects that propose novel and creative ML approaches to solve global problems, while providing students access to pressing real-world industry research and realistic data. Several exciting ML-related research projects are currently under way or have been completed within the Chair in the application domain of satellite broadcasting and internet video streaming. Topics include, but are not limited to, the automated genre labelling of motion picture (movie) trailers, the automated analysis of audio and video content to extract meaningful and descriptive metadata, the automated generation of closed captions through automated audio processing, automated audio and video segmentation for scene skipping, automated movie trailer creation, and even the forecasting of weather-related impacts on DStv's service delivery.

Some of these projects address Big Data challenges, where the volume, velocity, variety, veracity and value (the 5 Vs of Big Data) of video and audio content have become so overwhelming that it is impossible for humans to process it. As ML is a very specialised field, the partnership between MultiChoice and UP is a forward-looking way to nurture and improve these skills in South Africa, while addressing problems of research and commercial interest through interesting collaborative projects.

WHAT IS MACHINE LEARNING?

According to Prof De Villiers, machine learning can be described – at the most elementary level – as teaching computers and robots to learn and act safely in cases where humans may be overwhelmed with information. This can either be achieved by providing the machines with as many examples as possible, or by building a reward mechanism into their programming. The machine must then be able to act appropriately in situations for which it was not explicitly trained.

The objective of ML is not, as some people fear, to replace jobs, but rather to support and assist humans in economic and technological development. It is an enabling technology. Students and practitioners must be prepared with the requisite knowledge and skills for the current Fourth Industrial Revolution and the subsequent Fifth Industrial Revolution, or Society 5.0. The MultiChoice Chair in Machine Learning represents a significant step towards preparing and developing human resources for this exciting era that awaits us.

According to Prof Pillay, ML has contributed to various facets of life in South Africa, including industry, education and society.

It has made an impact in various areas of industry, such as reducing energy consumption, assisting in financial forecasting, and developing automated software, network optimisation and content management. In education, ML has enabled academics to provide students with individualised tutoring by means of intelligent tutoring systems. ML has also enabled lecturers to study student performance and identify learning difficulties that may exist.

THE WIDER IMPACT OF MACHINE LEARNING

One of the first ML initiatives implemented by the broadcasting industry was the automated creation of the 2017 Wimbledon segment. Where highlights of a major sporting event such as this would only be available hours later if compiled manually, ML enabled the highlights to be available immediately as automated content. This contributed to the improved productivity of broadcasting companies.

The impact of ML can be seen in several other elements of society as well, such as automated music composition, automated art, and enabling conversation in a natural language with computers. In the beginning of 2023, the online chatbot ChatGPT stunned the world with expertly crafted responses to almost any question in any subject area imaginable.

As we move towards a digital future, ML will play a pivotal role in meeting the challenges of digital transformation. It is anticipated that the incorporation of AI and ML to find industry solutions will improve economic growth rates in South Africa by 2035.

MULTICHOICE
ENRICHING LIVES

FLAGSHIP PROJECTS

AUTOMATIC THUMBNAIL SELECTION

Kyle Pretorius, a master's degree student, developed a system for automatic thumbnail selection using genetic programming and convolutional neural networks. This entailed feeding a movie trailer into the system and playing the video frames one after each other. The ML system then scores the frames based on how good the image would be as a thumbnail, which can be used in DStv's menu of what to watch. Once processed, the top five frames are ranked, from which one can select the most suitable one to use. By automating the thumbnail selection process, as opposed to generating it manually, benefits of time and cost-savings are achieved.

THE AUTOMATED DESIGN OF VIDEO MULTIMETHOD ASSESSMENT FUSION

Dr Ahmed Hassan is a postdoctoral fellow who hails from Sudan. His project focused on video quality assessment. He assessed a system to measure the quality of video streaming. Video streaming entails several processing steps, any of which can degrade the quality of a video. Being able to measure the visual quality of a video is essential to obtain the leading edge in many sectors of society. This can be done through video multimethod assessment fusion. The ML system learns from human perceptions of quality by imitating human preferences, which are configured to obtain optimal performance.

END-TO-END AUTOMATED SPEECH RECOGNITION

Alexander Loubser, a master's degree student employed at MultiChoice since the start of 2023, developed a system for end-to-end automated speech recognition using a character-based small-scale transformer architecture. This entailed using ML to recognise the speech signals embedded in a video, as well as their unique features, in order to convert them to text. This is utilised in the automated generation of subtitles, which is currently a manual process. While the database he used made use of American and British English, the challenge was to find enough data in South African local languages to apply the model to other languages as well.

A MOVIE RECOMMENDATION SYSTEM USING DEEP LEARNING FEATURES

Adolfo Almeida graduated with a master's degree in Computer Engineering in 2021 and has been working at MultiChoice for the past three years. He hails from Angola. His project focused on developing a video recommendation system using a range of deep learning features extracted from video content. What makes this system novel is that it actually watches thousands of movie trailers, making use of the same sound and visual perceptions that a human would. Based on what one has watched in the past, it makes informed recommendations within the user's viewing habits. It differed from other systems in use at the time as those systems only made use of users' viewing history and video content metadata.

A business model framework for education technology entrepreneurs

Adrian von Maltitz and Prof Elma van der Lingen

Education technology has been proven to make a positive impact on education outcomes in developed economies. There is immense untapped opportunity to introduce more education technology into the basic education ecosystem to help address South Africa's education crisis. Master's research conducted in the Graduate School for Technology Management (GSTM) developed a framework that can be used to identify key considerations for education technology entrepreneurs to create sustainable ventures.

In 2004, the South African Department of Basic Education released a White Paper on electronic education titled *Transforming learning and teaching through information and communication technologies (ICTs).* It identified various capacity constraints that limit ICT delivery, and called for the public and private sectors to work together. Entrepreneurship drives economic growth in Africa, and is increasingly defined as acting on an opportunity using innovation as an instrument.

These innovation opportunities can have multiple sources, including process need and changes in market structure, and are often fostered through new knowledge in science and engineering. The education technology entrepreneur is the entity in the ecosystem with the highest level of agility to take on such an opportunity, if properly positioned and supported.

By developing a framework that identifies key considerations for sustainable education technology entrepreneurship in an emerging economy, the study sought to answer the question: How can South African education technology entrepreneurs be better supported in the education technology value network.

The framework provides a blueprint for existing and new education technology ventures in an emerging economy to evaluate their business plans and models in the education technology value network.

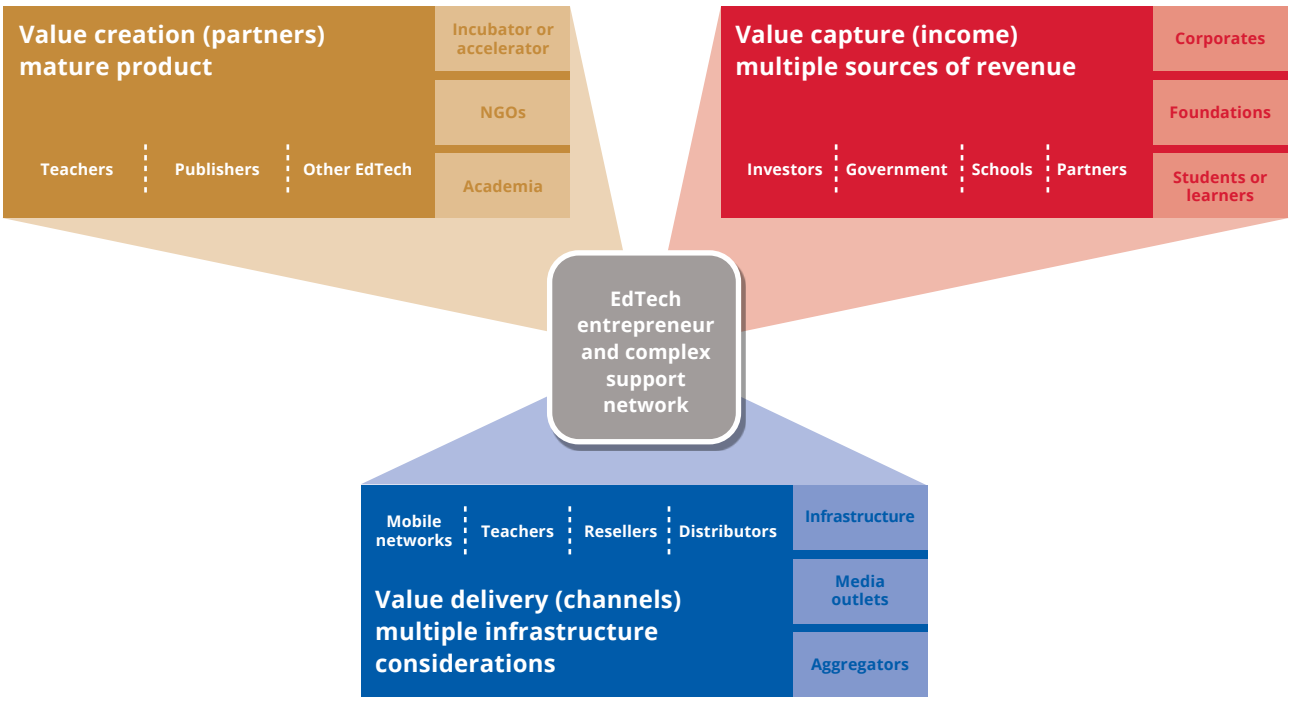
It identified four themes:

- A mature product that is endorsed by students and parents
- A complex support network
- Multiple infrastructure considerations
- Multiple sources of revenue

The study furthermore set three propositions that were related to the themes identified from the data collection:

- Teacher distrust has the greatest impact on value creation.
- Investor skepticism and government revenue streams have the greatest impact on value capture.
- Mobile network zero rating has the greatest impact on value delivery.

HOW CAN SOUTH AFRICAN EDUCATION TECHNOLOGY ENTREPRENEURS BE BETTER SUPPORTED IN THE EDUCATION TECHNOLOGY VALUE NETWORK? THIS FRAMEWORK PROVIDES A BLUEPRINT TO EVALUATE THEIR BUSINESS PLANS AND MODELS.



Business model framework for educational technology (EdTech) in South Africa.

Providing a mature product as part of the value proposition opens up the rest of the opportunities in the value network. Getting to this point would seem to be best achieved by starting with what you have, or being means-driven, and partnering with teachers and other education technology companies to enhance the value proposition with bootstrapping, competition or grant funding. One of the key relationships is with the South African Department of Basic Education, even if only to align with the curriculum or receive product endorsement.

Once the mature product is ready, which includes alignment with the country's curriculum and languages, multiple streams of revenue can be accessed via a complex support network. This support network includes negotiations with infrastructure providers to provide free or discounted access, as the education technology offering for basic education has a major social impact that provides positive brand alignment.

Education technology ventures should find the right support structures, which include finding incubator and accelerator support, as well as an advisory board. The education technology ventures should actively search for multiple sources of revenue, including those from corporates and government, which come from building multiple meaningful relationships.

In a review of progress in the basic education sector issued in 2019, government reported on partnerships with the private sector as funding sources and providers of connectivity and infrastructure. Government could therefore consider extending and improving partnerships with small- and medium-sized education technology companies in the private sector. This could be done through even more clear and updated policy guidelines, as well as consistent implementation at the provincial level, which includes a clear policy-to-budget-to-procurement alignment.

Another key partnership is between education technology providers and corporates, which could extend to a partnership between these two parties and government. Corporates should continue to support education technology companies with social impact grants, but ultimately only as a stepping stone to a more sustainable arrangement that includes value for the corporate, in exchange for revenue streams to the education technology companies.

An incubator support system has significant value: apart from building a business plan and getting mentorship on how best to pitch it to investors, it could provide access to a broader set of stakeholders in the value network. Some of the key relationships that could be built on the back of this incubator support are long-term coaching and mentorship arrangements, access to infrastructure providers and access to funding. Incubator and accelerator support functions should support education technology ventures, even if they do not exactly fit the entry profile into their programmes.

Education can make a big difference to the global challenge experienced by society. With better support, more education technology companies can become sustainable, and so help improve the quality of education in South Africa.

Growing connections through structural timber

Schalk Grobbelaar

Mass timber construction using advanced engineered wood products is emerging as a viable alternative to concrete and steel globally. The York Timbers Chair in Wood Structural Engineering, located in the Engineering 4.0 Building on the University's Innovation Africa Campus, is making great strides in stimulating the development of a sustainable, mass engineered timber construction industry in South Africa and the African continent based on advanced engineered wood products sourced from locally grown forest plantations.

Worldwide, timber buildings have many advantages. Timber has stood the test of time: one of the oldest temples in Japan, the Horuy-ji Temple, constructed in 607 AD, is the oldest wooden building in the world. Furthermore, timber construction is attractive, strong and good for the environment. Its behaviour during a fire can be predicted, it can be used to manufacture large structural components, and it promotes modular construction.

Researchers at the University of Pretoria are involved in programmes to promote timber construction at different levels and in overlapping capacities. At one level, the Graduate School of Technology Management (GSTM) is conducting research into timber construction from an innovation and technology management perspective. It was also involved in a feasibility study, in collaboration with Enterprises University of Pretoria (E at UP), for the Department of Trade, Industry and Competition, to investigate the promotion of timber construction in South Africa. At another level, the York Timbers Chair has launched a programme in wood structural engineering in collaboration with the departments of Civil Engineering and Architecture.

The technology management research into timber construction makes use of open innovation as a business concept that emphasises the importance of using external resources, including ideas, technologies and talent, to drive innovation and growth. It involves collaboration between an organisation and external partners, such as customers, suppliers, universities, start-ups and other organisations to co-create value and solve problems. It makes use of the minimum viable product concept, based on the idea of creating a product that is simple, functional and meets users' core needs.

Another concept that has been examined in this regard is that of frugal innovation. This is characterised by a focus on simplicity, affordability and functionality. It involves finding creative ways to reduce costs and increase efficiency in the product development process, such as using locally available materials, leveraging existing infrastructure and designing products that are easy to manufacture and maintain.

Timber construction can benefit from both these concepts. It can also benefit from the model of diffusion of innovations. This model is based on the premise that the adoption of new ideas, products or technologies follows a predictable pattern. It identifies five key stages in the adoption process: awareness, interest, evaluation, trial and adoption. It also identifies different types of adopters based on their behaviour and attitudes towards new ideas. These include innovators, early adopters, early majority, late majority and laggards.

Technology and innovation management in the timber construction industry can also utilise scale-free networks. This is a type of network where a few nodes have a high number of connections, while the majority of nodes have only a few connections. In social networks, these highly connected nodes are known as hubs or influencers, while the less connected nodes are known as peripheral nodes. The York Timbers Chair is utilising this concept in developing connections between industry and academia.

Its activities are focused on growing the industry by stimulating a sustainable, mass engineered timber construction industry in South Africa. It takes some lessons from the engineering and technology management research conducted in the GSTM.

TIMBER HAS STOOD THE TEST OF TIME. IT IS ATTRACTIVE, STRONG AND GOOD FOR THE ENVIRONMENT.

This includes people naturally wanting to be part of something new, trendy and cutting edge. It therefore makes use of this "fear of missing out" to encourage the construction industry to explore timber construction even further.

It highlights the benefits of using timber, showcases successful and innovative timber construction projects in South Africa and globally, and encourages influencers such as architects, engineers and industry experts to endorse timber construction. It organises community engagement events, workshops and seminars, and shares engaging and relevant content on social media.

To grow the industry and to grow connections with associated professions, the York Timbers Chair has expanded its capacity with the appointment of a full-time architect, as well as an architectural intern. It has established a Structural Engineering Working Group, comprising researchers and academics from the Department of Civil Engineering, as well as an Architectural Working Group, comprising members from the Department of Architecture. Additional working groups are envisaged to cover the fields of sustainability, innovation management, wood genetics, chemistry and chemical engineering, marketing and financial management.

Architects and civil engineers play an important role in stimulating timber construction in South Africa. By encouraging these professionals to work with wood, the Chair is promoting the use of mass engineered timber products. This material also has a more environmentally friendly footprint than concrete and steel.

During the past year, the York Timbers Chair has been presenting timber design and construction training to architecture, interior design and civil engineering students in collaboration with two architectural firms, Earthworld Architects and RAW Modular.

The training by Earthworld Architects was presented to three groups of 10 students each. It provided designers with both theoretical knowledge and practical experience in the construction of timber buildings. It focused on different timber construction methods and manufacturing techniques, followed by a practical session, in which the students utilised various applications to design, draw and nest the different components of their designs.

The training by RAW Modular was presented to three groups of 15 students each. It focused on plywood and mass timber design and construction. The training aimed to familiarise designers with the processes associated with designing and manufacturing with plywood and other mass timber products using contemporary CAD and machining techniques. It formed the baseline of exploratory structural applications and manufacturing techniques, and included topics such as material, design, machining strategies and preparation.

These activities were concluded with a timber design competition, which attracted entries from the University of Pretoria, Inscape Design College, Nelson Mandela University and the University of KwaZulu-Natal. The aim of the competition was to challenge designers to interpret, invent and deploy methods of building systems, with a focus on emerging technologies in timber design, on a real-world site. Architecture students from the University of Pretoria took both first and second place: Shannon Govender won the competition with an entry titled "Grass roots", while Nicola Smuts was the runner-up with an entry titled "Symbiotic craft". The winners were announced during York Timbers' annual Timber Construction Conference, held on 12 September 2023 with the theme "Growing timber connections."

The competitors were required to make use of a site in the Greater Bakenburg area in the Mogalakwena Municipality in Limpopo. The land had been donated by the Lapalala Wilderness School. They had to design an agricultural and environmental skills training centre for the Waterberg community, which should include public facilities, education and administration facilities, as well as building infrastructure – all constructed from timber.

Collaboration with the Department of Architecture was further extended with the presentation of two honours studios, which included the timber construction competition.

These activities play an important role in advancing sustainable forestry management.

Built environment students recognised for their sustainable thinking

Students in the University of Pretoria's School for the Built Environment are displaying their commitment to sustainable building practices and have been recognised by industry for their innovative approach to promoting a circular economy.

Shannon Govender and Nicola Smuts, two students in the professional Architecture programme, earned first and second place in York Timbers' annual Timber Design Competition. This competition challenges designers to interpret, invent and deploy numerous methods of building systems, with a focus on emerging technologies in timber design, on a real-world site.

Govender explains that her design concept offered a regenerative and sustainable solution that creates new materials while restoring agricultural development and conserving local culture. The competition provided her with an interesting avenue to explore how building and making can influence construction on a large scale. Smuts, on the other hand, believes that South Africa has a vibrant spirit of craft, placing great importance on community involvement in the construction process. The competition allowed her to explore how digital craft processes can further enhance and enable participatory construction practices, while continuing to uphold the essence of artisanship.

Dr Calayde Davey, a senior lecturer in the Department of Architecture, expressed her excitement at the impact students in the School for the Built Environment are making in addressing global challenges that extend beyond their individual disciplines. By focusing on the entire construction value chain, they are developing innovative, transdisciplinary approaches to transform unsustainable building practices.

UP participants with the judges. From left: Christo van der Hoven, Shannon Govender, Emma Ayesu-Koranteng, Nicola Smuts and Tlhologello Sesana

This furthermore illustrates how the University of Pretoria is not only providing its graduates with the necessary technical skills, but is also producing well-rounded individuals who can meet the needs of their profession. In the process of developing unique solutions to industry challenges, they are acquiring soft skills like teamwork, leadership skills, communication and negation skills, and the ability to collaborate with their colleagues to co-create new outputs.

By learning to work together in a way that is different to that traditionally associated with their profession, and applying what they have learnt to other disciplines, these students are ready to impact the global sustainability challenges the world is facing today.

Research in the built environment contributes to urban upliftment

Postgraduate students in the School for the Built Environment have been making a difference in the informal settlements within the City of Tshwane Metropolitan Municipality since 2016. The research activities of the Department of Architecture's Unit for Urban Citizenship (UUC) are not only addressing the need of the residents of Plastic View and Melusi for a sustainable built environment, but also for basic services and infrastructure.

The Unit's activities are driven by a desire to embed a culture of participation to achieve collaborative urban citizenship. Under the supervision of the Unit's Director, Dr Carin Combrinck, and professional architect and PhD candidate, Jason Oberholster, members of the Department's Urban Citizenship Studio have been collaborating with students from the Reality Studio of the Chalmers University of Technology (CUT) in Sweden for the past five years to respond to urban settlement challenges.

As part of this collaboration, Oberholster was invited to spend five months at the CUT in Gothenburg, Sweden, teaching Architecture students from September 2022 to February 2023. His input in this institution's master's programme in design and planning for social inclusion, as well as its short course, Beyond Sustainability, will form part of the case study of his doctoral research.

Furthermore, the input of students from CUT's Reality Studio in the Unit's research activities since 2018 has had an impact on the lives of the residents of the informal settlements of Plastic View, Melusi, as well as those around Mamelodi. This work has also been the topic of Oberholster's doctoral research, which relates to how architects facilitate complex urban integration in informal settlements.

Dr Combrinck observes that rapid urbanisation in South Africa is exacerbating the socio-spatial inequities of apartheid planning. "This is resulting in the emergence of informal settlements across the urban landscape." She states that, since the dawn of democracy in South Africa, policies have been established to assist in the process of urbanisation, most of which 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 remarks.

The importance of collaborating with community members and stakeholders to develop spatial

proposals for urban development lies in the fact that residents of informal settlements cannot make a meaningful contribution to the co-production of the urban space without a collective seat at the table, remarks Dr Combrinck. "Their voices are currently not being included in the implementation of policies pertaining to them."

She furthermore observes that high-level data collection, surveys and imposed intervention strategies fail to include the communities themselves when unpacking the micro-scale challenges and potential solutions that could serve to address immediate concerns. "Through the continued exclusion of communities in the process of research and the production of knowledge, policy instruments remain ineffective in addressing the most pressing concerns of human dignity and safety in these settlements."

It is estimated that half the world's urban population resides in informal settlements. In South Africa, the number of settlements increased from 300 in 2002 to 2 225 in 2016, with almost five million people estimated to be living in informal settlements in and around the major metropolitan areas. This indicates the scale of the issue and the urgent need to address socio-spatial upgrades locally and internationally.

The Department of Architecture believes that the socio-spatial inequalities of the past need to be remedied through meaningful collaboration and negotiation by all parties concerned. Current research in the Urban Citizenship Studio forms part of a three-year transdisciplinary study on co-creating wellness and human dignity in urban settlements. The facilitation of inclusive community-based research and science engagement that forms part of the study received grant funding from the National Research Foundation (NRF) and the South African Agency for Science and Technology Advancement, an agency of the Department of Science and Innovation, in 2022.

The study aims to document and map the community services and the built environment structures in the urban settlements of Plastic View and Melusi. This will enable stakeholders to understand the living conditions in these communities, and how it affects the residents' wellbeing. 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 of early childhood development, health and sanitation.

Students affiliated with the community-based project module of the Faculty of Engineering, Built Environment and Information Technology also perform work within these communities.

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. The research is expected to contribute to the necessary reconsideration of long-term urban upgrading policies.

Dr 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.

The nationwide roll-out of upgrading policies through collaboration with the City of Tshwane Metropolitan Municipality and the Department of Human Settlements' National Upgrading Support Programme (NUSP) is anticipated to establish a systemic strengthening of urban citizenship in marginalised communities. This will enable residents to collaborate with government, the non-governmental organisation (NGO) sector and other stakeholders in creative urban emergence.

THE DEPARTMENT OF ARCHITECTURE BELIEVES THAT THE SOCIO-SPATIAL INEQUALITIES OF THE PAST NEED TO BE REMEDIED THROUGH MEANINGFUL COLLABORATION AND NEGOTIATION BY ALL PARTIES CONCERNED.

According to Oberholster, the research follows the UkuDoba Method by collecting fine-grained visual and qualitative spatial information through participatory action research, community mapping and geographic information system (GIS) methodologies. The geolocated data then becomes available for future studies in various disciplines. By making use of this method, transdisciplinary research can provide stakeholders with access to the same data, so that countermeasures can be put in place to address the communities' needs.

This method was the outcome of a project funded by the NRF and the Swedish Foundation for International Cooperation in Research and Higher Education (STINT) from 2018 to 2021. It was a collaborative endeavour between the University's UUC and CUT's Social Inclusion Design Studio in Hammarkullen, Sweden.

Despite the fact that many of the spatial design challenges that UP's students and researchers need to address are typical of a developing-world context, some parallels have surprisingly been identified in the development of low-cost urban housing in the Global North. This led to the ongoing collaboration between the Architecture departments of UP and CUT since 2018 in the form of a comparative study on the role of architects in urban upliftment. This includes challenging the traditional role of the architect to incorporate meaning-making and cultural inclusion in informal settlements.

The UkuDoba method of field research is not limited to Architecture. The information obtained is stored in a data warehouse and can be utilised in multiple fields to envision spatial and social outcomes. Transdisciplinary collaboration that is taking place in these informal settlements includes community engagement projects by UP's Department of Occupational Therapy, the Community-oriented Substance Abuse Programme of the Faculty of Health Sciences, the Department of Family Medicine, the Department of Geography, Geoinformatics and Meteorology, the Faculty of Law, the Faculty of Theology and the Reality Studio at CUT.

The University of Pretoria's involvement in the informal settlements of Plastic View and Melusi was initiated by the Community-oriented Primary Care (COPC) Unit in the Faculty of Health Sciences, who trained field workers and community health workers to gather information using the UkuDoba Method. The data gathered during these participatory action research activities can be used to perform a full-scale contextual needs analysis to determine the communities' social, as well as their physical needs. Based on this information, spatial recommendations can be made, and proposals formulated that are relevant to the community.

The Department's multi-level study by honours, master's and doctoral researchers is considering the proposed displacement of inhabitants and the redevelopment of cities. It will determine how the legal frameworks related to migration and refugee-ism impact on socio-spatial strategies of displacement or urban integration.

These activities are guided by the Department of Human Settlement's comprehensive Breaking New Ground (BNG) Policy, developed in 2004. This policy clearly articulates government's intention to develop sustainable human settlements, and to alleviate asset poverty through housing. The policy describes asset poverty as inadequate access to housing, including inadequate shelter, which manifests in badly located, low-cost and overcrowded dwellings, and the inadequate provision of appropriate infrastructure and basic services such as health, safety and emergency services, as well as education facilities.

Oberholster explains that informal settlements are governed by the Department of Human Settlements' Upgrading of Informal Settlement Programme (UISP), which was introduced in the BNG Policy. It focuses on the urban integration of informal settlements. This policy, which falls within the National Housing Code, aims to support upgrading on an area-wide basis, maintain fragile community networks, minimise disruption and enhance community participation through a four-phased process.

This programme provides the typical process that municipalities should be following in the establishment of informal settlements in terms of infrastructure tenureship and their *in-situ* upgrading. It also addresses the communities' needs for the settlement's optimal functioning. This covers the initiation of the settlement, registration of households and application for the settlement to be recognised as an informal settlement.

It includes the settlement's interim access to shared basic services such as waterborne sanitation, a potable water point, access routes for emergency services, refuse removal access points and assistance to establish community-based janitorial and basic repairs, and maintenance monitoring.

This is typically followed by the planning of the settlement through a feasibility study in which sustainability aspects are investigated and assessed, including the establishment of social amenities and infrastructure.

The final stage of development examines the area's construction readiness and housing consolidation – the options for land acquisition and ownership (tenureship).

"The role played by Architecture in the upgrading of informal settlements," says Oberholster, "is to provide input in terms of spatial outcomes and to add value to the process by developing skills and professional competencies". The identification of the problems to be solved and needs to be addressed, however, calls for the contributions of an interdisciplinary team. "In this way, better integrated and more multidisciplinary solutions can be envisaged." Following the development of an informal settlement, the focus needs to be on ensuring the sustainable livelihoods of the residents.

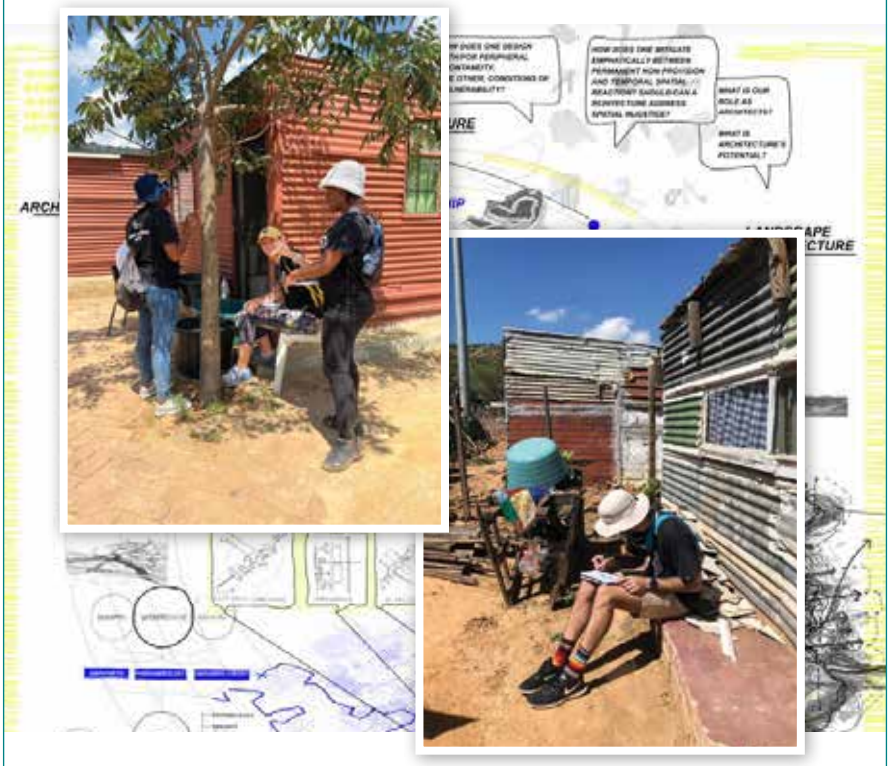
Since 2016, the research activities of the UUC have been focused on strengthening interim solutions for the residents to access shared basic services. This has been made possible by the strength of the interdisciplinary team's joint involvement in the respective communities.

This became particularly evident during the recent COVID-19 pandemic and during the fires that broke out in Plastic View in 2016, which led to 227 informal shelters being destroyed and the loss of five lives. During these events, members of the UUC, the University's COPC Unit and NGOs were able to establish a proper disaster relief programme to service the residents of the informal settlement.

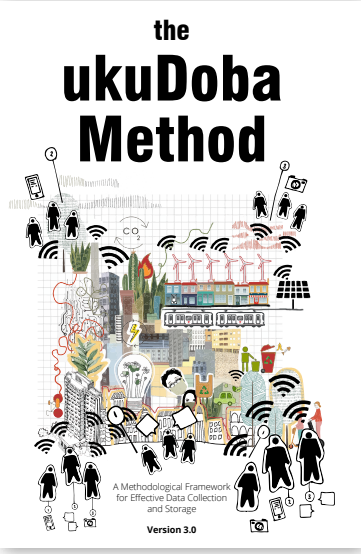
The research furthermore aims to address the United Nations' Sustainable Development Goals (SDGs) related to no poverty (SDG 1), good health and wellbeing (SDG 3), quality education (SDG 4), clean water and sanitation (SDG 6), and sustainable cities and communities (SDG 11). It is also focused on meeting the basic needs of all citizens, as contained in the South African Constitution, including the right to tenure.

"A typical feature of informal settlements," says Oberholster, "is that they are located in close proximity to job opportunities, and offer a solution to the financial burden that excessive travel costs impose on economic advancement". It is an unfortunate fact that the remnant apartheid spatial legacy perpetuates economic marginalisation. "Residents of informal settlements include economic migrants from within the country, as well as migrants and refugees from neighbouring countries, and represent all age groups, genders and income levels, although most come from the lowest income group." In Plastic View, the residents include South African rural migrants, and citizens from Mozambique, Lesotho and Zimbabwe (both documented and undocumented).

By focusing the project on the intersection of essential primary care, including maternal and child health, dietetic and sanitation challenges, as well as early childhood development and social entrepreneurship, the immediate impact of the Department's interventions would be on the women and children living in the informal settlements. In this way, they can address the immediate challenges of health, dignity, safety and education faced by the residents of informal settlements.



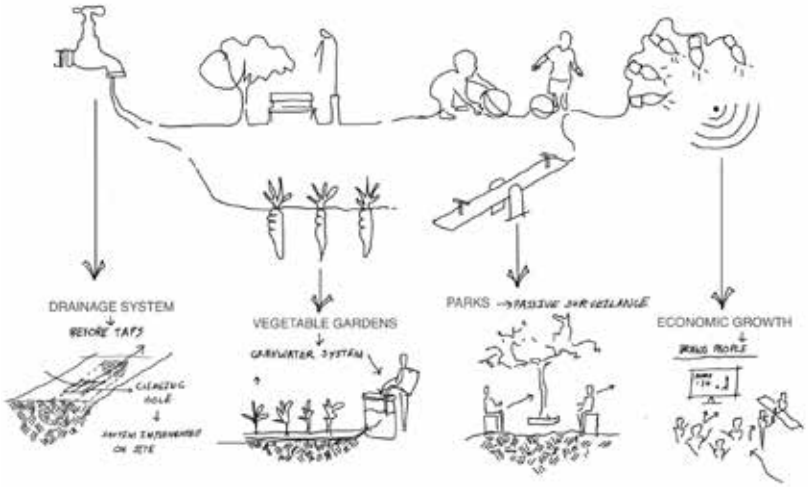
Following the mapping of the Melusi and Plastic View informal settlements, the researchers conducted voluntary questionnaires within the community to establish their needs. These findings were presented to the community and stakeholders at a stakeholder presentation hosted at the two informal settlements, respectively, on 3 April 2023. Dr Combrinck explained that the focus of this first step of the three-year programme was on deepening the understanding of the community, and giving them the opportunity to articulate their needs to the authorities. This would enable the co-creation of community action plans, which is the next phase of the project.



THE UKUDOBA METHOD

The ukuDoba Manual is available for download.
The Department of Architecture welcomes feedback and enquiries.

Contact: Prof Chrisna du Plessis *chrisna.duplessis@up.ac.za*



UNIT FOR URBAN CITIZENSHIP

The University of Pretoria's Unit for Urban Citizenship (UUC) in the Department of Architecture strives to develop the scholarship of civil engagement and participatory development within the context of a complex, emergent African urbanism. It simultaneously strives to embed a culture of responsible and collaborative urban citizenship in both its graduates and the communities within which it works.

It has the following aims:

- Facilitate transdisciplinary research on urban citizenship
- Focus community engagement and strengthen social impact through evidence-based multi-scalar interventions
- Support the socio-economic and spatial transformation imperatives of the national development agenda
- Give effect to the United Nations' Sustainable Development Goals

The Unit offers a platform for vertical integration between study years to incorporate a socially responsive teaching and learning philosophy into the programmes of the Department of Architecture. It also establishes an interdisciplinary network of collaboration that can achieve the horizontal integration of its objectives with specific stakeholders through inter-faculty engagement.

According to Dr Carin Combrinck, Director of the UUC, by facilitating collaboration with its internal and external stakeholders, the Department's teaching and research can be aligned to improve impact. "Spatial design plays an integral role in community development, especially when an interdisciplinary view is taken towards social innovation and urban citizenship." In the process, the role of a university, as an anchor institution and social actor is embedded in the community, and is promoted and supported through a scholarship of engagement.

Its focus on the transformation of the curriculum rests on three pillars: engaged pedagogy, engaged research and community action laboratories. Its objective of participatory engagement is achieved by accompanying its students on a journey of engagement. It starts in students' undergraduate years by creating an awareness of community engagement.

This proceeds to the act of philanthropy through their involvement in the Faculty's community-based project module. As students progress through their undergraduate programme and participate in internships, they become aware of their role as activists for the community. Solidarity is achieved in their postgraduate studies, followed by collaboration in their master's research, and citizenship during their doctoral studies.

Student projects provide suggestions for community upliftment

Research by Architecture students under the supervision of academics in the Unit for Urban Citizenship are focused on examining the infrastructural challenges in the two informal settlements of Plastic View and Melusi. Their mapping of the residents' need for a sustainable built environment has given rise to several promising suggestions for community upliftment.

PLASTIC VIEW

Plastic View developed in 2001 as an organic informal settlement where people were living in makeshift shelters on an open stretch of veld near Moreleta Park in the east of Pretoria that belonged to the Tshwane Metropolitan Municipality. Their settlement in this area was prompted by the prospect of work on developments taking place in the vicinity of Woodlands and Mooikloof.

By 2006, about 3 000 documented residents were living in the informal settlement, which was without basic infrastructure for water, sanitation and security. The population of this settlement has been expanding due to the resettlement of immigrants, the homeless and people from surrounding townships as the area is closer to transport and job opportunities. It currently has a population of almost 10 000 residents.

The Department of Architecture's involvement in this area was initiated in 2016 when honours students undertook site visits to gather quantitative and qualitative data through observations and interviews, and to start building relationships with community members. Its initial interest was to teach the residents to use building materials such as timber, plastic, steel and bricks in new ways to build more permanent dwellings that would not be destroyed by fire, and to encourage skills development.

The mapping of the area by the honours students would contribute to the co-creation of a community action plan by the honours students of 2023. This entailed the identification of a network of stakeholders, the identification of existing support services such as a clinic, access to potable water and sanitation in the informal settlement, and the identification of existing systems that could contribute to economic growth, such as parks and vegetable gardens. Based on this information, a needs analysis could be performed. The most prominent needs identified were those for basic services, hand-washing facilities and sanitation, and employment. Interventions to meet these needs would be included in the action plan, which could be co-created with the community, with a view to improving residents' quality of life.

Based on the research performed by the honours class, students following the professional master's programme could then proceed to focus on realising residents' right to housing.

They examined the typical layout of a main street in Plastic View, as well as the typical types of dwellings (collective, public and private dwellings), the typical layout of the dwellings (closed courtyards, open courtyards and single dwellings) and typical materials used.

This was followed by the urban integration of the dwellings in the informal settlement. The students' activities focused on challenging the role of the architect. This entailed making meaning of the urban settlement and focusing on cultural inclusion.

The first step was the mapping of seven locations in the informal settlement by interacting with the settlement to understand the sensitivity of the terrain. This was done by applying different lenses: environmental, technical, and socio-political.

The environmental map focused on physical aspects of the environment, as well as aspects that impact the direct and surrounding environment. This identified water runoff, infiltration and possible pollutants that severely impacted the wetland and river area south of the site.

The technical map started touching on typologies of spaces, such as courtyards, construction techniques and materiality. The social and political map explored systemic influences, where there is a focus on understanding the actors and politics around certain infrastructure, such as water tanks and sanitary closets. An important element that impacted all three maps was the presence of blackwater in the settlement. This is water that may contain faecal matter and other pathogens.

The next step was the needs analysis. Four groups conducted a needs analysis, each focusing on a different element: creation and affection; subsistence, participation and freedom; protection and leisure; and understanding and identity.

They made use of a participatory process of data capture. The data from the site was collated into a useable format so that important elements could be identified. Possible bridges could then be identified between the existing state and the ideal future state. This enabled the researchers to approach the community action plan in an informed way. The resulting action plan comprised three categories: services, education and public spaces. The students embarked on three individual projects that would meet each of these needs.

The first project was the suggested upgrading of a water tank. This project was selected following the identification of the health challenge associated with black water in the settlement, as well as the residents' limited access to potable water. The creation of wet spaces was identified as a catalyst, which could assist in developing a community gathering node, and establish a sense of place for Plastic View.

Reflecting on their time spent in the community, the students found that it allowed them, as designers, to synthesise the intrinsic needs of the community into an immediate catalyst project, which would allow the intervention to grow and expand over time.

They considered the idea of temporality, and related their design process and catalyst project back to this undeniable essence of Plastic View. Although the settlement was temporary, it exhibited patterns and elements intrinsic to permanence: a community wanting to make this their home. With the upgrading of the water tank, a spatial node could be appropriated and adopted by the community to become their own. This could be seen as a structure that can encompass the residents' sense of place-making and being.

The second project entailed suggestions for the expansion of an existing crèche. This intervention sought to meet the community's need for improved education, keeping in mind and elaborating on the incremental ripple effect that it could have. The team members concentrated on developing more classrooms for the existing school, as well as larger classrooms.

They also considered expanding the existing on-site kitchen and food programme, thereby enabling the owner of the kitchen to run it as a business.

The group's future vision for the site includes the involvement of stakeholders such as shop owners, workshop facilitators and community builders in the incremental growth of the crèche, enabled and financed by the school kitchen, which they anticipate not only serving the children of the school, but also the community. The team members also anticipate the existing garden on the school ground employing local landscapers and garden cultivators, and for the school boundary to be activated and appropriated by shop owners. The ideal future state will see the business space along the boundary of the school becoming a highly desired space for trade, with the classrooms formalised and certain zones of the school used by the community as skill sharing and educational spaces.

The third project was the suggested development of a sportsground. As a principle of social justice, everyone should have the right to participate in sporting activities, free of any form of discrimination. Participation in sporting activities allows people to be active citizens who can encourage social change.

Sport was already a key element of Plastic View. This could be seen in the conservation of the sports field, which was the largest open public space within the boundary of the settlement. Although the settlement is densifying, the community had left the sportsground untouched. After identifying problems associated with the use of the sports field, the students proceeded with plans to upgrade the sports fields. This included a stakeholder analysis. Proposed actions that would form part of the action plan entailed improving the soccer fields and surrounding infrastructure. This entailed both spatial and non-spatial interventions.

Using sport as a catalyst for urban integration would lead to the creation of movement and successfully activated public spaces. This could be done by consolidating transportation nodes, sports fields, institutions, commercial spaces and the incorporation of urban spatial typologies.

These become catalysts for future economic activity to uplift the community members of Plastic View and the further integration of temporary services that could create greater community cohesion and improvements in terms of economic activities, infrastructure, services and spatial planning.

MELUSI

Melusi is an informal settlement northwest of Pretoria's central business district. It occupies land that belonged to the Tshwane Metropolitan Municipality. It is one of 240 informal settlements around the city, and is characterised by a low standard of living. It is vulnerable to several risks.

The settlement developed in 2008 as a result of urban sprawl. The original settlement is known as Melusi 1. Due to rapid urban growth, the area expanded into Melusi 2 in 2013 and Malusi 3 in 2018. A section of the land has been zoned as Industrial 1. This zoning is typically reserved for standard factories, warehouses or storage depots. The remainder of the land has been zoned as Residential 4. This zoning is usually applied for when constructing blocks of flats, as it permits a density of between 41 and 120 dwellings per 10 000 m^2. However, there are almost 5 000 households in Melusi, with an average of 3.32 persons per household. The total area is inhabited by between 18 000 and 20 000 people, and it is without any formal services. The area has a wetland, which is polluted and impacts on the residents' health and wellbeing, as well as a quarry, which also fills with water.

The Department of Architecture's involvement in this area started in 2019 when honours students conducted site visits to gather quantitative and qualitative data through observations and interviews, and to start building relationships with community members. In 2023, the students engaged with the community to complete a co-creating wellness questionnaire. This questionnaire interrogated aspects such as the settlement's public space and infrastructure, individual dwellings, livelihood and food security, health and wellbeing, and social resilience and leadership. The students also conducted fieldwork and made physical observations regarding the dwellings and resources.

Following this initial data gathering phase, three research groups were formed to propose suggested interventions for some of the issues that had been identified. The first group focused on skills and business, the second group on Melusi's wet sources, and the third group on knowledge exchange.

The objectives of the skills and business team were to identify economic activities, fuel the residents' ambitions and dreams, uplift existing businesses and create business opportunities within Melusi.

The skills and business team identified three individuals in the community for whom they could develop a narrative and uplift to improve the wellness of the community. These were George, who repaired tyres; James, a brickmaker who had a local hardware shop; and Andreas, who ran a tuck shop.

The first stage of the research project was that of needs identification. Based on their findings, the students were able to derive a development model to increase the community members' wellbeing and quality of life. They documented the economic activities on the site, and developed a questionnaire to determine which skills the community members have to start and run a business, and if they were aware of support and training opportunities for entrepreneurs.

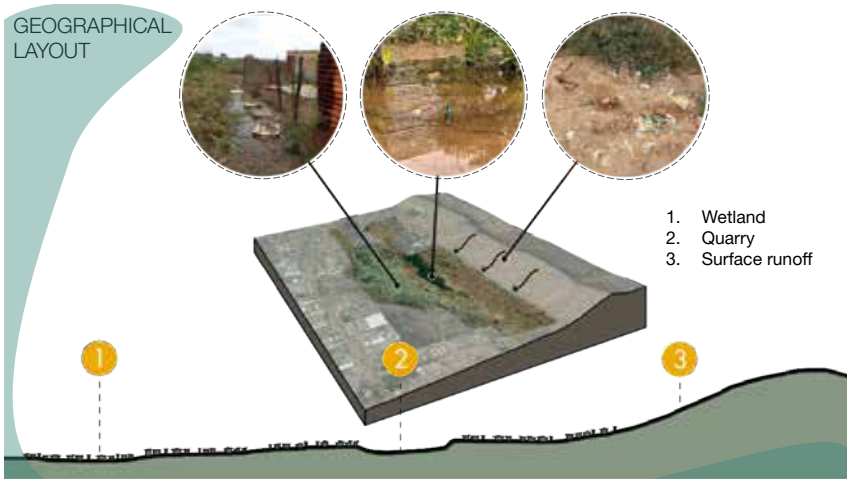
The students then visited the Melusi Youth Development Organisation to see where community members could receive business support. The organisation's initiatives included after-school care, a feeding scheme and a youth empowerment programme. It also offered workshops on entrepreneurship, basic computer skills and life skills. By expanding existing networks, the students could make suggestions for the development of an action plan.

The objectives of the second team, Bridging Melusi, were to investigate wet sources and their impacts; investigate the ripple effect of the wet sources in Melusi 2; explore the community's responses and solutions; bridge the community with water knowledge and education; and make recommendations for future implementation.

The team started off by performing a qualitative and quantitative analysis of the vulnerabilities associated with the quality of life and wellbeing of Melusi's residents according to the cumulative effects of natural wet sources, man-made wet sources, rainfall and geographical input in the flooding of the area, and existing resilience and responses to circumstances.

Four wet sources were identified: the wetland, the quarry, ground-water and surface runoff. There was also a lot of standing water, which had associated health risks. The wetland is a distinct ecosystem that is flooded or saturated by water, either permanently or seasonally. The team also examined rainfall and extreme weather conditions experienced by the community, which could have an impact on the wet sources.

Finally, they recorded vehicular access to the area, the commercial and other activities performed in the area, and challenges experienced by the community in terms of access to healthcare. These challenges include no money for transport, long or irregular working hours and no transport. This is a never-ending circle, as if the community members have no transport, they cannot get to their place of work, and if they cannot get to their place of work, they will have no money for transport.

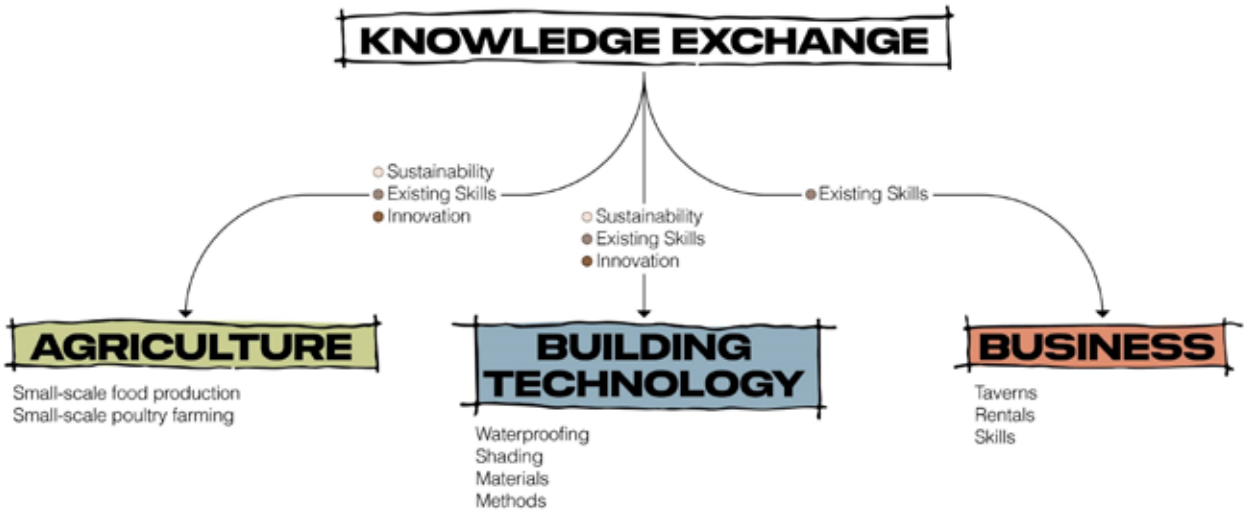


The team also analysed community responses to existing vulnerabilities in terms of the wet sources in the area. This included building bridges, building a boundary infrastructure, developing water channelling systems and filtering the water. The team then identified ways to plug into existing knowledge and provide facilitating tools for the community to uplift itself.

Examining external solutions to Melusi's problems, they found that the City of Tshwane had a relocation proposition, in which it had uprooted 776 residents of Melusi and moved them to land in Orchards Ext 110. However, the community has a sense of belonging and pride. Relocation should therefore only be considered as a last resort. Residents of Melusi 1 indicated that they want development where they are, and that the municipality must provide services and roads, electricity, water and sanitation facilities.

Partnerships for co-creating wellness include engaging with existing frameworks, such as the National Development Plan (NDP), which endeavours to ensure that all South Africans have access to clean running water, can realise a food trade surplus, with a third produced by small-scale farmers or households, and are ensured of household food and nutrition security.

The outcomes of the team's engagement with the community therefore entailed suggestions for community upliftment, elevating resilience, strengthening integrity, establishing a sense of local identity and ensuring self-sufficiency.



The objectives of the third team, which focused on knowledge exchange, was to support knowledge spread and empower the residents, establish ease of access to common interests, improve relations between people, the community and the environment, and incorporate a daily knowledge exchange. The question posed by this team was how mutual participation in knowledge exchange can impact the visibility and accessibility of knowledge to positively contribute to Melusi's challenges.

They considered it essential to stimulate relationships between residents, the broader community and the surrounding environment through mutual participation in the spread of knowledge. They followed both a quantitative and a qualitative approach, making use of three lenses: sustainability (the need for self-sustainment and the reuse of materials), existing skills and existing innovative solutions.

The knowledge exchange that took place focused on three areas: agriculture (small-scale food production and poultry farming), building technology and business.

In terms of agriculture, the team identified a lack of gardens, and gardens not being considered a source of food as needed in the community. This gave rise to opportunities for the establishment of small-scale food farming.

With regard to building technology, the team observed a lack of effective construction methods, and a lack of preparation for extreme weather. This gave rise to opportunities to teach the residents waterproofing techniques, as well as promising construction techniques. It also provided the opportunity to introduce them to innovative construction material.

Knowledge exchange related to business revealed that community members suffered from the challenges of unemployment and financial instability. This gave rise to the opportunity to enhance existing small business skills, and to learn new business-oriented skills.

The team found that the relationship between existing knowledge and skills and the desire to learn provides opportunities for an appropriate, sustainable and mutually beneficial knowledge exchange system.

A collaborative approach to green infrastructure planning, protection and use

Dr Ida Breed, Dr Kristine Engemann and Dr Maya Pasgaard

The Integrative Green Infrastructure Planning (GRIP) project is a transdisciplinary research project that aims to provide new knowledge on urban green infrastructure in South Africa. Urban green infrastructure includes the environmental features that are spread out across a city, from nature reserves and natural streams to parks, street trees and gardens.

The research project focused on knowledge exchange and capacity building to improve the coordination, planning and maintenance of urban green infrastructure in the administrative capital of South Africa, the City of Tshwane. A systematic integration of green infrastructure concepts in urban planning shows promise in protecting biodiversity, reducing climate hazards and improving health as Tshwane faces rapid urbanisation and struggles to address the depletion and degradation of existing green infrastructure. Therefore, the research team aimed to co-develop context-specific proposals and actionable principles to realise multifunctional green infrastructure benefits in Tshwane together with public and private partners.

To the best knowledge of the researchers, this is the most comprehensive multidisciplinary study on urban green infrastructure in sub-Saharan Africa. The project extended over a period of two years, with most of the fieldwork conducted between May 2021 and October 2022. The project considered both managed and unmanaged green space areas in the city, and how to improve their multifunctionality so that they can meaningfully contribute to improving social and ecological health, while reducing climatic risks.

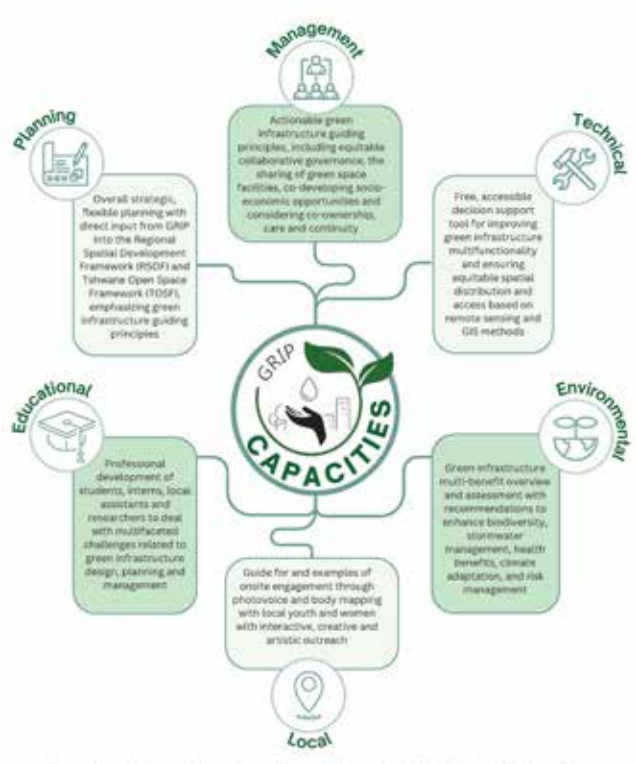
The two study areas were selected unmanaged green spaces located in Mabopane, Region 1 and Atteridgeville, Region 3 (Photographs: Ida Breed)

Two municipal-owned 100-hectare study sites were co-selected with municipal stakeholders to consider unmanaged green spaces with social and ecological potential and challenges on river systems. On the ground, the project conducted a community survey among 200 residents, a rapid assessment of multifunctional benefit provisions, and first-hand observations of local stormwater systems. At metro level, 28 policy documents were reviewed and 18 semi-structured interviews conducted with officials. Four design studios were held with landscape architecture students, as well as eight cross-sectoral co-creation workshops that explored green infrastructure benefits, spatial planning and design in the city. The researchers examined the challenges, opportunities and local proposals for green infrastructure applications, and facilitated the uptake of green infrastructure principles in planning and management.

Student and stakeholder workshops (Photographs: Ida Breed)

The researchers found that on-the-ground green infrastructure challenges include a complex mix of undefined ownership, low maintenance, invasive plants, safety risks and current informal and illegal uses. These challenges infringe on vulnerable ecologies through erosion, sewer leaks, blocked stormwater pipes and dumping, which can decrease ecological integrity and increase risks, including the increased risk of flooding. Opportunities for green infrastructure enhancement include co-ownership and maintenance, which can be achieved by creating socio-economic incentives for stronger human-nature relations, multifunctional benefit provision and greater care for green infrastructure in local communities.

Challenges on the study sites included low maintenance, invasive plants, safety risks and current informal and illegal uses (Photographs: EYEscape Studios)



The GRIP project managed to build capacity at various levels (Image: Lue-Shane Cloete)

At the metro level, green infra-structure planning challenges include scarce resources, the low valuation of green infrastructure, competing interests, limited enforcement and cross-coordination, and the need for technical knowledge and skills. Opportunities to overcome these lie in collaborative investment and partnerships towards a shared vision to co-create multifunctional urban green infrastructure.

On the ground, there is a general conflict among human presence, the quality of nature and bio-diversity in green infrastructure. However, the study proposes that interactive, creative research can facilitate increased local awareness, engagement and co-existence, with green infrastructure leading to greater benefits across stakeholders in time and space.

Access to green infrastructure benefits is physically constrained and socially determined by knowledge, networks and safety factors. However, there are current benefits and potential in unmanaged green spaces that could become accessible through design. This includes co-design with municipal departments and communities.

There is a willingness and potential within current communities to co-manage green spaces. The study therefore argues for socio-economic incentives that could encourage stronger human-nature relations, the provision of multifunctional benefits and greater care for green infrastructure in local communities across genders and generations.

The GRIP project managed to build capacity at various levels. At the metro level, it addressed green infrastructure planning and management by proposing and integrating green infrastructure guiding principles that target Tshwane's planning policy documents.

Remote sensing and geospatial analyses led to a green infrastructure decision support tool to inform large-scale green infrastructure planning for the protection and upgrading of urban green infrastructure.

The study improved the aptitude of students and researchers to engage with multifaceted green infrastructure design and planning problems across disciplines, and to develop socially just and environmentally sound multifunctional solutions.

Its creative outreach projects moved beyond typical one-way dissemination towards community dialogues that spoke to local capacities and the means to engage with residents on green infrastructure.

The projects also effectively expanded environmental potential by shedding light on green infrastructure benefits and enhancement for risk management across sectors and stakeholders involved.

RECOMMENDATIONS

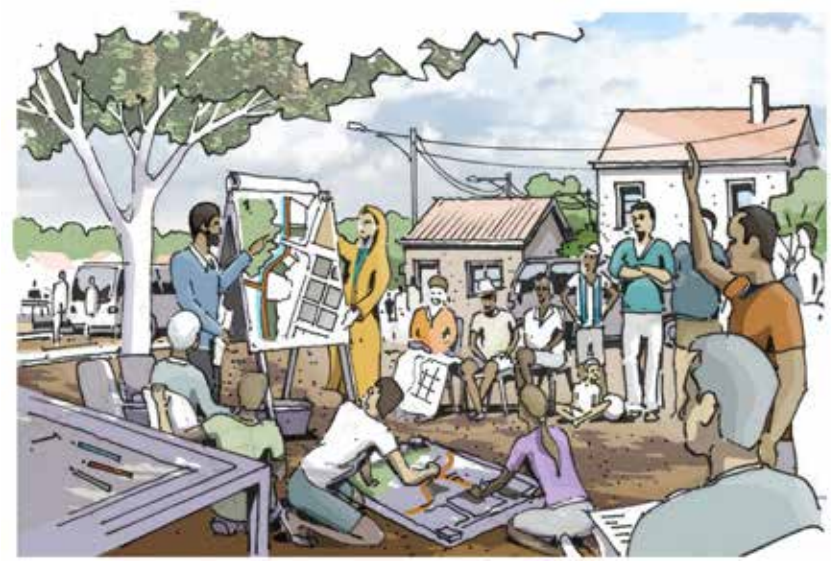
Urban green infrastructure planning in Tshwane requires an emphasis on environmental protection, multifunctionality, multi-scaled approaches and safety. This can be achieved locally by encouraging and elaborating on a joint, metro-wide vision that includes collaborative governance, active citizenship and cross-sectoral partnerships.

A cross-sectoral co-development of policies is required to formalise and legalise activities that are enhancing green infrastructure locally. Socio-economic activities create local income. Together with other informal uses, such as pocket parks and urban gardening, they create an incentivised basis for co-ownership and care, which preserves green spaces for different activities and uses. Existing policies have the potential to formalise such engagements if they are creatively adjusted.

Use and over-exploitation must be balanced through educational activities and community initiatives, strengthening social connectivity and nature appreciation through enhanced ownership and care.

South Africa faces a future with a higher risk of the heat island effect and severe flooding, where urban green spaces can be a part of nature-based solutions and increase resilience, making their protection and optimisation for multifunctionality an urgent matter.

Green infrastructure's spatial planning and built fabric integration can mediate current habitat fragmentation and alleviate climatic hazards, which coincide with non-motorised transport routes where people can move about safely while appreciating contact with nature. The spatial decision support tool developed by the GRIP project can aid the metro with sound decision making on the development, upgrading and upscaling of green infrastructure.



Green infrastructure planning needs collaborative governance, active citizenship and cross-sectoral partnerships (Image: Dario Schoulund)

In South Africa, there is still a need for access considerations to be broadened to explicitly embrace both spatial and socio-political barriers that shape people's ability to benefit from green infrastructure. Physical access can be improved through design that specifically targets access, diversifies use and increases safety through visual access and surveillance.

The provision of benefits and access can be further enhanced through strategic and inclusive planning and design that builds upon transdisciplinary and interdisciplinary collaboration and the co-management of green space. Building on communities' inherent local knowledge and innovative power, effective participation must be expanded to include empowerment and the instilment of a sense of care and ownership. The follow-through requires the co-development process to continue, anchored and embedded in the metro.

Green infrastructure's spatial planning and built fabric integration can mediate current habitat fragmentation and alleviate climatic hazards (Image: Dario Schoulund)

Further reading

GRIP Research Project: https://bio.au.dk/en/research/research-centres/biochange/research/grip

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Built environment graduates set to make an impact

Five graduates from the School for the Built Environment are keen to make a difference in the world. After studying for the undergraduate degree in Architecture, they have identified areas of specialisation such as landscape architecture and interior architecture, as well as town and regional planning, in which to conduct research that will make an impact on the future city.

Designing sustainable spaces

Alex Swart, a postgraduate student in the landscape architecture programme, believes that urban designers are increasingly focused on developing ways to design sustainable spaces, towns and cities for the people who will live in them. This comes from the knowledge he gained through his degree in town and regional planning, obtained from UP in 2016.

However, Alex realised that he could make a greater impact on the urban design of the future city by pursuing postgraduate studies in landscape architecture, where he could work on design-based projects. Fortunately, the Department of Architecture has the necessary flexibility to accommodate people like Alex, and he was able to do a bridging course, which enabled him to enrol in the honours programme in landscape architecture.

Looking back at his undergraduate studies, he observes that his bachelor's degree in town and regional planning added a lot of value to his postgraduate work, and that it prepared him exceptionally well for the future world of work. He furthermore believes that a postgraduate qualification from the University of Pretoria will ensure that he can make a meaningful contribution to the landscape architecture profession, not just in South Africa, but internationally. "As a discipline, landscape architecture is becoming more human-centred. We are striving to improve the social, institutional and living conditions of people, not of buildings or landscapes."

Alex is of the opinion that his background in town and regional planning gave him an added advantage when he switched to landscape architecture. "The skills I acquired in the Department of Town and Regional Planning, combined with the landscape design interventions I have encountered in the Department of Architecture, have proved to be a very powerful combination to prepare me for my career as a landscape architect."

In practice, urban designers often need to combat poor city planning. "It is important for a practitioner to focus on how the city of the future can become more liveable, people-oriented spaces where communities and individuals can thrive to ensure the sustainability of both people and the planet." What he is learning as a future landscape architect is perfectly aligned to the idea of a smart city and the disruptive engineering practices that accompany it.

Alex believes that landscape architecture is definitely a career for the future. "The need to integrate the natural and the urban environment is becoming increasingly important. As a result, landscape architects are becoming all the more relevant."

He would recommend the University of Pretoria's landscape architecture programme to prospective students who are interested in making an impact on the urban design space.

Creating interior spaces that make a difference in society

Cara Potgieter, a postgraduate student in the interior architecture programme, believes that her qualification is helping her design spaces that will provide a solution to real-world industry issues. "It is enabling me to understand complex societal issues, as well as how interior architects can make a difference."

Cara has always been interested in interiors. "My position is that we design for people and how they use space to ensure that their interiors make more sense. People occupy the interiors of buildings, and I want to create spaces that will help them carry out their tasks in the best way possible, while enhancing their overall interior experience."

She explains that the Department of Architecture's postgraduate programme focuses on the development of smart cities. The work of an interior architect concentrates on the habitation of cities as a way to understand why humans inhabit spaces the way they do. This makes it a very human-centred discipline. "Every conversation throughout my studies has included the effect and repercussions of design for humans in the spaces they inhabit." This manifests in different ways, such as considering how people relate to space, how they move, how they use or inhabit spaces, how they navigate space, where they congregate and where they pause.

Cara believes that interior architecture is definitely a career with good future occupational prospects, both locally and overseas, "especially if we see interior architects as spatial and human habitation or movement specialists." Interior architects have the opportunity to work in a multitude of industries, from residential to commercial and corporate spaces. They can even cross over to urban upgrades and the rejuvenation of cities as specialists in node activation across cities. On a smaller scale, they can make a career for themselves as furniture designers and material specialists. There are also great opportunities for interior architects when it comes to the restoration and preservation of heritage architecture.

Even when considering a career abroad, UP's postgraduate degrees compare quite well with what is available on the global market. She would recommend the interior architecture programme to anyone interested in this field.

Designing solutions to real-world problems

Architecture graduate **Mariëtte de Kock** is currently completing her honours degree in landscape architecture, which she hopes to follow up with a master's degree. She believes that a degree from the Department of Architecture provides many opportunities as it is accredited both local and internationally. "You can be assured that the hard work you put in during your studies will open many doors for you afterwards."

Mariette chose to pursue studies in architecture because she found it to provide a good balance between art and science. She feels that it is really important for architects in all fields of specialisation to become vision makers for the smart cities of the future, and to guide the direction of urban development. "In landscape architecture, specifically, there are so many opportunities to improve the current urban design of cities in ways that are more self-sufficient." She explains that a landscape architect helps ensure that the urban landscape does not become an over-engineered city, but rather one that helps improve our lives, while protecting the natural environment. She considers landscape architecture to be a human-centred discipline as its main focus is to improve people's lives through the built environment. Mariëtte believes that landscape architecture is definitely a career with good future occupational prospects, both locally and overseas. "There is increasing concern about protecting our natural environment, and landscape architecture is the perfect way to ensure this. It focuses on systems that benefit the built environment, while sustaining nature." Landscape architects will therefore continue to be in high demand.

"I would recommend this degree to anyone interested in making a difference in the world. I have gained so much knowledge about so many different aspects that affect our lives through the programmes in the Department of Architecture." This includes the environment, global economic and social circumstances and construction. "But the most rewarding for me is being able to balance these to find solutions to real-world problems."

Designing spaces that respond to a user's needs

Mutago Nanus, a postgraduate student in the interior architecture programme, is currently pursuing her honours degree. Although she finds the programme challenging, she is excited to learn about the intricacies and human-centred approach to design, which form an important part of her studies. She is looking forward to applying this knowledge to real-world design projects when she enters the world of work. She considers the value of a degree in Architecture from UP to lie in the fact that many companies are confident about what the Department's students are taught.

Mutago decided to specialise in interior architecture because she wanted to obtain a better

understanding of how architecture can affect a user's day-to-day life on a smaller scale. "It is interesting to see the level of human psychology that comes with understanding how to make spaces better for the user," she explains. "We are taught to be more conscious of the materials we use in our design, as well as the effect the life cycle of the design has on the environment in the long term, particularly in the context of smart cities. I am learning to make sure that my design practices add to the wellbeing of the people who inhabit those spaces."

As the Department's undergraduate programme focuses on general architecture, she had to make a paradigm shift when she started to specialise in interior architecture in the honours programme. "I had to really put myself in the shoes of the person or company I am designing for. It is almost like removing the ego and truly listening to what the user needs, rather than what we, as professionals, would like to impose on a user. It is important to deliver a design that adds value to the user. This makes it a truly human-centred discipline."

Mutago considers interior architecture to be a career with good prospects. "As long as there is a need for people to improve their spaces, there will be a need for interior architects." As part of the construction team, interior architects can make a contribution with their understanding of materiality and the human scale.

Looking back at her studies thus far, she expresses the view that both the Faculty of Engineering, Built Environment and Information Technology, and the Department of Architecture show compassion for their students. "They care about helping me define my voice and my place as a designer in this world."

She would recommend the Department's programmes to anyone interested in a career in architectural design.

Cultivating green spaces that merge social, economic and environmental needs

Architecture graduate **Phumzile Konile** believes that she can make the greatest impact in developing regenerative green spaces as a landscape architect. Intent on using her skills in art, design and research to interrogate the relationships people have with the urban environment, she decided to specialise in landscape architecture, and obtained her honours degree in this field in 2022.

Currently enrolled for a master's degree in landscape architecture, Phumzile believes that the knowledge she has gained in the subjects that make up the architecture and landscape architecture programmes at UP gave her the opportunity to engage with a myriad of issues related to a spatial design project.

She considers the value of her honours degree in landscape architecture to lie more in the journey than in the qualification itself. "My learning experiences have been rich thus far, and I have enjoyed the fact that the courses offered in the Department of Architecture are not taught as isolated subjects, but rather as connected parts that make up the whole." This has given her the courage to engage with all the varied components of landscape architecture.

"My decision to pursue a career in landscape architecture is based on the fact that this field is meeting me where I am at right now in terms of my interests and skills."

She explains that, over the years, she has been drawn to green spaces for a variety of reasons, including the overall health and wellbeing they engender, and the rich sensory experiences that are associated with the outdoors. "This growing interest is reflected in how my academic career has evolved thus far, transitioning from architecture to landscape architecture." With the growing need for regenerative green spaces, particularly in urban environments, Phumzile sees green spaces as providing the urban dweller with refuge, pause and stillness in an ever more fast-paced and digitally saturated world.

As a human-centred discipline, she believes there is a growing awareness of the need for green spaces, particularly in urban environments, so that residents can gain increased access to food and medicine, improved air quality, and mental and physical wellbeing.

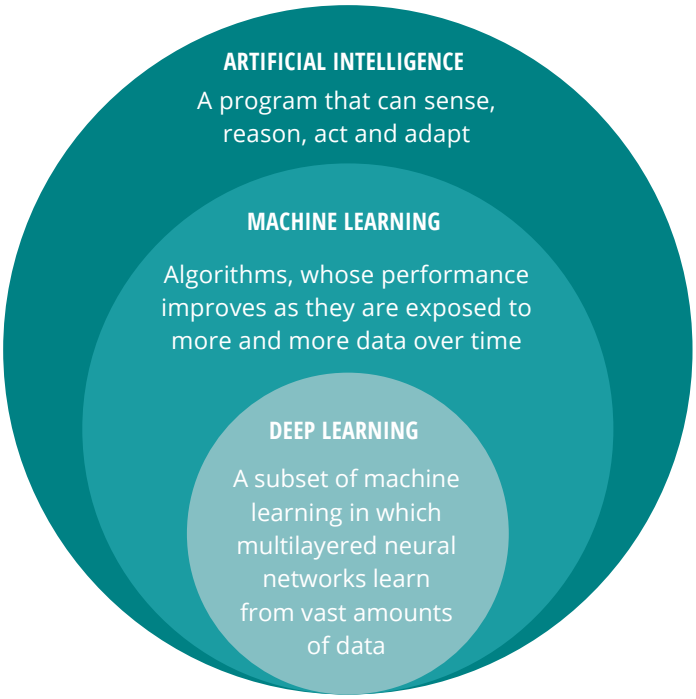
Engaging with a complex society such as South Africa, landscape architects are confronted with many conflicting issues, including those related to political and economic freedom, and access to and ownership of land. As a result, landscape architects trained in South Africa can approach society and intervene in dynamic environments across the world. "Even if I was to work overseas, my qualification from UP will enable me to engage and navigate through a layered context in a way that makes provision for a contextually sensitive and empowering spatial outcome."

Phumzile would recommend the University of Pretoria's landscape architecture programme to anyone whose ideals resonate with landscape architecture as a discipline. "I am learning to trust my intuition in approaching and engaging with my work. I would advise prospective students to do the same."

The implications of AI for postgraduate research

Prof James Maina

"Artificial intelligence" (AI) is a term coined as early as the mid-1950s to describe a two-month study known as the Dartmouth Summer Research Project on AI. The study was based on the conjecture that every aspect of learning, or any other intelligence feature, can, in principle, be so precisely described that a machine can simulate it. This was the birth of machine learning (ML), in which an attempt was made to develop a way for machines to use language, form abstractions and concepts, solve previously reserved problems for humans, and improve themselves.



Source: https://towardsdatascience.com

Internationally, more than 24 industries are already being impacted on by AI. AI's market size in the education sector exceeded $1 billion in 2020, and is expected to grow by more than 40% between 2021 and 2027. This includes innovations such as personalised learning and tutoring, automatic assessment and feedback, and improving study guides. The most prevalent use of AI is associated with academic integrity.

The advent of the latest AI platform, ChatGPT, has accelerated concerns related to AI use, with cases reported of ChatGPT passing exams from law and business schools, as well as Google's coding job test.

In education, AI and related ML tools have implications for writing and assessment integrity. In postgraduate research, there are already ML algorithms that can assist researchers in defining their research direction and finding initial leads for research papers, suggest research topics and explore connected papers, generate a hypothesis by guiding humans towards new experiments and theories, generate and analyse research data, and report on research findings. These have significant implications for postgraduate research, including potential benefits and opportunities.

Conversational AI is already being called a game-changer for science. Expounding on the potential benefits of AI, an article published in *Nature* in 2023 encourages scientists to embrace the benefits of AI, and develop rules for accountability (Van Dis et al., 2023).

Chatbots provide opportunities to complete tasks quickly, from finalising doctoral dissertations to drafting a quick literature review for a grant proposal. This could significantly accelerate innovation and potentially lead to breakthroughs across many disciplines. The article suggests that, rather than engage in a futile arms race between AI chatbots and AI chatbot detectors, the research community should determine how to use large language models with integrity, transparency and honesty.

Despite these benefits, there is also the potential for misuse. The first such risk is when researchers use automatic article generation software. These programs have access to extensive databases, including old and new academic articles, books and reports. These programs search databases according to user-given keywords, and then compose related articles in a requested style.

One can look at the example of Ike Antkare, who published over 100 articles in 2009 using an automatic article generator developed at the Massachusetts Institute of Technology (MIT)'s Computer Science and AI Laboratory. This publication output brought Antkare to the 21st position of the most cited scholars in the world, which is higher than Einstein's, with an h-index of 94.

Among the limitations of ChatGPT, however, is the potential for serious errors. Warnings on its use include the fact that it may occasionally generate incorrect information, sometimes produces harmful instructions or biased content, and has limited knowledge of world events after 2021. According to an article published in *Scientific American* in 2022, AI platforms like ChatGPT are easy to use, but potentially dangerous (Marcus, 2022). Although these systems are enormously entertaining, and even sound startlingly human, they are unreliable and could create an avalanche of misinformation.

As academics, it is necessary to consider the ethical principles that should guide the use of these tools. The European Union's High-level Expert Group on AI has identified four ethical principles and seven core requirements for using AI platforms. These ethical principles include respect for human autonomy, the prevention of harm, fairness and explicability. The core requirements include human agency and oversight, technical robustness and safety, privacy and data governance, transparency, diversity, non-discrimination and fairness, societal and environmental wellbeing, and accountability.

The Partnership on University Plagiarism Prevention (PUPP) principles focus more on preventing plagiarism in the academic world than on punishment, where academics, researchers and students are encouraged to use strategies such as digital scrapbooking (PUPP, 2023). These strategies facilitate the search for information in academic articles, books and reports and its integration into writing (sorting, evaluating, taking notes, quoting, paraphrasing, etc.), as well as the referencing of authors to produce an academic work.

UP aligns itself with the values of honesty, trust, fairness and responsibility, which are integral to the principles of academic, professional and personal integrity in teaching, learning and research.

These principles are reflected in UP's Code of Conduct for Students, which states that "the principles of academic integrity and honesty are inherent requirements for the preservation of the integrity of the qualifications awarded by the University of Pretoria". This is ultimately what will add value to a qualification obtained from this institution, and will improve its global ranking and research impact.

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CLARIFICATION OF CONCEPTS

Artificial intelligence
Artificial intelligence (AI) is a wide-ranging branch of computer science concerned with building smart machines capable of performing tasks that typically require human intelligence. Artificial intelligence leverages computers and machines to mimic the problem-solving and decision-making capabilities of the human mind.

Generative AI
Generative AI is a type of AI that can create a wide variety of data, such as images, videos, audio, text and 3D models. It does this by learning patterns from existing data, and then using this knowledge to generate new and unique outputs.

Large language models
This is a type of Generative AI model that is trained to understand and generate human language. It works by analysing a large amount of text, such as books, articles and websites, and learning patterns and relationships within the text. Once it has been trained, the model can generate new text that is similar to the text it was trained on. An example is OpenAI's GPT 4, Microsoft's Bing and Google's BERT.

AI content generators
An AI content generator is a tool that automatically creates content (text or images) based on user inputs. It helps users quickly create different types of content, such as social media posts and email messages.

Generative AI tools
Generative AI tools exist for various modalities, such as text, imagery, music code and voices.

Ethical concerns related to Generative AI

Prof Marlene Holmner

Artificial intelligence (AI), particularly its generative forms, is revolutionising various facets of human life, from communication to entertainment, and education is no exception. This category of AI specialises in creating new, original content, including writing text and code, producing images or music, or even generating predictions for complex problems. The fundamental principle behind Generative AI is that these models can learn patterns in data and use this understanding to produce new content, similar to the input data, but distinct and unique in its own right.

At the end of November 2022, OpenAI launched ChatGPT, a content creation platform that uses Generative AI. This generative pre-trained transformer (GPT) chatbot allows users to refine and steer a conversation towards a desired length, format, style, level of detail and language. It is the largest multimodal Generative AI model. It was launched as a free tool, allowing everyone with access to the internet to use it. It made headlines in 2019 when Microsoft invested $1 billion in it. Following its launch, it gathered a million users in five days. It currently has over 100 million monthly active users, while OpenAI's website achieves approximately a billion visits a month. Users have been found to spend an average of 20 minutes a day on ChatGPT. The most popular tasks are generating text, translating languages and answering questions, while the most common users are students, researchers and writers. Its popular use sparked a significant debate about the impact of AI by role-players in higher education.

Of particular interest to members of the Department of Information Science's Data, Information and Computer Ethics Research Group are the ethical concerns related to ChatGPT and other forms of Generative AI. This has given rise, among other things, to research conducted in the Department's African Centre of Excellence for Information Ethics, as well as the development of a guideline document for lecturers to leverage Generative AI for the enhancement of teaching and learning.

There are six crucial issues regarding Generative AI that are of concern in the information ethics landscape. These can be summarised as relating to privacy, accuracy, property (intellectual property), accessibility, security and society.

PRIVACY

As a large language model-based chatbot, Open AI's ChatGPT is trained on 300 billion words obtained from digital books, articles, websites and posts on the internet, including personal information obtained without consent. This makes its use a potential privacy issue. It records conversations and shares its logs with other companies and IT trainers. Microsoft's AI chatbot, Bing, even threatens to expose personal information and can ruin a user's reputation. Italy became the first Western country to block the use of ChatGPT over privacy concerns.

ACCURACY

ChatGPT has an accuracy level of just over 85%. It answered the medical licensing exam at a level similar to that of a third-year medical student with an accuracy of around 60% for the most difficult set of questions. However, it is not capable of verifying the accuracy of information in training data, and may generate responses that are false or misleading. As the model's output is dependent on its input, it can be fooled into creating incorrect, racist, sexist and biased content that is devoid of common sense and real-world sensibility.

INTELLECTUAL PROPERTY

As AI-generated content becomes more prevalent, questions arise about the ownership and protection of such content under existing intellectual property (IP) laws. For instance, can an AI-generated logo be trademarked, and if so, who should be considered the owner? The AI developer or the user who commissioned the work? These questions will require lawmakers and legal professionals to re-evaluate and adapt existing IP

frameworks to accommodate the rapidly evolving AI landscape. In addition, text generators do not always cite their sources. They can write in a particular person's style without giving credit to the original author. This amounts to plagiarism.

ACCESSIBILITY

Text generators can be used to create fraudulent messages to gain access to one's personal information and thus breach one's security. Traditionally, phishing could be detected by the presence of odd salutations and grammatical errors. This is the result of many threat actors not being native speakers of English. With the use of ChatGPT, this is no longer the case. Furthermore, the paywalls in some of these tools can create a new digital divide.

SECURITY

ChatGPT can be used to create a complex type of malware, such as a polymorphic or metamorphic virus that is programmed to repeatedly mutate its appearance or signature files through new decryption routines. This results in many traditional cybersecurity tools, such as antivirus and antimalware solutions, which rely on signature-based detection, which fails to recognise and block the threat.

SOCIETY

Generative AI has a large environmental footprint. A simple conversation with ChatGPT consumes 500 mℓ of water. Consumption is higher during the hotter parts of the day when more water is needed to cool the data centres. Training GPT-3 in Microsoft's data centres in the USA can consume 700 000 ℓ of clean freshwater over 15 days.

In the words of Stephen Hawking, "Success in creating AI would be the biggest event in human history. Unfortunately, it might also be the last, unless we learn how to avoid the risks.

Equipping citizens for the AI era

Rachel Fischer

The contemporary world is immersed in an epoch of unparalleled technological advancements, prominently driven by information and communication technologies (ICTs) and Artificial Intelligence (AI). As these transformative forces redefine societal dynamics and individual experiences, the necessity of informed citizens who are capable of responsibly navigating the AI era becomes paramount. It is therefore important to consider the crucial role of policies, media and information literacy within the context of universities and information ethics.

The rapid integration of AI across sectors underscores the urgency of establishing comprehensive policies that guide its ethical design and deployment. Policies serve as the ethical compass of technological development, aligning AI systems with the core values of justice, fairness and human rights. Transparent and accountable AI policies not only protect individuals from the potentially adverse consequences of technology, but ensure that AI becomes an empowering tool rather than a destabilising force. These policies must encapsulate the principles of equity, privacy and non-discrimination, echoing the aspirations of Sustainable Development Goal (SDG) 16: Peace, justice and strong institutions.

The digital era ushers in a deluge of information. Yet, amidst this abundance lies the challenge of discernment. Media and information literacy emerges as an indispensable skill set that empowers citizens to navigate the complexities of the digital landscape adeptly. It equips individuals with the competence to critically evaluate information sources, identify misinformation and make informed decisions. This skill set is the antidote to the proliferation of fake news and disinformation, enabling citizens to engage meaningfully in democratic processes and advocate for responsible AI governance. Media and information literacy not only strengthens the fabric of societal dialogue, but aligns with the principles of SDG 16, fostering an inclusive society through informed participation.

As AI reshapes industries and employment paradigms, the skills required for meaningful participation in the AI era extend beyond technical expertise. Essential skills encompass critical thinking, adaptability, creativity and emotional intelligence. The symbiotic relationship between human skills and technological augmentation forms the foundation for a harmonious AI-human collaboration. The ability to understand AI systems, leverage their potential and mitigate their shortcomings requires a blend of technical know-how and humanistic acumen. These skills empower individuals to drive AI's ethical development, ensuring that technology remains a tool for societal progress rather than a threat.

THE TRANSFORMATIVE ROLE OF UNIVERSITIES IN SHAPING AN ETHICAL AI FUTURE

As the world grapples with the ethical implications and societal shifts brought about by ICTs and AI, universities emerge as pivotal players in shaping an ethical and responsible AI future. With their unique blend of research, education and influence, universities can play a transformative role in navigating the challenges and harnessing the potential of these technologies. Universities can play a multifaceted role in this context, addressing the integration of ethics, education, research and societal impact. There are specifically five dimensions through which universities can contribute to global dialogues and development:

- **Ethical education and awareness:** Universities can serve as bastions of ethical education and awareness. By incorporating ethical considerations into their curriculum across disciplines, they can equip students with the knowledge and critical thinking skills needed to navigate the complexities of AI.

Offering courses on AI ethics, data privacy and responsible technology development ensures that future professionals are well versed in the moral dimensions of their work. These initiatives cultivate a generation of AI practitioners who are conscious of the ethical implications of their decisions.

- **Research and innovation:** Research conducted within universities has the power to shape AI development. By prioritising research into ethical AI, universities can contribute to the creation of guidelines, policies and frameworks that govern the responsible use of AI technologies. Collaborative efforts between researchers, ethicists and technologists can lead to advancements that prioritise human welfare, social equity and accountability. Furthermore, universities can be testbeds for evaluating the ethical impact of AI technologies, providing valuable insights for policy makers and industry leaders.

- **Societal impact:** Universities are deeply embedded in their local communities and have a profound societal influence. They can actively engage with stakeholders to raise awareness about the ethical implications of AI, organising workshops, seminars and public lectures. By initiating dialogues that bridge academia, industry, policy makers and the public, universities can foster an environment where diverse perspectives converge to define the ethical contours of AI development and deployment.

- **Ethical guidelines for AI development:** Universities can take the lead in formulating ethical guidelines for AI development. These guidelines can serve as beacons for industry practitioners, guiding them in designing AI technologies that are transparent, unbiased and aligned with societal values. By collaborating with industry partners, universities can ensure that these guidelines are both practical and reflective of the evolving ethical landscape.

- **Global collaboration:** Universities have a unique advantage in fostering global collaboration on ethical AI. Through partnerships with international institutions, they can facilitate cross-cultural dialogues on ethical considerations. These collaborations can lead to the establishment of universal principles that transcend borders, ensuring that AI technologies uphold human rights, social justice and inclusivity.

THE ROLE OF INFORMATION ETHICS IN THE GLOBAL CONTEXT

The University of Pretoria, and, in particular, the Faculty of Engineering, Built Environment and Information Technology (EBIT), plays an important role in the global debate on the ethical implications of AI and other emerging technologies. The Department of Information Science has championed the applied ethics theory of information ethics for more than two decades.

Information ethics plays a pivotal role in the context of emerging technologies, especially AI, due to its profound implications for global challenges and opportunities. The convergence of AI and information ethics is essential for navigating the ethical complexities of the digital age, where technological advancements have the potential to reshape societies and economies on a global scale. Information ethics is crucial in this context for the following reasons:

- **The ethical implications of AI:** AI technologies have the capacity to impact individuals, communities and societies in profound ways, from autonomous decision making to algorithmic bias. Ensuring that these technologies are developed, deployed and governed ethically requires a comprehensive understanding of the ethical considerations associated with AI. Information ethics provides the framework to evaluate the implications of AI applications on various aspects of society, including privacy, transparency, accountability and human rights.

- **Global challenges:** As AI and other emerging technologies transcend geographical boundaries, the information ethical challenges they pose are not confined to specific regions. Global challenges such as data privacy, cybersecurity, misinformation and digital inequality require coordinated ethical frameworks that can guide international regulations and standards. Information ethics offers a platform for cross-cultural and interdisciplinary dialogue, fostering collaborations to address these challenges collectively.

- **Human-centered design:** AI systems are designed to interact with and impact human lives. It is crucial to uphold human values and dignity throughout the development and deployment of these technologies. Information ethics emphasises a human-centered approach that prioritises the wellbeing of individuals, safeguards their rights and ensures equitable access to the benefits of AI.

- **Responsible innovation:** The rapid pace of technological innovation often outpaces the formulation of ethical guidelines. Information ethics encourages

responsible innovation by promoting anticipatory ethical considerations at every stage of technology development. This helps prevent the unintended negative consequences of emerging technologies.

- **Algorithmic transparency and accountability:** AI systems are often opaque and difficult to understand. Information ethics underscores the importance of transparency and accountability in AI algorithms and decision-making processes. Transparent AI systems are not only ethically sound, but are essential for building public trust and mitigating biases.

- **Cultural pluralism and diversity:** Different cultures and societies hold distinct ethical values and norms. Information ethics encourages a nuanced understanding of these cultural variations and strives for shared ethical values that respect diversity. This approach fosters meaningful dialogue and collaboration in addressing global ethical challenges related to AI.

- **Ethical decision making:** AI systems can make decisions that have significant ethical implications, raising questions about how these decisions are made and who is accountable for them. Information ethics promotes critical reflection on the ethical reasoning behind algorithmic decisions, ensuring that the choices made by AI systems are aligned with societal values and norms.

- **Mitigating bias and discrimination:** AI technologies can perpetuate and amplify biases present in training data. Information ethics compels AI developers to actively mitigate biases and discrimination in algorithmic outcomes, safeguarding against unintended harm to marginalised communities.

Information ethics serves as a guiding framework to navigate the transformative landscape of AI and other emerging technologies. It enables a global conversation on how to harness the opportunities presented by these technologies, while addressing the ethical challenges they pose. By fostering collaboration, promoting human values and ensuring responsible innovation, information ethics empowers societies to harness the potential of emerging technologies for the collective benefit of humanity.

A HOLISTIC APPROACH TO GLOBAL CHALLENGES

The interconnected nature of policies, media and information literacy, information ethics and essential skills underscores the necessity of a holistic approach to address the global challenges posed by AI. Policies lay the groundwork for ethical AI governance, guided by the principles of SDG 16. Media and information literacy empowers individuals to decipher the information landscape accurately, fortifying society against the onslaught of misinformation. Equipping individuals with essential skills not only prepares them for technological changes, but ensures that they can contribute meaningfully to shaping the AI landscape.

The synergy of policies, media and information literacy, and essential skills forms the blueprint for a society that can harness the potential of AI, while navigating its complexities responsibly. Policies grounded in ethical considerations and aligned with SDG 16 uphold the principles of justice, peace and inclusivity. Media and information literacy empowers citizens to critically engage with technology and contribute to a vibrant and informed public discourse. Essential skills foster a workforce that can seamlessly collaborate with AI systems while safeguarding human values.

SHAPING A TECHNOLOGICALLY EMPOWERED FUTURE

The challenges and promises of the AI era necessitate a collective and comprehensive response. Policies, information ethics, media and information literacy, and essential skills are not isolated components, but rather interwoven threads in the tapestry of a technologically empowered future. The global community's recognition of these elements as integral to AI governance, and responsible technology use is essential for shaping a future where AI augments human potential, fosters justice and embraces inclusivity.

In the midst of the AI revolution, universities emerge as custodians of ethical technology development. Their role ranges from instilling ethical values in students to driving research that informs policy decisions. By promoting AI education, ethical awareness and research, universities contribute to the creation of a harmonious ecosystem where AI and human values co-exist. Through their influence on education, innovation and societal discourse, universities have the power to shape a future where AI serves humanity's best interests, upholding the principles of justice, peace and inclusivity.

The choices made today in the realm of policies, information ethics, media and information literacy, and essential skills will ripple through generations, defining the essence of the AI era. The journey towards a society that navigates the complexities of AI with wisdom and ethics is both a challenge and an opportunity. As citizens, institutions and governments collaboratively strive to embrace the transformative power of AI. They must leverage policies, foster an information ethical awareness, cultivate media and information literacy, and nurture essential skills to create a harmonious synergy that safeguards humanity's values and aspirations in the technological landscape.

Using UX design to improve chatbots

Prof Hanlie Smuts and Amore Rossouw

The evolution of digital technologies enables a ubiquitous computing environment in which the processing of information is linked with how we engage in society (such as through e-government), with service providers (such as banks) and with friends and family (through social media). Features such as chatbots, natural language processing and voice recognition have changed our interface with technology.

An honours research study conducted in the Department of Informatics examined key principles pertinent to user experience (UX) design for conventional user interfaces. Despite the potential of the application of conversational interfaces, it recognised that methods from human-computer interaction (HCI) and UX design mostly associated with digital interfaces are often directly applied to conversational interface design, rather than recognising the unique design requirements of such interfaces. Key issues identified include a too strong focus on technology only, the application of a graphical user interface (GUI) mindset, the application of generic UX principles and a lack of social characteristic considerations.

Conversational user interfaces (CUIs) or chatbots may be applied for the automation and innovation of multiple user tasks across a diverse range of organisational functions (such as marketing, customer service and sales). By considering the key UX principles applicable to CUIs, designers and developers may be better informed of what to consider when designing and implementing optimal CUIs.

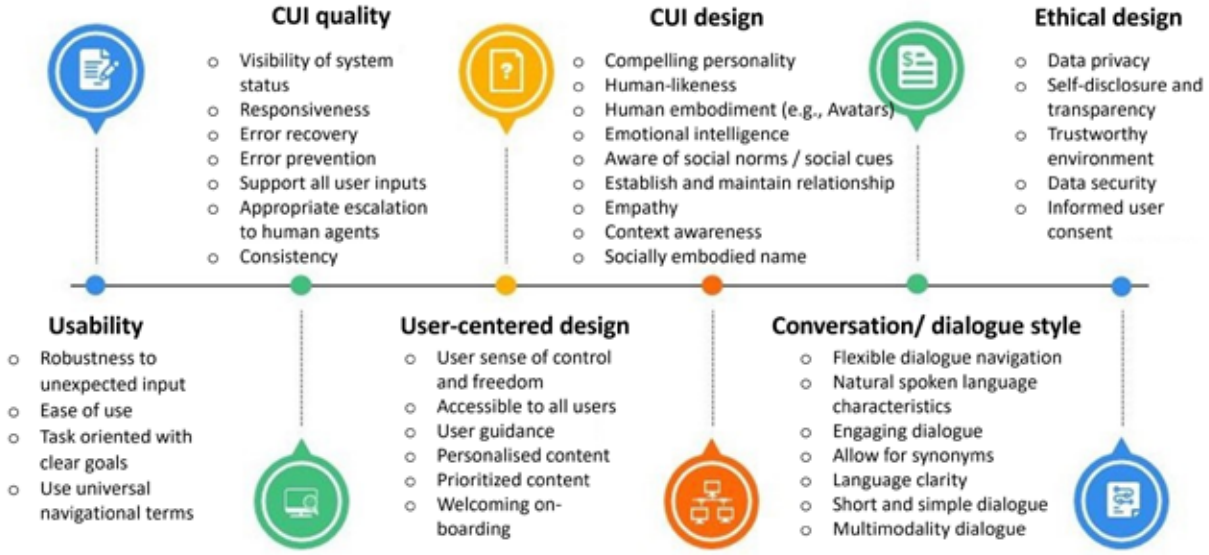
CONVERSATIONAL USER INTERFACES

A CUI refers to an interface that allows human-computer interaction through voice or text. CUIs generally rely on conversational AI to make this human-like conversation possible. Conversational AI uses machine learning, natural language understanding (NLU) and natural language processing (NLP) to extract meaning from written or spoken text, enabling a machine to engage in human conversations through language.

There are different classifications of CUIs, such as chatbots, while others are defined as voice user interfaces (VUIs). Chatbots are conversational agents that can engage with users through natural language conversations using text as its primary communication channel. Traditional chatbots seemingly have the same conversational characteristics as conversational AI. However, in reality, they identify keywords using pre-written scripts and dialogues to mimic conversational behaviour. Conversational AI can be used to develop comprehensive unscripted AI chatbots. These AI chatbots can deliver quick and efficient interactions that can offer more personalised value to their users.

KEY UX PRINCIPLES FOR CUI DESIGN

To enable designers and developers to apply fit-for-purpose UX-CUI design principles, a set of six design principles were identified, each with a series of sub-themes.



Usability

Usability describes features that attribute to the overall practicality and functionality of a CUI such as ease of use and robustness to unexpected input. The research suggested that these factors are often overlooked, therefore creating significant usability issues. Furthermore, CUIs should make use of subthemes such as using universal navigational terms to allow users to navigate the CUI effectively and efficiently. The CUIs need to be task oriented and should be optimised to help users achieve their goals. This will, in turn, enhance the usability of the CUI.

Conversational user interface quality

The CUI quality refers to the key attributes of a CUI that enhances its ability to meet the user's expectations and expected quality standards. CUIs of high quality have extensive error prevention and error recovery methods in place. Another key factor that contributes to its perceived quality is consistency. A consistent CUI creates a sense of familiarity and reliability. Additionally, quality CUIs provide users with a variety of input options, as well as the option to communicate with human agents if necessary.

User-centered design

The interface should focus on understanding the user's needs and rely on ample research to create a truly user-driven design. A user-driven design gives the user a sense of control and freedom by allowing user autonomy. It also provides guidance to the user to guarantee that the user can achieve their goals. The CUI should create a welcoming environment by providing a welcoming on-boarding experience. Moreover, the user interface must prioritise content that the user may perceive as being important, while simultaneously allowing the user to personalise the content that is presented to them. Most importantly the CUI should be accessible to all its users, including users with limited abilities or resources.

Conversational user interface design

The CUI design points to key characteristics of the CUI that distinguish it from other similar interfaces. One of the most important characteristics of a CUI is its human-like nature. A CUI can be perceived as being human-like when it has emotional intelligence, empathy, a compelling personality with a socially embodied name (e.g. Alexa) and a human embodiment (e.g. Avatar). CUIs with these character traits tend to create a better UX and are able to easily establish and maintain relationships with their users.

Conversation/dialogue style

The conversation or dialogue style describes the manner in which the CUI communicates with the user. It is suggested that the dialogue should follow a natural spoken language structure, while being short, simple and engaging. The conversation should be clear and concise and must allow for synonyms and flexible dialogue navigation.

Ethical design

Ethical design encompasses an interface design that is based on moral and ethical standards, and considers the impact the design will have on its users. An ethical design creates a trustworthy environment that prioritises its user's data privacy and data security. If the user's data is collected, the user should be made aware of it and be given the option to deny access to their data. Moreover, a CUI should be transparent in its abilities and avoid portraying features it is not capable of performing. An ethical CUI should also disclose that the user is merely conversing with a conversational agent and not a human being.

Knowledge management in Society 5.0 as a sustainability strategy

Prof Hanlie Smuts

The world is experiencing radical advances in science and technology. With the evolution of digital technologies comes a growing recognition that most workplaces are experiencing change. Digital technologies, which are evolving at an exceptional rate, automate not only labour-intensive and repetitive work, but also influence knowledge work. This necessitates understanding and managing greater complexity.

Knowledge work relies, to a greater extent, on individuals' cognitive abilities, as opposed to work that consists primarily of the execution of known procedures and manual actions. Furthermore, knowledge is now recognised as being central to sustained organisational success.

Knowledge workers drive knowledge management processes. The evolution of digital technologies has also changed the landscape and nature of knowledge management. The growing use of digital technologies has created completely new business models and means to create value. Some of these include control and monitoring through computer-based algorithms, the on-demand availability of computing power and data storage, cognitive computing and the rise of a connected world. Maintaining a knowledge management emphasis in this context is important, as intelligent machines, such as those that use artificial intelligence (AI) and machine learning, are altering knowledge creation and sharing in organisations. A key contributor to the viability of AI applications and the maturity of AI technologies is the availability of data that may be applied in computer learning processes. In addition, structured and unstructured Big Data structures are used for the extraction of value. In light of the big technological changes that the emergence of intelligent machines and Big Data structures have brought about in every organisational facet, it becomes relevant to revisit assumptions about the nature of knowledge management. These assumptions are interrogated further based on the merging of cyberspace and the real world following the emergence of Society 5.0, the knowledge-intensive society.

SOCIETY 5.0 AND ITS KNOWLEDGE-INTENSIVE NATURE

Society 5.0 is the vision of a super-smart, human-centered, knowledge-intensive society that produces sustainable solutions to differentiated needs and social problems through technological advances. Cyberspace meets the physical world in this super-smart society to address deep-seated deterrents to sustainability so that people can lead a fulfilling and quality life. Within Society 5.0, sustainability focuses on increasing the potential of the individual-technology relationships in promoting social good.

In 2015, the United Nations (UN) ratified 17 Sustainable Development Goals (SDGs) at the UN SDG Summit, which raised awareness of global challenges. The purpose of the 17 SDGs is to guide sustainability policies in countries and regions around the world, to be achieved by 2030.

The SDGs are ultimately designed to fulfil the UN's pledge that no one will be left behind, fostering close alignment with the vision of Society 5.0 to apply the cyber–physical world to the benefit of society as a whole. The impact on organisations in this context is to share common goals and plan environmentally sound business activities with global perspectives from the outset. The purpose of this is to achieve sustainability in the true sense and, in some instances, restructure the business. The implementation of Society 5.0 might simultaneously yield social, economic and ecological benefits that enhance society's sustainability and stability.

Knowledge-based development (KBD) provides a vision of development that considers knowledge as the central structuring element of a development strategy for cities, regions and countries.

This is "the collective identification and enhancement of the value set whose dynamic balance furthers the viability and transcendence of a given community". Therefore, the KBD methodology measures the value that takes many dimensions and aspects of life into consideration. It goes far beyond traditional assessment views and provides a basis for sustainable development, emphasising the relevance of the process of transforming knowledge resources into local development.

SOCIAL SUSTAINABILITY

Key knowledge management concepts in Society 5.0 related to social sustainability (people) emphasise the requirement to foster organisational learning by enhancing knowledge acquisition, capturing experience-based information and enhancing digital skills, ICT literacy and abilities. Such accelerated improvement of the quality of human capital may be achieved by focusing on integrative methods for organisational learning (e.g. learn from experience, optimise daily routines), developing user independence and creativity, and creating a working environment and open culture where different thoughts are respected, and delays are not penalised.

Furthermore, by harnessing unique human qualities to transform and change (e.g. creativity, problem solving) and by creating knowledge as it relates to human and intellectual capital improvement, an organisation may secure future success as it, in fact, utilises knowledge assets strategically to attain strategic objectives and address digital transformation requirements. Information distributed to operational and functional organisational units empowers decision making and develops higher levels of effective change management.

The knowledge management system in support of social sustainability may be optimised based on advanced human–technology interaction.

SOCIO-ECONOMIC SUSTAINABILITY

Socio-economically, organisations should implement advanced knowledge management systems to manage intangible assets in the form of data, information, knowledge and insight. By elevating the meaning of implicit knowledge as a knowledge asset and commodity, organisations may combine knowledge in people and in machines to add organisational value, as well as create new value by driving knowledge production. Such produced knowledge may guide techniques to manage new or disruptive technologies adequately, apply data to inform customer-relevant product design, apply insight from data to improve productivity, and better understand the impact of digitalisation factors on human capital.

By applying the multidisciplinary nature of knowledge management and adopting a knowledge management approach to implementing new ideas and supporting innovation with different ideas, organisations may invest time and effort in knowledge management in support of digital transformation. Ultimately, organisations should develop skills for the knowledge-based economy and apply knowledge assets to organise and streamline their daily work, enhance information communication and speed, and ultimately gain a competitive advantage.

ECONOMIC SUSTAINABILITY

For economic sustainability, organisations should manage all aspects of the knowledge-based economy by capturing effective representations of operational information; overlaying knowledge acquisition with data, Big Data and information layers; capturing differentiated knowledge; and applying insight from data to generate higher revenue.

Organisations, therefore, apply relevant knowledge for decision making to measure their performance and create differentiated solutions derived from data and information within the context of organisational characteristics and purpose. Furthermore, by accelerating knowledge management for organisational development, organisations can integrate operating practices and models that are grounded in innovation, flexibility, knowledge, agility, adaptability and capability.

This enables organisations to deliver rare and valuable products and services that may be difficult to imitate. Additionally, by applying organisational capabilities such as information management, knowledge management and responsive decision making, an organisation's ability to offer immediate reaction to change and its demands is enhanced. Essentially, knowledge is created through innovation.

ECO-EFFICIENCY SUSTAINABILITY

From an eco-efficiency perspective, organisations should focus on continuous value creation with a strong emphasis on developing capabilities to deliver rare and valuable outputs, differentiated products that may be difficult to imitate, or products that are eco-friendly and easy to recycle. Organisations should gain an understanding of human capital and quality of life (e.g. smart cities) through knowledge management as a tool to sustain economic growth, improve supply performance

(e.g. smart contracts) and enable conditions for the creation and development of human capital in regions and territories by ensuring access to the internet and relevant information technologies. In this instance, organisations may consider delegating tasks of innovation development for economic growth in the territory to the private sector or universities.

ENVIRONMENTAL SUSTAINABILITY

Some strategies that organisations may follow to achieve environmental sustainability include using technology to inform risk management through the automated identification of potential hazards, planning and controlling the manufacture of products needed by humans to ensure sustainable development, collaborating in the scientific development of main areas of business (e.g. energy alternatives) and creating advanced knowledge and insights of business processes and business environments (e.g. green manufacturing). The development of natural capital assets allows for a better adaptation to territorial prerogatives. By transforming intangible assets into tangible assets for the long-term wellbeing and prosperity of different stakeholder groups in the ecosystem, knowledge of nature to provide sustainable living for residents and visitors may be harnessed.

SOCIO-ENVIRONMENTAL SUSTAINABILITY

For socio-environmental sustainability, organisations should create and foster new perspectives on sustainable development, such as creating value through win–win ecosystem relationships by accelerating knowledge management for community development, improving citizen digital literacy and investing adequately in ICT infrastructure, as well as in human and social capital development. The application of social intelligence by involving the community in the creation of a smart community requires the application of technology to enable substantial and particular knowledge sharing across geographical barriers.

Knowledge management supports the distilling of the core competencies required for long-term sustainable organisational success and for the harvesting implicit and explicit knowledge from all stakeholders with the aim of creating collective intelligence by sharing knowledge, data and skills with territories for the purpose of solving societal issues. Organisations gain an understanding, through knowledge management, of the entire ecosystem, which consists of a number of interconnected systems (e.g. climatic, cultural conditions, natural resources, political systems and religion), by incorporating technological devices into urban environments to the benefit of the people (citizens) towards improving or solving socio-economic problems and lifestyle issues.

CONCLUSION

The organisation that emerges in Society 5.0 needs to confront the shifting needs of a new environment, more demanding customers and smarter knowledge workers in highly integrated cyber-physical surroundings. By integrating multidisciplinary and heterogeneous knowledge, organisations may increasingly rely on their knowledge-generating resources and leverage knowledge management as a means of development to enhance alignment with the guidelines of economic, environmental and social sustainability.

Extracted from the publication:

Smuts, H and Van der Merwe, A. 2022. Knowledge management in Society 5.0: A sustainability perspective. Sustainability 14, 6878. https://doi.org/10.3390/su14116878.

WITHIN SOCIETY 5.0, SUSTAINABILITY FOCUSES ON INCREASING THE POTENTIAL OF THE INDIVIDUAL-TECHNOLOGY RELATIONSHIPS IN PROMOTING SOCIAL GOOD.

Will AI change teaching and learning as we know it?

Prof Alta van der Merwe

The Faculty of Engineering, Built Environment and Information Technology (EBIT) is at the forefront of the latest trends in technology, especially as they impact traditional modes of teaching and learning, and student success. While many information and communication technology applications have already found their way into students' perception of the "new normal", others are waiting to be embraced.

One such new application, **ChatGPT**, is set to change the way students and researchers search for information on the web. It is also causing many to rethink traditional forms of teaching and learning. Prof Alta van der Merwe, EBIT's Deputy Dean: Teaching and Learning, gave this new application her consideration to determine whether its use would be beneficial or detrimental to the academic project.

ChatGPT IN HIGHER EDUCATION

The application was developed by the research organisation OpenAI. This organisation's principal objective is to promote and develop friendly artificial intelligence (AI) in a responsible manner to the advantage of humanity as a whole. This is in alignment with the Faculty's approach of using technology to the benefit of mankind, and not developing technology that will replace the human operator. Human beings and their emotions should be the most important consideration when developing technology.

This latest application of OpenAI makes use of the Generative Pre-training Transformer (GPT) language model.

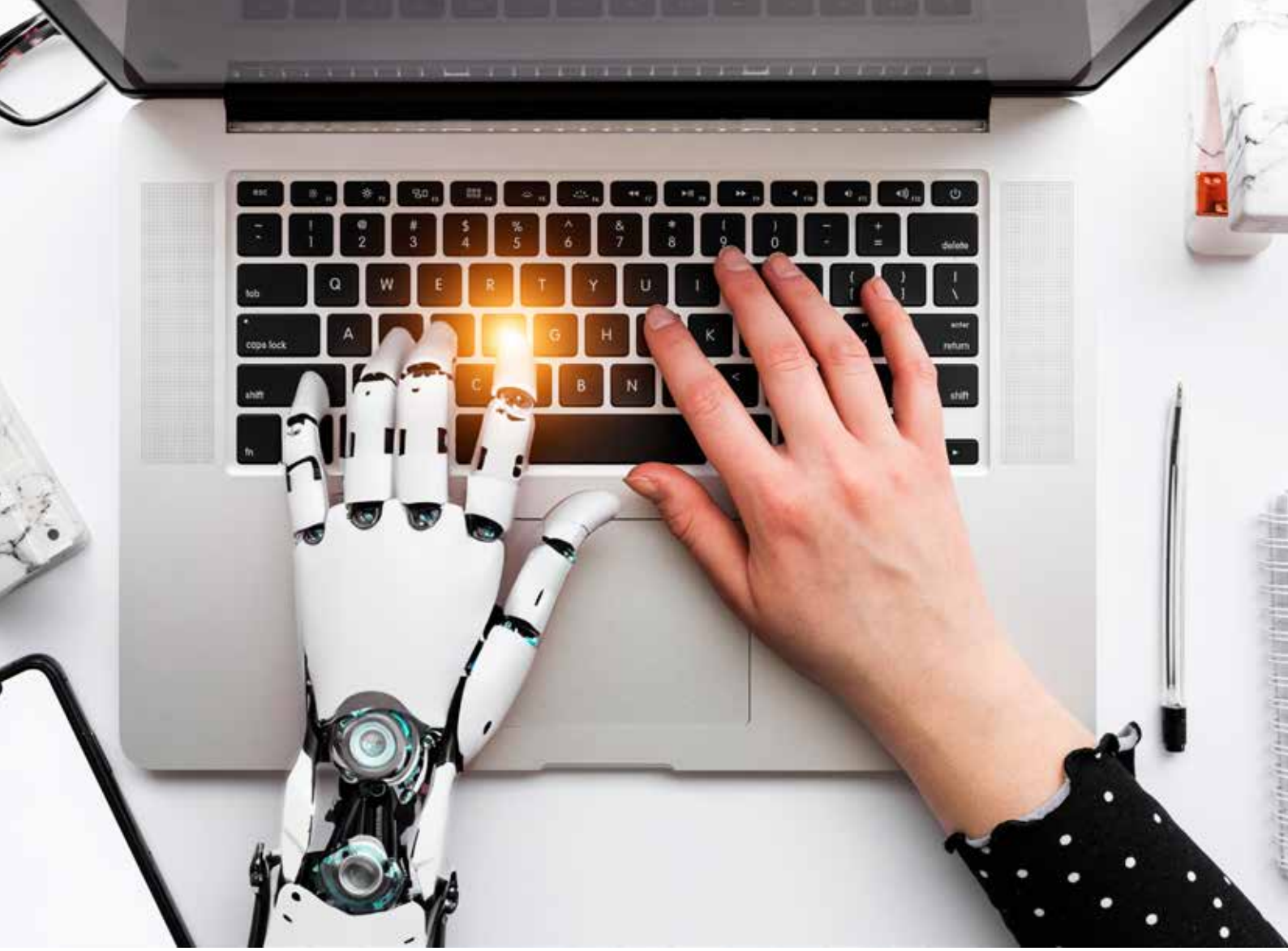
By utilising machine learning and artificial intelligence, it can optimise language models for dialogue. It has been trained to interact with the user in a conversational manner. This makes it possible for the application to answer follow-up questions, admit its mistakes, challenge incorrect premises and reject inappropriate requests.

According to the company, its goal is to help people understand and make informed decisions about the development and deployment of AI. Such an application has the potential to make a significant impact in fields such as health care, finance and education. As such, AI can be used to personalise teaching, adapt to student needs, and provide real-time feedback to improve educational outcomes. This may furthermore improve the efficiency of teaching and learning, and enable the development of new educational technologies.

It can be used to analyse student data, and adapt the learning experience to individual needs and abilities. It can provide real-time feedback and support to students as they work through learning material, helping them understand concepts more quickly and effectively. It may also free up more time for teaching staff to focus on more important activities by automating routine tasks such as assessment and recordkeeping.

GENERATIVE AI HAS THE POTENTIAL TO ENHANCE THE LEARNING EXPERIENCE FOR STUDENTS AND IMPROVE EDUCATIONAL OUTCOMES. HOWEVER, IT IS IMPORTANT TO ENSURE THAT AI IS USED IN AN ETHICAL WAY.

In addition to the ChatGPT application, AI can be used to create interactive and immersive learning environments, such as virtual reality (VR) classrooms or personalised learning games. Overall, it has the potential to enhance the learning experience for students and improve educational outcomes. However, it is important to ensure that AI is used in a way that is ethical and equitable, and does not disadvantage any particular group of students.



USING ChatGPT RESPONSIBLY

Following the experimental use of the application, one stands amazed at what ChatGPT can do. Answers are well structured, and limited editing is necessary when insights are required from information requested from the application. This does, however, bring up several concerns regarding the originality of research, and whether research obtained via this application can be seen as a form of plagiarism.

While AI is a useful tool to generate drafts of reports, suggest alternative language or provide fact-checking or data analysis, it needs to be used responsibly, appropriately and in an ethical manner. It is important to remember that AI will never replace human judgement and critical thinking.

One needs to carefully review and evaluate the output of any AI tool, and ensure that the information obtained in this manner is accurate and appropriate before including it in a report. Universities will need to rethink the writing of reports and recognise that the writer of a report can use tools such as ChatGPT.

It is also important to be transparent about the use of AI in report writing. If an AI tool has been used to assist with the writing of a report, it should be clearly acknowledged, and the limitations of the tool explained. This will ensure that readers have a clear understanding of the role that AI played in the writing of a report, and can evaluate the information it contains accordingly.

There is no doubt about the benefits of this application as a support tool to obtain better information than is obtained from existing search engines.

By analysing data from a variety of sources, including news articles, research papers and social media posts, it can provide a more comprehensive overview of a particular topic, or identify trends and patterns that might not be obvious to a human researcher. However, it is important for users to carefully evaluate the output of such a tool, and use their own judgement to determine the relevance and reliability of information so obtained.

We are entering an exciting new era, and need to rethink traditional methods of teaching and learning if we are to keep abreast of the latest technological trends.

Leveraging Generative AI to enhance teaching and learning

The launch of ChatGPT in November 2022 sparked a significant conversation about the impact of AI in higher education, particularly its disruption of the status quo when students started using it to craft their essay submissions.

ChatGPT is a prime example of a powerful large language model that is capable of mimicking human conversation. By leveraging its extensive database of trained language patterns, large language models can provide generated textual responses that accurately reflect the context of the user's output. With their command of languages, they can write comprehensive and coherent essays, analyse topics in depth and present arguments persuasively.

It is important to ensure that the Faculty of Engineering, Built Environment and Information Technology keeps abreast of the latest technological developments that may affect students' performance. The challenges associated with Generative AI, such as ChatGPT, is no exception.

While this application has great potential to augment our productivity and learning processes, it also contains inherent risks. Large language models do not truly comprehend the semantic content of the text. Instead, they generate text based on patterns and relationships between words identified during their training phase. They should thus serve as a tool to support learning, rather than replace human creativity and critical thinking. They can inadvertently produce inaccurate information, and privacy concerns.

The underlying principle of using an application such as ChatGPT to enhance teaching and learning is that it should be used ethically, and lecturers and students should understand how to use it effectively for the utmost academic benefit. Among the important considerations for its use in an academic context are to ensure data privacy and confidentiality, and to uphold academic integrity. Plagiarism is an important issue that needs to be addressed.

A comprehensive understanding of the implications of using AI can help students maintain a high standard of academic honesty. To further reinforce these principles, implementing a rigorous honour code can be a constant reminder of the importance of academic integrity and the potential consequences of violating these principles.

The effective use of Generative AI can enhance students' comprehension of various topics, foster critical thinking skills and assist them in their planning. In this way, it can be used as an effective tool to improve academic performance. Generative AI can also be leveraged by lecturers as a tool for planning and preparation and for various assessment-related purposes.

It is, however, essential for students to ensure that they use this application ethically and appropriately. As responsible users of Generative AI, students should prioritise ethical considerations, such as respecting privacy, avoiding discrimination, acknowledging source of information, and critically evaluating the advice provided to ensure that their use of the technology benefits themselves and society as a whole.

Since the value of a qualification from the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology depends on the academic integrity of its teaching and learning, the Faculty is committed to ensuring that technological advancements that enter the public domain are used responsibly. It will therefore continue to provide guidance wherever appropriate.

STUDENTS CAN MAINTAIN A HIGH STANDARD OF ACADEMIC INTEGRITY WHILE USING AI BY RESPECTING PRIVACY, AVOIDING DISCRIMINATION, ACKNOWLEDGING SOURCES OF INFORMATION AND CRITICALLY EVALUATING AI-GENERATED TEXT.

Bringing life to the engineering curriculum

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 that are implementing innovative strategies in their engineering curriculum.

An integrated curriculum carefully interconnects the content with the appropriate mode of delivery 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, and is mentoring other institutions to follow suit.

INNOVATIVE ENGINEERING CURRICULUM

An exciting collaboration was launched in 2021 between UCL, ten South African engineering schools, the South African Society for Engineering Education (SASEE), the South African Department of Higher Education and Training (DHET) and the Royal Academy of Engineering. The collaboration, which operates under the name Innovative Engineering Curriculum, is showcasing strategies for engineering curriculum transformation across South African higher education institutions. It has the potential to radically change the South African engineering education landscape.

Innovative
ENGINEERING CURRICULUM

The collaborating institutions are the University of Pretoria, the University of Johannesburg, the University of the Witwatersrand, the University of Cape Town, North-West University, the Vaal University of Technology, the Nelson Mandela University, the Cape Peninsula University of Technology, the Walter Sisulu University, the University of KwaZulu-Natal and UCL, in collaboration with SASEE.

The project seeks to leverage the cooperation and participation of these institutions to allow for the sharing of ideas and experiences. This overcomes some of the limitations that exist when institutions attempt curricular reform independently.

Dr Lelanie Smith, one of the project's representatives from the University of Pretoria, explains that "built into this project is cross-institutional collaboration and opportunities for the training and development of academic staff, which makes it uniquely positioned to effect curricular change in engineering education in the South African landscape."

DEVELOPING A FRAMEWORK FOR A SOUTH AFRICAN INTEGRATED CURRICULUM

The first phase of the project was launched on 30 June 2021 when Prof John Mitchell, Director of the Centre of Engineering Education at UCL, addressed the deans of 16 engineering schools on the process of developing an integrated curriculum, and the value of such a project. This was followed by interviews with 28 programme coordinators at different institutions between July and October 2021.

A series of five workshops was presented between 27 January and 7 April 2022, focusing on topics such as the benefits and challenges of an integrated curriculum, how institutions can partner with the Engineering Council of South Africa (ECSA) and what integrated innovative assessment entails. Participants also deliberated on the concept of sustainable integration, and how they could make their integrated ideas a reality.

IMPLEMENTATION OF PILOT PROJECTS

Once clear direction had been obtained on the strategy to follow for the implementation of an integrated curriculum, the second phase of the project could be initiated. This entailed the identification of areas that were feasible for the implementation of integrated curricular approaches as pilot projects within faculties.

Invitations were issued to all the deans and programme coordinators at the partner institutions, and institutional engagement took place with the participating engineering schools, as well as the Independent Institute of Education (IIE).

A series of institution-specific workshops were held to develop programmes internally, followed by a series of national workshops. Presented between 16 September and 24 November 2022, the workshops focused on topics such as the integrated first-year experience, and the authentic development and assessment of complex graduate attributes.

An industrial indaba was also held in which delegates embarked on an exercise of simulating the workplace. "It is important that students, while working towards a technical goal, are informed by industry partners. In this way, the student has a reliable experience of what the workplace environment will offer," says Dr Smith.

An outcome of the workshops was a case study report on institution-specific education models. The articulation of graduate attributes by the workshop participants contributed to an expansion of ECSA's policy documents, as well as the delivery of a further series of workshops launched on 26 April 2023. These workshops were focused on introducing the third phase of the project. The first two workshops considered the impact of the identification of the Engineering Work Regulations 2021 on engineering academics, both from the perspective of the role of the engineering academic, and by describing and evaluating engineering academic work. The final workshop considered contextual and integrated mathematics education for engineering students.

STAFF READINESS

The final outcome of the project was the development of a comprehensive, holistic training programme, designed for engineering educators by engineering educators. It enabled academics to become expert facilitators of active integrated learning. This final phase of the project is addressing the readiness of staff to facilitate active integrated learning.

SIGNIFICANT CHANGE CAN ONLY BE ACHIEVED THROUGH THE DEVELOPMENT OF LONG-TERM COMMUNITIES OF PRACTICE.

The staff readiness pilot took place during SASEE's Engineering Education Seminar on 12 July 2022, when three hybrid workshops were held across the country to empower engineering educators to teach in a more sustainable and innovative manner. This was followed by a full process pilot between 24 and 26 February 2023, with a core team demonstrating, in person, how the new integrated curriculum would be rolled out. The national roll took place at the SASEE Conference 2023 on 10 and 11 July 2023. The theme of this conference was: "Change makers in engineering education."

The project will be concluded with supervised implementation and further development between July 2023 and March 2024. Based on the current staff profiles in the partner faculties and departments, it is anticipated that more than 300 lecturers will benefit from this initiative and – through them – thousands of students at the various partner institutions once the new integrated curricula are rolled out.

The project partners believe the value of this initiative to lie in the fact that long-term benefits cannot be achieved through once-off interactions.

Significant change can only be achieved through the development of long-term communities of practice, where the continued exchange of people, knowledge and ideas is enabled.

The spontaneous and organic growth of an integrated curriculum

A team across the three domains of electrical, electronic and computer engineering have succeeded in combining their talents to develop a unique intervention for students to apply what they have learnt in an engaging and a stimulating way across several modules.

This team, which was the joint winner of the Faculty's Teaching and Learning Award for 2022, taught several modules in the Department's curricula. The team comprised Prof Tania Hanekom (third-year Microcontrollers), Prof Trudi Joubert (second-year Digital Systems and third-year Analogue Electronics), Prof Tinus Stander and Dr Werner Badenhorst (third-year design modules), Prof Ian Craig and Prof Derik le Roux (third-year Control Systems), Pieter Roodt (the Robot School) and Willem van Jaarsveld (EBIT Robot Race).

This integrated initiative had two objectives: to provide world-class engineering education to enable students to make a meaningful contribution to addressing local and global challenges through technology; and to spark an interest in electrical, electronic and computer engineering among learners.

The initiative had its origin as early as 2013 when Prof Tania Hanekom developed a project-based learning initiative known as the EBIT Robot Race. Students had to work together in small groups to design and build a microcontroller-based autonomous robotic vehicle. The outcome of the project was for the autonomous vehicle to navigate a coloured line laid out to purposefully cross over other coloured lines and not veer off course, in the shortest time possible.

In 2015, Prof Trudi Joubert identified a potential alignment opportunity between the design of an analogue sensor system and the embedded system facets of the robotic vehicle, particularly as the third-year Analogue Electronics module runs concurrently with the third-year Microcontrollers module, in which the Robot Race was being presented at the time. At the same time, second-year Digital Systems students were introduced to a practical assignment in which they had to design a rudimentary navigation strategy for a robotic vehicle, and implement this strategy on the programmable component platform. This was in anticipation of the design and implementation of the robotic vehicle to be built in their third year.

The impetus for the current intervention occurred in 2020 with the advent of the COVID-19 pandemic. As students could not come to campus, they received component kits with which to build their robotic vehicles. A staffing shortage also led to the combination of individual design modules for electrical, electronic and computer engineering. Prof Tinus Stander then approached Prof Hanekom about using the contextual framework of the microcontroller-based autonomous robotic vehicles to teach engineering system design in the Department's third-year design modules. This provided the perfect opportunity to implement a new level of integration.

In the Department's third-year design modules, the design of the robotic vehicle was split into three separate subsystems, and a software hub was written to allow the remote integration and testing of the individual subsystems. Each of the subsystems targeted a specific discipline, although the three programmes (electrical, electronic and computer engineering) had sufficient background to master the design challenges associated with all the subsystems.

Another module that had to find an emergency hands-on home-based alternative to laboratory-based work during the pandemic was the third-year Control Systems module presented by Prof Ian Craig and Prof Derik le Roux. This module runs concurrently with the design modules.

According to Prof Hanekom, the logical approach was to piggyback on the design module hardware by using the microcontroller-based autonomous robotic vehicles as the plant to be controlled. Students were therefore asked to implement a rudimentary control system, similar to the one required in the Microcontrollers and Design modules, while they had to analyse the robotic vehicles to design and implement a sophisticated proportional integral derivative control system for the Control Systems module.

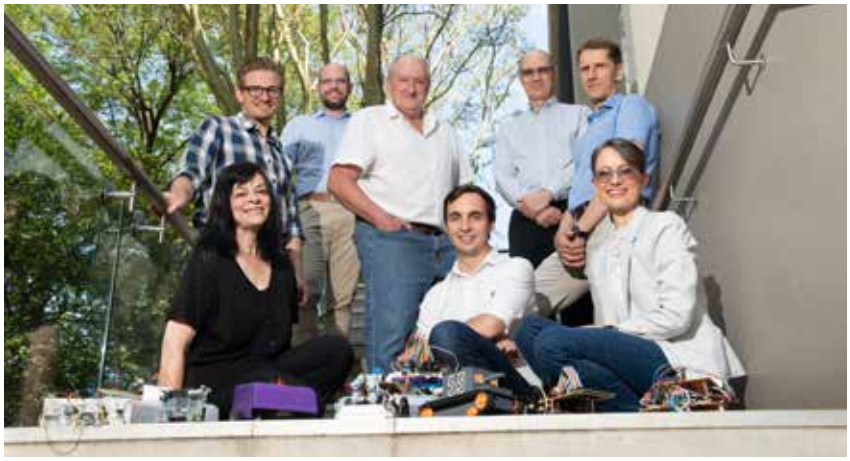
This allowed cross-module comparison between different control system strategies to develop a deeper understanding of the behaviour of control systems implemented at different levels of complexity.

In 2021, while pandemic conditions were still prevailing, the EBIT Robot Race was taken online in the Microprocessor and Analogue Electronics modules. Dr Werner Badenhorst joined the design modules with the responsibility to build on the foundation that had been laid in 2020. His mandate was to review and amend the practical challenge so that students could reiterate the design of their robotic vehicles from a systems engineering perspective.

A new dimension was introduced to the traditional EBIT Robot Race challenge when students had to connect two types of sensors to the same hardware platform. This was done to satisfy the requirements of the Control Systems module. "The project in its present shape is being refined," said Prof Hanekom. "It is now in its third iteration, and is reaching maturity."

A further outcome of this initiative has been its utilisation as a community engagement initiative in the Faculty to encourage school learners to follow a career in science, technology, engineering and mathematics. A project such as the EBIT Robot Race provides the ideal platform to drive social change, and alter the perception that engineering is predominantly a male career.

This led to the founding of the Robot School in the Department. Second-year students can use this platform to teach robotics to school learners as part of the community work they are required to perform as part of their curriculum. This programme has the added advantage of exposing more students to the principles of robotics.



The integrated team: From left (back): Pieter Roodt, Prof Tinus Stander, Willem van Jaarsveld, Prof Ian Craig and Dr Werner Badenhorst; (front): Prof Trudi Joubert, Prof Derik le Roux and Prof Tania Hanekom.

Annual Robot Car Race Day

It was with much excitement that the Faculty of Engineering, Built Environment and Information Technology's third-year students in Electrical, Electronic and Computer Engineering counted down the days to the much-anticipated Annual Robot Car Race Day. This year's event marked a decade of innovation and engineering excellence.

Initially conceptualised as an engaging, enjoyable practical project for students in the Department's Microcontrollers module, it has developed into a highlight on the Faculty's calendar. The Robot Car Race has since been extended to other modules, enabling the horizontal and vertical integration of learning content in the different programmes. The event has attracted just as much attention from the Department's industry partners, who sponsored prizes to the value of almost R200 000 this year. These sponsors included Microchip, Rapid M, MWR, BBD Software, Gendag Software, Grassroots, RS Components, Hensoldt, PPS Insurance, Microrobotics, ST Microelectronics, Omnigo and Keystone. The success of this year's event is largely due to their unwavering support of the Faculty.

More than 70 teams took part in this year's Robot Car Race. Prizes were awarded to the first nine teams whose vehicles passed the finishing line of the five-meter track. The first prize went to Team 8 (Maurice Fourie, Karl Kleynhans, Christof van Veijeren and Aldo Vos) with a time of just over nine seconds. In second place was Team 1 (Cameron Eales, Heinrich le Roux, Rynhardt Lules and Michael van Jaarsveld) with a time of just over 12 seconds. In third place was Group 65 (Stephen Barnard, Tyron Serradinho, Lara van den Heever and Luke Winterton) with a time of just over 15 seconds.

These youngsters are clearly illustrating their worth when it comes to making a difference in the things that matter by proudly harnessing the powers of technology for the good of mankind.

Teaching urban citizenship

Dr Carin Combrinck is a senior lecturer in the Department of Architecture and Director of the University's Unit for Urban Citizenship. She was the joint winner of the Faculty's Teaching and Learning Award for 2022. Dr Combrinck is responsible for several courses in the Department that collectively contribute to developing a sense of urban citizenship.

She teaches from a position of conviction. "I believe that our societal transformation relies on the development of thought leaders through an engaged and a transformative education." Over more than a decade of teaching, she has sought to embed critical thinking in her students with the aim of transforming the architectural profession to be more responsive to South Africa's socio-spatial legacies of segregation and injustice. Her teaching methods synthesise philosophies of cognitive transfer, reflection and transformation according to the appropriate levels of moral and ethical development in the different year groups, resulting in a scaffolded approach in which epistemic shifts may occur.

By including the academic programmes she teaches in the activities of the Unit for Urban Citizenship, she is able to embed a culture of participation in graduates to achieve deep-seated, knowledge-based transformation. Dr Combrinck identifies any uncertainty students may experience during her weekly classes so that she can address any issues that come up timeously. "I encourage students to question the process and outcomes, so that they can take ownership of their decision-making processes." Seminars, studio time and online tutorials are arranged according to the overall class schedule, but are adapted when the need arises, depending on the students' workload.

In her teaching, she makes use of seminars, embedded community engagement, collaborative groupwork and peer evaluation, along with regular reflection and facilitated discussion. Her students are encouraged to engage with the requisite theory and prescribed reading in her classes, as this forms an integral part of their engagement in the field. It also enables them to assimilate what they have learnt into their creative output. "In the third-year Citizen Design course, for example, students are expected to co-evaluate the work of their peers based on their own understanding of the literature." This encourages students to take responsibility for their own learning through what is known as "reflection-inaction".

In her Urban Citizenship Honours Studios, students review the exam rubric according to their processes and weighting. "In this way, an increased level of accountability is encouraged." Transparency in the reviewing process assists students to manage their expectations and offers them the opportunity to impact on the parameters and criteria of evaluation. Themes and community networks that are identified in the honours programme are taken further in the Urban Citizenship Master Studios. Over the years, the participatory approach that is encouraged in the architecture studios and the meaningful engagement with key stakeholders have formed part of the Mamelodi Community of Learning Collaborative, which has opened up post-secondary school opportunities for the residents of Mamelodi through the reciprocal exchange of ideas.

Despite the fact that many of the spatial design challenges that the University of Pretoria's architecture students need to address in their practical projects are typical of a developing-world context, some parallels have surprisingly been identified in the development of low-cost urban housing in the Global North. This led to collaboration between the architecture departments of the University of Pretoria and the Chalmers University of Technology in Sweden, which has been ongoing since 2018.

Dr Combrinck believes that spatial design plays an integral role in community development, especially when an interdisciplinary view is taken towards social innovation and urban citizenship.

In the process, the role of a university, as an anchor institution and social actor, is embedded in the community, and is promoted and supported through a scholarship of engagement.

[See article on page 74.]

Exploring the metaverse

Laetitia Cook, a lecturer in the Department of Construction Economics, found that her students really missed the personal contact they had typically experienced in the classroom after teaching had to be taken online during the COVID-19 lockdown periods. Despite her best efforts, she found students' participation in class deteriorating and the sense of intimacy and cohesion that usually characterised her classes to be lacking. That was until she discovered the metaverse!

Presenting her modules to students in Quantity Surveying, Construction Management and Real Estate via Blackboard Collaborate, she found that even students who had initially participated via the chat box or microphone function became increasingly less enthusiastic to volunteer their opinions as the module progressed. This differed distinctly from her in-person lectures on campus, where she generally experienced good participation from the class.

She investigated some of the reasons for this lack of enthusiasm, and found that some students were just shy, and did not enjoy speaking in front of classmates in an online environment, while others feared they would be perceived as trying to ingratiate themselves. At the same time, she observed that those same students liked to participate in virtual reality gaming sessions. This gave way to the idea of a virtual reality class, in the metaverse. In the realm of virtual reality, the metaverse comprises several virtual spaces in which users can interact with other users in a computer-generated environment.

As property investment is an element of construction management, her interest in the metaverse was sparked when she observed the trend of property being bought and sold in the metaverse. "I was fascinated by a media report of a patch of virtual real estate being sold for $2.4 million worth of cryptocurrency. This online environment is a place where users can buy land, visit buildings, walk around and meet people as avatars," she explains. "Such environments grew in popularity as the pandemic caused people to spend more time online."

On a WhatsApp group she started with her students, she asked the question: "Is this a new asset class?" Together with her students, they started sharing articles on the metaverse with each other, and the investigation began in earnest. This led her to wonder whether holding a class in the metaverse might be more participative than on a conventional online platform. As the metaverse included numerous experiences, ranging from virtual gaming to a sports lounge, Cook wondered why it could not include a lecture hall. So she invited her students to attend a non-compulsory lecture in the metaverse.

The response was overwhelming. What made it so accommodating was the fact that students did not require any special equipment – they could log in using their laptop or desktop computers. The class that she presented in the metaverse was repeated on Blackboard Collaborate during the scheduled time, so students who were unable or hesitant to attend did not miss out on the course content.

"I was fortunate to have been granted a few hours in the metaverse free of charge, and the students loved it."

Although it was still an online environment, the students experienced this virtual world on the same level as the "real world". "It is a completely intuitive platform, which led to the students being much more willing to participate."

Although attendance of the metaverse lecture required more data than a Blackboard Collaborate lecture, the cost of data is declining. To purchase space in a well-known metaverse such as Decentraland or Sandbox is costly, yet metaverse space in general is much more affordable or even free to use. Unfortunately, the free platforms or ecosystems do not have the full functionality required for lecturing.

She is thus investigating the potential purchase of metaverse space, especially for lecturing, as the costs are not prohibitive. "It presented a wonderful opportunity to expose students to the potential that the future holds – for education as well as real estate."

Impact through innovation

EBIT CONCERT 2023

The 2023 EBIT Concert pulled out all the stops to take its audience on a musical journey through the universe. With its unique combination of music and digital storytelling, the programme highlighted the incredible impact of innovation, achieved by upholding the dignity and wellbeing of all human beings.
This spectacular event is a collaborative showcase between the Dean's Office and the University of Pretoria Symphony Orchestra (UPSO), under the guidance of conductor Schalk van der Merwe. Its purpose is to thank the Faculty's alumni and partners for their continued support.

Watch the highlights

Academic Achievers' Awards

Doing research that matters is one of the core themes of the University of Pretoria (UP). The institution aspires to become an African global university, exerting influence through three major pathways: teaching and learning, research and service to society. The EBIT researchers who have been named Academic Achievers contribute significantly to this institutional goal.

UP has made significant progress in the 2024 QS World University Rankings, and is now ranked in the 323rd position worldwide. It is also ranked third in South Africa and fourth in Africa in the inaugural Times Higher Education Sub-Saharan Africa University Rankings for 2023. In addition, UP is ranked as a highly innovative university in the 2023 World University Rankings for Innovation (WURI) – placing it in the 101–200 band in the WURI Global Top 100 Innovative Universities' ranking. UP is the only South African university ranked in the 2023 WURI.

Prof Evans Chirwa
Exceptional Academic Achiever
C2 NRF-rated researcher
Department of Chemical Engineering

Prof Ian Craig
Exceptional Academic Achiever
B2 NRF-rated researcher
Department of Electrical, Electronic and Computer Engineering: Head of the Control Systems Research Group

Prof James Maina
Exceptional Academic Achiever
B3 NRF-rated researcher
Deputy Dean: Research and Postgraduate Education, EBIT

Prof Derik le Roux
Exceptional Young Achiever
Department of Electrical, Electronic and Computer Engineering

Dr Tendani Mawela
Exceptional Young Achiever
Y2 NRF-rated researcher
Department of Informatics: MIT ICT Management Programme Coordinator

Dr Carin Combrinck
Teaching Excellence Award
Department of Architecture: Director of the Unit for Urban Citizenship

Prof Tania Hanekom
Teaching Excellence Award
C2 NRF-rated researcher
Department of Electrical, Electronic and Computer Engineering

Inaugural adresses

EBIT is home to exceptional researchers. The following academics each delivered a thought-provoking inaugural address in 2023 to mark a highlight in each of their careers. The Faculty is proud to have these academics leading the EBIT Generation.

Prof Pieter de Villiers
Department of Electrical, Electronic and Computer Engineering

SEEING A DYNAMIC WORLD THROUGH THE EYES OF SENSORS

Prof De Villiers heads the Department's Signal Processing and Telecommunications Research Group, and is Co-Chair of the MultiChoice Chair of Machine Learning. The focus of his research includes statistical signal processing, machine learning (with a focus on signal processing), sensor and data fusion, fixed-line communication, information theory and cognitive radio.

The application areas of his current research include audio and video processing, radar, financial management and machine condition monitoring. His research has an impact across several of the Faculty's research focus areas, as well as two of the United Nations' Sustainable Development Goals (SDGs): SDG 9: Industry, innovation and infrastructure, and SDG 15: Life on land.

According to Prof De Villiers, the fusion and interpretation of data from multiple sources and sensors are important for automating complex tasks, such as tracking pedestrians or aircraft or coordinating robots or autonomous vehicles in complex and dynamic environments. During his public lecture, he introduced a philosophical view of the sensing problem, how it is formalised in Bayesian probability, how the Bayesian models are used to make inferences and predictions, and how these inferences are then used to take action.

Prof De Villiers explained that two things are needed to make inferences: models and data. "Current research in the field focuses on the parallelisation of information fusion algorithms and uncertainty representation and reasoning in information fusion." Other efforts focus on the intersection of machine learning and information fusion, as well as concepts of explainability and trust in these methods.

He discussed a few applications and use cases. Safety and security use cases include the classification of humans and animals using Doppler radar for anti-poaching operations and behavioural modelling, and the classification of maritime vessels for anti-abalone poaching and anti-piracy. Recently, he has been considering using Bayesian neural networks to quantify uncertainty in synthetic aperture radar image for target detection, as well as to improve training in scarce data applications.

He detailed further use cases of his research efforts in broader application domains, such as video broadcasting and video streaming, financial risk modelling, machine diagnosis and prognosis, and the modelling of gene expression lineages. Although this field is gaining increasing traction, researchers are experiencing some challenges. These include the computational efficiency brought about by parallelisation, where algorithms are split between processors, and the use of machine learning for modelling, where the target behaviour needs to be learnt. Furthermore, when human lives are at stake, it is difficult to put all one's trust in the answers provided by machines.

Due to the transdisciplinary nature of problems that need to be solved by adopting Bayesian and other probability methods, the solutions developed through signal processing and machine learning have many application areas.

Prof De Villiers concluded his presentation with a future vision for sensor and data fusion research, where intelligent sensing in machine automation is becoming increasingly prevalent.

Prof Raj Naidoo
Head of Department: Department of Electrical, Electronic and Computer Engineering

TRANSFORMING THE ELECTRICITY GRID THROUGH DIGITAL INTERVENTIONS

In addition to being Head of Department, Prof Naidoo also heads the University's Smart Grid Laboratory research. His passion lies in smart grids and a just energy transition, which includes smart distribution systems, and establishing a smart grid workforce for distribution utilities and optimal energy management.

According to Prof Naidoo, the Fourth Industrial Revolution (4IR) is a new epoch in social and economic life. It is driven by technological advancements that will broaden and deepen the connections between the biological, physical and digital worlds in unprecedented and unpredictable ways. Digitalisation has transformed many industries, and is continuing to transform the world. Driven by operational and business needs, it can accelerate electric grid transformation, while delivering security, reliability, operational excellence and cost objectives.

There are currently five geographic power clusters that service Africa's electricity demand. The continent's economic growth is not just affected by electrical connectivity, but also by internet connectivity. The conventional electrical grid can therefore benefit from 4IR connectivity, as well as sensors, smart devices and information sharing across the many components of the electricity grid.

In his presentation, Prof Naidoo illustrated several concerns that are being addressed through some thought-provoking research activities. "The Department's key research contributions relate to smart asset management and a just energy transition," he explained. This includes research focused on energy management and optimisation solutions within microgrids, and using advanced algorithms for model predictive control, machine learning and blockchain.

With digital transformation, multiple technologies, which have previously existed in isolation, are converging. The speed, breadth and depth of this revolution is forcing us to rethink how countries develop, how organisations create value, and even what it means to be human. These technologies typically include artificial intelligence, cloud computing and the Internet of Things (IoT). "Data from smart IoT sensors is applied to machine learning and advanced algorithms that connect the physical and digital worlds." Findings from this research indicate that utilities can change from being reactive to being predictive by utilising IoT intelligence. This can improve planning, operations and maintenance, and ensure a reliable, flexible and cost-efficient grid operation.

According to Prof Naidoo, a smart grid is a digitally enabled electrical grid that collects, distributes and works on the information it receives about the behaviour of all suppliers and consumers to improve the efficiency, reliability and sustainability of electricity. Enhanced operations are achieved through data collection and data processing. "By focusing research on the digitalisation of power system operations and protection, we are looking at mitigating the risks of renewable energy integration, as well as enhancing the quality of the power generated, while protecting the power system."

Virtual power plants are a dynamic and rapidly developing technology that is set to make a significant impact on the future of electricity generation, distribution and consumption. It enables distributed energy resources, including solar or battery storage devices, to connect to the electricity grid through smart inverters. Research in this regard relates to the development of smart algorithms for improved power system operation and control, as well as making use of digital twinning.

A problem that is often encountered is the fact that motors account for more than two-thirds of the electrical power consumption in some countries. This provides an opportunity to reduce energy consumption, which can be accomplished by replacing inefficient motors with high-efficiency motors; estimating the efficiency of an in-service induction motor, without withdrawing it from service. This led to the development of a method to make motor-driven processes more efficient.

Climate change and the increased need for decarbonisation have led to the mass penetration of renewable energy and new energy trading markets for solar, green hydrogen, wind and hydro energy. This has led to the need for localised energy markets to sell excess renewable energy.

A key concern of these new markets is the risk of them being inequitable in terms of market regulation. Research in this regard is addressing these concerns by developing a novel blockchain-based market mechanism that is capable of transparently facilitating and regulating decentralised energy market transactions and enabling peer-to-peer energy trading.

Prof Naidoo concluded his presentation by explaining how digitalisation can accelerate the transition from fossil fuel-based energy generation to renewable energy-based operations. "By creating new business models, we are able to create win-win tariffs." The work done in this area entails an analysis of the composition of municipal tariffs, which incorporates aspects such as municipal inefficiencies (including faulty metering and ghost vending), the increased penetration of renewable energy, increased purchase tariffs, load shedding and maximum demand charges. An important point of departure in this regard relates to system performance efficiency. Hydrogen fuel cell management systems is an emerging field that will also contribute vastly to the just energy transition.

Prof Mohsen Sharifpur
Department of Mechanical and Aeronautical Engineering

FINDING NEW FORMS OF HEAT TRANSFER ON THE NANO SCALE

Prof Sharifpur's research interests include heat transfer, convective nanofluids, boiling heat transfer, computational heat transfer and the thermal fluid analysis of nuclear reactors. He is a C2-rated researcher with the National Research Foundation (NRF), who has been on the University's teaching staff since 2009. The Nanofluids Research Laboratory, which he established at the University, is recognised as the most active and productive of its kind in Africa. In 2020, he published his long-term research on the source and sink theory, which attracted worldwide interest.

He describes nanofluids as nanoparticles mixed in a base fluid. They are novel heat transfer fluids and have provided evidence of unique behaviour in thermal fluid systems. These fluids are primarily used for their enhanced thermal properties as coolants in equipment such as heat exchangers, electronic cooling systems and radiators. Their application can, however, be extended to solar-thermal, nuclear heat transport, controlling optical properties, polymerase chain reaction, and even drug delivery and biomedical technology.

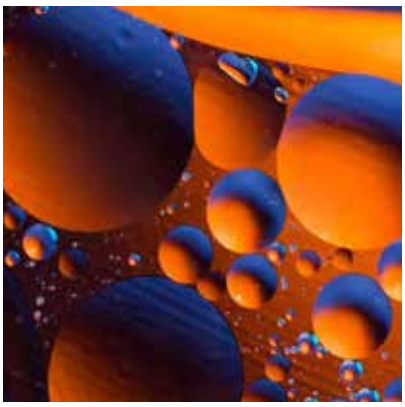
Experimentation with nanofluids as a heat transfer fluid finds expression across multiple disciplines, including chemical engineering, physics, mechanical engineering, materials science and medicine. Among the properties that make nanofluids an effective heat transfer fluid are their adjustable properties, their high specific surface area, and their ability to improve heat transfer. "Their effective thermal conductivity in heat transfer can be much higher than in conventional heat transfer fluids," he explains. "Magneto-rheological nanofluids can also control the viscosity and, consequently, heat transfer in an appropriate magnetic field."

This does not mean that they are without their problems. Nanofluids have generally shown more effective viscosity than base fluids. The challenge is to improve the stability of the nanoparticles in the base fluid. The idea, therefore, is to find the optimal way of preparing them and to find the optimum range for each nanofluid to provide the maximum heat transfer performance. One of the ways of doing this is to produce hybrid nanofluids. This entails producing two or more different nanoparticles in one base fluid. Nanofluids could significantly reduce the size and materials needed in heat transfer applications. Investigations into nanoparticles and nanofluids are consequently important in terms of material, energy and environmental management.

Their application in solar energy has economic, environmental and energy benefits. One can manufacture a smaller, more compact solar collector that can be operated using nanofluids. This will reduce the weight, energy and cost of manufacturing a solar collector. It will not only have less of an impact on the environment, nanoparticles' higher density and lower specific heat can lead to a higher thermal efficiency.

Given the advantage of using nanofluids for heat transfer, Prof Sharifpur considered the quandary of why there is not yet a market for nanofluids in industrial applications. This is an opportunity that should be exploited.

He concluded his address by observing that more research is required to improve our principal knowledge of different aspects of nanofluids. This includes the development of comprehensive hybrid models, determining the properties of nanofluids and improving their stability. He believes there to be a lack of principal research into methods to enhance heat transfer on the nano scale.



Prof Nico Wilke
Department of Mechanical and Aeronautical Engineering

WHEN NOTHING SEEMS TO GO RIGHT, WHY NOT GO LEFT? IN SEARCH OF ALTERNATIVE PERSPECTIVES AND PARADIGMS

Prof Wilke's research interests include state-of-the-art digital twin deployment based on data-driven generative modelling efficiently trained using gradient-only optimisation, and physics-based generative modelling using efficiently solved particle-based solvers on graphical processing units.

Prof Wilke aligned his perspective on research with that of the Hungarian biochemist and Nobel Prize winner, Albert Szent-Gyorgyi, who stated: "Research is to see what everybody else has seen, and to think what nobody else has thought". Prof Wilke offered a classical viewpoint of three categories of problems researchers typically encounter: problems with many solutions; problems with only one solution; and problems with no solution. He presented an alternative viewpoint, stating that a problem's category is not necessarily fixed. This epiphany inspires a researcher to search for alternative perspectives and paradigms.

Prof Wilke professed five lessons learnt in his search for alternative perspectives and paradigms, and how these alternatives have impacted research. He started his presentation by exploring how one can learn from one's mistakes. He discovered this when he was confronted, for the first time, by two unwitting inconsistent algorithmic formulations prevalent in particle swarm optimisation research. Instead of ignoring the existence of the two formulations, he realised that the fundamental differences between them resulted in the identification of a new class of particle swarm optimisation optimisers.

In computational mechanics, Prof Wilke compared the maturity of mesh-based and particle-based solvers with the industry's modelling needs. Evidently, the second-most processed substance by mass on the planet after water is granular materials, and yet the computational maturity of modelling granular materials up to 2014 was largely limited to two-dimensional simulations of a few thousand spherical particles. By embracing new computing technology offered by Nvidia graphical processing units, a paradigm shift resulted in discrete element modelling that enabled three-dimensional simulations using tens of millions of faceted particles. In 2022, all major commercial discrete element modelling software now supports graphical processing compute and faceted particle shapes.

Quoting the British statistician, George Box, who stated that "all models are wrong, but only some are useful," Prof Wilke reflected on the sequence of events that are required to make "models useful". He remarked that one of the essential ingredients – parameter identifiability with subsequent parameter identification from experimental data – is often neglected. The implication of neglecting this is that models cannot be used to predict the unseen, but only to reproduce what has been seen. Prof Wilke illustrated how vices of laziness and frugality inspired virtual calibration by only using what is available, and essentially developing a shortcut to properly quantify the usefulness of models, as well as guiding what additional experimental data is required to make them more useful. He remarked how some vices, such as frugality, are steadily becoming traits as we are increasingly judged not only on what we have achieved, but on what resources we required to get to those accomplishments.

In highlighting the computational cost of up to millions of dollars to train machine and deep learning models, he contrasted it to the elementary nature of choosing *a priori*-selected learning rates or learning rate schedules. The choice of learning rate plays a dominant role in the cost of training.

A potentially more efficient approach that adaptively resolves learning rates is line searches, which has gained almost no traction in machine learning training. The main reason is that, during training, only a few samples are used to evaluate the loss and gradient functions. To reduce the bias, the samples are changed every time the loss and gradient functions are evaluated. The consequence is that the loss function is point-wise discontinuous, negating the developed optimisation theory and approaches of Kepler, De Fermat, Newton, Leibnitz, Euler, Lagrange, Gauss, Legendre, Cauchy and Dantzig.

Prof Wilke demonstrated how a simple and elegant approach that only considers gradients enables the utilisation of line searches by resolving non-negative gradient projection points as opposed to minimising along a search direction. Gradient-only optimisation essentially enables the potential of line searches to be investigated and is showing significant promise in reducing the computational cost of machine and deep learning training.

Drawing from his research on gradient-only optimisation, Prof Wilke illustrated how

gradients are transforming other domains, with specific reference to the development of deep digital twins from sensor data and high-dimensional surrogates. He highlighted the importance of the generalisation of concepts and ideas to harness commonalities in transdisciplinary research that can lead to the transfer of perspectives to circumvent fundamental stumbling blocks across fields and disciplines.

He concluded his address by stating that academia needs to value ideas and thinking again, as it is only by continuously considering existing knowledge from new perspectives that researchers can ensure sustainable growth in science.

Prof Tinus Stander
Department of Electrical, Electronic and Computer Engineering

MAKING BIG WAVES WITH SMALL WAVES: TODAY'S CHALLENGES IN MICROWAVE AND MILLIMETRE (MM)-WAVE ENGINEERING

Prof Stander is associated with the Carl and Emily Fuchs Institute for Microelectronics (CEFIM). He is involved in cutting-edge research in the field of microwave and mm-wave microelectronics, with its transdisciplinary applications, including radio astronomy and transportation.

According to Prof Stander, systems that operate in the microwave and mm-wave frequency range have applications that span the breadth of human endeavours. They are used to connect, see, navigate, heal and understand our universe. The breadth of these applications is matched only by the breadth of challenges facing the microwave engineer to develop better, smarter, smaller, cheaper, greener and more impactful solutions to these challenges.

He introduced the audience to the concepts involved in communication through radio-frequency waves, specifically those related to frequency and bandwidth. He explained that the key trend is to strive for higher frequencies and wider bandwidths to accomplish faster communication and better imaging, particularly in the fields of terrestrial communications, radio astronomy and radar.

During his address, he reflected on a few key challenges across these application domains, and the key research inquiries that contribute to addressing them. He highlighted some of the problems of wide bandwidth signal processing and packaging for 5G and mm-wave communications, and explained how new modelling and frequency filtering approaches can alleviate some of these shortcomings.

He discussed how on-chip filtering and signal routing can be used to improve integrated circuit operation at higher frequencies and higher bandwidth. This is done by integrating as much of the microwave and mm-wave system on a single integrated circuit as possible.

"However, radio astronomy presents a wide range of challenges," he explained, "not least of which is the need for continuous site monitoring, where low-cost water vapour radiometry has found application". He explained how water vapour radiometry can be used to estimate the delay and attenuation of radio waves in radio astronomy. His research team has made great strides in developing cheap, low-cost, compact integrated water vapour radiometers.

Outlining some of the challenges faced by a nascent consumer access terminal industry in satellite communications, he described how some challenges can be addressed by using additive manufacturing or 3D printing to produce microwave components. "Additive manufacturing is a valuable technology that can be used as a rapid customisation tool for small-scale production, especially for complex designs," he explained. This is not only cost effective, but allows one to go through faster iterations of prototyping, which allows one to develop new technologies much sooner.

However, there are challenges in using 3D printing in the production of microwave and mm-wave components, especially with regard to the metallisation of smooth, porous 3D printed parts with non-toxic processes. "Resolving these challenges formed an important part of our research."

Prof Stander then went on to discuss the role and unique difficulties of microwave and mm-wave systems in space. An important element in this regard is the reliability of the technology. "Our development of new approaches to built-in self-testing have made an important contribution to solving challenges related to the use of this technology for improved performance," he explained.

He concluded his address with an overview of future research his research team plans to conduct to address continuing challenges. "Ongoing research in key areas can help equip the next generation of microwave engineers to face new challenges that arise in the field of microwave and mm-wave microelectronics."

Prof Chrisna du Plessis
Head of Department:
Department of Architecture

REGENERATING A COLLAPSING WORLD: EFFECTING TRANSFORMATION THROUGH HEAD, HEART AND HANDS

Prof Du Plessis' research focuses on developing the principles and guiding frameworks for the practices of urban sustainability and human settlement development at both the theoretical and technical levels. She is known internationally for her work on the evaluation of policy and research strategy for sustainable building and construction within developing countries, as well as developing the field of regenerative design and development.

According to Prof Du Plessis, the global polycrisis that was created by the interplays among global socio-political instability, increasing inequality, accelerating climate change, ecosystem loss and pervasive pollution by the residues of the second and third industrial revolutions, and the lifestyles they enable, is creating an unfamiliar and essentially unknowable world in which the cities of our future will have to function.

Nonetheless, crisis and collapse also bring opportunities for renewal as the cracks in old, dysfunctional systems provide fertile ground for the seeds of systems transformation to take root. However, creating an abundant and thriving future in which all members of the community of life can flourish requires a radical change in how we see the place and role of humans in the future development of the global socio-ecological system.

In her address, she mapped the evolution of sustainability thinking and how this evolution results from a shift in the worldview, providing new values and purpose. She discussed how a regenerative approach changes the processes and products of built environment design by integrating pathways laid out by the head (knowledge systems and reflection), the heart (values and attitudes) and the hand (praxis).

While we know that our choices shape the world, we need to establish how we got to this point, and what needs to change for us to remedy the faults in the world as we know it to create a better world for future generations. She explains that our beliefs about the world are shaped by our particular worldview. Over the past 500 years, Western society has been dominated by a worldview that separates humans from nature, ignoring the limits to growth posed by a finite and interconnected planet.

Sustainability thinking, on the other hand, holds that humans should protect nature and improve human wellbeing by developing technologies that decouple human development from environmental impacts. This is aligned to the goal of sustainable development, which aims to create a civilization in which basic human needs can be met within the ecological limits of the planet. She believes that urban sustainability can best be achieved by adopting an ecological worldview, which sees the world as a system of interconnected and interdependent living systems. This includes humans and their socio-techno systems.

Essential to this worldview is the conviction that humans can play a positive role in the development, regeneration and evolution of the global socio-ecological system. By creating regenerating systems, humans can be a force for good. This happens when our relationship with nature becomes one of collaboration, partnership and co-evolution.

But how do we fix what is wrong with the world? Prof Du Plessis is convinced that new ways of thinking will lead to new ways of doing. By adopting an ecological model for sustainability, we can regenerate the biophysical environment, as well as society. And by cooperating with nature and within communities, we can transition to a more sustainable model of human development in which humans can establish a symbiotic relationship with their social and biophysical environment.

Building forth on this ecological model for sustainability, Prof Du Plessis developed a revised evolutionary trajectory of ecologically responsible design. She explains that, working from an ecological worldview that is focused on growing positive impact, we can develop practices and environments that integrate natural and socio-techno systems, and can work with nature to create an abundant world. Such a worldview is regenerative and restorative, dynamic, resilient and adaptive, and recreates natural and social environments. It sees the city as a collection of processes, and not a collection of objects.

However, regenerative work requires a new kind of practitioner: someone who is self-aware, and who can work creatively with ambiguity and uncertainty. This would enable them to welcome the complexity of natural systems, and the diversity of perspectives that characterises living communities. As a co-creative and collaborative process, regenerative practice is also an exercise in non-attachment; being able to look beyond preconceived ideas to see what should be developed for the benefit of both the people and the planet.

Finally, how does one go about creating a better world? Prof Du Plessis believes that if we can acknowledge that humans are part of nature, it follows that we should honour the laws of nature, cooperate with nature and learn from nature.

As a future research endeavour, she proposes exploring the possibility of a potential Sixth Industrial Revolution, rooted in concepts such as biomimicry, bio-fabrication and circularity, which can regenerate the planet and transform our societies to create a radically different, life-affirming future in which all our descendants will not only survive, but also thrive.

Prof Hannes Gräbe
Head of Department:
Department of Civil Engineering

TRACKS OF DISCOVERY, INNOVATION AND EDUCATION: INSPIRING A NEW FUTURE FOR RAILWAY ENGINEERING

Prof Gräbe is a registered professional civil engineer with experience in track technology, track geotechnology, advanced laboratory testing, field investigations, maintenance models and the numerical analysis of track structures. He is also the Chairholder of the Railway Safety Regulator Chair in Railway Safety.

In his presentation, Prof Gräbe explained how the railway structure's foundation, supporting ballast, sleepers and rails significantly influence load-carrying capacity and the quality of a journey by rail. While laboratory settings facilitate the development of innovations in this area, industry applications necessitate the ability to measure track component performance through sensor technologies on operational railway lines. He explained how innovations in this field have focused on smart railway monitoring and smart track components. This followed the development of optics, sensor technologies, communication protocols, artificial intelligence and machine learning.

Presenting some of the innovations in track condition monitoring developed in the Department, he explained how use was made of a "smart ballast stone" to give researchers insight into the complete three-dimensional formation stress regime brought about by the movement of the train. This enabled them to monitor the transportation of fresh produce such as tomatoes and avocadoes. It entails a 3D-printed shell housing a minute battery-powered, wi-fi-enabled wireless microprocessor with onboard storage and high-frequency sampling. This device can record rotations, accelerations and magnetic flux in three directions, allowing researchers to advance from remote video monitoring to inertial measurements of track deflection as a result of dynamic train loading.

A second smart track component that is used is a 3D-printed rail pad instrumented with two accelerometers and a half-bridge strain gauge. The accelerometers detect any wheel or rail irregularities, while the strain gauge measures the load transferred from the rail to the sleeper. The smart rail pad functions as a remote condition monitoring system with a micro-controller mounted to the rail that records data from the strain gauge and accelerometers. It has an automatic triggering system that allows it to remotely measure railway traffic without human intervention, producing accurate wheel load results for weighing and impact detection.

Another innovation is the use of light detection and ranging (LiDAR) to identify and segment water leakage in railway tunnels. The LiDAR scanner records up to 300 000 points per second and

produces a point cloud in 3D with an indication of the intensity of the reflected light. The variance in the reflection of light from dry to wet surfaces allows researchers to track moisture and water leaks in dark, inaccessible tunnels, enabling remote data analysis.

Yet another innovative study aimed to determine whether track geometry can be derived from optical measurements instead of conventional, costly geometry vehicles and inertial measurement systems. This culminated in the development of three innovative smart track instrumentation systems. These entailed a system to acquire the photographic sequence of the rail, a low-cost, centimeter-accurate GPS and a neural network pipeline that produces the 3D reconstruction of the rail profile. These innovations enable researchers to deduce track geometry with reasonable accuracy, comparable to conventional instrumentation.

In addition to projects focused on autonomous track structure monitoring, the Department recognised the possibility of using its road-rail vehicle to benefit research in other disciplines as well. A research project was conducted in collaboration with ecologists in Mpumalanga to mitigate train-wildlife collisions in the greater Kruger National Park. By mapping the rail reserve and infrastructure assets, a digital infrastructure inventory of the railway line and adjacent area was developed to identify factors that contributed to collisions with wildlife on the railway line, which caused damage to the train and posed risk to human life.

Prof Gräbe concluded his overview of research in railway engineering by discussing the concept of a digital railway for research purposes. This involves the use of digital twins, augmentative and virtual reality training, Big Data and deep learning. He explained that digitalisation transcends the mere application of digital technologies. It revolves around people, making them central to the transformative concept. This enabled researchers to design a real-time track condition monitoring system for the Gautrain in 2022.

Training practitioners for the challenges that lie ahead for railway engineering is essential for a sustainable rail industry in South Africa: both in terms of freight transport and passenger rail. This includes making use of three railway test tracks constructed on the University's Hillcrest Campus. In this way, postgraduate and continuing education training programmes can incorporate practical examples to provide hands-on experience that emphasises safety, creativity and engineering skill.

The underlying vision of the University's postgraduate railway engineering programme is to make railways work better for the common good, and as such, it is making an impact in inspiring a new future for railways in South Africa.

Prof Karina Landman
Head of Department: Department of Town and Regional Planning

EVOLUTIONARY URBANISM: BREAKING THE CYCLE OF "MECHANISTIC" CHANGE

Prof Landman's work focuses on spatial transformation, including research on gated communities, and safer and more sustainable neighbourhoods. Her work on public space revolves around inclusivity, regeneration and decolonisation, while her research on sustainable development focuses on urban resilience, and regenerative development and design.

According to Prof Landman, cities and urban spaces are changing rapidly, both worldwide and in South Africa. "New challenges force planners to deal with these changes in ways that will consider the future wellbeing of the planet and its people." African cities are urbanising at a rapid rate, while poverty and inequality create significant challenges for service delivery and housing provision. Urban areas are characterised by fragmentation, segregation, low-density sprawl and a disconnect from nature. In response, post-apartheid planning and development legislation and policies have repeatedly called for spatial transformation to address many of these challenges.

She reconsidered these challenges by focusing on spatial mitigation, adaptation and regeneration in the country since 1994. She highlighted prominent areas, processes and products that influenced the urban landscape during different periods and at various levels – regions, precincts and public spaces. In the process, she reconsidered the meaning of these changes for sustainable development, and the implications for urban planning in South Africa.

Prof Landman noted that all the country's leading planning and development policies emphasise the need for accessibility and integration. However, the levels of crime and violence in the country threaten the ideals of spatial integration. Despite the best intentions, South African cities are characterised by isolated interventions that represent mechanistic change. This gave rise to the tendency to deal with symptoms in isolation, such as the establishment of low-income, low-density housing, and gated communities – often located on the urban periphery with little

connection to the surrounding environment. However, as a form of spatial mitigation, these interventions have many unintended consequences, such as the abovementioned spatial fragmentation, separation, low-density sprawl and exclusion. Ironically, these are the very characteristics that the post-apartheid city aimed to eliminate.

Considering the changing socio-economic landscape and growing urbanisation in South Africa, she recognised the need to reevaluate the types of housing and common spaces that are being established in our cities, and to work with change in a different way.

Increasing urbanisation has huge implications for urban planning, infrastructure development and service delivery. Government's National Development Plan, launched in 2012, acknowledged the importance of integrated economic, social and spatial development, while realising our dependency on the natural environment. This led to an emphasis of the need for resilience thinking to support sustainable development. This philosophy is concerned with the adaptive capacity of cities as socio-ecological systems.

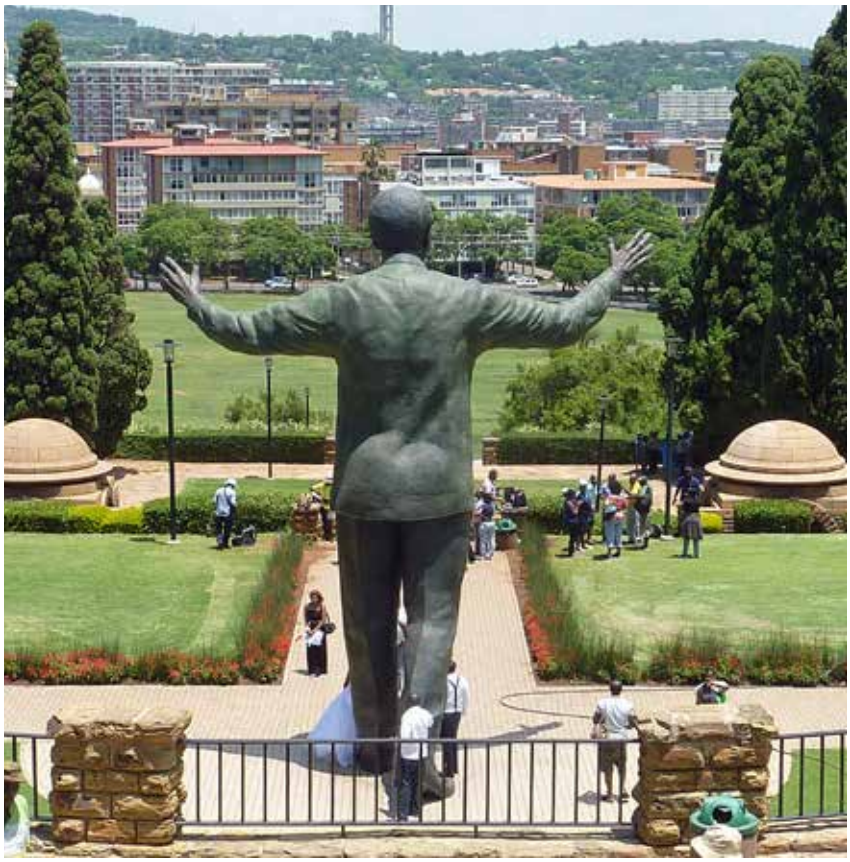
Researchers have addressed the challenges associated with separated and low-density housing by examining critical success factors for medium-density, mixed housing developments that are linked to sustainable settlements in an enabling environment. She explained that one cannot consider housing in isolation from the broader settlement and supporting facilities and amenities.

When considering residential development and transformation, it is critical to understand the dynamic relationships that exist between the practical and symbolic nature of residential dynamics in the physical and the social space. This is especially important where there is a growing need for integrated housing development that can accommodate increased diversity and density.

She explained that the transformation of the South African urban landscape takes place through a process that involves space, need, idea, order, form and function, meaning and response, informed by the specific socio-spatial context. The adaptive capacity or resilience of cities and urban spaces has many dimensions. The spatial resilience of cities and public spaces is informed by four directives at a micro level: diversity, proximity, intensity and connectivity. These directives have been used to compare the spatial resilience of public spaces in the City of Tshwane through both qualitative and quantitative methods, utilising GIS. However, resilience is not only influenced by the form and function of various parts of the city, but by its adaptive capacity over time. This can be understood through the four phases of the adaptive cycle: growth, consolidation, release and reorganisation. Applying the adaptive cycle in settlements could provide planners with a mechanism to understand transformation at various scales, including at street level.

However, the health and wellbeing of our cities and the people living in them do not only depend on the adaptive capacity of settlement systems, but also on their regenerative potential. She therefore highlighted the need to move beyond a simplistic interpretation of spatial transformation, and to break the cycle of mechanistic change. True transformation requires the recognition of all knowledge systems and modes of production through the creation of settlement systems that are capable of producing and supporting mutual benefits between all living systems.

In conclusion, she proposed the notion of evolutionary urbanism, which encompasses radical evolution and planning to allow nature and humans to thrive by harnessing the power of resilience and spatial regeneration.



Honorary doctorates awarded to industry leaders

During the University of Pretoria's autumn graduation ceremony in May 2023, two eminent industry leaders were recognised for their support to the Faculty of Engineering, Built Environment and Information Technology.

Prof Kevin Wall is an extraordinary professor in the Department of Construction Economics and a fellow of the South African Academy of Engineering. He is also the past president of the South African Institution of Civil Engineering (SAICE), and has received both the SAICE gold Medal, the highest honour that the civil engineering profession can bestow in South Africa, and the Lifetime Award of the National Science and Technology Forum, the highest honour that can be bestowed by the science, engineering and technology community in South Africa.

Prof Tarek Khalil is a global academic leader with an outstanding career in the management of technology. He is the founder and President of the International Association for the Management of Technology (IAMOT) in the USA, as well as the founder and past President of the Nile University in Egypt. Over the years, his collaboration with the Graduate School of Technology Management has contributed to the ongoing improvement of its research and educational activities.

GLOBAL LEADER IN THE MANAGEMENT OF TECHNOLOGY CONSIDERS FUTURE EMERGING TRENDS

The Graduate School of Technology Management (GSTM) welcomed honorary doctorate recipient Prof Tarek Khalil to the University's campus on 8 May 2023 to join colleagues and alumni of the GSTM contemplate future trends that will influence teaching and research in the field of Technology Management.

The GSTM's collaboration with Prof Khalil over the years has contributed to the ongoing improvement of its research and educational activities. Its involvement in the activities of the International Association for the Management of Technology (IAMOT) has furthermore enabled the GSTM to develop global networks, which have enhanced the international status of its academic programmes.

During his talk, Prof Khalil considered the past, present and future of the discipline of management of technology. As an academic discipline, Management of Technology started to develop in the 1990s. This was when schools of business and engineering came to the realisation that a different management approach was needed to ensure job creation and economic growth. Since the 1990s, the world has seen rapid technological innovation,

characterised by both the scale and speed of change, a highly competitive market and the creation of trade blocks. This also gave rise to an emerging academic field: management of technology.

When contemplating the future of technology management as an academic discipline, Prof Khalil encouraged delegates to prepare for the future by anticipating the next technological age, which he calls Industry X.0. "Technologies that are already trending include AI applications such as Generative AI and Augmented Reality (AR)."

Prof Khalil predicts that four emerging trends will disrupt the world over the next three to eight years. These are neuromorphic computing, self-supervised learning, the metaverse and human-centred AI. He concluded his talk by reminding delegates that the challenge of management of technology is to manage these emerging technological resources.

Leaders in the Department of Mining Engineering

PROF WEBBER-YOUNGMAN RECEIVES INTERNATIONAL RECOGNITION

Prof Ronny Webber-Youngman, Head of the Department of Mining Engineering, received the Günter Fettweis Award of the international Society of Mining Professors (SOMP) at its annual conference, held in Clausthal, Germany, from 9 to 16 September 2023. This award recognises active members of the society for accomplishments and excellence in education, research and professional service to advance the discipline, and for significant contributions to the society. Prof Webber-Youngman received the award, in particular, for his contributions to mining education, his vision and leadership to promote the activities of SOMP in South Africa and the region, and his commitment and innovations to bridge the path between the academic discipline and mining practice.

The society represents mining academics from all over the world. It is committed to making a significant contribution to the future of the minerals discipline internationally. Its main goal is to guarantee the scientific, technical, academic and professional knowledge needed to ensure a sustainable supply of minerals for mankind. It facilitates information exchange, research and teaching partnerships, as well as other collaborative activities among its members. Prof Webber-Youngman served as its President for the 2013/14 term of office and has been co-opted to its Council until 2025.

INTERNATIONAL APPOINTMENTS FOR MINING ENGINEERING ACADEMICS

Two senior academics in the Department of Mining Engineering have received international recognition for their contribution to the mining industry and the professional community.

Prof Francois Malan, the Department's Research Lead, has been recognised as a Fellow of the International Society for Rock Mechanics (ISRM). This highest and most senior grade of membership of the ISRM is conferred on individuals who have achieved outstanding accomplishments in the field of rock engineering, and who have contributed to the professional community. Prof Malan is also Director of the Department's Mining Resilience Research Centre and Acting Chairholder of the Harmony Gold Chair of Rock Engineering and Numerical Modelling. His key research interests include numerical modelling techniques for the mining industry and the strength of hard rock pillars in the Bushveld Complex.

Jannie Maritz, the Department's Teaching and Learning Lead, has been elected Vice-President for Africa of the International Society for Rock Mechanics and Rock Engineers (ISRM) for the term 2023–2027. He will be representing the three countries in Africa that are associated to the ISRM: South Africa, Tunisia and Zimbabwe. Maritz has been a Council member of the South African National Institute of Rock Engineering since 2011, and is the institute's past president. He spearheads the Future Education portfolio, providing guidance in converting the industry certificate of competence into a formal qualification with international relevance.

Academic Excellence Award for QS lecturer

Danie Hoffman, a senior lecturer in the Department of Construction Economics and leader of the Department's Quantity Surveying (QS) Programme, was nominated for the Pacific Association of Quantity Surveyors (PAQS) Academic Excellence Award by the Association of South African Quantity Surveyors (ASAQS). He received the award at the PAQS Conference in Kuala Lumpur in September 2023.

This award recognises individuals or institutions that excel in the area of academic performance or research and development. The result should have beneficial application in the profession, and should transcend national boundaries. The nomination of the ASAQS was supported by the Green Building council of South Africa (GBCSA) and the Royal Institution of Surveyors Malaysia (RISM). The PAQS is a quantity surveying association of 15 different countries, including Australia, Canada, China, Hong Kong, Indonesia, Japan, Malaysia, Singapore, Sri Lanka and New Zealand, representing 134 000 quantity surveyors.

He was nominated for his work on the costs and trends of green buildings. In 2014, the GBCSA, ASAQS and the University of Pretoria started a combined research study to describe the cost premium of certified green office buildings in South Africa. This study is still ongoing. Three industry publications were published: in 2016, 2019 and 2022.

Hoffman is the academic researcher on this study. His PhD thesis is based on the data from this study. This study has provided the built environment and the GBCSA's members with valuable local data that can inform decision making in a more sustainable direction. It has been incredibly useful, benefitting from academic rigor and industry collaboration.

QS student takes gold

The Association of South African Quantity Surveyors (ASAQS) recognises outstanding academic achievements of quantity surveying (QS) students nationally. The ASAQS gold medal award is presented annually to a student whose academic achievements are of outstanding merit and whose personal qualities promise to positively contribute to the profession.

During the 2022 ASAQS Virtual Presidential Address and Awards Ceremony, the gold medal was awarded to Mckayla McMaster who completed her BSc Quantity Surveying honours degree with distinction at the University of Pretoria in 2021. This milestone achievement is not surprising as McKayla has received no less than 15 top academic awards during her four years of study. McKayla refers to herself as an ambitious quantity surveyor with a great passion for the profession.

Research into sustainable energy solutions receives international support

The development of renewable energy solutions is one of the key elements in the global quest for a sustainable future: for both mankind and the planet. It is also the catalyst that will empower and transform Africa. This is the shared vision of the University of Pretoria (UP) and the Italian Renewable Energy Solutions for Africa Foundation (RES4Africa), which was given added impetus through the signing of a Memorandum of Understanding (MoU) between the two parties on 24 April 2023.

Established in 2012 as a network of utilities, industries, agencies, technical service providers, and research and academic institutions, RES4Africa is focused on promoting clean energy solutions in the southern and eastern Mediterranean countries and in sub-Saharan Africa. Its mission is to support the deployment of renewable energy (both large-scale and distributed energy) and energy-efficiency solutions, as well as their integration into local and regional markets to satisfy energy needs.

The identification of UP as a collaboration partner was prompted by the University's recognition in the subcontinent in terms of the quality, relevance and impact of its research. This includes its focus on energy security. In addition to research on the efficient use of energy, UP concentrates its efforts on optimising alternative sources of energy in keeping with the United Nations' target of achieving a zero-carbon economy by 2050.

The purpose of the MoU is to establish a general framework of cooperation for the parties to engage in mutually beneficial information sharing, consultation, knowledge exchange and network building, and to collaborate on projects, capacity-building initiatives, studies and events of mutual interest on a non-exclusive basis.

The parties will collaborate through joint initiatives on renewable energy and climate change to support sustainable development for resilient economies in Africa. The particular focus will be on capacity building and training, the generation of knowledge products and data, programmes and project implementation initiatives, outreach activities, advocacy and communication for the accelerated uptake of renewable energy in Africa.

The activities associated with UP's research into sustainable energy will be aligned to the research, academic and capacity-building objectives of the Department of Electrical, Electronic and Computer Engineering within the Faculty of Engineering, Built Environment and Information Technology.

Young engineers set to impress with the Freedom Won Range

Traditionally, the University's final-year laboratories and student projects relied on lead acid batteries, until a sponsorship from the LiFePO4 battery manufacturer, Freedom Won, changed the landscape on 17 August 2023. The donation of Freedom Won 12V 100Ah batteries and a LiTE 5/4 model marked the inception of a shift towards a lithium iron phosphate-powered laboratory.

In pursuit of solving real-world challenges, the University's final-year electrical engineering students engage in design projects that transcend theory to become tangible solutions. Prof Johan Hanekom, a professor in the Department of Electrical, Electronic and Computer Engineering, elucidated that among the almost 250 students enrolled for their final-year project module, the new LiFePO4 batteries will be instrumental in energising laboratories and projects.

The transition from lead acid to LiFePO4 is not merely a shift between outdated and modern technology; it is a multifaceted upgrade. Emphasising safety and longevity, LiFeEPO4 batteries surpass lead acid counterparts in both aspects. They are inherently safer in nature, have reduced maintenance requirements, and their extended operational lifespan underscore the meticulous considerations that have gone into this transformation.

Freedom Won believes that by empowering students in the Department of Electrical, Electronic and Computer Engineering, they are inspiring more electrical engineering students to research energy solutions.

"Supporting young engineers allows a better future to start with a sound foundation. With resource constraints, even a talented person cannot go further. By giving back to the engineering community, Freedom Won is committed to being the backbone for these young engineers who will build a better South Africa," says Freedom Won's non-executive director, Prof Alice Chan.

The University's final-year students transition their projects from theoretical constructs to practical systems. For these students, the newfound access to clean energy stands out as a pivotal asset in advancing their respective projects.

This shift to cutting-edge energy technology not only powers devices, but also charges the atmosphere of innovation and progress within the University's educational journey.

Currently, South African businesses and industries rely on off-grid solutions to avoid loss in production during power cuts. However, the country now has the capacity to design the required large inverters.

Introducing robotics to school learners

Students in the Faculty's Community-based Project (JCP) module joined forces with Sifiso EdTech, a South African-based international provider of specialised coding and robotics products, teacher training, technology curricula and services, to present a Robotics Holiday Bootcamp for school learners.

The holiday programme was presented by 14 students enrolled in the Faculty's compulsory service-learning module. The programme took the form of an educational and robotics training camp, hosted at the Future Nation Schools-Fleurhof Campus in Randburg.

The bootcamp programme had a clear vision of introducing robotics to public school students. It had the following objectives:

- Provide students with a comprehensive understanding of robotics, fostering awareness of its potential and applications.
- Offer hands-on experience by allowing learners to interact directly with robotics components, reinforcing their theoretical knowledge.
- Impart the foundational principles of robotics, including the role of coding, and the functions of various parts.
- Encourage creativity and innovation by empowering students to work on unique projects, promoting problem-solving and innovative thinking.
- Raise awareness about information and communication technology, and robotics career paths by involving university students as training assistants.
- Stimulate an interest in science, technology, engineering and mathematics (STEM) education, showcasing its exciting possibilities for future academic and career pursuits.

The collaboration yielded several mutual benefits. It fulfilled UP's commitment to community engagement, providing practical teaching experience for the Faculty's students, while promoting STEM education in the local community. In the process, the JCP students enhanced their teaching, communication and leadership skills, enriching their educational journey.

The bootcamp successfully inspired interest in coding, robotics, and STEM subjects among the learners, aligning it with UP's mission to contribute to a knowledge-based society. Despite its success, however, the project faced a number of challenges. This included adapting to diverse student needs, given varying ages and skill levels, which demanded creativity and teamwork from the JCP students. Teaching complex robotics and coding concepts was made manageable by leveraging the diverse skills of the JCP students. Meticulous logistical management was crucial for organising a bootcamp for a large group of students and teachers. This challenge was overcome through the exceptional organisational skills demonstrated by the JCP students. The collaboration showcased the power of university-community partnerships.

The project not only achieved its objectives, but also had a meaningful impact on the local community by fostering STEM interest among learners. The dedication, adaptability and professionalism of the JCP students were instrumental to the project's success. Their contributions will continue to benefit future bootcamp sessions.

This collaboration exemplifies the University of Pretoria's commitment to community engagement and educational excellence, reinforcing the idea that education is a shared responsibility that can lead to positive change.

The power of human interaction

The mentors who assist students completing the Faculty's Community-based Project (JCP) module are a critical link between the coordinators and the second-year students in the programme. They guide more than 1 600 students by supporting them in navigating their projects with their community partners, which means that they need excellent communication and people skills.

According to Patrick Mbongo, a senior JCP mentor, interactive mentorship development workshops, facilitated in collaboration with Curiosity Campus, train the mentors through a series of meta patterns and basic facilitation skills. These skills include supporting and listening, giving and receiving feedback, asking clarifying questions and learning the responsibility of care.

One of the most meaningful meta patterns is the dynamic of matching and mismatching. This allows mentors to identify a style of communication that builds relationships and contributes to the solution of a project, but which might be disruptive for a relationship. The mentors are given the opportunity to practise their newly developed skills, initially on each other, and later with the JCP students.

Since the mentors are developing the same skills as those that the JCP students start acquiring while completing the module, the guidance towards perfecting those skills is best facilitated through human engagement. The JCP students are essentially prepared to engage with their team-mates and community partners through a combination of online content, and structured and unstructured in-person engagements with their mentors.

JCP mentorship gives individuals a unique opportunity to engage with community projects, while developing and facilitating managerial, organisation and mentorship skills. JCP brings together unlikely coherent elements and combines them to make significant contributions to society.

Mbongo explains that, as mentors, they are part of a system that is much bigger than themselves; a system that provides the opportunity to apply technical and professional skills. This system connects them to younger students, and through them, to multiple community members. Being a part of a system such as this, which enables sustainable human connections on many levels, is humbling and enlightening, and emphasises the power of human interaction.

Recruiting a future generation of leaders in collaboration with industry partners

The Faculty of Engineering, Built Environment and Information Technology has an active recruitment drive in place to attract prospective students who wish to make an impact in the lives of people and the planet, and to innovate our tomorrow. Its recruitment of a new generation of leaders and innovators focuses on immersive learning. This formed an important element of both its annual EBIT Week programme and the #Choose UP Day. A new initiative was the Faculty's involvement in the Aardklop Pronk Podium event, which featured dramatic talent at school level, which brought art and technology together. Eight lucky learners received bursaries to study at the University of Pretoria. Collaboration with the Faculty of Health Sciences at Sasol Techno X led to the Faculty receiving an Innovation Excellence Award (see page 13).

Mourning the passing of a stalwart member of the engineering community

It is with great sadness that the University of Pretoria learnt of the passing of a Dean in the former Faculty of Engineering and former member of the University's executive management, Prof JAG (Jan) Malherbe, on 7 May 2023 at the age of 84. As a distinguished scholar, researcher and innovator, he leaves behind a lasting legacy in his field.

Born in Cape Town in 1940, Prof Malherbe completed his BSc, BEng and PhD degrees at the University of Stellenbosch, followed by a DEng at the University of Pretoria in 1987. After spending a couple of years in industry, he started his academic career at the University of Stellenbosch in 1970. In 1981, he accepted a professorship in the University of Pretoria's Department of Electronic Engineering, and in 1988 was appointed Head of Department. In the following year, he was appointed Dean of the former Faculty of Engineering. He served on the University's executive management from 2000 to 2003, first as Executive Director: Projects and then as Vice-Principal. In this capacity, he developed the University of Pretoria's first Research Strategy. Prof Malherbe was then appointed an institutional professor until his retirement in 2005. He continued to serve as an extraordinary professor in the Department of Electrical, Electronic and Computer Engineering.

Prof Malherbe played an instrumental role as Managing Director and Chairman of the Laboratory for Advanced Engineering (LGI) from 1981 to 1999 and as Director: Industrial Programmes and member of the management team of the Foundation for Research Development (FRD), the precursor of the National Research Foundation (NRF). He founded the University's Electromagnetics Research Group in 1996 as one of the FRD's first centres of excellence. This formed the basis for teaching and research at every South African institution in which notable work is done in this field. It also led to the establishment of the University's Compact Antenna Range in 1990 as the first facility of its kind in the southern hemisphere.

He was the University's representative in the establishment of a strategic alliance between the University of Pretoria and the Council for Scientific and Industrial Research (CSIR), which culminated in the formation of the Southern Education and Research Alliance (SERA) in 2001. He was subsequently Chairman of the Board of SERA (Pty) Ltd. An output of this alliance was the development of the Innovation Hub.

Prof Malherbe earned numerous accolades and honours during his illustrious career, including the prestigious Havenga Prize for Engineering, the Bill Venter Prize and the Third Millennium Medal of the Institute of Electrical and Electronics Engineers (IEEE). He received a University of Pretoria Commemorative Research Medal in 2008 as one of the University's leading minds between 1908 and 2008. In 2008, he also became a life fellow of the IEEE.

His devotion to his students, colleagues and the pursuit of knowledge will long be remembered. His warm presence and keen intellect will be sorely missed by those who had the pleasure of working with him. Staff members and postgraduate students in the Department of Electrical, Electronic and Computer Engineering continued to benefit from his incredible knowledge as an active member of the Department until relatively recently.

LAST WORD

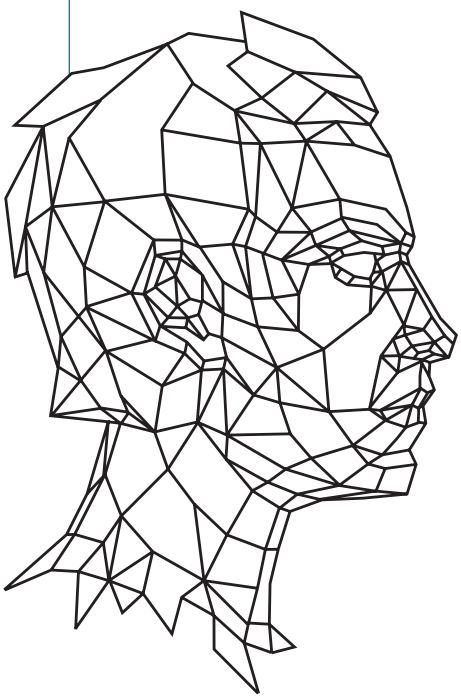
The pioneers of artificial intelligence and machine learning:

Alan Turing and Arthur Samuel

Janine Smit

When Jonathan Swift wrote his satirical novel *Gulliver's Travels* in 1726, the idea of a machine capable of speculative knowledge by practical and mechanical operations was no more than fiction. Yet, this imaginary device, known as "The Engine", which generates permutations of word sets, was indeed an early depiction of artificial intelligence and machine learning.

According to Swift, by using this "contrivance", "the most ignorant person, at a reasonable charge, and with a little bodily labour, may write books in Philosophy, Poetry, Politics, Law, Mathematics and Theology, with the least assistance from genius or study". The field of Artificial Intelligence (AI) has a long and rich history. Two of the early pioneers that have made significant contributions to its development are Alan Turing and Arthur Samuel.



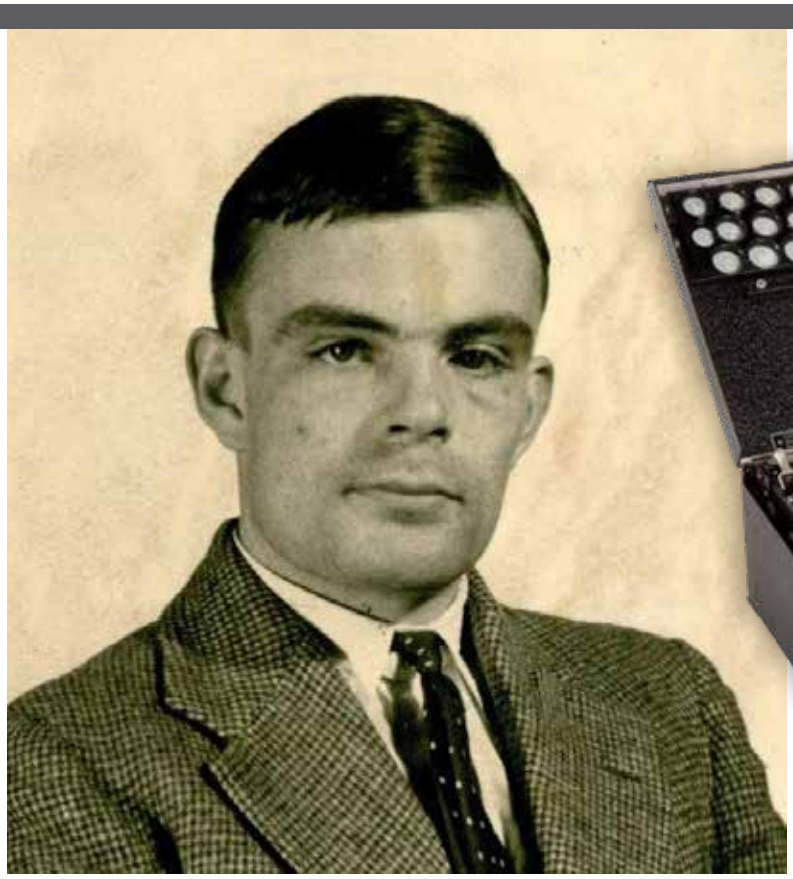
ALAN TURING

The earliest substantial work in the field of AI was performed in the middle of the 20th century by the British mathematician and computer scientist, Alan Turing. He is generally accredited as being the father of computer science and artificial intelligence.

Turing was born in London on 23 June 1912 and passed away in June 1954 at the age of 42. He made major contributions to mathematics, cryptanalysis, logic, philosophy and mathematical biology, as well as to new areas of science later called computer science, cognitive science and artificial intelligence. He studied mathematics at the University of Cambridge, graduating in 1934. He was then elected to a fellowship at King's College in recognition of his research in probability theory.

In 1935, Turing described an abstract computing machine that had a limitless memory and a scanner that moves back and forth through its memory, symbol by symbol, reading what it finds and writing further symbols. In 1936, his seminal paper, "On computable numbers with an application to the decision problem", was recommended for publication by the American mathematical logician, Alonzo Church, who had just published a paper that had reached the same conclusion as Turing's, but via a different method. Turing's method had profound significance for the emerging science of computing. Later that year, he enrolled for a PhD in mathematical logic at Princeton University under the supervision of Church.

Turing gave what can possibly be considered the earliest public lecture in London in 1947 to mention computer intelligence, saying: **"What we want is a machine that can learn from experience,"** and that **"the possibility of letting the machine alter its own instructions provides the mechanism for this."**



THE *ENTSCHEIDUNGS-PROBLEM*

What mathematicians called an "effective" method for solving a problem was simply one that could be carried out by a human mathematical clerk working by rote. In Turing's time, those rote workers were, in fact, called "computers", and human computers carried out some aspects of the work later done by electronic computers. Turing's *Entscheidungsproblem* (decision problem) sought an effective method for solving the fundamental mathematical problem of determining exactly which mathematical statements are provable with a given formal mathematical system and which are not.

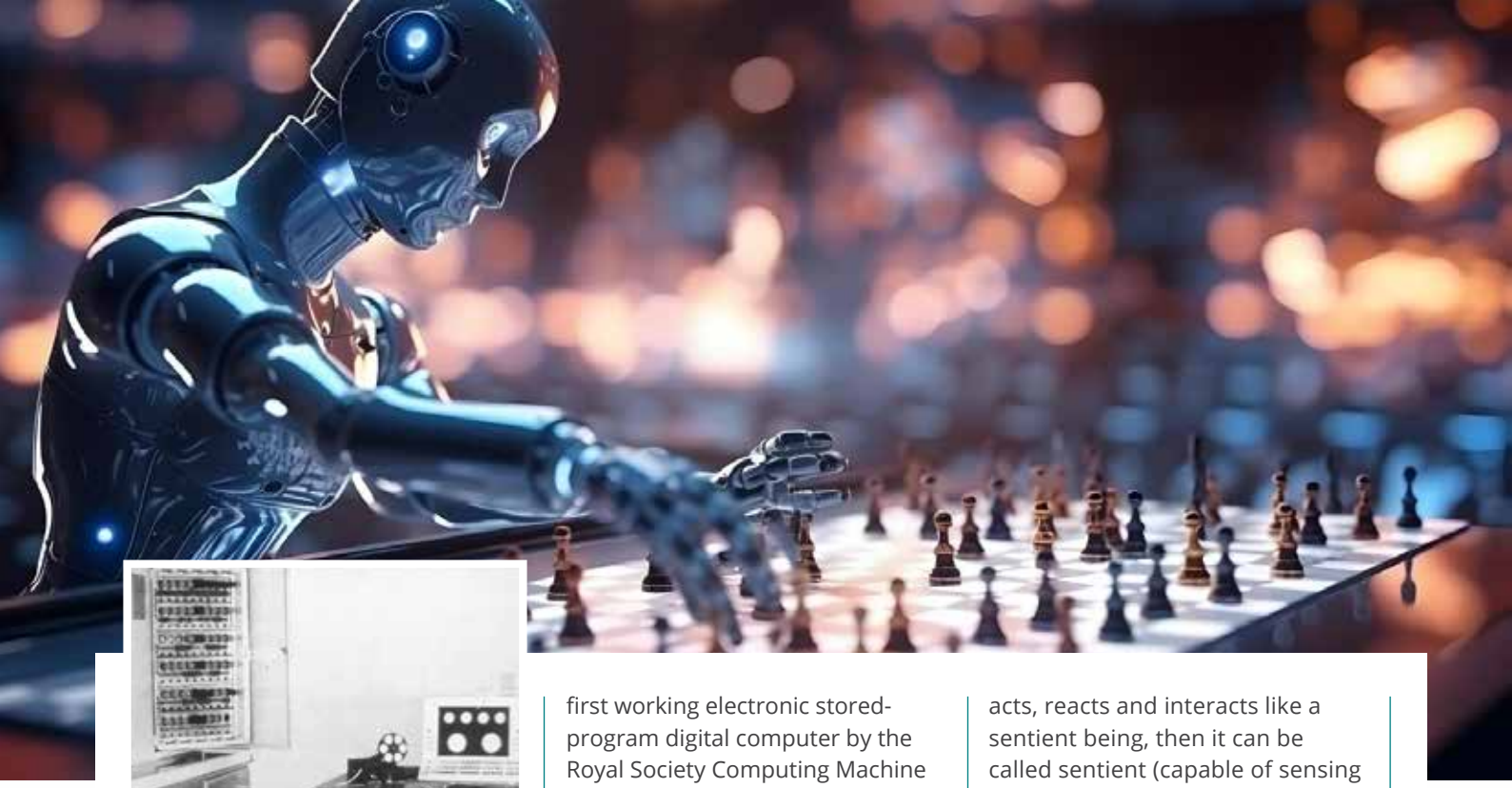
During the course of his work on the *Entscheidungsproblem*, Turing invented the universal Turing machine, an abstract computing machine that encapsulates the fundamental logical principles of the digital computer. He claimed that it could compute everything that is humanly computable. His concept of the Turing machine subsequently laid the foundation for the development of modern computers and AI.

BREAKING THE ENIGMA CODE

Upon completion of his doctoral studies, Turing returned to King's College in 1938. He then joined the Government Code and Cypher School. With the outbreak of World War II in 1939, he moved to the organisation's wartime headquarters in Buckinghamshire. The Polish government had just given Britain and France details of the Polish successes against Enigma, the German coding device used to encode strategic military messages in radio communications.

As early as 1932, a small team of Polish mathematician-cryptanalysts, led by Marian Rejewski, had succeeded in deducing the internal wiring of Enigma. By 1938, Rejewski's team had devised a code-breaking machine they called the *Bomba*. This machine depended on German operating procedures for its success. A change in those procedures in May 1940 rendered the machine useless. In late 1939 and early 1940, Turing and others designed a related, but very different code-breaking machine known as the *Bombe*. For the remainder of the war, this machine supplied the Allies with large amounts of military intelligence.

By 1942, the British cryptanalysts were decoding about 39 000 intercepted messages a month. This figure rose to more than 84 000 messages a month – two messages a minute day and night. Turing also devised the first systematic method for breaking methods encrypted by the sophisticated German cipher machine that the British called the *Tunny*. At the end of the war, Turing received the award of an Officer of the Most Excellent Order of the British Empire (OBE) for his code-breaking work.



THE DIGITAL COMPUTER

Following the war, the National Physical Laboratory (NPL) in London recruited Turing in 1945 to create an electronic computer. His design for the automatic computing engine (ACE) was the first complete specification of an electronic stored-program-all-purpose digital computer. Had his ACE been built as he had planned, it would have had vastly more memory than any of the other early computers, and would also have been faster. However, his colleagues at NPL considered the engineering too difficult to attempt, and a much smaller machine was built in 1950, the Pilot Model ACE.

Discouraged by the delays at NPL, Turing took up the deputy directorship of the Computing Machine Laboratory in 1948. His earlier theoretical concept of a universal Turing machine had been a fundamental influence on the development of the world's first working electronic stored-program digital computer by the Royal Society Computing Machine Laboratory at the University of Manchester. After Turing's arrival in Manchester, his main contributions to the computer's development were to design an input-output system and its programming system. He also wrote the first-ever programming manual, and his programming system was used in the Ferranti Mark I, the first marketable electronic digital computer, in 1951.

PIONEERING AI

Turing was a founding father of AI and of modern cognitive science. He was a leading early exponent of the hypothesis that the human brain is, to a large extent, a digital computing machine. He theorised that, at birth, the cortex of the brain is an "unorganised machine" that, through "training", becomes organised "into a universal machine". He proposed what subsequently became known as the Turing test as a criterion for whether an artificial computer is thinking. The advent of ChatGPT late in 2022 reignited the conversation about the likelihood that the components of the Turing test had been met.

His test set out to determine if a computer can think. His argument was that if a computer acts, reacts and interacts like a sentient being, then it can be called sentient (capable of sensing or feeling). To avoid the prejudicial rejection of evidence of machine intelligence, he suggested an "imitation game". A remote human interrogator must, within a fixed time frame, be able to distinguish between a computer and a human subject based on their replies to various questions posed by the interrogator. By means of a series of such tests, a computer's success at "thinking" can be measured by its probability of being misidentified as the human subject.

During his time at the Government Code and Cypher School, Turing illustrated his ideas on machine learning by reference to the game of chess. He considered this a useful source of challenging and clearly defined problems against which proposed methods of problem solving could be tested. In principle, a chess-playing computer could play by searching exhaustively through all the available moves, but in practice, this was impossible as it would involve examining an astronomically large number of moves.

Although Turing experimented with designing chess programs, he had to content himself with theory in the absence of a computer that was able to run his chess program.

ARTHUR SAMUEL

The first AI program to run in the USA was not a chess program, but a program that could play another popular board game, checkers. One of the first programs that could play checkers at a competitive level and improve itself through learning was written in 1952 by Arthur Samuel, an American computer scientist. Samuel is considered a pioneer in the development of self-learning systems. He coined the term **"machine learning"**.

Samuel's program is considered a milestone in the journey of the development of AI. His ambition was to program a computer "so that it will learn to play a better game of checkers than can be played by the person who wrote the program." His inclusion of mechanisms for both rote learning and generalisation led to the program winning a game against a former Connecticut checkers champion in 1962.

Samuel was born in Kansas, USA, on 5 December 1901 and passed away in July 1990 at the age of 89. He received a master's degree in electrical engineering from the Massachusetts Institute of Technology (MIT) in 1926. In 1928, he joined Bell Laboratories, where he worked mostly on vacuum tubes, including improvements of radar during World War II. After the war, he moved to the University of Illinois at Urbana-Champaign, where he initiated the Illinois automatic computer (ILLIAC) project, a series of supercomputers built at various locations. In 1949, he went to IBM in New York, where he would conceive and carry out his most successful work.

Here he developed the first checkers program on IBM's first commercial computer, the IBM 701. The program was a sensational demonstration of the advances in both hardware and skilled programming, and caused IBM's stock to increase 15 points overnight. His pioneering non-numerical programming helped shape the instruction set of processors, as he was one of the first people to work with computers on projects other than computation.

Images: Wikkimedia Commons and IBM

His checkers program was also notable for being one of the first efforts at evolutionary computing. It "evolved" by pitting a modified copy against the current best version of his program, with the winner becoming the new standard. Evolutionary computing typically involves the use of some automatic method of generating and evaluating successive "generations" of a program, until a highly proficient solution evolves.

These concepts have given rise to many of the developments in artificial intelligence and machine learning that we know today, from the first industrial robot, Unimate, which started working on an assembly line in a General Motors plant in New Jersey in 1961 to the Generative AI chatbot application, ChatGPT, that was developed by OpenAI in 2022.

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Images

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