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Innovation news

Low-cost tensiometer

AI reinforced concrete

Performance-based guidelines for wind turbine foundation design

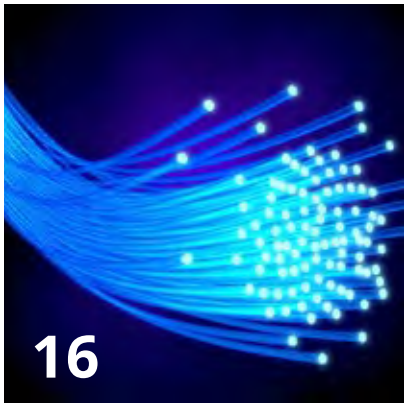
SA Hydropower Atlas

Fibre optic leak detection on water pipelines

Faculty of Engineering, Built Environment and Information Technology

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

Content



Editorial
4IR – it's all about integration 1

Message from the Dean
Innovating our tomorrow 2

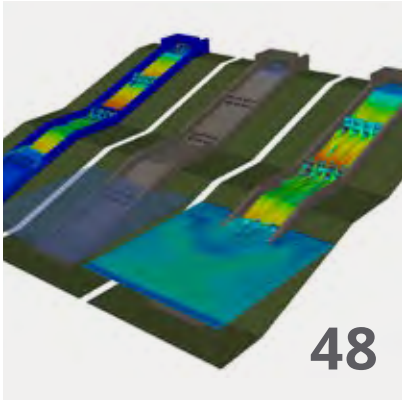
Note from the Vice-Chancellor and Principal
South African economy requires 4IR research-intensive boost 4

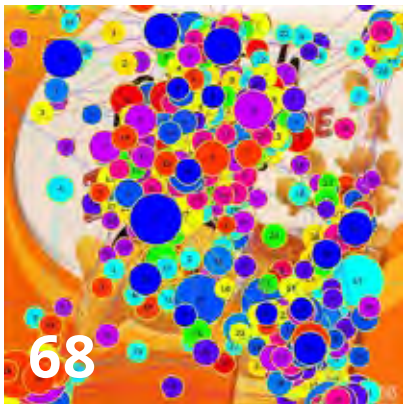
INNOVATION FOCUS

Developing a low-cost tensiometer 6
AI reinforced concrete: Algorithms predict concrete strength without training on experimental data 8
Wind Africa develops performance-based guidelines for wind turbine foundation design 11
Developing a hydropower atlas for South Africa 14
Fibre optic leak detection on water pipelines 16
Innovative designs provide the homeless with a form of urban domesticity 20

RESEARCH FOCUS

Advancing the SDGs in South Africa through 4IR 24
The role of information ethics in the 4IR 28
Condition monitoring on the digital railway 32
What is the hype about disruptive technologies? 35
Investigating the potential of bicycle-sharing on campus 38
E-topia, Utopia or Dystopia? A critical reflection on the smart city dream 42
Bibliometrics reveals trends in climate change research between Africa and Europe 46
Using CFD modelling as a tool for small-scale hydropower development 48
Modelling cave mining in the geotechnical centrifuge 51
Determining safe clearance distances during mine blasting operations 54
Assembled and re-assembled public spaces in South Africa 56
Spatial Revolution 4.0: A vehicle towards the realisation of spatial justice in contemporary African cities 58
How does consumer personality and architecture affect the retail trade? 61
Building a data science competency model for organisations 65
Evaluating the effectiveness of knowledge visualisation using eye tracking 68





TEACHING AND LEARNING FOCUS

Teaching and the Fourth Industrial Revolution 70
They are here: What Generation Z is trying to tell us 72
Turning teaching philosophies into learning experiences 73
Developing social responsibility skills for the future workplace 74
Using virtual reality applications in the Civil Engineering laboratory 78
Educating and leading mining engineers to become imagineers 79
Virtual reality provides an “explosive” teaching experience 82
Graphical communication intervention project prepares students for success 84
ClickUP Goals tool measures alignment with programme outcomes 86
Developing work-ready graduates 89
GSTM empowers students with project management skills 90
Creating a yearning for learning: initiatives for increasing student engagement 92

FACULTY NEWS

Celebrating the Faculty’s exceptional achievers 96
International young researcher award for EBIT hydropower researcher 100
Exceptional female scientist 100
Chinese Government Friendship Award 101
IEOM Society International Fellowship 101
Data science student wins international professional award 101
EBIT researchers honoured in NSTF-South32 Awards 102
Top industry awards for Mining Engineering researchers 103
EBIT researchers launch award-winning professional title 104
New partnership between UP and the CBE 104
Collaboration in car manufacturing and transport industries 105
Engineering 4.0 is set to take transportation into the future 106
Making world-class knowledge accessible to local researchers 107
2020 WEEF & GEDC Conference 108
Artificial Intelligence Student Society takes shape 109
EBIT students fly UP flag high 110
TuksBaja is victorious 110
Robot Race Day helps students drive the Fourth Industrial Revolution (4IR) 111
Celebrating World Book Day with a book launch 111

LAST WORD

The roots of computer engineering 112

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Innovation in 4IR integration

Future-thinking through excellence in cross-disciplinary research

4IR – it's all about integration

The amount of time and money invested in Fourth Industrial Revolution (4IR)-related activities by industries and governments around the world continues to grow, obviously because of the impact these investments already have and will continue to have on our economies and societies in future.

In the editorial of the previous issue of *Innovate*, I raised the much talked-about topic of unemployment as a major impact of 4IR. While policy makers are developing proposals on how the impacts of 4IR should be dealt with, both private and public organisations are planning and implementing numerous new 4IR systems to achieve their organisational goals and remain competitive and relevant. An interesting question is, of course, how successful the many implementation projects are.

Examples of seemingly successful 4IR system implementations are increasing. In recent months, the global banking industry announced the closure of many of its branches, mainly due to a lack of customers who are now enabled by new technologies to do their banking through the internet instead of visiting a branch. Retailers are developing new marketing strategies in the wake of fierce competition from companies doing their business online, accelerating the development of logistics systems for the distribution and delivery of their products.

In some industries, the picture looks a bit different. I recently listened to a speaker at a conference reporting that the success rate of 4IR implementations in, for example, the mining industry is quite low. In other engineering-related industries, the feedback on the success rate of 4IR implementation also varies from good to bad.

It seems that service-orientated organisations are having more success than engineering-oriented organisations with their 4IR implementation projects. This conclusion sounds fair to me, but it is the task of researchers to investigate the factors that contribute to the success of 4IR projects.

It is well known that 4IR systems are characterised by complex technological structures. Since the initiation of the first 4IR projects in Germany, engineers have realised that they need a better understanding of these complex systems. Researchers and consultants proposed different 4IR system architectures to assist system planners and implementers with their tasks. The RAMI 4.0 architecture was developed for the manufacturing industry in Germany, for example, and clearly illustrated the complexity of these systems.

The architecture defined the build-up of a 4IR system, from its physical asset layers, through the digitisation

layers to the decision-making layers of businesses. Except for being an excellent guideline to practitioners, the architecture also highlighted the numerous interfaces between the different technology platforms and system layers that needed to be managed. If this sounds a bit confusing, believe me, it is! It is all about the complexities of integrating different technological systems.

For the successful implementation of systems, engineers, IT specialists and business decision makers will need a good basic understanding of the constitution of completely integrated 4IR systems and their operation. The research agendas of the departments in the Faculty of Engineering, Built Environment and Information Technology (EBIT) cover many of the themes and topics in the 4IR spectrum that are required to understand complex 4IR systems. This ensures that the University of Pretoria's research outputs strongly support the needs of industry.

I hope you enjoy the selection of contributions to this issue of *Innovate*.

Editor
Prof Tinus Pretorius

Message from the Dean

Prof Sunil Maharaj

The University of Pretoria (UP) is committed to future-focused research and innovation in its efforts to propel the country into embracing the Fourth Industrial Revolution (4IR). In order to do this, its initiatives must address the 4IR skills challenge. The Faculty of Engineering, Built Environment and Information Technology (EBIT) is ideally positioned as a catalyst for the University's 4IR drive.

EBIT
Innovating our tomorrow

Over the past two years, the Faculty has dedicated its research, teaching and learning efforts to embracing the 4IR. This has been particularly effective, considering its dedication to cross-disciplinary projects and interventions aimed at consolidating the knowledge and skills required to thrive in this exciting new world.

The current challenges faced by both industry and society require researchers to break away from working in discipline-specific silos, and cross academic boundaries to approach challenges from different perspectives. The Faculty is home to a unique combination of academic disciplines. This encourages the incorporation of multiple approaches to research problems, and allows for vivid cross-disciplinary work.

The Faculty is organised into four schools:

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

These schools host 14 vibrant academic departments, each of which is supported by high-quality academic and support staff.

The Faculty offers 23 undergraduate degree programmes that are locally relevant and internationally competitive. Where available and applicable, the programmes are accredited by statutory and professional bodies at national and international level. The undergraduate programmes are structured in such a way as to ensure that the Faculty delivers work-ready graduates who are able to overcome future challenges.

The Faculty also hosts 141 postgraduate study programmes across honours, master's and doctoral levels. In this regard, its research strategy encourages researchers to look at the larger challenges faced by both industry and society, and engage in cross-disciplinary research efforts to devise meaningful solutions. The overarching goal is to deliver results that will have an impact locally, regionally and across the globe, aligned to the Sustainable Development Goals (SDGs).

Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology.

The work of 30 cutting-edge research chairs and entities contributes to the Faculty's research programme.

Through its teaching, learning and research activities, EBIT enjoys high global rankings. According to the 2019 QS rankings of universities worldwide, the University of Pretoria is ranked in the Top 450 universities globally for engineering and technology. In 2019, it appeared in the QS World University Rankings by Subject for computer science and information systems, electrical and electronic engineering, and mechanical, aeronautical and manufacturing engineering, all of which are presented in EBIT's academic departments. In addition, the Faculty contributed to the University's Top 100 position in the Academic Ranking of World Universities (ARWU) subject rankings for mining and mineral engineering. The November 2018 Clarivate Analytics Essential Science Indicators for citations puts UP Engineering in the top 1% in the world and as the highest in South Africa.

In order to ensure that the Faculty remains relevant, it maintains close ties with industry partners.

EBIT has dedicated its research, teaching and learning efforts to embracing the 4IR, contributing to the sustainability of industry and working towards the improvement of society.

This facilitates opportunities for collaboration, which is essential to the Faculty's efforts to enhance the relevance of its academic and research programmes. Such collaboration enables students to acquire scarce and highly specialised skills, and researchers to focus on relevant problems.

In the ever-changing world brought about by the 4IR, the ability to remain competitive is essential for survival. Universities, through their teaching, learning and research, function as drivers of competitiveness. EBIT remains eager to embrace this mandate in order to contribute to the sustainability of industry and the improvement of society in South Africa and the world.

Prof Maharaj is pictured at the Rand Merchant Bank (RMB) THINK Bench on UP's Hatfield Campus. This 10-ton concrete bench is a contemporary functional piece designed to celebrate and encourage innovative and collaborative thinking. It was designed by artist Louis Olivier and his team from the Workhorse Bronze Foundry. The bench spells out the word "THINK" from one side, while another perspective reveals life-sized human silhouettes in different thinking poses. It acts as a reminder to students passing by that sometimes one needs to change one's perspective to think differently. This notion is echoed in EBIT's renewed commitment to innovative, cross-disciplinary work.

South African economy requires 4IR research-intensive boost

Prof Tawana Kupe, Vice-Chancellor and Principal: University of Pretoria

In the context of the Fourth Industrial Revolution (4IR), universities worldwide are expected to be central actors of scientific, social and technological change in the drive for innovation and economic growth. It is against this background that countries are enhancing their international competitiveness by strengthening their research-intensive universities. The strategy varies from allocating additional research resources to universities to creating centres of excellence.

> **The University's 4IR initiatives are stimulating the convergence of its research and expertise from a range of disciplines to co-create new understandings and breakthroughs to transform society for the better.**
>
> *– Prof Tawana Kupe*

In South Africa, there needs to be far more commitment and policy certainty regarding the research mandate of our universities in national development. It is important for the state to properly support research, and this should be extended beyond our handful of research-intensive universities, as no university can excel in all domains. Universities that are not considered research-intensive overall, but have proven strengths in particular research niches, also need to be given research support to enable them to excel.

It is indeed not a choice, because if a 4IR-targeted research boost is not forthcoming, neither will future-focused programmes. This, in turn, will mean that increasing numbers

of students are inappropriately educated for the 4IR – compounded by the massification imperative in our universities – resulting in the country being faced with a growing graduate population that cannot find work.

The same applies throughout Africa. Peter Darvas, a senior economist in the Education Global Practice of the World Bank, reported in 2017 that enrolments in tertiary education in sub-Saharan Africa had grown from 400 000 in 1970 to about 7.2 million in 2013. This growth has been accompanied by diversification of institutional types, especially the proliferation of private universities. However, while private universities have begun to venture into science programmes, most of them mainly specialise in business and management programmes. This has resulted in expanded growth that is not adequately addressing the 4IR skills challenge.

Transdisciplinary research between science, technology, engineering and mathematics (STEM) subjects and the humanities is critical for navigating the 4IR. This is manifested by the STEAM movement at universities globally (which refers to science, technology, engineering, the arts and mathematics). Its intention is to match the growing demand for arts and humanities skills in STEM fields with the advent of disruptive technologies such as 3D printing and robotics.

Based on this, Prof Joseph Aoun, President of Northeastern University in Boston, USA, in his 2017 book, *Robot-proof: higher education in the age of artificial intelligence,* lays out the framework for a new discipline and research field – humanics – which prepares students to compete in a labour market in which smart machines work alongside human professionals. He identifies the following three graduate literacies as vital for navigating the 4IR: data literacy, technological literacy and human literacy.

Students require data literacy to make sense of big data and information flowing from devices; technological

Students need to prepare to compete in a labour market in which smart machines work alongside human professionals. Data literacy, technological literacy and human literacy will become crucial to their ability to thrive in the 4IR.

literacy to know how their machines work and to navigate disruptive technologies; and human literacy, explored through the humanities, to know how to function optimally as human beings. With the automation of work, artificial intelligence (AI) experts have observed that it is that which makes us human – our emotional intelligence and creativity – that is in demand in the transition to automation. As Aoun writes: "As machines continue to surpass their old boundaries, human beings must continue to hone their mental capacities, skills and technological knowledge."

In response, universities worldwide are establishing 4IR-focused institutes and campuses with inter- and transdisciplinary academic and research programmes. The Massachusetts Institute of Technology (MIT) is planning a new US$1 billion Quest for Intelligence college of computing, which will combine AI, machine learning and data science, and bring together researchers from cognitive science, neuroscience and computer science.

As one of South Africa's research-intensive universities, the University of Pretoria launched the Future Africa Campus in March 2019 as a hub for national and international transdisciplinary research networks to maximise 4IR innovation and address the "wicked challenges" our continent and world are facing. The University also launched Engineering 4.0 through the Faculty of Engineering, Built Environment and Information Technology as a hub not only for smart cities and transportation, but also to link its vast resources in technology and data sciences to other faculties via the Future Africa Campus. These initiatives are stimulating the convergence of research and expertise – from agriculture to AI, autonomous vehicles, big data, cloud computing, logistics modelling, synthetic biology and bioprospecting, to name a few.

The main driver of the 4IR lies in the fusion of knowledge for economic advancement and, equally, social justice. Research expertise from a range of disciplines is required to co-create new understandings and breakthroughs to transform society for the better. The foundation of this is a university community that is sustainable, well resourced, at the leading edge of research and future oriented.

That which makes us human is in demand in the transition to automation.

Acknowledgements

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Developing a low-cost tensiometer

Prof SW Jacobsz

In South Africa and other arid parts of the world, soils occur in an unsaturated state. This means that the pore spaces between the solid soil grains are filled with both air and water. Soil is therefore a three-phase material, comprising solid, liquid and gas phases. The phenomenon of surface tension affects the interface between pore air and pore water between the soil grains, resulting in negative water pressure in the pore water. This negative water pressure draws soil grains together, increasing the normal stress between soil grains. It therefore also significantly affects soil strength.

In the field of soil mechanics, the magnitude of negative pore pressure is an important parameter that needs to be measured. Negative pore water pressure is also important in agriculture because, as soil dries out, the negative pressures increase so that it becomes increasingly more difficult for plants to extract water from the soil, resulting in the plants wilting.

The magnitude of negative pore water pressure can vary from zero in the case of saturated soils to many mega-Pascal, and is dependent on the grain size distribution of the soil. Because of the tendency of water to cavitate under negative pressure once the pore pressure reduces below absolute zero, it is difficult to measure it directly. A number of techniques are available to measure pressure indirectly, often by measuring the water absorption of filter paper, ceramics, gypsum blocks or other porous media placed in contact with the soil sample for some time, or by measuring the relative humidity of the air in a confined space around the soil sample of interest. Although these methods are well established in practice, they suffer from low resolution, i.e. a lack of sensitivity to register small changes in pore pressure. This problem can be circumvented by directly measuring the negative pore pressure using tensiometers.

Tensiometers are pore pressure sensors (piezometers) that measure negative water pressure. High-capacity tensiometers are sensors that can measure negative pore pressure below absolute zero. To allow the sensors to register large negative pressures, the pressure sensor element is covered by a ceramic filter of very low permeability (referred to as a high-air entry ceramic). For best performance, it is important for the space between the sensor and the ceramic filter to be as small as possible. Before the tensiometer can be used, the sensor must be saturated with high-quality de-aired water. The capacity of the sensor is limited by the air entry value of the ceramic used for the filter.

High-capacity tensiometers are not readily available on the market and can generally only be found at universities and research institutions, some of which will sell them for many hundreds of US dollars or even more. The high cost of these sensors is hampering research in the field of unsaturated soil mechanics. Unsaturated soil mechanics is an important field of work in South Africa as virtually all our soils are unsaturated. It is also very important to the tailings industry. The stability of tailings dams in the mining industry is currently under scrutiny internationally because of the number of very large tailings dam failures that occurred in Brazil and Canada, resulting in the loss of many human lives. During deposition cycles on tailings dams, it is important that tailings must be allowed to dry out to generate sufficiently large pore water suction to increase the strength of the tailings placed.

A low-cost, high-capacity tensiometer has recently been developed in the Department of Civil Engineering at the University of Pretoria.

These sensors make use of the MS54XX series of sensors from Measurement Specialties™. These miniature pressure sensors are available with full-scale ranges of 1 bar, 7 bar, 12 bar and 70 bar. The MS54XX sensors, shown in Figure 1, are typically used to measure altitude and atmospheric pressure in the industrial, medical, automotive and consumer electronics industries. Typical applications include barometers, diving watches and electronic scales. The sensors have a high output, allowing pore pressure measurements of excellent resolution. They are powered by a direct current excitation voltage up to a maximum of 20 V. The active sensing element is housed in a metal ring of anticorrosive alloy and is covered in silicone gel to protect against humidity and water, while still allowing the sensor to register hydrostatic pressure, which can be seen in Figure 1A.

The low-cost tensiometer is created by gluing a ceramic filter of the desired air entry value to the metal ring surrounding the sensing element (see Figure 1B). Power and sensing wires are soldered to the sensor and the assembly is inserted into a specially machined stainless steel surround (see Figure 1C), which is filled with a special structural epoxy with low water absorption characteristics. This is important for long-term sensor performance. The sensors are then saturated by subjecting them to a vacuum in a pressure cell. High-quality de-aired water is then allowed to fill the cell, after which the cell pressure is returned to atmospheric pressure. The tensiometer is then allowed to equilibrate to the cell pressure. Depending on the air entry value of the ceramic disc used, this could take from a few minutes to in excess of 24 hours (for 15 bar ceramics). Once the tensiometer has equilibrated to the cell pressure, the cell pressure is raised to in excess of the air entry value of the ceramic filter. The filter is then left for 24 hours at high pressure to fully saturate.

The performance of the tensiometer can be illustrated by allowing the saturated tensiometer to dry out in air, while monitoring the

The Department of Civil Engineering has developed a low-cost, high-capacity tensiometer to allow for pore pressure measurements of excellent resolution.

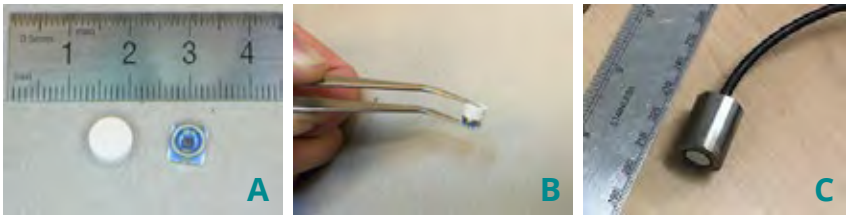


Figure 1A: Ceramic filter and pressure sensor; 1B: Filter-sensor assembly; and 1C: The completed tensiometer.

pore pressure response. As water evaporates from the ceramic filter, water menisci are drawn into the small pore spaces of the filter, creating increasing suction in the small space between the ceramic and the sensor element. The suction increases until the air entry of the ceramic or cavitation of the water in the sensor occurs. The performance of such a tensiometer is illustrated in Figure 2, which shows suction measurements over time as the sensors are slowly dried out in silty sand. A maximum suction of 1 700 kPa was measured before cavitation of the tensiometer occurred. This suction value can be compared to the capacity of tensiometers typically used in agriculture, which have traditionally been able to measure to approximately -100 kPa (at sea level).

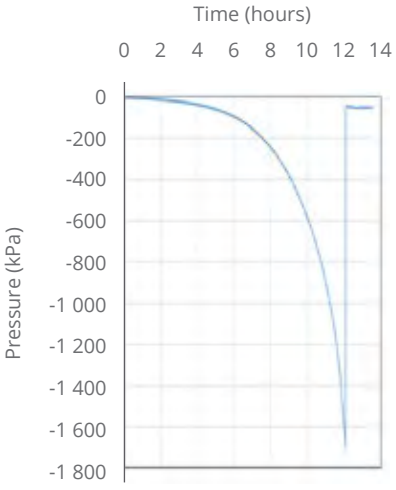


Figure 2: The performance of a high-capacity, low-cost tensiometer during a dry-out test, measuring to a negative pressure of 1 700 kPa before cavitation occurred.

The tensiometers are manufactured at a cost of approximately R300 each. This cost can be compared to tensiometers available from overseas research institutions that sell for as much as R18 000 each. The low cost means that many of these sensors can be made and used for laboratory research and field monitoring applications. A number of tensiometers have been installed in an active gold tailings dam since April 2019, providing new insight into the pore pressures associated with tailings deposition cycles and tailings dam operations. The sensors are also used in the Department of Civil Engineering to measure the soil water retention curves of a variety of soils. Apart from applications in geotechnical engineering, there is significant scope to use the low-cost tensiometer in agriculture to measure suction pressure around plants to a high resolution; research that could have implications in terms of food security. The development of the low-cost tensiometer is an example of how ingenuity can overcome cost constraints in a developing country such as South Africa.

AI reinforced concrete: Algorithms predict concrete strength without training on experimental data

George Markou and Nikolaos P. Bakas

Artificial intelligence (AI) and machine learning (ML) algorithms are involved in a vast variety of scientific and industrial projects, contributing to the solution of emerging problems, from data modelling and analysis to automatic literature reviews, face recognition and self-driving cars. In recent years, researchers and professionals have been engaging with AI algorithms in an unusually wide range of scientific, technological and business fields. Regardless of the database, their basic purpose is to construct a prediction algorithm that will be accomplished by a mathematical model describing the complex interactions among some input variables and a corresponding response (Dimopoulos, Tyralis, Bakas and Hadjimitsis, 2018).

A new research project has been initiated between the Civil Engineering departments at the University of Pretoria and Neapolis University in Cyprus with the main objective of developing design formulae for the prediction of the maximum capacity of reinforced concrete structural members through the use of software-generated data that will be used to train machine learning algorithms. This innovative approach aims to replace the actual physical experiment with 3D detailed state-of-the-art finite element modelling that will be used to generate millions of results for different types of reinforced concrete structural members, assuming different concrete and rebar material properties, while various geometries and reinforcement configurations will be considered. The artificially generated data will then be used to develop predictive models and construct new design formulae, in closed mathematical form, for the needs of modern reinforced concrete structural design methodologies. The research project also foresees a validation phase to verify the ability of the developed numerical models to capture physically derived experimental data found in the international literature.

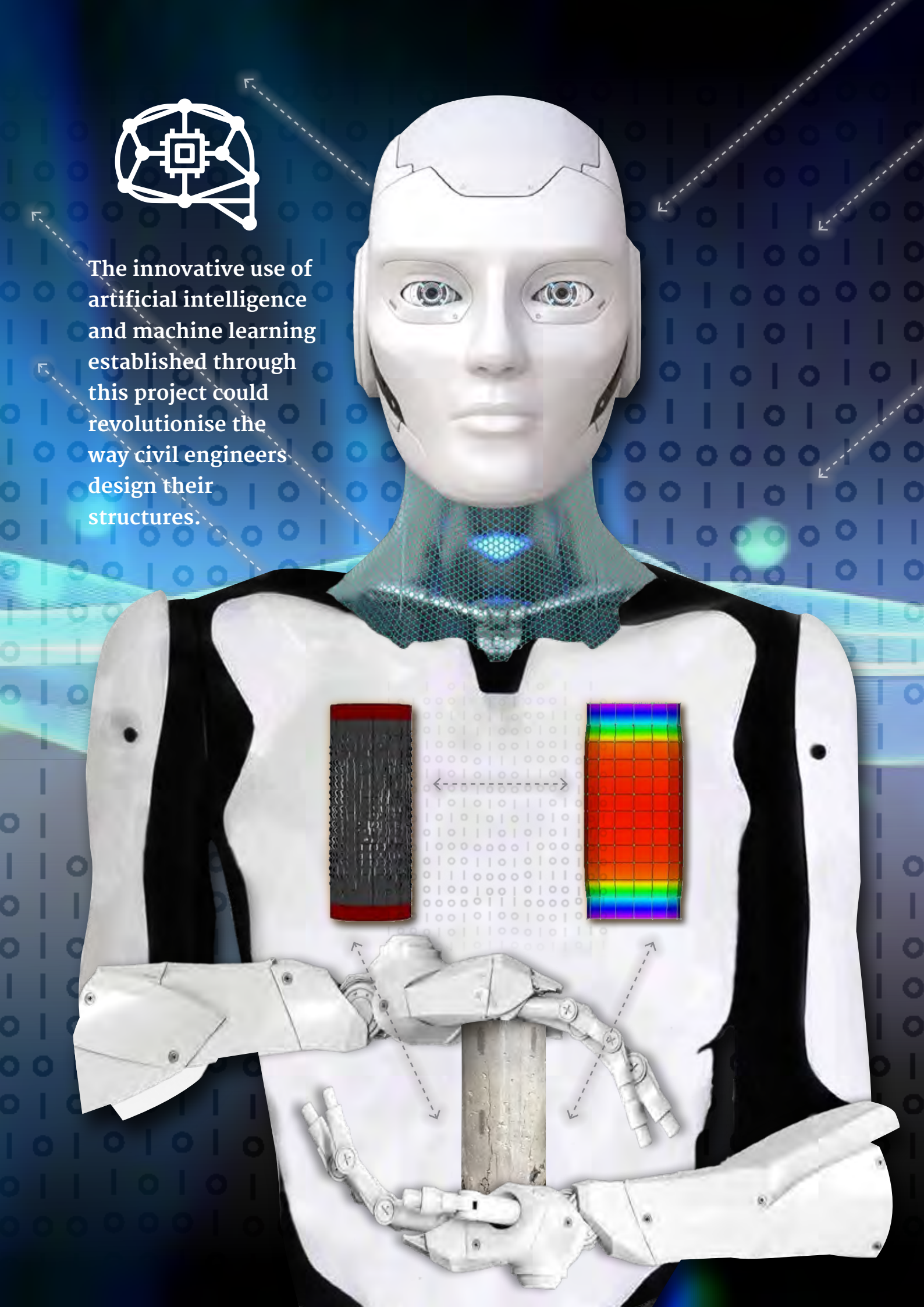
The relationship between independent and dependent variables is often highly non-linear, and mathematical models are aiming to form a generalised relationship that will be able to objectively link them. The mathematical models' success depends on the formulation and the underlying theory, the algorithmic application, the handling of the prediction errors, as well as the generalisation of the results.

The final aim is to develop a numerical model, capable of predicting new outputs for new, out-of-sample inputs, which may be within the given domain (interpolation), or even outside the domain (extrapolation). Predicting out of the limits of a given domain is a hard and highly unstable problem without interesting results. However, recently, a numerical solution with extended prediction horizons was published (Bakas, 2019). This significant breakthrough is one of the main reasons why the current research project is now feasible through its provision of new mathematical tools and insights for predictions.

Major advancements in the 3D detailed modelling of reinforced concrete structures have been published in the last decade, and more recent work managed to present numerical solutions that are able to capture the mechanical behaviour of full-scale reinforced concrete structures under extreme cyclic loading conditions. Through a recent breakthrough, the ability to capture the static cyclic and dynamic non-linear mechanical behaviour of reinforced concrete structures is now feasible. The proposed algorithm, integrated within Reconan FEA, was excessively validated through the use of experimental results found in the international literature. These experiments foresaw the study of reinforced concrete beams with and without stirrups, shear walls under monotonic and cyclic loading conditions, piles embedded in soil and the investigation of full-scale reinforced concrete structures that undergo cyclic static and non-linear dynamic ultimate limited state loading.

The proposed modelling approach foresees the use of the isoparametric hexahedral element for discretising the concrete domain, while the

The innovative use of artificial intelligence and machine learning established through this project could revolutionise the way civil engineers design their structures.



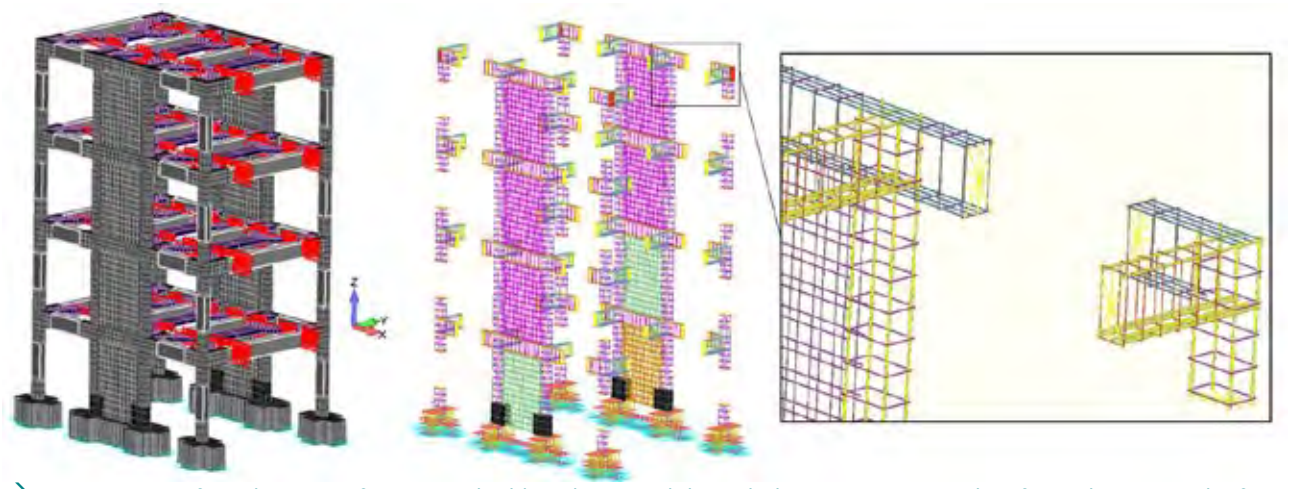


Figure 1: Reinforced concrete four-storey building discretised through the HYMOD approach. A finite element mesh of concrete and rebars.

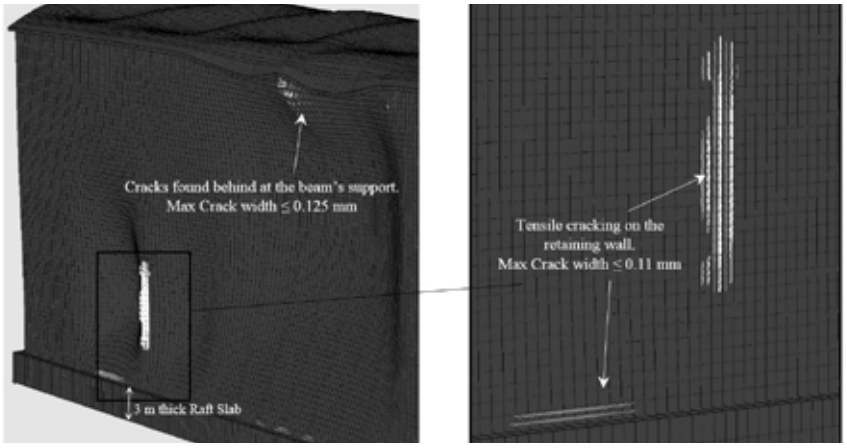


Figure 2: Nuclear reactor building. Crack patterns and deformed shape due to the serviceability load combination that foresees soil pressure.

reinforcement is modelled as embedded rebar rods or beam elements within the hexahedral mesh. This is shown in Figure 1. The microcracking is also accounted for during the non-linear analysis, whereas macrocracking is modelled through the smeared crack approach. Furthermore, the approach has the ability to numerically handle the opening and closing of cracks for both monotonic and cyclic conditions, where the deterioration of the concrete and steel materials is also accounted for through the newly introduced material damage factors. These factors are directly connected to the number of opening and closing cracks during the non-linear loading time history.

Figure 2 shows the predicted crack patterns of a NuScale reactor building that comprised around 181 000 hexahedral elements and more than 2.7 million embedded rebars. This nuclear reactor building had a 2 260 m^2 plan view area and a total height of 40 m. Given the numerical superiority of the developed algorithm, Reconan FEA is computationally efficient in handling large-scale numerical problems. It is thus currently the software that has managed to solve the largest model found in the international literature in terms of the number of embedded rebars.

This project aimed to utilise the ability of Reconan FEA to generate a massive data set that will be fed to the state-of-the-art AI algorithms in order to train models that will be able to predict the maximum capacity of reinforced concrete structural members. The construction of new design formulae will also be performed based on the scheduled research activities of this research work by using advanced ML codes. This will set the base of revolutionising the way that civil engineers design their structures.

For the needs of this research project, Reconan Multirun was also recently developed and is currently utilised to generate hundreds of thousands of finite element models that will be used to analyse reinforced concrete beams without stirrups through the use of Reconan FEA. This first data set generation phase will be followed by the construction of beam models with stirrups. Thereafter, reinforced concrete structural columns and shear walls will be analysed in line with the framework of the research project.

Upon successful completion of this first critical step, a second stage will follow that will foresee an ultimate objective in the development of an AI software that will be able to non-linearly analyse reinforced concrete structures, among other tasks, under static and dynamic ultimate limited state loading conditions for seismic assessment requirements and the development of fragility curves.

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Wind Africa develops performance-based guidelines for wind turbine foundation design

Prof SW Jacobsz

Large parts of Africa, such as the Sudan, are underlain by deep expansive soils. Many parts of Africa also have the potential for the generation of wind energy. Wind turbines are tall structures, up to 90 m in height, and are subjected to very large, imposed moments and forces from wind loading.

Wind turbines require sturdy foundations as they have very strict tolerances in terms of acceptable movements of their support structures. In areas that are underlain by expansive soils, seasonal weather cycle fluctuations result in water ingress into the foundations. In expansive soils, this results in volume changes, resulting in foundation movements. Upon drying out during the following dry season, volume contraction occurs. These volume changes result in foundation movements, which may be detrimental to the long-term performance of the wind turbine. Wind turbine foundations must therefore be designed to resist these seasonal foundation movements.

The University of Pretoria's Department of Civil Engineering, working with collaborators at Durham University and the University of Cambridge in the United Kingdom and the University of Khartoum in Sudan, is conducting research on the development of performance-based guidelines for the design of wind turbine foundations on expansive soils. The work carried out by UP includes the physical modelling of wind turbine foundations using the University's geotechnical centrifuge. This work complements a series of field tests, comprising the construction and load testing of large-scale trial foundations, which will also be carried out in South Africa.

Durham University is responsible for the development of numerical code and modelling that can be used as a design tool in the design of the wind turbine foundations, while the University of Cambridge is carrying out laboratory testing to characterise the soil properties required for design. The project is funded by the Engineering and Physical Sciences Research Council (EPSRC) of the United Kingdom and includes allowances for equipment, regular coordination meetings and knowledge dissemination such as conference attendance.

Seasonal weather cycle fluctuations result in water ingress into the wind turbine foundations, resulting in foundation movements that may be detrimental to the long-term performance of the wind turbine. The foundations must therefore be designed to resist these seasonal foundation movements.

The Department of Civil Engineering is conducting research on the development of performance-based guidelines for the design of wind turbine foundations on expansive soils. The work includes the physical modelling of wind turbine foundations using the University's geotechnical centrifuge, which complements a series of field tests comprising the construction and load testing of large-scale trial foundations.

Due to the large loads that wind turbines need to withstand, piled foundations are typically required to support wind turbines on expansive soils. A number of different piled foundation types are available, but the foundations investigated for this project are bored piles. Bored piles are constructed by drilling a deep hole in the ground to the required foundation depth, inserting a steel reinforcement cage and filling the hole with concrete.

The foundations need to extend to a significant depth below the zone of soil, which is affected by seasonal moisture fluctuations. The foundations of a typical wind turbine comprise about 10 to 12 piles installed in a ring. A heavily reinforced concrete slab, referred to as the pile cap, is constructed over the piles, which support the wind turbine mast.

The research to be carried out as part of this project comprises the installation of a number of bored piles in an expansive clay profile in the field. These piles will be subjected to cyclic horizontal loading to study the changes in pile behaviour as the number of load cycles on them increase. A number of tests will be carried out under the *in situ* moisture content on site, while on a second test site, the pile behaviour will be studied where the ground around the piles has been allowed to swell by introducing water through infiltration wells. The uplift behaviour against the pile shafts caused by the swelling clay will also be studied by anchoring two piles at depth and using instrumentation to measure the mobilised loads as the soil around them expands. The piles will be instrumented with an array of conventional and fibre optic strain measurement systems, many of which will be tested in South Africa for the first time.

Although much benefit can be realised by testing large-scale piles in the field, the research will be specific to the soil profile in which the piles have been installed. In order to expand the general applicability of the research work, the field testing will be complemented by physical modelling that involves the testing of small-scale models of piled foundation. This work is currently underway in the Department of Civil Engineering.

Model piled foundations, constructed at a scale of 1:30, are being tested using the University's 150 g-ton geotechnical centrifuge. Because of the soil's non-linear stress-strain behaviour, it is necessary to test the models at the same stresses as those acting in the field. This required the models to be accelerated to 30 g, or 30 times earth's gravity. The University's geotechnical centrifuge is capable of accelerating a model weighing up to 1 ton to 150 g, from there the 150 g-ton rating referred to above.

The first challenge that had to be overcome to allow the effect of expansive clays on foundations to be studied was to devise a means by which a significant amount of swell can be obtained in a short space of time. Due to the extremely low permeability of typical expansive clays in the field, water ingress that will cause swell can take many months.

Tests of such a long duration are not feasible in the geotechnical centrifuge. In the field, seasonal water ingress into expansive clays occurs along fissures, with minimal water ingress into the clay body itself. For the model tests, it was therefore necessary to create artificial fissuring to facilitate water ingress to allow the clay to swell. This was achieved by breaking down the structure of intact lumps of clay by means of grating (using actual cheese graters) and then recompressing the clay to the bulk density in the field. This allowed a substantial amount of swell to mobilise in only a few hours, which, for the first time, allowed the influence of significant clay expansion to be tested on foundations in centrifuge model studies. Figure 1 shows broken-down (grated) clay ready to be compressed into slabs for the centrifuge modelling. In Figure 2, compacted clay slabs can be seen stacked in the assembly of a centrifuge model.

After the clay slabs have been stacked to form a model soil profile, holes are drilled into the clay using a miniature hand auger for the construction of the model piles. A range of model piles was developed for the project, starting with instrumented aluminium tubes. These were strain-gauged to allow the distribution of bending moments along the length of the piles to be measured as they are subjected to horizontal cyclic loading.

Pile loading actuators were developed in-house in the Department of Civil Engineering using off-the-shelf linear actuators by FSX. These were converted into load-controlled or displacement-controlled actuators by referencing load cells fitted to the system or a built-in displacement transducer in the actuator respectively. The control system comprised an Arduino micro-processor programmed by the students working on the project.

→ *Figure 1: Broken-down (grated) clay before being recompressed into slabs.*

→ *Figure 2: Clay slab formed by compressing clay gratings to impose artificial fissuring to allow rapid swelling in the assembly of the centrifuge model. The slabs are instrumented with moisture content and suction probes.*

In order to demonstrate repeatability between tests, it was necessary to characterise the clay profile in each test. This was done by using a miniature cone penetrometer, specifically developed for the project, which was driven into the clay during each test, while accurately measuring the penetration resistance against depth.

It was soon realised that there are significant limitations to using aluminium piles as a substitute for reinforced concrete. It was important that this aspect of behaviour should be modelled. Miniature reinforced concrete piles were therefore developed, incorporating instrumentation to allow the bending moment distribution on these piles to be measured.

An important aspect to be addressed in the research project was the question of whether expansion of the clay soil results in an increase in the pull-out resistance of the piles. As clay swells, it is likely that the contact stress against the pile shaft will increase. However, it can also be argued that, as the clay swells, a significant amount of softening can occur, which may lead to a reduction in the pull-out capacity. It is suspected that this behaviour depends on confinement around the pile shaft that is provided by depth below ground level. A sophisticated model pile, fitted with lateral stress cells that are capable of measuring normal stress against the pile shaft, was developed and is currently being tested to shed new light on our understanding of pile behaviour in expansive clays.

The Wind Africa Project is making a major contribution to raise the standard of geotechnical research carried out by the University of Pretoria's Geotechncial Research Group. Not only is it providing significant investment in terms of equipment for the Geotechnical Centrifuge Laboratory, but it is also exposing the University's team to interaction with established research groups and Cambridge and Durham universities. The research interaction, travel opportunities and interaction stemming from this work are assisting to attract future researchers to carry out high-quality research on a problem that is relevant to the development of renewable energy resources in Africa.

Acknowledgements

The University of Pretoria's Wind Africa research team is led by Prof SW Jacobsz, who is assisted by postdoctoral researcher, Dr Gerrit Smit, who is responsible for the centrifuge modelling, and Dr Talia da Silva-Burke, who is responsible for the fieldwork phase of the project. Tiago Gaspar, a PhD student, is working on selected aspects of pile behaviour in expansive clays in the centrifuge. He is assisted by Hendrik Louw, a master's degree student working on the development of the concrete model piles. They are both advised by Prof Elsabé Kearsley. In terms of hardware and software development, the team is assisted by several technicians in the Faculty of Engineering, Built Environment and Information Technology and PhD student, André Broekman. The project is led from Durham University by Dr Ashraf Osman, assisted by postdoctoral researcher, Dr Tim Charlton. The Cambridge team is led by Dr Mohammed El Shaffie and Dr Giovanna Biscontin, assisted by postdoctoral researcher, Dr Khalid Al-Haj.

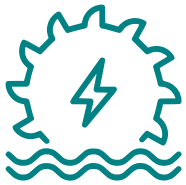
Developing a hydropower atlas for South Africa

Marco van Dijk, Anja Bekker and Christine Brown

Hydropower has various advantages, including the fact that water, as a source of energy, is continuously available. Such advantages make this type of renewable energy a very attractive alternative to fossil fuels. It is understandable why hydropower should be considered the "low-hanging fruit" of renewable energies, and why its development should be encouraged all over the world.

The development of hydropower plants in South Africa is restricted, due to a lack of and limited access to data and knowledge of where this potential is located in existing water infrastructure and rivers. The development of the South African Hydropower Atlas (SAHA), funded by the Water Research Commission (WRC), aims to provide a geographic information system (GIS)-based platform where the data required for the evaluation of hydropower can be shared freely.

The development of the atlas also aims to provide an indication of the hydropower potential available from different types of water infrastructure and rivers in South Africa. This will enable owners of water infrastructure and other structures alongside rivers in South Africa to realise their potential for hydropower development. This will not only encourage owners to consider the development of hydropower, but will also encourage them to collect the necessary data for the further assessment of potential sites, and build up a database of all rivers and water infrastructure in South Africa.



The hydropower atlas will enable owners of water infrastructure and structures alongside rivers to realise the potential for hydropower development.

Criteria development for the hydropower atlas

The evaluation of hydropower potential requires the available head and flow to be known, with the exception of the hydrokinetic type of hydropower where the velocity in the river or channel is the primary driving factor. The restricted access to the available water infrastructure and river data limits hydropower development as the parameters necessary to evaluate hydropower potential cannot be quantified. An evaluation framework and criteria were therefore developed for the different hydropower types to allow an estimate of the hydropower potential to be calculated based on the data available.

The primary aim of developing the evaluation framework and criteria is to include as many water infrastructure sites and rivers as possible in the hydropower evaluation process for the SAHA, even that infrastructure and those rivers with very limited data. The following steps were required to develop such a framework and criteria:

1. All data sources with accessible data for water infrastructure and rivers in South Africa were identified. Even though some of these data sources are either not very reliable or of limited extent, the data will be used in the final evaluation process to estimate the total potential hydropower in South Africa. The potential provided in the atlas for most sites will be a first-order estimate to encourage further investigation into hydropower feasibility and provide more accurate data in the process.
2. Case studies on existing hydropower atlases across the world were identified, such as

in Madagascar, Tanzania and Norway, specifically focusing on the frameworks and evaluation criteria used to develop these atlases. Many of these atlases focused primarily on run-of-river hydropower, and generally provided little to no information on the evaluation frameworks and criteria used in the development of the atlases.

3. Initial frameworks and criteria were developed based on several assumptions and knowledge of existing hydropower atlases. These evaluation frameworks provided information on the source of the water infrastructure and river data, and the handling of the data (outliers, minimum record length, etc.). The process of obtaining the relevant parameters to allow for hydropower evaluation, including the assumptions that should be made if there is limited data available, as well as the minimum potential power output of a site, is included in the atlas.
4. The assumptions made during the development of the evaluation frameworks and criteria were validated using data of existing hydropower installations in South Africa. This step was necessary to ensure that the estimation of the hydropower potential is realistic and representative.

Proposed layout of the hydropower atlas

The web-based GIS hydropower atlas was developed in the Department of Civil Engineering, in collaboration with the Department of Geography, Geoinformatics and Geomorphology. The atlas's proposed layout was developed using ArcGIS Online, created by Esri. This platform allows a web-based GIS map to be created where users can view, print and share information, measure distances and areas, and click on features for pop-up attribute information.

The base layer of the web-based atlas is the imagery hybrid layer, which is accessed from the ArcGIS Online base map collection. This layer consists of satellite imagery, as well as orientational features, such as roads and place names. Additional layers that can be toggled on and off by the user include the following:

→ *Proposed layout of the web-based atlas.*

- Esri's OpenStreetMap
- Municipal boundaries layers
- Eskom's electricity transmission lines and substations
- Dam and river layers from the South African National Space Agency (SANSA)
- A layer of existing hydropower installations in South Africa

The final web-based atlas aims to provide the following information:

- All existing and decommissioned hydropower sites, as obtained from Hydro4Africa (Klunne, 2012): this includes the name of the site, province in which it is situated, river (if applicable), coordinates, owner, hydropower type, power output, and flow and head for each site.
- The locations of all potential hydropower sites identified during the evaluation process: this includes the name of the site, province in which it is situated, river (if applicable), coordinates, hydropower type, potential power output, and flow and head for each potential site.
- Links to other relevant studies of specific sites, including pictures and reports.
- Links to tools to assist developers with further detailed analysis.
- A feedback page where users can provide feedback and make their own contributions to the atlas.

Although South Africa is a water-scarce country, it has numerous river systems, more than 4 500 dams, thousands of weirs, an irrigation network of more than 6 500 km of canals, hundreds of water and waste water treatment works and hundreds of thousands of kilometres of water supply and distribution networks, with numerous pressure-reducing locations. Most of these are untapped resources.

Acknowledgements

This research was made possible with the financial support of the Water Research Commission, whose support is acknowledged with gratitude. In addition, this research will assist the Department of Water and Sanitation, which gazetted a General Notice: Draft Policy on Sustainable Hydropower Generation.

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Fibre optic leak detection on water pipelines

Prof SW Jacobsz

It is estimated that approximately 26% of the potable water distributed by the City of Tshwane is lost due to leakages from the ageing distribution system. This amounts to approximately 75 million m³ lost per annum in the capital city. In towns like Grahamstown, which has older infrastructure, the percentage loss is substantially greater. In a water-scarce country with a growing population and growing urbanisation, such losses can barely be afforded. A similar situation is prevalent in practically all arid countries around the world.

Perhaps the most significant problem with water lost from the distribution system is that the presence and location of leaks are not easily detected before a very large volume of water has been lost. Remedial action is therefore normally only taken very late. Many water leaks do also not appear at the surface, resulting in detection difficulties and considerable water losses.

In the last approximately 20 years, fibre optic instrumentation has been developed to measure temperature and strain with an unprecedented resolution that exceeds that of conventional instrumentation. It is possible to take continuous strain and/or temperature readings along the length of a conventional communication-grade fibre optic cable extending up to 50 km or, by creating imperfections referred to as fibre Bragg gratings (FBGs) at known locations along the length of a fibre optic cable, strain can be measured at up to 20 discrete locations at a high sampling rate. A major advantage of such systems is that fibre optic cables are cheap and completely inert in that they are not affected by the electrical disturbances from which electric monitoring systems typically suffer.

The Department of Civil Engineering at the University of Pretoria has been investigating the use of fibre optic cables as a means of leak detection in pipelines through a research project funded by the Water Research Commission (WRC). At the time of devising the leak detection concept for this study, it was hypothesised that a leak could be detected by registering sudden changes in temperature, usually associated with colder water leaking from the pipe into the ground. Several such systems are implemented on oil and gas pipelines around the world, but there seems to be reluctance to adopt this technology in the water industry.

As part of the project, a short length of pipeline was installed on the University's Hillcrest Campus. The pipeline was equipped with three artificial leak points that could be opened from the ground surface to induce a water leak. The installation is shown schematically in Figure 1. Approximately half of the length of a fibre optic cable, equipped with 16 FBGs, spaced 1 m apart, was attached to the pipe using a structural adhesive. The fibre optic cable was doubled back and the other half was located in the corner of the pipe trench before the trench was backfilled with soil. The FBGs were located in such a manner that for every FBG attached to the pipe, there was another one immediately opposite it, located in the ground in the corner of the pipe trench.

In addition to the fibre optic cable, thermal sensors were installed around each of the leak locations to measure temperature changes in the vicinity of each of the leak locations. When connected to the appropriate readout unit, each FBG reflects light with a wave length that is sensitive to changes in both temperature and strain. These wave lengths can be measured at an extremely high resolution of a few picometre, which allows strain and temperature to be resolved at a very high resolution.

If a leak detection system based on temperature measurement is to succeed, it is important that the leak-induced temperature change must be distinguishable from normal daily and seasonal temperature fluctuations. A number of thermal sensors were therefore installed in the ground at 0.25 m depth increments to 3 m to measure changes in ground temperature with depth over the two-year study period.

Water temperatures were also recorded in a water distribution pipe.

The reason for recording these temperature readings was to assess whether a significant temperature differential exists between the water in the distribution network and the surrounding ground. Figure 2 shows temperature records from the ground and the water distribution pipe over several months, showing that the water temperature was consistently approximately 2 °C lower than the ground temperature. This demonstrates the potential success of a leak detection system based on temperature detection. After the experimental installation had been completed and monitored for a number of months, the first leak test was carried out by opening one of the leak valves and monitoring the influence on the FBGs and thermal sensors. Unexpectedly, upon leak initiation, the thermal response first showed a slight temperature increase, followed by the expected reduction in temperature as cold water entered the soil.

The initial temperature increase was not anticipated. A literature search revealed that this was due to the release of surface energy from the soil grains upon wetting. Wetting soil with water, if it occurs spontaneously, is an exothermic reaction that occurs as the solid-air interface is replaced by a solid-liquid interface.

Given the large specific surface area of a small volume of soil, wetting releases a measurable amount of energy, causing a slight temperature increase. The leak-induced temperature increase and subsequent temperature reduction measured by four FBG sensors are demonstrated in Figure 3. The start and end of the leak test is clearly evident from the temperature record.

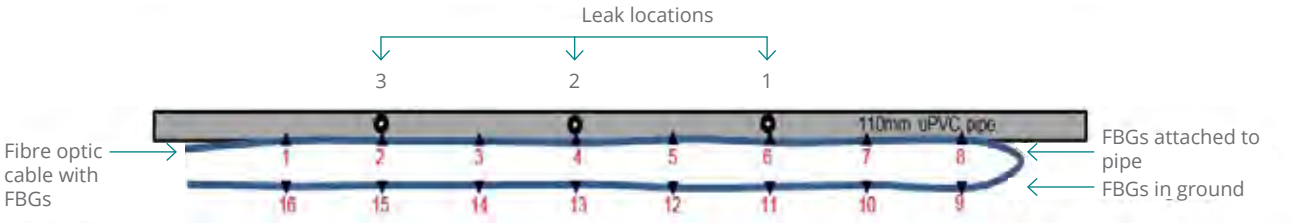


Figure 1: Schematic of the pipe installation.

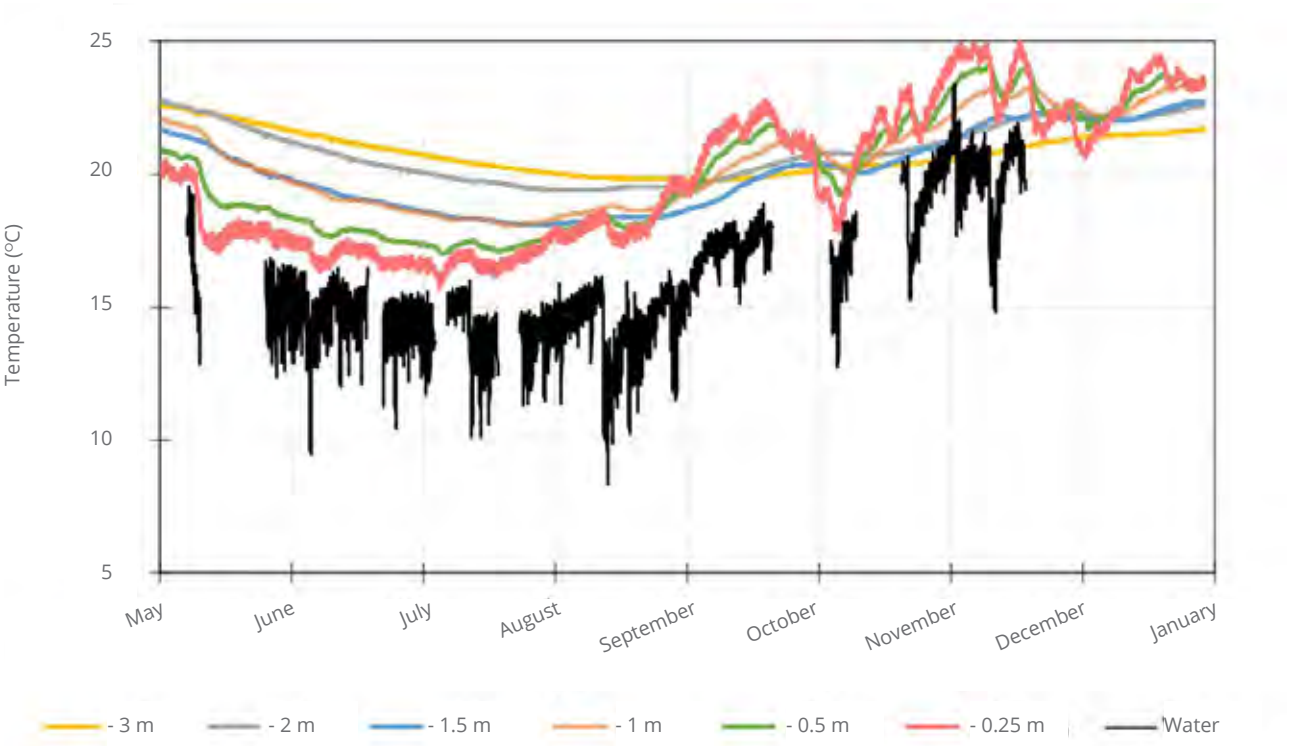


Figure 2: Temperature records measured at various depths over several months, also showing in-pipe water temperature.

When examining wavelength records measured by the FBGs during the leak tests, it was found that the changes in wave length were much higher than could be expected if only thermal effects played a role. A water leak results in the softening of the soil, causing settlement and bending of the pipe. The FBGs attached to the pipe were very sensitive to leakage-induced bending strains thus induced. The problem with measuring leakage-induced strains in the pipe wall is that strain changes also occur due to daily pressure fluctuations in a pipe network. These changes occur throughout the day due to continuous changes in water supply and demand patterns in most water networks, and result in difficulties in distinguishing leakage-induced strain changes.

Interestingly, the FBGs not attached to the pipe, which were simply

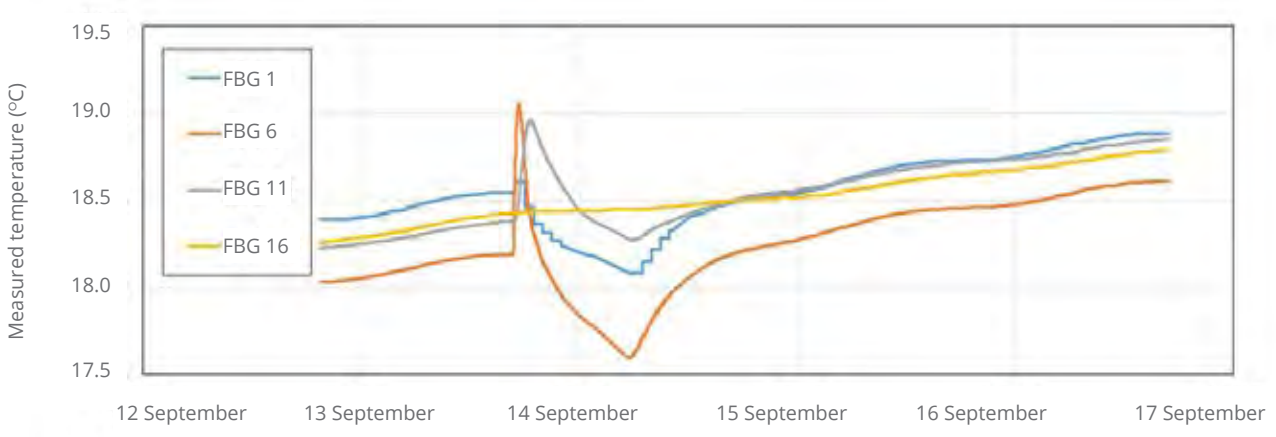


Figure 3: Temperature record from four sensors during a leak test. The rising trend reflects the seasonal temperature variation associated with warming conditions during spring.

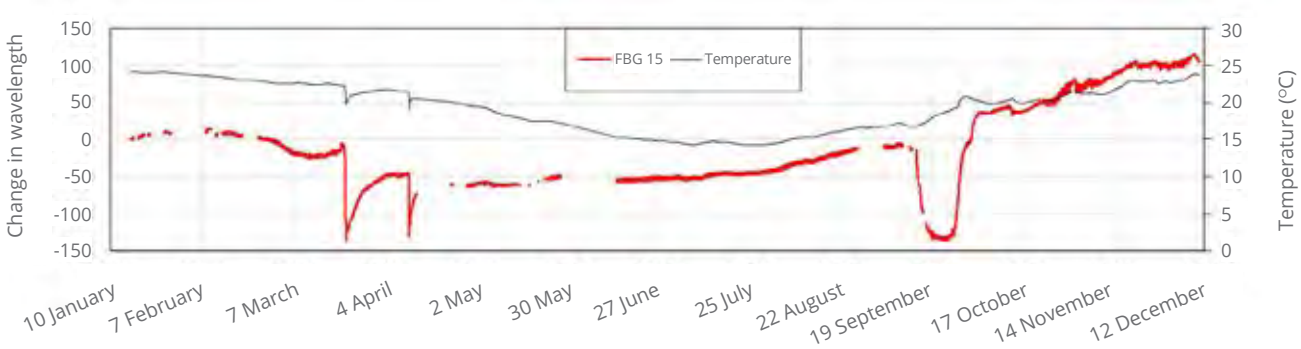


Figure 4: The FBG and thermal records over the course of a year, showing their respective responses to water infiltration events.

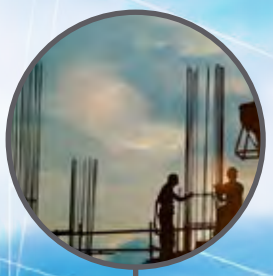
buried in the pipe trench, also showed substantial leakage-induced wavelength changes. As they were not joined to the pipe, they were not affected by pressure fluctuations in the pipe. Why then did they respond to water leaks? When water migrates through partially saturated soil, capillary action that results predominantly from surface tension effects induces large negative pressures in the pore water, referred to as matric suctions. These large matric suctions result in effective stress changes in the soil, which, in turn, result in ground deformation or strains. A fibre optic cable buried in the ground will also be subjected to these deformations, resulting in strain changes in the cable. When FBG sensors are present on the fibre optic cable, strain changes can be measured at a very high resolution, possibly inducing a water leak.

Figure 4 shows FBG wave length changes measured during the course of 2018 by a particular FBG sensor in the ground (not attached to the pipe), as well as the temperature variation measured over the same period (on the secondary axis). It can be seen that the record varies smoothly with three exceptions. The deviations in March and April were the result of heavy rainfall events; events of first wetting of the material in the pipe trench after construction. The September deviation was the result of an artificially induced leak test. It is clear that the output on the FBG wavelength record (the red curve in the figure) is much greater and easier to detect than the effect on ground temperature (the black curve). This illustrates the potential application of fibre optic monitoring as a means of leak detection.

There are leak detection systems currently available on the market that make use of temperature detection. As mentioned, applications are typically found in the oil and gas industry. A literature and patent search have not produced evidence of any systems making use of ground strain measurements as a means of leak detection. The University has therefore filed a provisional patent application to patent this means of leak detection.

When implemented in practice, the observed wavelength record will need to be interpreted against the rainfall record so that false alarms resulting from rainfall events can be identified. Because only a limited number of FBGs can be measured in a single optic fibre, an alternative technique (already available in the form of a continuous fibre optic strain measurement) will have to be used.

This will allow many kilometres of fibre optic cable and long lengths of pipeline to be monitored. By installing fibre optic cables with new pipes and linking these to a centrally located readout unit, a regional leakage detection centre can be set up. A significant advantage of the proposed leakage detection system is that it provides for a passive means of leak detection. It will therefore not be necessary to appoint a contractor to search for leaks through active leak detection.



Innovation focus on civil engineering

We are on the path of a technological revolution that is radically shaping our world. Here, at the threshold of the Fourth Industrial Revolution, the focus should be on the amalgamation of existing and new technologies to solve real-world problems. The Department of Civil Engineering at the University of Pretoria is embracing the opportunity to provide relevant solutions to some of South Africa's most pressing civil engineering concerns. These include transportation development, structural development and hydropower, among others.

The Department's innovative contributions to sustainability through its projects related to soils, renewable energy and reinforced concrete reveal a commitment to embracing the Fourth Industrial Revolution, while bridging the country's inequality gap. In this regard, its research can provide the country with better-performing infrastructure and contribute to more responsible environmental impacts.

– Prof Wynand Steyn, Head of Department: Civil Engineering, University of Pretoria

Innovative designs provide the homeless with a form of urban domesticity

Nadia Ghillino and Anika van Aswegen

Street homelessness is a social problem that is part of the fibre of the urban landscape. Ever since the institution of the South African Constitution in 1996, which granted all citizens the right to access adequate housing, no legislation or official policy has been developed to address homelessness. While there are policies to eradicate homelessness, there are none that support the wellbeing of the homeless.

"[The] street homeless are the proverbial skeletons at the feast, the excluded poorest who enter unobserved and stand by gaunt and starved. Terrifying to the invited guests, but deprived of any capacity to join the party."
Cross et al., 2010.

Inspired by a desire to consider the relevance of this issue to the theoretical premise of the "urban interior" and its relation to the South African streetscape, master's degree student Nadia Ghillino in the Faculty's Department of Architecture proposed the development of an adaptable, flexible, temporary cubical design that will take interior architecture to the streets, introducing human dignity in environments without basic amenities.

The title of her dissertation was: "The secret life of streets: Deployable domesticity tested along Minnaar Street". Through this study, she focused on the potential of a city precinct to accommodate domesticity, and in the process succeeded in promoting urban domesticity and urban interiors as valuable avenues of future investigation within the discipline of interior architecture.

The precinct that formed part of her study was in the central business district of Pretoria, and stretched roughly from Nana Sita Street in the north to Pretoria Station in Paul Kruger Street in the south, and from Schubart Street in the west to Nelson Mandela Drive in the east, with Burgers Park in the centre and Minnaar Street running through it.

Minnaar Street is populated by several nomads. The residents of the street are not necessarily unemployed, and have homes elsewhere, but not within easy access of their places of work.

→ *Illustration of the precinct that formed part of the investigation.*

These residents include car guards, waste pickers, newspaper sellers, street vendors, gardeners and handymen. The precinct is one of many similar sites in any urban centre in South Africa, thus showcase a universal issue. Nadia's proposed designs can therefore be rolled out to any urban area with a similar social script.

The streets are defined by certain physical and formal components: furniture takes the form of benches and street lamps, and the structures that combine to form the urban architecture include corners, squares, sidewalks and boundary fences. While these attributes have inherent formal functions (for example, a bench for sitting and a sidewalk for walking), they also have informal functions (for example, the same bench for sleeping and the sidewalk as a meeting place). In addition to these functions, domestic rituals are performed on, under, around, within or alongside streets.

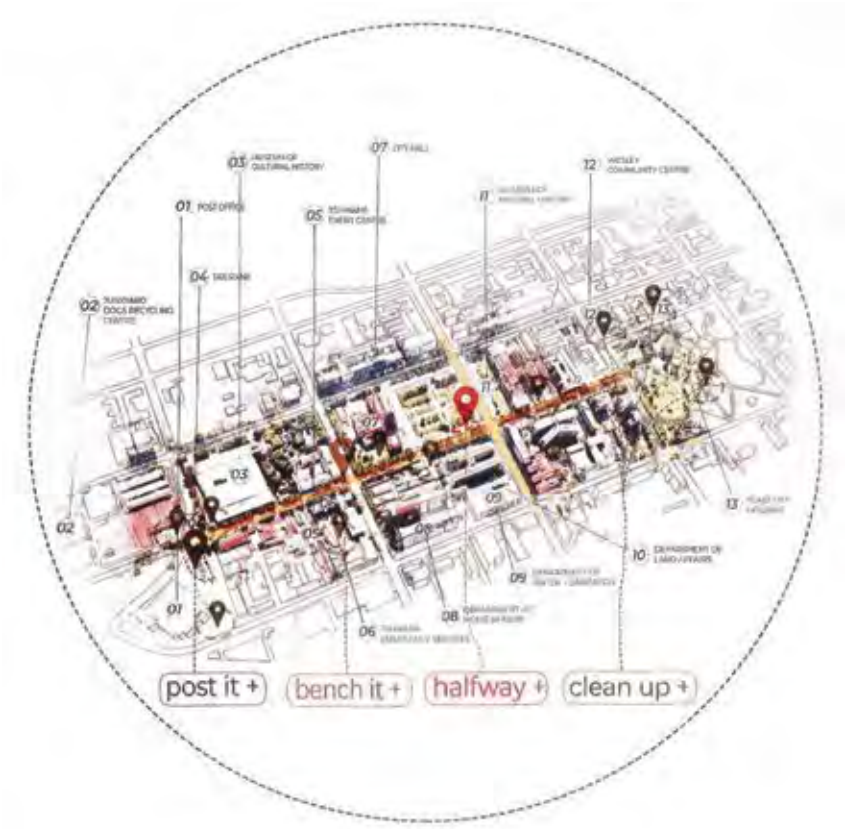
On Minnaar Street, in particular, new, informal, domestic functions have emerged. Here, people loosely attach themselves to streets as tools for territoriality, domesticity and belonging. However, the street does very little to reciprocate. In contemplating her study, Nadia felt that design should respond to both

the formal and the informal domestic functions of the street. She believed that such a design thinking could draw from its social context, and not just from its physical context; thereby rendering a design thinking applicable to various contexts.

Her research was focused on determining what could be added to the existing design of Minnaar Street (and other socially similar streets) to better accommodate its informal domestic functions. She considered how interior architecture can contribute to the urban condition and strengthen the built environment's connection to the social reality of the city. In addition, she considered how a design intervention can accommodate urban domestic rituals, while emphasising a sense of empowerment and belonging.

"Good design should appeal to the humanity and imagination of the user," says Nadia. "It is about creating accessibility in both product and process. The primary focus should be on the needs of the user and the social forces that impact on them, rather than the limitations of architectural form. The interior architect should therefore be an enabler and facilitator of solution-generating thinking," she says.

This innovative study considers how interior architecture can contribute to the urban condition and strengthen the built environment's connection to the social reality of the city.



→ *Conceptualisation of Minnaar Street.*

Her research project views design as an experimental tool to engage with the real-life complexities of society and the role the built environment could play. Her focus was to design a system – rather than a building – that could impact on more than one context. It questioned the feasibility of permanent architecture in socially turbulent conditions and considered "nomadic" architecture instead. In this way, it provided a design that incorporated a degree of flexibility to create a sense of belonging and ownership. It sought to marry the archetype of domestic space with that of public amenities, creating an interface between public urbanity and the domestic interior. The design component of her study therefore sought to identify and accommodate the domestic activity surrounding the streets.

An important component of her study was that of urban domesticity: the understanding that the relation between interior architecture and the urban environment creates a potential for domestic territories. Domesticity is often connected with ideas of comfort, intimacy, familiarity and belonging, and how these are transferred outside the house through need, which may also produce political and social collective cultures. The domestic boundaries of inside-outside are continually shifting in response to the relationship between bodies and objects within spaces, both temporary and permanent.

Combining urban and interior spatial practices provides a new way of considering multi-scalar, multicultural, multidisciplinary approaches to the built environment. Despite urban interiors not necessarily being framed by an architectural context, they focus on ways of living, questions of wellbeing and belonging, and socio-cultural practices.

Her study also entailed a contextual analysis, which served to unpack the broader urban condition and uncover existing patterns and relationships between various facets of urban life. This included pedestrian activity, sound, transport, barriers, typology, shade, associations, and daytime and night-time public activity.

This analysis found that, during the day, the precinct is dominated by pedestrian activity; transport hubs and construction in the inner city add to the noise within the precinct. The recreational spaces buffer these noises by washing them out with sounds of nature and water. Between Burgers Park and Pretorius Square (at the Tshwane City Hall), a social pavement is created through informal trading, pedestrian activity and the proximity to government buildings or museums. At night, the precinct is defined by boundary and sidewalk activity. Pedestrian activity migrates south towards food hubs and bars. This exodus of activity creates a sleep corridor along Minnaar Street.

In terms of domestic ritual, the components of the street also take on various functions. During the day, they predominantly revolve around the buying and selling of food and social activities, such as gambling and street art. However, at night, they move away from Minnaar Street, and the predominant function is that of shelter, keeping warm and sleeping.

An analysis of the urban interior revealed spatial qualities with a strong resemblance to rooms within a home, such as the bedroom (a private, enclosed, intimate space), the living room (a public, multifunctional, flexible space) and the entrance hall (a linear access ritual, with access filtered from most public to most private; the transition from exterior to interior).

Street homelessness formed an important element in her study. This refers to individuals who physically live without any form of shelter on the street, on pavements, in city parks or other vacant urban spaces. It includes temporary overnight sleepers. This is a widespread issue in South African cities. An aim of her study was therefore to propose a system that could be deployed in different contexts through assembly and disassembly.

While street homelessness exists predominantly within the inner city, it combines groups of people living on the street. What these people have in common along Minnaar Street is that they return night after night to sleep in the same spot. Without the presence of a physical house, there is evidence of a home and belonging.

By identifying what could be termed "urban furniture", Nadia identified components separate from the street (a bench, signage, an electrical mini substation, a rubbish bin, a lamp post), components on the street (a telephone booth, a bus stop, a billboard), and components with defining edges (a wall, a fence, foliage, paving, a parking area). These components house a number of functions, from way finding and lighting to fireplaces and sleep spaces.

The relevance of this research lies in the development of the contextual analysis, and accompanying behavioural mapping process, into a method to identify similar sensitive sites in any city or urban context. The design output of this research involved exploring the concept of deployability by proposing an adaptable and flexible temporary cubicle design to address the lack of basic amenities in public urban areas.

In her design, Nadia presented several technical explorations in materials, modularity and manufacturing, as well as integrated services and systems. The eventual design should appeal to the three scales of product, space and system.

The cubicle design questioned the feasibility of permanent architecture in socially turbulent conditions and considered "nomadic" architecture instead.

Building on the premise of formal and psychological attitudes towards function, she conceptualised a catalogue of modular structures for urban domesticity by unpacking 12 activities, and grouping them into four spatial configurations.

Based on these spatial configurations, she conceptualised a modular structure that could accommodate the various functions and activities that formed part of life on the street, both for the individual and for the

Nadia Ghillino (right) with her supervisor, Anika van Aswegen (left), and Prof Chrisna du Plessis, Head of the Department of Architecture, at the Neighbourhood 4.0 Off-the-Wall Technology Showcase.

collective. The main consideration was its deployability in terms of materiality (material combination and joinery techniques), assembly (ergonomics, fabrication methods and assembly) and design as a system (integrating sanitation services, furniture systems and the use of standard components, and the relation of one module to the whole spatial scenario). This ensured that the designed structures were not only portable, but were flexible, could accommodate services, were adaptable to context, and could be transformed and disassembled.

The first of the four modules, which serves as the centre of the system, accommodates both private and public activities. Private activities such as washing and toilet are performed in intimate interior spaces, while public activities such as growing, socialising, cooking and washing (things) take place in open, visible spaces. Each domestic activity in this module is conceptualised as a catalogue item that can be removed from the larger layout and used as a product elsewhere in the urban environment. For example, the toilet can be rolled out to a separate location, and still function successfully on its own. The initial design of this module will serve as the base upon which further modules will be developed.

The second module accommodates two activities: drink (a public water point) and sleep (a platform on which to sleep). Both these activities relate directly to the existing design of the benches along Minnaar Street. Drink is conceptualised as a permanent installation that makes use of the currently vacant service cavity in the centre of the base of the existing bench. Sleep is conceptualised as a temporary installation, comprising two parts that loosely attach to the underside of the bench. The first part is a base, which is a sturdy platform that is durable, recyclable, lightweight and modular. The second part is a bag, which serves as a mattress that is placed on top of the base. Both the base and the bag operate optimally together, but can be used as separate products.

The third module accommodates the function of sending and receiving mail (including salaries) for the homeless, as well as recreation, by providing a well-lit, covered platform for shelter during rain, social interaction and bicycle storage. It is conceptualised as a semi-permanent modular installation that interfaces with the Post Office, due to its money transferal capabilities and potential to create a physical address for the homeless. It can also interface with any other government institution.

→ *Model of the cubicle design.*

The design of the fourth module stems from a typical waste picker's trolley. This space is focused around the production of 15 x 20 mm thick KimmoBoard (a patented honeycomb fibreboard used in the bulk transport packaging industry). It is used primarily for the sleep base and as insulation board within two of the other modules. The initial design encompasses a trolley used for paper collection and a workshop bench for cutting and assembling modules of the sleep base.

In February 2019, Nadia's project was exhibited at the Neighbourhood 4.0 Off-the-Wall Technology Showcase of the Department of Human Settlements. Her project was one of five to be invited to a final project pitch and received a special commendation from the judges. The plight of homelessness was also highlighted locally and internationally when the SABC and Chinese Global Daily News featured her project.

The potential of this innovative modular design to ease the hardships experienced by the homeless is clearly evident. However, institutional, commercial, corporate and municipal buy-in is needed in the form of funding for this solution to move from blueprint to physical reality.

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Advancing the SDGs in South Africa through 4IR

Prof Nelishia Pillay

It is anticipated that the Fourth Industrial Revolution (4IR) will bring with it an era of robotics, artificial intelligence (AI), internet of things (IoT), autonomous vehicles, cyber-physical systems, nanotechnology, biotechnology and quantum computing, among others.

In a study conducted by Accenture and the University of Pretoria's Gordon Institute of Business Science (GIBS), it is anticipated that the 4IR, specifically AI, will increase the economic development of South Africa by 2035. Can the 4IR advance the Sustainable Development Goals (SDGs) in South Africa? Furthermore, what possible hindrances will the 4IR place on achieving these goals and how can these be overcome? This article examines these questions within the context of each of the SDGs.

SDG 1: End poverty in all its forms everywhere

This goal aims to reduce poverty. Causes of poverty include a poor economy and agricultural skills, and natural disasters. Artificial intelligence techniques have been successfully employed to detect poverty-stricken areas in Malawi, Nigeria, Rwanda, Tanzania and Uganda with accuracy rates of between 88% and 99%. This will enable governments to identify such areas and put mechanisms in place to alleviate poverty. Artificial intelligence, combined with IoT, has also been effective in predicting natural disasters such as floods, earthquakes and volcanic disruptions.

SDG 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture

This goal aims to bring an end to hunger by improving food security and agricultural practices. Artificial intelligence, combined with robotics and IoT, has helped increase productivity in agriculture by means of automated irrigation, determining soil fertility, crop monitoring, the picking of crops, and predicting pests, diseases and weeds. Artificial intelligence and IoT have also assisted in improving nutrition by providing personalised diets and identifying nutritious meals at a minimum cost. Food prices and their regulation can also contribute negatively to food security. Artificial intelligence techniques can be used to predict and regulate food prices.

SDG 3: Ensure healthy lives and promote wellbeing at all ages

The IoT is already making an impact on elderly care, medicine and health care. A subarea of IoT, the internet of medical things, which focuses on the development of systems such as SmartHealth that monitor health remotely and provide emergency notification, is an emerging field. Hospitals have been employing "smart beds", which emit a notification if a patient attempts to get out of bed. Artificial intelligence has been effective in predicting epidemics, such as dengue outbreaks, in China, Columbia, India, Kuala Lumpur, Manila and Rio de Janeiro, as well as providing pregnant women with self-help systems that monitor pregnancies and report any signs of risk. Artificial intelligence has also been effective in detecting diseases such as malaria, heart disease and hepatitis B, lung disease, tuberculosis and HIV with accuracy rates ranging from 70% to 90%.

SDG 4: Ensure inclusive and equitable education and promote lifelong learning opportunities for all

This goal aims to promote quality education for all and lifelong learning. One of the challenges facing teaching and learning is the lack of manpower to provide individualised tuition to overcome learning difficulties. This has led to the use of AI for the development of automated teaching assistants and intelligent tutoring systems. Intelligent tutoring systems provide individualised tuition by identifying specific learning difficulties and have been employed in the teaching of Mathematics and Computer Science. The AI for Good foundation is working with the United Nations Educational, Scientific and Cultural Organisation (UNESCO) on an Open Education Resources (OER) project to provide open access to learning resources. Artificial intelligence is also making major contributions in learning analytics to predict student success and automated assessment.

SDG 5: Achieve gender equality and empower all women and girls

The aim of this goal is to end discrimination against girls and women and achieve gender equality. The 4IR is an era that will rely on technological advancements and hence computer science skills. One of the challenges faced internationally is that computer science is a male-dominated field and hence could lead to further gender inequality. An awareness of computer science, its benefits and career opportunities need to be introduced at school level. Programmes that involve parents, teachers, students and the industry need to be put in place. An example of such a programme is Technology Education and Literacy in Schools (TEAL) in the USA. This programme partners industry with school teachers to promote computer science. Artificial intelligence and IoT have also been used to promote literacy and support for women abuse. The Sage Foundation, in collaboration with AI for Good and the Soul City Institute, launched an AI app in Johannesburg in November 2018 that provides abuse victims with information on support and their rights.

SDG 6: Ensure availability and sustainable management of water and sanitation for all

The aim of this goal is to provide a sustained supply of clean water and sanitation for all. Artificial intelligence and IoT can be used to plan for water scarcity. Artificial intelligence has been used to predict droughts in Nigeria and Queensland, Australia. In California, USA, IoT has been used to reduce water usage in agriculture by 30%. The IoT has also been employed in the USA to minimise water lost due to pipe leakages and reduce household water consumption. In India, AI, in combination with IoT,

has been used to detect and prevent overflowing bins and manholes.

SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all

It is essential that a sustained energy supply is provided for all without negatively impacting on climate change. Artificial intelligence and IoT have proven to be effective in reducing energy consumption. Smart thermostats have helped reduce energy consumption in households by about 12%. Artificial intelligence has been used to design solar panel installations to maximise the energy gained, while at the same time reducing the effect of environmental noise. Artificial intelligence has also been used to develop devices that maximise energy storage.

SDG 8: Promote inclusive and sustained economic growth, full and productive employment and decent work for all

In order to ensure sustained economic growth, this goal aims at ensuring employment for all. With the 4IR will come a skills shift that needs to be planned for in order to prevent the 4IR from negatively impacting on this goal. As with the previous industrial revolutions, some jobs will be made redundant while new jobs will be created. National working groups should be established to identify jobs that will be made redundant by the 4IR and skills that will be needed. Plans need to be identified to develop these necessary skills in order to prevent unemployment and inequality. Forward planning by governments is imperative to prevent a shortage of the necessary skills for the 4IR and unemployment.

SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation

A further contributor to sustained economic growth is sustainable industrialisation. This goal aims to maintain sustained industrialisation by means of a resilient infrastructure and innovation. It is predicted that the 4IR and AI will improve countries' economic growth by contributing to various sectors of industry and commerce. For example, in the mining industry, Goldspot discoveries have employed AI techniques to predict gold deposits with an 86% accuracy. Similarly, Rio Tinto's use of autonomous vehicles has improved productivity by 10%. Artificial intelligence is also playing a major role in the broadcasting industry by means of data analytics. This will assist in predicting customer churn, optimising networks and creating movie trailers (such as for the movie "Morgan") and managing content (such as the Wimbledon 2017 segment). These are just some examples of the impact that the 4IR will have on attaining this goal.

SDG 10: Reduce inequality within and among countries

This goal aims to reduce inequalities among countries internationally, as well as to reduce inequalities within countries. It is anticipated that the 4IR will bring about further inequalities within and among countries. Countries with greater economic stability, resources and infrastructure will embrace the 4IR at a faster pace, improving economic development sooner and thereby increasing inequality among countries. One area in which the 4IR will have a positive impact is in reducing inequalities for the disabled. Artificial intelligence techniques have been successfully employed to assist those with sight and speech problems with text-to-speech and object recognition devices. Autonomous vehicles will further reduce inequalities for the disabled. The IoT has brought with it smart homes that will allow for appliances, lights and wheelchairs to be voice-activated and cater for speech impediments. Artificial intelligence and IoT devices have been employed that enable the blind to recognise faces and other objects, including text and money, and to cross the street.

SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable

The aim of this goal is to provide sustained, clean and safe living conditions for all. The IoT, combined with AI, is being used to identify the causes and fluctuations of pollution throughout the world, including in Brazil, China, Croatia, Germany, Greece, London and Saudi Arabia. The IoT has also been successfully implemented for public safety in Kenya and Nanjing. In South Africa, AI techniques have been employed to predict crime, including the theft of power cables and rhino poaching, and preventing these crimes from taking place.

SDG 12: Ensure sustainable consumption and production patterns

The aim of this goal is to prevent damage to our environment and the depletion of natural resources due to the increased consumption of natural resources to meet production needs. The aim is to change consumption and production patterns so as to reduce the use of natural resources. One of the contributing factors is waste. Artificial intelligence, robotics and IoT have started making strides in reducing the impact of waste, such as smart recycling to sort waste from a conveyor belt, and picking out recyclable waste. Another contributor to environmental damage is water pollution. Artificial intelligence and IoT have been successfully employed to determine water quality in various countries, including China, India, Korea and Malaysia. Attaining this goal also includes reducing carbon emissions. Artificial intelligence has been successfully employed to reduce CO_2 emissions. AI techniques were used to predict CO_2 emissions in India from 2017 to 2030, and the predictions indicated that drastic steps were needed to reduce emissions.

SDG 13: Take urgent action to combat climate change and its impacts

Climate change is caused by our current way of life. The aim of this goal is to change the way we live in order to reduce climate change. A major contributor to preventing climate change is reducing the energy that is utilised. Artificial intelligence and IoT are contributing to attaining

this goal by monitoring and reducing energy consumption. Renewable energy is another means of attaining this goal. Artificial intelligence, combined with IoT, has proven to be effective in the development of renewable energy systems. Artificial intelligence has been used to design solar energy plants. Renewable energy sources are dependent on the weather, and hence accurate weather forecasts. Artificial intelligence techniques have been proven to be effective in forecasting the weather.

SDG 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Oceans provide the natural resources that we require on a daily basis. They also contribute to combatting the effects of storms and decomposing of certain waste. Hence, the aim of this goal is to preserve our oceans. Marine pollution, ocean acidification, overfishing and damage to coral reefs are degrading our oceans and seas. Robotics, combined with AI, is providing a solution to reducing marine pollution by identifying plastic in the oceans. Phytoplankton contributes to maintaining oxygen levels. Artificial intelligence has been employed to monitor phytoplankton levels in the ocean. It has also been applied to determine the state of coral reefs to identify potential threats, and has been combined with IoT to predict damage to reefs caused by cyclones. The IoT has been successfully employed to monitor oceans by determining ocean acidity levels, fish populations and the quality of water, identifying pollution, and predicting underwater flooding, earthquakes and tsunamis. This has led to the area of internet of underwater things (IoUT) for monitoring oceans.

SDG 15: Protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt biodiversity loss

Forests play a major role in ecosystems, contributing to biodiversity, overcoming climate change and providing food and homes

It is anticipated that the 4IR, specifically AI, will increase the economic development of South Africa by 2035.

to various species. The aim of this goal is to maintain biodiversity and eliminate deforestation, desertification and poaching, which are destroying our forests. Artificial intelligence techniques have successfully been employed to monitor the fertility of the soil to prevent desertification and detect deforestation. The IoT, in combination with AI, has been employed to detect eminent poaching threats in Kenya and Tanzania. The IoT has also been successfully employed to predict illegal logging in forests in the USA. Illegal wildlife trade is one of the main causes of the degradation of biodiversity. Artificial intelligence techniques have been employed to detect illegal wildlife trade on social media.

SDG 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

The aim of this goal is to maintain peace and reduce violence, crime and injustice. Artificial intelligence techniques have been successfully employed to predict crime. A Cape Town software development company has employed an AI system to detect crimes before they occur. Artificial intelligence techniques have also been used to predict the theft of power cables, which is a common crime in South Africa. Artificial intelligence and IoT have also been used to prevent human trafficking. Artificial intelligence has been used to assist victims of domestic violence, providing victims of domestic violence with advice online, while at the same time detecting the safety of the victim and detecting child sexual abuse online. In the USA, IoT tools have been used to detect crime, such as determining gunfire in real time. Artificial intelligence has also been successful in detecting corruption and fraud. An AI system developed in Spain has been used to successfully identify fraud in politics and corruption in tender bidding in the Ukraine.

SDG 17: Strengthen the means of implementation and revitalise the global partnership for sustainable development

This goal aims to bring together different stakeholders, both nationally and globally, to achieve the SDGs. Various stakeholders, including national and global hubs for SDGs, relevant government departments, relevant research institutes, global initiatives to promote the SDGs using 4IR, such as the AI for Good Foundation, and relevant industry partners, will have to come together to achieve this.

As can been seen from initiatives that have already been put in place in other countries, the 4IR brings AI, IoT and robotics together to achieve the SDGs. However, this requires sufficient finance, infrastructure and manpower with the necessary skills. Collaboration with industry partners is also essential. Global support needs to be obtained from companies such as Microsoft, which are involved in various initiatives to achieve the SDGs.

Planning is also essential to ensure sufficient manpower with the right skills to make this happen timeously so that the 4IR does not hinder the achievement of the SDGs. It is anticipated that the 4IR will result in improved economic development for the country. This needs to be predicted, and business models of how improvement can be put back into the country to support the SDGs need to be put in place.

The role of information ethics in the 4IR

Rachel Fischer

The term Fourth Industrial Revolution, also known as 4IR, has no doubt become a proliferated term. It seems as though academic institutions, industry, government and civil society organisations have all jumped on the bandwagon to partake in and contribute to the dialogue. Together with the *en masse* publications comes the implicit – and indeed explicit – call to duty. This call extends to practical considerations that ask: "How can we substantially contribute to society?"

The interest of the African Centre of Excellence for Information Ethics (ACEIE) in the 4IR is the current growth, and future need, for individuals and communities to have access to data, accessible digital information, the ability to use that data, as well as the benefit of the internet of things (IoT) as part of their rights and quality of life. The ACEIE sees its role through the dual focus of engaging with all sectors of society, thereby ensuring inclusivity, but also emphasising the importance of basic literacy skills and training, enacting one's ethical responsbility to society by means of education.

Education is the top priority of the United Nations Educational, Scientific and Cultural Organisation (UNESCO). It is a "basic human right that forms the foundation on which to build peace and drive sustainable development. UNESCO is the United Nations's specialised agency for education. This sector provides global and regional leadership in education, strengthens national education systems and responds to contemporary global challenges through education with a focus on gender equality and Africa" (UNESCO, 2013). All the ACEIE's activities are aligned with UNESCO's Information For All Programme (IFAP), which prioritises information ethics, literacy, development, preservation, access and multilingualism as a cross-cutting theme.

The Global Education 2030 Agenda is UNESCO's main focus. It is part of a global movement to eradicate poverty through 17 sustainable development goals (SDGs) by 2030 (UNESCO, 2017). Education is essential to achieve these goals, with Goal 4 dedicated to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all".

The ACEIE, through its close relationship with the Department of Telecommunications and Postal Services (DTSP), seeks to align its research with national priority areas. In South Africa, President Cyril Ramaphosa recently appointed the Presidential Commission on the Fourth Industrial Revolution, which will assist government in taking advantage of the opportunities presented by the digital industrial revolution. The task of the Commission, which will be chaired by the President, is to identify relevant policies, strategies and action plans that will position South Africa as a competitive global player in the way it uses technology in reshaping the way people work and live.

As reported by Business Live, the "operational support to the Commission will be provided by a secretariat of officials of various national departments, led by the Department of Communications" (Business Live, 2019), while the Minister of Communications, Ms Stella Ndabeni-Abrahams, will coordinate Government's 4IR programme. Further to this, Mr Ramaphosa presented the first State of the Nation Address of the sixth Parliament on 20 June 2019, and committed to building an ethical state and to creating economic growth, employment opportunities and houses. The President also shared his vision for a new smart city in South Africa.

On 11 July 2019, during her Budget Vote Address, Ms Ndabeni-Abrahams addressed Parliament on the theme: "Growing the economy and driving a digital society through the Fourth Industrial Revolution". In her address, she said that "our response to the 4IR presents a unique opportunity to harness our individual and collective talents, energies and strengths to decisively address the economic and social challenges that we currently face". She added that it "presents an opportunity for all in society to participate in the digital economy, whether it be for social welfare or

business interests; as creators or consumers of goods and services; and whether trading locally, regionally or internationally" (ITWeb, 2019).

Against this background, the ACEIE has organised and attended a number of events locally and abroad over the past year.

African Centre of Excellence for Information Ethics

The interest of the ACEIE in the 4IR is the current growth, and future need, for individuals and communities to have access to data, accessible digital information, the ability to use that data, as well as the benefit of the internet of things as part of their rights and quality of life.

International activities

Russia

The ACEIE delivered a presentation at the Second International Conference of the Russian Committee of UNESCO's IFAP: "Tangible and intangible impact of information and communication in the digital age", which was held in the Russian town of Khanty-Mansiysk from 9 to 13 June 2019.

This event addressed multiple IFAP priorities, together with other pressing issues, such as artificial intelligence (AI), the role of 4IR and related technologies, as well as international psychological security. The Ugra Resolution on Information and Communication in the Digital Age is an outcome of the conference, and is highly relevant to all stakeholders.

→ *Delegates of the Second International Conference of the Russian Committee of UNESCO's IFAP, June 2019.*

"The Conference urges national governments, agencies of the United Nations (particularly UNESCO) and other relevant international, regional and national stakeholders to:

i. Complement public and private investments in AI and Industry 4.0 technologies by funding probing and comprehensive research on the societal impact of technologies in order to grasp their potential detrimental effects and ensure their beneficial use. This includes transdisciplinary issues in robotics, computer science, economics, law, ethics, labour, psychology and social studies.

ii. Undertake research into regulation models that monitor and evaluate digital intermediaries in order to secure the public interest in the following problem areas:
   - ensuring that people can control their own data in responsible, secure and transparent ways;
   - securing transparency and accountability in the operation of digital platforms;
   - taking steps to reduce tax evasion by digital corporations; and
   - preventing the proliferation of psychological warfare pursuing "cognitive hacking" on people's cultural and social identities.

iii. Determine, analyse, evaluate and clarify malicious use of artificial intelligence threats to international psychological security in order to make it possible to formulate concrete recommendations in this area. Establishing an international network of research centres for a better understanding and counteraction to these threats is also desirable.

iv. Promote consideration of information ethics across all disciplines, both theoretical and practical, and encourage bottom-up and top-down dialogue on ethical issues of information and communication among civil society, academia, the media, and the private and public sectors.

v. Recognise the importance of the media and information literacy skills in the digital era and promote them at all levels and forms of education, including lifelong learning.

vi. Foster research on more accountable, democratic and humane alternatives to the modern economic model of the internet that has evolved around the commodification of personal information."

→ *The Ugra Resolution on Information and Communication in the Digital Age is an outcome of the Second International Conference of the Russian Committee of UNESCO's IFAP.*

The ACEIE sees its role through the dual focus of engaging with all sectors of society, thereby ensuring inclusivity, but also emphasising the importance of basic literacy skills and training, enacting one's ethical responsbility to society by means of education.

Serbia

The ACEIE attended and contributed to the International Expert Consultation on the UNESCO Media and Information Literacy (MIL) Curriculum in Serbia on 12 and 13 September 2019. This international consultation was jointly organised by UNESCO and the Republic of Serbia. The ACEIE is also on the drafting committee for one of the key outcomes of the meeting: the Belgrade Recommendations on Global Standards for MIL Curriculum for Teachers. It is envisaged that these recommendations will guide future deliberations on the updating of the MIL Curriculum Framework for the next few years.

→ *Delegates of the International Expert Consultation on the UNESCO Media and Information Literacy Curriculum, September 2019.*

Local activities

The ACEIE participated in three activities held in South Africa, which focused on the role of information ethics in 4IR.

Are smart cities and smart communities possible without sustainable energy as a basic human right?

This ACEIE and UNESCO/IFAP workshop on the importance of access to energy was held on 13 August 2019. It established the critical importance of access to energy as a basic human right, particularly as it relates to sustainable energy and the available electricity supply. The event focused specifically on a proposed energy solution to address the South African housing crisis within the current electricity shortage.

The discussions focused on significant and critical matters such as ethical and legal questions, purposes (such as the satisfaction of human rights) and preparation for the 4IR, ensuring sustainable energy supply for housing, health and education, the consideration of future sources of energy, obligations and institutional responsibilities, the development of suitable infrastructure, and creating a wider awareness of the challenges and opportunities in these areas.

A number of recommendations were made, which were submitted to UNESCO and DTPS.

Information ethical implications of artificial intelligence

UNESCO has long-standing experience in global normative work and developed reflection on bioethics and ethics of science and technology through its World Commission on Ethics of Scientific Knowledge and Technology (COMEST). COMEST started to reflect on the ethical implications of IoT at the end of 2017, and in August 2018, the Commission was requested to prepare a preliminary study on the ethics of artificial intelligence to help inform UNESCO's reflection in this area.

A workshop on the information ethical implications of AI, held on the University of Pretoria's Future Africa Campus on 27 August 2019, involved themes of inclusion, access and participation. According to UNESCO, AI is one of the technologies with multidisciplinary implications for human beings. These implications influence cultures, societies and the environment. Through these impacts, AI is likely to transform the future of education, sciences, culture and communication. The integrated impact of AI requires a pluralistic, multidisciplinary, multicultural and multistakeholder approach, which opens questions about what type of future we want for humanity. It has the potential to transform the future of humanity for the better and in favour of sustainable development.

Participants included representatives from UNESCO, government, civil society and academia. Prof Peter Paul Verbeek, Chairperson of COMEST, discussed the results of a preliminary study on the ethical implications of AI. Prof Emma Ruttkamp-Bloem, holder of the Ethics of AI Research Chair in the Centre for AI Research at the University of Pretoria, discussed the ethical considerations of AI, and made the following recommendations:

- Policies should be generated and agreements signed in collaborative contexts that include government, industry, the private sector and institutions of higher learning.
- Training is not the responsibility of universities alone. Universities should change their understanding of curricula and degree structures, and corporations should take responsibility for in-house training.
- If skills such as communication, collaboration, creative and critical thinking form a focus area from basic education onwards, and all students have basic AI literacy and 4IR technology abilities, including some formal training in the ethics of AI, the positive rewards of AI and other 4IR technologies may have a better chance of being realised.

Outcomes that were achieved during the workshop included the sensitisation of stakeholders on the importance of the appropriate development of information ethical dimensions related to AI, and the identification of the challenges and opportunities related to the ethical implications of AI in respect of national development. An agreement was reached between attendees to continue collaboration on this topic.

Working towards universal internet access and digital equality in South Africa

The 2019 International Day for Universal Access to Information (IDUAI) was celebrated on the University of Pretoria's Future Africa Campus on 27 September 2019. In addition to the ACEIE and an international network of human rights organisations under the leadership of the South African Human Rights Commission (SAHRC), participants included several local online and media industry bodies, the South African National Editors' Forum (Sanef), IAB SA (the online industry association) and Media Monitoring Africa (MMA), with the support of the Association for Progressive Communications.

A seven-point plan was presented at this event, which will assist the government with proposals to take steps towards progressively realising a basic level of universal free access to online information, both within government itself and through engagements with private entities and other stakeholders.

These events illustrate the central role that information ethics has to play in the 4IR, particularly in positioning the role of stakeholders to enact their social responsibility towards information ethics.

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Condition monitoring on the digital railway

Prof Hannes Gräbe and André Broekman

The Chair in Railway Engineering at the University of Pretoria is partnering with a number of researchers in the Faculty of Engineering, Built Environment and Information Technology, as well as industry collaborators and sponsors, to make an impact in the fast-developing world of condition monitoring on the digital railway.

The focus in this research is on big data and artificial intelligence, supported by the envisaged test track on the Hillcrest Campus, as well as the development of a special road/rail vehicle for sophisticated infrastructure condition monitoring.

The primary components and associated aspects of big data in railway engineering and monitoring solutions can be summarised by the five Vs:

- **Velocity:** Daily or weekly inspection data, which is a requirement for early defect detection and rate of growth.
- **Variety:** A number of data-collecting systems leads to a wide variety of available data.
- **Veracity:** For visual monitoring solutions, only visible problems will be detected; the quality of each data source and the reliability of the conclusions that are drawn will differ.
- **Value:** The improved availability of public transport services is one of the most evident social aspects where added value is realised by leveraging new technology, data analytics and condition-based maintenance policies.
- **Volume:** The analysis of information in a distributed system should be considered in both spatial and temporal dimensions; for high-frequency data, terabytes of data can be generated daily, which requires analysis in some shape or form to distil useful information.

Artificial intelligence

The rapid advancement and proliferation of artificial intelligence during the preceding decade – in particular, deep learning – aligns itself to address and simplify some of these challenges. The Chair in Railway Engineering has partnered with 4Tel (Pty) Ltd, headquartered in Newcastle, Australia, to develop innovative solutions for the purpose of railway condition monitoring, fusing artificial intelligence approaches with traditional methods. This evolving technology offers the opportunity for the rail industry to improve the safety, efficiency and cost-effectiveness of rail and train control systems. These intelligent systems, which consist of detection, localisation, awareness, dynamics and monitoring, provide the necessary capability to identify hazards instead of acting on static and pre-programmed rules that are insufficient in complex and varied rail environments. The information is gathered from a dedicated sensor

platform and integrates data from a variety of sensors, such as colour and infrared-imaging cameras and radar, each suited to different environmental operating visibility conditions.

The current policy of condition monitoring utilises a dedicated instrumentation vehicle that periodically measures the track geometry, quantifying parameters such as the gauge, profile, alignment, twist and cant. These vehicles are specialised and are frequently unavailable for the entire network of track that carries regular traffic. For the purpose of geometric measurements, relatively slow, but effective, traditional methods such as simultaneous localisation and mapping (SLAM) and photogrammetry, which produces high-resolution surface mapping, can be replaced entirely by end-to-end pipelines that incorporate and combine state-of-the art neural network architectures.

Recent advancements of recurrent neural networks and long- and short-term memory architectures have seen successful adoption for sequence modelling and depth estimation. This research project aims to fuse these developments for the purpose of precise, real-time mapping of the track components. The models can be expanded with ease to incorporate new capabilities such as hazard identification, optical odometry, and the tracking and tagging of railway assets.

Extensive training renders the networks unaffected by changing environmental and lighting conditions and integrates new information into their latent space representations. New data can be gathered daily when deployed on revenue-earning vehicles that traverse the entirety of the line, continually updating the track model and performing predictive analytics to identify potential failures before they occur.

With the advent of graphic processing hardware and open-source 3D software (Blender), photorealistic virtual reality environments can be synthesised together with the associated ground truths. The entire process of data generation and training of neural networks can be accomplished in a virtual, digitised version of a railway track, saving a substantial amount of time and cost, without the need of track occupation.

The Chair in Railway Engineering's research project in artificial intelligence aims to fuse the latest developments in the field for the purpose of precise, real-time mapping of the track components.

These environments are parametrically defined with an integrated Python API to allow for controlled track roughness and geometric variations. The required sensor performance for optical sensors, positioning and lens selection can be modelled and optimised prior to purchase and installation. Incorporating transfer learning to merge synthetic and data recorded in the field provides increased accuracy, and reduced training time and complexity than would otherwise be required.

Real-world testing will be executed using the newly commissioned road rail vehicle (RRV) on the envisaged rail loop that forms part of the next phase of construction for the University's Engineering 4.0 facility.

Test track

The envisaged test track will have two tangent sections of 250 m each and three circular curves (2 x 475 m and 1 x 470 m in length) with a minimum radius of roughly 150 m. The total track length will be just under 2.0 km. Instead of building the test track level with a 0% vertical gradient, the proposed vertical gradient reduces the cut and fill by more than 50%. As a result of this design, the ruling gradient will be 1:200 if operated anti-clockwise, whereas the ruling gradient will be a 1:50 compensated gradient when operated clockwise.

To enhance the functionality of the test track, the following have also been included in the preliminary design:

- A 4 m level crossing to access the inside of the balloon
- A 1:9 turnout taking off from the inside balloon
- A short stopblock line with an RRV access platform, an RRV shed and a section of track for the delivery of rolling stock

Possible test sections for the outer balloon would include the following:

- A 26 tonne/axle track structure (fill on a straight)
- A 26 tonne/axle track structure (cut on a straight)
- An N2/N3 general freight track structure (cut and fill on a curve with a radius greater than 150 m)
- An N1 general freight track structure (cut and fill on a curve with a radius greater than 150 m)

Regarding turnouts, it is proposed to include a 1:12 60E1 tangential turnout (on the right) on concrete sleepers, a 1:9 48 kg secantial turnout (on the left) on a concrete flat slab and a 1:9 48 kg secantial turnout (on the left) on universal sleepers.

The sections of track could further be broken down into test sections for the following:

- Different formations, sub-surface designs, fastening systems and rail pads

The University of Pretoria's road rail vehicle.

- Slope rehabilitation products and methods
- The evaluation of novel products such as geosynthetics, ballast mats and foam reinforcement
- Track signalling, circuits and vehicle detection systems
- Track condition monitoring with autonomous systems
- Defect identification with optical machine learning equipment
- The testing and installation of prototype track instrumentation systems

Road rail vehicle

The test track described above will be the ideal testing ground for the road/rail infrastructure monitoring system (RIMS) that is currently being developed in collaboration with the Department of Mechanical Engineering and the Department of Systems and Industrial Engineering. This special and unique research equipment is funded by the National Research Foundation and the University of Pretoria as part of the National Equipment Programme.

The RIMS comprises a custom-built road/rail vehicle that can travel on both road and rail infrastructure. It will be equipped for condition monitoring, characterisation and the maintenance of road and rail infrastructure, as well as the measurement of vehicle dynamics. The RIMS will have four main measurement components: a global positioning system (GPS), high-accuracy light detection and ranging (LiDAR) to create digital elevation models, 360° video cameras and a sophisticated vehicle response measurement system (VRMS). The VRMS comprises a range of sensors that will measure the dynamic behaviour of the vehicle in response to the condition of the infrastructure.

Researchers in the Faculty are working to make an impact in the fast-developing world of condition monitoring on the digital railway.

The RRV is capable of reaching measuring speeds of 90 km/h and 120 km/h on rail and road, respectively, and will be used across disciplines by different departments. The vehicle and the proposed measurement system will be world class and unique, with high-impact research being carried out in the following fields:

- Transportation logistics and the use of high-accuracy GPS data to improve route planning
- Road condition monitoring and the use of telematics data to address a range of road/vehicle interaction issues
- Vehicle dynamics measurements on road and rail to improve various aspects related to the design of road and rail vehicles
- Track condition monitoring by using vehicle dynamics, optical data and machine learning

In the final development stage of the integrated measurement system, an autonomous system will be developed that can be installed on standard road and track vehicles to carry out the proposed measurements and stream the data to cloud storage. Software will be developed to analyse the data and produce road, rail and vehicle condition and performance index values for improvement and maintenance actions. The equipment is extremely versatile, and will be able to perform condition monitoring on the South African road network, as well as the railway lines of Transnet Freight Rail and the Passenger Rail Agency of South Africa (PRASA).

What is the hype about disruptive technologies?

Prof Aurona Gerber

Nowadays, it is impossible to read any discussions about the future without encountering discussions of disruptive technologies such as autonomous vehicles, 3D printing, robotics, artificial intelligence (AI) and wearable technology. These technologies bring about Fourth Industrial Revolution (4IR) systems that integrate the services and operations of businesses and meet the needs of humankind more efficiently.

Predictions about the impact of disruptive technologies usually range from a rosy picture of abundant future life for all to dire forecasts of an AI-controlled future and a jobless society in which robots do all the work. Several futurists use cases of historic technology disruption to predict major upheavals in health care, finance and education (Wadhwa, 2014; Kalis and Trulsen, 2018). These predictions are based on examples such as Sophia the humanoid robot. Sophia caused a stir at the Consumer Electronics Show 2019 when she quite convincingly talked to humans about religion and what it means to be alive.

When one reads articles about disruptive technologies, the conclusion is that technology will influence and change the future significantly. However, understanding how life will change or what the impact will be on society and business remains a daunting task. Some of the so-called disruptive technologies have been around for a while, so disruption does not necessarily refer to new technologies.

John McCarthy coined the term "AI" as early as 1956, so why is it regarded as a disruptive technology more than 50 years later? The term "disruptive" is also vague. What is being disrupted and how are things disrupted? Does disruption mean new ways of doing what one has always done (such as teaching online instead of in a classroom) or does disruption mean that there is no place for the way things were done before (such as digital photography replacing film photography)?

To help us understand disruptive technologies, researchers in the

→ *Sophia, the robot.*

University of Pretoria's Department of Informatics embarked on a research study using document analysis as a research strategy to develop the conceptual framework (illustrated in Figure 1).

The conceptual framework shows three categories of technology development. In the first category, foundational technology developments represent developments that underpin modern technology. Technologies that are referred to as disruptive technologies mostly represent a technology fusion with integrated technology development (the second category). The third category comprises technology solution development because the novel application of technology fusions that provide for the needs of humans, society and businesses is a central determining factor that explains disruption.

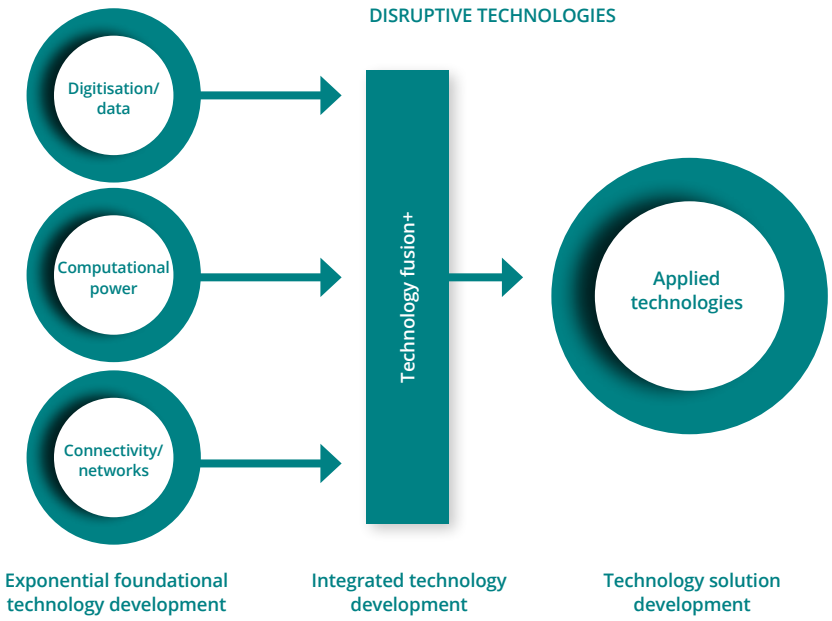
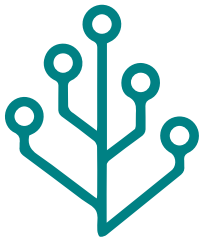


Figure 1: A conceptual framework for disruptive technologies

The category of exponential foundational technology development includes three core technologies that exhibit exponential growth: digitisation and data, computational power, and connectivity and networks.

The ability to create a digitised representation of reality by connecting users and devices and to collect measurements through a mass of deployed sensors is causing exponential growth in data. Discussions of big data, its uses and impact abound, and new related terms, such as data science and big data analytics, have recently emerged (Sathi, 2012; insideBIGDATA, 2019). It is predicted that the digital universe will double every year until at least 2020, which would result in more data being generated than ever before in the history of humankind (Gantz and Reinsel, 2012).

Since Moore coined his famous Moore's Law in the 1960s, computing power has experienced exponential growth. Today, an ordinary smartphone contains computing power that was only available in mainframe computers a decade ago. The size of microprocessors, which are shrinking so quickly that they are commonly described in terms of nanometres, is associated with the growth in computing power.



Articles about disruptive technologies typically state that technology will influence and change the future significantly. However, understanding how life will change or what the impact will be on society and business remains a daunting task. The disruptive technologies conceptual framework seeks to shed light on such uncertainties.

Because these microprocessors are so small, they can now be embedded in pervasive technology such as smartphones and smart sensors. This technology distributes significant computing power to almost everywhere.

The internet's incredible growth is representative of the exponential growth in connectivity and network technologies. It is estimated that the web grows by approximately a million users a day. Almost 1.7 billion people have been connected to the internet since January 2012, and these trends show no signs of slowing down. Mobile coverage is being expanded to more areas, including remote rural areas, as demand increases. Initiatives such as SpaceX's plan to cover the world with satellite internet will ensure that connectivity remains in the exponential growth phase for the foreseeable future.

What does this exponential growth mean? The exponential growth of core technologies has drastically changed the technology landscape. When these technologies are integrated, fused and enhanced (see "technology fusion+" in Figure 1), disruptive technologies emerge. Even though AI has been around for a while, the significant increase in data, combined with available computing power that is accessible through connectivity as cloud services, allows for the development of innovative machine learning and deep learning applications. Similarly, robotics and autonomous vehicles combine immense computing power, access to large data stores, intelligent algorithms (for instance for speech recognition and video processing), and smart sensors to develop current breakthroughs. Any so-called disruptive technology is a technology fusion that exploits the exponential development of the foundational technologies that the functionality provides.

Technologies cannot be disruptive without a human component. Figure 1 presents this component as the category of applied technology

The exponential growth of core technologies has drastically changed the technology landscape. When these technologies are integrated, fused and enhanced, disruptive technologies emerge. Technologies cannot be disruptive without a human component. This represents developments in the category of "technology fusion+" that are applied to satisfy the needs of humans, society and businesses.

development. This category represents developments in the category of "technology fusion+" that are applied to satisfy the needs of humans, society and businesses. When intelligent technology platforms connect smartphone users who need rooms with users who have rooms, disruptive businesses such as Airbnb emerge. When refined AI algorithms are allowed to learn from vast amounts of medical data (including images), we see diagnostic results for diseases that promise to outperform human specialists.

The increase in the number of unicorn companies (privately held start-ups valued at $1 billion or more) that focus primarily on AI to solve unique problems is significant.

Unicorn platform companies continue to be at the forefront of disruption, focusing on diverse human needs such as chat services and social networking, connecting farmers and restaurants, or providing intelligent services to corporations to store and analyse data.

The applications of technology fusion are diverse and novel. As society adopts these technology solutions, the solutions themselves are being altered. How humankind operates is being changed, or disrupted, in other words. For example, it is virtually impossible to function effectively in modern society without email for communication or platforms like Facebook for marketing business services.

In conclusion, disruptive technologies affect all aspects of human life and will increasingly change and disrupt society. These rapid changes occur as a result of technology development. The exponential growth in foundational technologies allows for innovative technology fusions, and disruption is inevitable when these developments are used to provide for the needs of business and society.

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Investigating the potential of bicycle-sharing on campus

Christo Venter, Themba Mangane, Niell du Plooy, Klaas van Zyl, Imelda Matlawe and Thato Krynauw

The Fourth Industrial Revolution (4IR) is rapidly gaining momentum in many economic sectors throughout the world, and the transport sector is no exception. Although bicycles as we know them have been around since 1885, integrated bicycle-sharing technology has transformed this mode of transit to a sustainable 21st-century smart mobility solution.

Bicycle-sharing is the shared use of bicycles, typically in exchange for a fee, for short, point-to-point journeys. It differs from short-term bicycle rentals, which are usually aimed at tourists. It has been growing exponentially internationally, and the economic, social and health benefits of bicycle-sharing for cities have been proven. These benefits include a growing awareness of cycling as a mode of mobility, enhanced first- and last-kilometre connectivity to the public transport network, decreased greenhouse gas emissions, and the increased physical activity of users.

Owing to its fast growth, bicycle-sharing has been challenging cities' ability to plan, regulate and manage its integration into the smart urban transport system. South African cities have shown tentative interest in bicycle-sharing, but the unknown demand for bicycle-sharing amid the lack of a cycling culture, its associated cost and subsidy implications could hinder its success.

Bicycle-sharing research

Researchers in the University's Department of Civil Engineering implemented a bicycle-sharing system on the Hatfield Campus as a pilot project from the middle of 2018 until the end of November 2018. The research aimed to test the feasibility of a bicycle-sharing scheme among students and staff members and to develop the capacity of officials of the City of Tshwane Metropolitan Municipality (CTMM) to assess and implement such a project as part of the city's municipal transport service delivery.

The project was funded by a research grant from the Tirelo Bosha Public Service Improvement Facility and administered by the Department of Public Service and Administration (DPSA). Project partners included Enterprises University of Pretoria, the University's Centre for Transport Development, Royal HaskoningDHV (an international engineering consultancy firm), the CTMM's Department of Roads and Transport, the University's Department of Research and Innovation, and the City Sustainability Unit.

Bicycle-sharing has been challenging cities' ability to plan, regulate and manage its integration into the smart urban transport system. South African cities have shown tentative interest in bicycle-sharing, but the unknown demand for bicycle-sharing amid the lack of a cycling culture, its associated cost and subsidy implications could hinder its success.

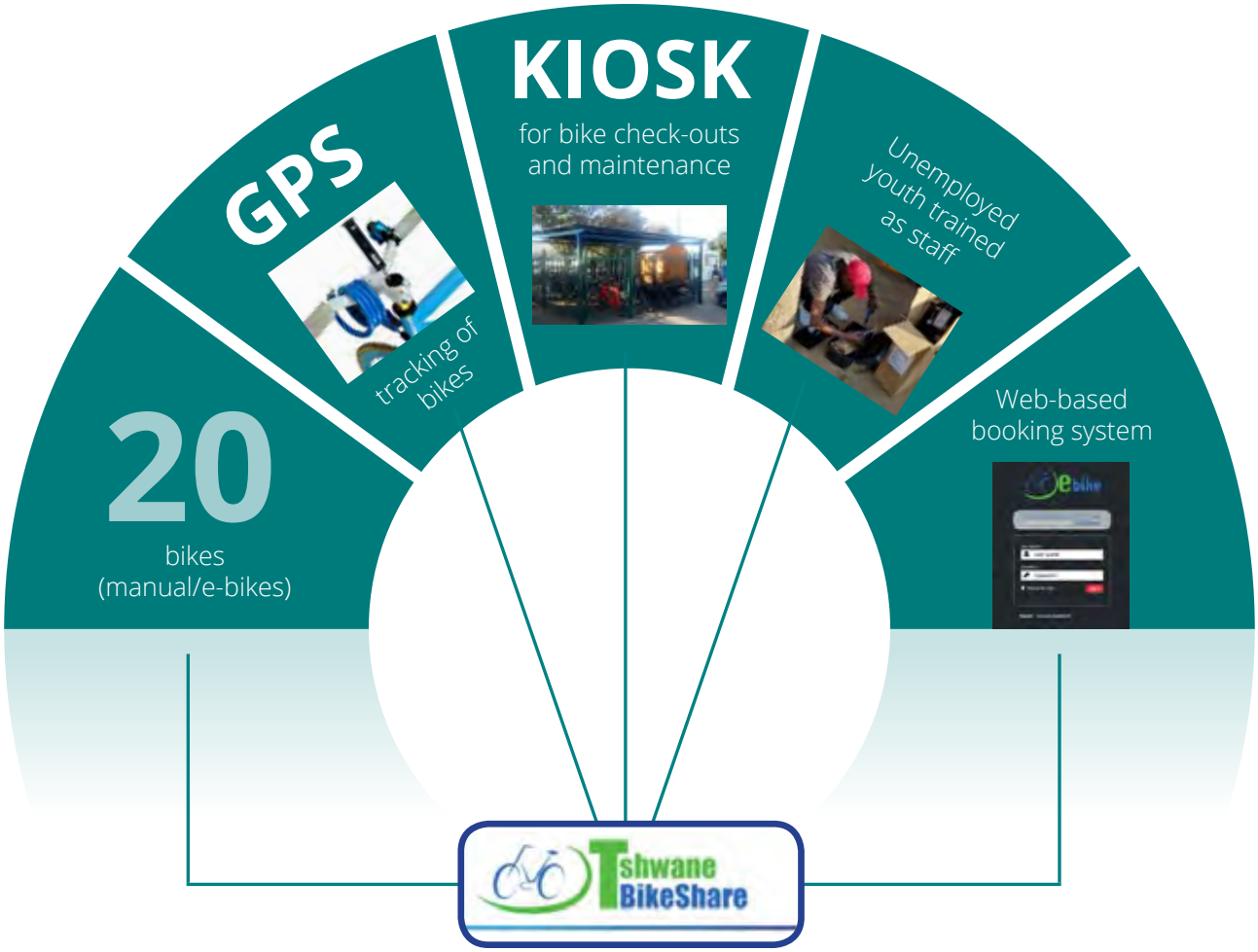


Figure 1: Key components of the bicycle-sharing system.

Figure 1 shows the project's key components. Ten manual and ten pedal-assist electric bicycles (e-bikes) were procured. The researchers included e-bikes in the pilot project to test the hypothesis that they significantly improve the utility and attractiveness of bicycle-sharing.

A single kiosk was constructed on the Hillcrest Campus near the student residences, only 1.5 km from the Hatfield Campus. It served as a point of bicycle dispatch and return. The bicycles were also maintained and stored at the kiosk. While a single kiosk was not the best way to serve diverse travel patterns, it was adequate for the pilot project. Its location allowed users to ride bicycles to and from class or work on the Hatfield Campus. Unemployed youths who were identified via the Expanded Public Works Programme (EPWP) in Tshwane worked at the kiosk and received training in bicycle care and maintenance.

Two information and communication technologies (ICTs) were integral to the project. First, all bicycles were tracked using GPS equipment. This provided real-time information on their location for bicycle management and security. The data that was stored on the bicycles' devices could be analysed later. Second, an online booking system was developed to allow users to register, book bicycles and communicate with the kiosk's staff members. Booking was essential given the limited number of bicycles.

The initial cost for the bicycle-sharing was R5 per day, but this fee was waived after a slow initial uptake. Users were also issued with a helmet and lock when they checked out a bicycle. After the fee was waived and social media marketing efforts were intensified, the number of users increased dramatically. In total, 363 users registered by the end of the project and 164 unique users made more than 830 bookings. On average, between the middle of 2018 and the end of November 2018, 14 bookings were made per day, with the maximum number of bookings being 40. There was some interest in weekend bookings, but the service only operated on weekdays.

Figure 2 shows a heat map of the density of tracking points across the Hatfield area. Bicycles were used for trips to a variety of destinations. Individual tracks, which are not shown in Figure 2, revealed trips of up to 16 km to adjacent suburbs and Pretoria's city centre.

Two major hotspots in Figure 2 reveal frequent destinations: the main entrance to the Hatfield Campus, and the area around the Hatfield commercial node. The bicycles were frequently used for social or shopping trips.

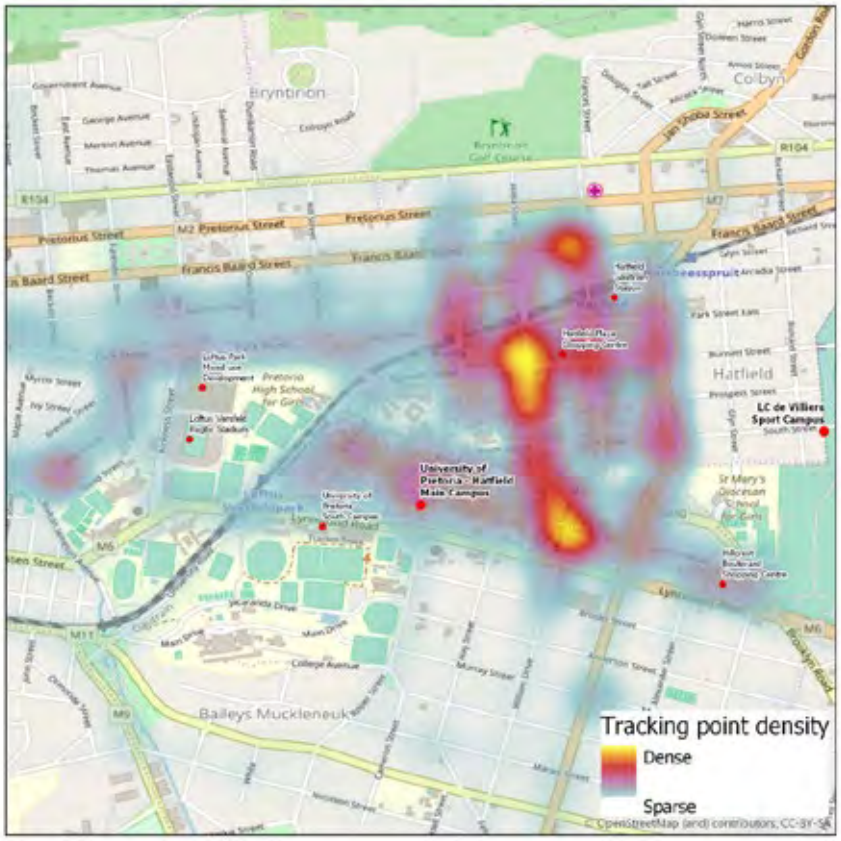
Without generalising to the broader population, the project demonstrated a definite demand for bicycle-sharing, at least in some niche markets. However, it also showed that some of the other potential barriers to the adoption of bicycle-sharing in South African cities, including mandatory helmet use, theft and vandalism, and limited bicycle infrastructure, need not prevent its successful implementation.

The demand for bicycle-sharing was by far the largest among users who travel on foot. In this sense, the pilot project confirmed the arguments of De Beer and Valjarevic (2015) and Jennings (2015) that bicycling, with or without bicycle-sharing, could ease the mobility burden by reducing the time and effort residents of low-income communities spend on walking.

Young people also indicated that they are willing to increase their use of bicycles for a variety of trip types. The pilot project also showed that bicycle-sharing has a discernible, but modest, ability to attract car users and contribute to environmental goals and congestion relief, but only for specific trips.

The findings suggest that the marketing of cycling or bicycle-sharing should focus on creating positive and attractive images of cycling, and emphasise its time-saving ability and security benefits to reduce the barriers to its adoption. The limited offer of e-bikes, although expensive and of uncertain utility to users, might form part of this strategy.

What about the financial sustainability of bicycle-sharing systems? As a free service, the pilot project did not provide information about users' willingness to pay for bicycle-sharing. Affordability is a key constraint among potential users. However, after experiencing the service, users indicated a definite willingness to pay for bicycle-sharing because they found the service useful. It is unlikely that user fees will cover the full cost of bicycle-sharing systems in South Africa, except perhaps those that are aimed at high-end users such as tourists.



→ *Figure 2: A heat map of movements around the greater Hatfield area.*

However, arguments can be made in favour of public subsidies for bicycle-sharing on the grounds of its sustainability objectives. Subsidies might also be justifiable on the grounds of cycling's demonstrated ability to attract some vehicle users and to support public transport as a first- or last-kilometre service.

Overall, the pilot project suggests that there is a role for short-term bicycle-sharing in South African niche markets. The campus environment is one such market in which short trip lengths, the ability to control and closely monitor access to the system, and the user population's characteristics favour its success. Future research should test variations of the concept in other niche markets, including additional funding and operational models. One particularly promising extension is to test bicycle-sharing's ability to promote entrepreneurship and job creation. However, given the fact that travel habits that are formed during people's early years tend to affect their behaviour at a later stage, bicycle-sharing might be a valuable investment in reaching long-term sustainable transport goals.

Acknowledgements

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The project demonstrated a definite demand for bicycle-sharing, at least in some niche markets. The demand for bicycle-sharing was by far the largest among users who travel on foot. It also showed that some of the potential barriers to the adoption of bicycle-sharing in South African cities, including mandatory helmet use, theft and vandalism, and limited bicycle infrastructure, need not prevent its successful implementation. The findings suggest that the marketing of cycling or bicycle-sharing should focus on creating positive and attractive images of cycling, and emphasise its time-saving ability and security benefits to reduce the barriers to its adoption.

E-topia, Utopia or Dystopia? A critical reflection on the smart city dream

Prof Chrisna du Plessis

When William Mitchell published his book *E-topia* in the last year of the previous century (Mitchell, 2000), he envisioned "lean, green cities that work smarter, not harder". Mitchell's E-topia became the inspiration for what came to be called "smart cities". Townsend (2013) defines smart cities as "places where information technology is combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic and environmental problems." This definition goes beyond describing what smart cities are, but also what their purpose should be: to address real-world problems.

Smart cities have a crucial role to play in meeting sustainable development goals and improving urban resilience. Sensors and cameras in monitoring networks alert us to dangers; smart grids and the internet of things allow us to optimise energy use and streamline logistics; social media communities allow more participative forms of governance and greater democracy. These are all good things.

However, in the excitement about the possibilities of smart cities vested in the internet of things (IoT), artificial intelligence (AI) and all the other inventions of the Fourth Industrial Revolution (4IR), we do not stop often enough to ask ourselves hard questions about the paths we pursue. Are they appropriate? Is this the best use of energy and scarce resources? And most importantly, what can go wrong?

Are our smart city models appropriate?

In his 2019 State of the Nation Address, President Cyril Ramaphosa held up a vision for the future of South Africa: "to build a new smart city founded on the technologies of the Fourth Industrial Revolution". He called on the country to imagine a city of skyscrapers, modelled on the new Beijing. In this, he is not alone.

A Google image search shows the typical smart city dream as business-as-usual glass and concrete skyscrapers, sometimes covered in a bit of greenery and making use of green technology operated by various smart applications. Usually there are some autonomous vehicles in the streets, drones in the air and a plethora of IoT devices. This is the standard smart city vision, from Bill Gates's Blockchain Innovation Park in Nevada to the proposed Eko Atlantic city in Lagos.

It is fuelled by the dreams of engineers, academics and the elite in wealthy countries.

The truth is that this vision of the smart city suffers from a failure of imagination – not in envisioning paradise in newly built cities, but in envisioning the integration of this Utopian thinking into the reality of the existing urban fabric and social and environmental conditions. One such reality is the nature of the cities that are predicted to be the large urban centres of the future. The United Nations (2018) foresees that, by 2050, the global urban population would have doubled, with most of that growth being centred in cities like Cairo, Delhi, Dhaka, Kinshasa, Lagos and Mumbai.

In the excitement about the possibilities of smart cities, we do not stop often enough to ask ourselves hard questions about the paths we pursue. Are they appropriate? Is this the best use of energy and scarce resources? And most importantly, what can go wrong?

Far from being shiny symbols of technological efficiency and wealth, they all share certain characteristics: huge inequalities, severe overcrowding, problematic authoritarian political leadership, overburdened infrastructure, dangerously high levels of air pollution and significant vulnerability to climate change. These are supposedly the cities of the future. And they all want to be smart. Or at least, they are planning smart cities on their peripheries as enclaves for tech-savvy elites. The existing cities themselves remain chaotic, self-organising messes constantly hovering on the brink of collapse, yet surprisingly resilient. While smart technologies can do much to improve circumstances in these messy conditions, the visions of African and Asian smart cities, as punted by politicians, planners and technology companies, seem to abandon the existing city and its citizens in favour of flashy and unaffordable, but smart, new settlements.

This highlights one of the main pitfalls of the smart city dream: it convinces excitable politicians to support billion dollar investments in the construction of new cities that are at heart badly disguised aspirational property speculation that is doomed to fail, as evidenced by the hundreds of ghost cities scattered across Africa and Asia. In the meantime, these vanity developments redirect resources that could have been used to improve living conditions in existing cities.

Is this the best use of energy and resources?

A second reality often ignored in the excitement about smart cities is the broader environmental context of the 21st century. Whereas the First Industrial Revolution was premised on the availability of abundant cheap energy and mineral resources, the Fourth Industrial Revolution is situated in a world of increasingly scarce resources and the consequences of the unfettered burning of fossil fuels.

All smart city technologies use energy to power devices and crunch data. Andrae and Edler (2015) anticipate that, by 2030, the production and operation of information and communication technology (ICT) will rise to 21% of global electricity consumption. This raises questions regarding the trade-off between the energy costs of processing power and the contribution to climate change, and the benefits of big data mining.

Despite considerable improvement in the energy efficiency of data centres, by 2015, the world's data centres were responsible for 2% of global carbon emissions. This is about the same as the airline industry, and continues to grow as the IoT expands. Belkhir and Elmeligi (2018) predict that the relative contribution of the ICT sector to the global carbon footprint by 2040 could be as high as 14%, unless there is a major global shift towards renewable energy.

However, a threat barely considered yet is the availability of rare earth

minerals. As both renewable energy infrastructure and ICT hardware relies on the same rare earth minerals, there may come a time when we will have to choose between energy and information; and if most of these resources are in the hands of one country, this can only increase the vulnerability of smart cities.

The increasing dependence on energy, particularly electricity, to complete the simplest of tasks not only increases the global carbon footprint, but also increases demand on existing energy infrastructure. Much of smart city infrastructure is reliant on the grid, making smart cities very vulnerable to power failures, damage to energy infrastructure, and competing demands for electricity. Climate change-related increases in temperature will place additional burdens on the grid, resulting in competition for electricity between smart city technologies and technologies that support human health and wellbeing.

While smart technologies can do much to improve circumstances in these messy conditions, the visions of African and Asian smart cities, as punted by politicians, planners and technology companies, seem to abandon the existing city and its citizens in favour of flashy and unaffordable, but smart, new settlements.

What can go wrong?

The very technologies that can be so helpful in identifying risks and managing disasters can themselves negatively impact on a city's resilience and increase its vulnerability to disaster and other disruptions. Imagine a city where all transactions are digital and cash no longer exists; where all communication happens over the internet; where artificial intelligence regulates the movement of autonomous vehicles, the distribution of energy through the smart grid, the temperature in your home, and the delivery of your groceries; where your smartphone broadcasts your movements and preferences to all who may pay for such information; where your email provider not only reads all your mail, but owns all the data you transmit through any of its services; where surveillance and facial recognition technology follow you wherever you go. Now imagine what will happen in the event of a collapse of the energy grid; or if a

hacker accesses your home security via your smart fridge; or if you find yourself living in a fascist police state where every citizen is obliged to implant a microchip that tracks every movement and transaction. These are not speculative scenarios, but are already part of our reality.

Shifting to automatised, centrally managed control systems that draw data from a multitude of sources makes cities more vulnerable to cyber-attacks. In 2017, hackers operating from Iran and targeting hospitals, state agencies, city governments and municipalities in the USA shut down the City of Atlanta's municipal system, the port of San Diego in California, a number of large hospitals and the University of Calgary, causing millions of dollars of damage in 45 US states (Cerrudo, 2015). So, while we are making our cities more efficient, we are also making them more vulnerable.

Smart city technologies also present a number of ethical and social justice issues. One of the social justice concerns of smart cities in the developing world is that it would further exclude those who cannot afford smartphones or the data required to access apps and email. Or those who do not have the required skills to navigate a digital world. Smart city technologies that engage directly with end users usually assume that such users have access to interface devices (such as smartphones) and data. This means that those who cannot afford the technology or the data are excluded from participating in the day-to-day activities of the city, as well as any participation in citizen engagement platforms, thus increasing the so-called digital divide. How smart can a city be if it creates an underclass that will never be able to participate meaningfully in the life of the city?

Conclusions

Before we go too far down the road, we need to critically interrogate the smart city model we pursue. A more appropriate smart city vision for a country like South Africa would ask what opportunities smart city technologies provide to improve conditions in the chaos of our current and future cities, and there are many. For example, digital platforms can empower an engaged citizenry by providing them with opportunities to directly engage with city management, whether to provide input on planning decisions, thereby leading to more democratic decision-making, or to alert the city to service delivery issues. Using social media platforms, citizens can also self-organise to take ownership of their city, help each other, establish resource sharing and other exchanges, and build communities. Already these platforms encourage bottom-up self-organisation, which supports initiatives such as ride-sharing, community clean-ups and alerting local authorities of areas requiring maintenance.

However, it is important to keep in mind that the various technologies used are value neutral, meaning they can be used for good or bad. The same technologies that assist law enforcement can be used by governments to shut down civic protests or monitor its citizens; the data collected by the city through its many avenues can be used to improve service delivery or punish citizens, or can be sold to data mining agencies to increase the city's revenue. At the moment, there are no real mechanisms to protect citizens from the misuse of these technologies by governments and the invasion of their privacy. We are increasingly entering a world of total social control, enabled by smart cities. And as George Orwell predicted in his book *1984*, we are doing this to ourselves – voluntarily inviting Big Brother into our lives.

So, where do we draw the line? How much infrastructure and economic functionality should be placed in the cloud? What data are we prepared to share? How far will we push the trade-offs between privacy and security or convenience? How intrusive will we allow the sensor technology to become? Or as Ratti and Claudei (2016) ask: "How smart must your bed be before you are afraid to go to sleep at night?"

The increasing dependence on energy, particularly electricity, to complete the simplest of tasks, not only increases the global carbon footprint, but also increases demand on existing energy infrastructure.

But the biggest threat is when we start thinking of cities as a network of intelligent devices – a super cloud computer of sorts with humans as interface devices. This makes it easy to forget that cities are meant for humans, with all their quirks and imperfections, and not androids. In the face of coming global changes, a truly smart city would create community and foster relationships outside of cyberspace. It would nurture whatever nature is left, and create spaces for new communities of life to emerge.

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Bibliometrics reveals trends in climate change research between Africa and Europe

Prof Anastassios Pouris

The Department of Science and Innovation commissioned the University of Pretoria's Institute for Technological Innovation (ITI) to undertake an investigation for the Network for the Coordination and Advancement of Sub-Saharan Africa-European Union (EU) Science and Technology Cooperation (CAAST-Net), funded by the EU.

This project entailed a bibliometric analysis of co-publications between Africa and Europe in the field of climate change to inform relevant policy by revealing trends in bi-regional research collaborations and the publication of research. The goal statement of CAAST-Net was to contribute to an increase in the quality and quantity of bi-regional cooperation in science and technology between Europe and Africa, targeting areas of mutual interest and benefit through the greater use of instruments under the EU's Seventh Framework Programme (FP7) for research and technological development, as well as through other instruments of international cooperation, and by lobbying for greater synergy between research and development instruments.

Climate change is one of the top priorities in the bi-regional cooperation between Africa and the EU. The Joint Africa-EU Strategy acknowledges that the significance of climate change lies in its global interconnection and impacts on water resources and food security. Environmental degradation and climate change undermine sustainable development and represent threats to the achievement of the Millennium Development Goals (MDGs). The issue of climate change is also of particular importance for the European partners.

The EU decided that at least 20% of its budget for 2014 to 2020 – as much as €180 billion − should be spent on climate change-related actions. To achieve this increase, mitigation and adaptation actions will be integrated into all major EU spending programmes.

The results and recommendations of the current investigation are based on an in-depth literature review and a set of bibliometric analyses. The bibliometric analyses utilise the Web of Science and are based on an information retrieval approach that emphasises precision.

The review related to research collaboration recognised that international collaboration is an international phenomenon fuelled by a multitude of factors such as access to facilities and funds. A number of authors suggest that international collaboration is replacing other models as the preferred method of building scientific capacity in developing countries.

Collaborative research, as it is manifested in co-authored articles, including those by African authors, has increased substantially since 2003. While it takes place in particular disciplines, it neglects the scientific and technological disciplines that underpin modern economies, such as engineering, which are emphasised in other countries, such as China. The literature also identified that there is limited collaboration with African researchers and that individual African countries exhibit substantially higher collaboration patterns than the rest of the world.

Apart from international forces, such as globalisation, which lead to collaborative research, the availability of resources appears to lead collaboration in Africa. Local historical and cultural characteristics are further superimposed on this phenomenon. The literature related to climate change identifies a weak link between research and the implementation and efforts to influence policy making; and that potential African partners in bi-regional consortia are financially constrained and in need of seed

funding before they can take part in projects (from project design to the submission of proposals). The lack of seed funding may contribute to the finding that specific local factors are not sufficiently accounted for in the generation and implementation of climate change knowledge.

The bibliometric analyses revealed the following:

- Climate change research in Africa and in collaboration with Europe increased substantially between 1993 and 2015, albeit from a very small base. The estimated increases were substantially higher than the growth of African articles (articles with African researchers from all disciplines) during the period. An estimation of the ratio of climate change research to total research shows that Africa's ratio is three times as high as that of China, India and Brazil, indicating a sensitivity of continental priorities to international collaboration. During 2015, the activity index of climate change research in Africa was 1.5. This means that Africa was undertaking 1.5 times more research related to climate change than was expected by the continent's total research outputs. The EU's activity index was 1.3.
- Some 46% of the climate change research in Africa is produced in collaboration with Europe. The Africa-EU collaboration (all disciplines) contributes 30% of the total research output of the African continent. The analysis supported evidence from the literature that international research support is critical for Africa. African researchers who collaborate with European researchers also publish articles without their European partners.
- The EU's Sixth and Seventh Framework programmes had a substantial impact on the number of co-authored articles on climate change. The estimated impact was substantially bigger than the growth of African climate change articles (without European participation) and the growth of all African articles (all disciplines).

Climate change is one of the top priorities in the bi-regional cooperation between Africa and the EU. The significance of climate change lies in its global interconnection and impacts on water resources and food security.

- Climate change articles with EU collaboration performed almost twice as well in terms of citations per article and citations without self-citations than those without EU collaborators. Similarly, the H-Index of the collaborative articles is higher than the index of those without EU collaborators.
- The identification of the funders in articles co-authored by African and EU authors shows that the EU was the most often mentioned funder. It was mentioned in 158 articles. The South African National Research Foundation (NRF) was the second-most often mentioned funder (mentioned 73 times). Other funders mentioned were the American National Science Foundation, the Leverhulme Trust and Wellcome Trust.

The report made the following recommendations:

- CAAST-Net and CAAST-Net Plus, supported by the Framework programmes, appear to have been successful in encouraging more and better bi-regional science, technology and innovation (STI) cooperation for enhanced outcomes related to climate change. The success is particularly important as Africa had limited, if any, expertise in the field in the 1990s. It is suggested that similar approaches can be utilised to develop research capacity and cooperation in other fields of common interest and priority.
- The collaborative patterns in a variety of African countries reveal dependency of the local research systems on international resources. Furthermore, the high degree of current collaboration indicates that there might be limited scope for additional expansion. African governments, multilateral organisations and their international partners should focus on developing research capacity. Providing funding rewards for research publications has proven to be effective in South Africa and can be used across the continent.
- The small scientific size of Africa and of African countries makes the issue of research priorities of critical importance. Prioritisation is required across the broad main domains and within each domain. The field of foresight has been identified to be useful in that domain. National and regional exercises can introduce the concept to the relevant authorities. Such exercises could also guide the European Commission in enhancing its collaborative efforts with Africa.
- The small size of research systems, lack of funds for co-financing and dependence on international resources are manifestations of the refusal or neglect of African governments to accept that innovation is the fundamental cornerstone of economic growth, employment, international competitiveness and development. African governments, multilateral organisations and their international partners should aim to institutionalise the governance and support of STI.

Using CFD modelling as a tool for small-scale hydropower development

Chantel Niebuhr, Marco van Dijk and Christiaan de Wet

Water engineering research mostly involves physical models: building large, heavy, labour-intensive tests with lifting equipment and expensive testing equipment. This is generally in an endeavour to form a picture of the complex flow behaviour needed to analyse the research objectives. However, as we enter the Fourth Industrial Revolution, we find ourselves working increasingly in a digital world, where the use of simplistic virtual testing environments is reaching incredible accuracy.

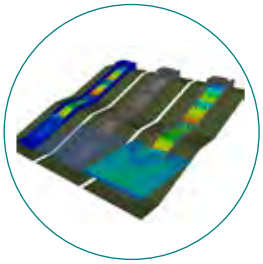
Developments in software-based modelling and machine learning allow the simulation of what may be referred to as a "digital twin" (Siemens PLM, 2019). This analogy is described as a virtual representation of a product or process, allowing the clear visualisation and prediction of performance or behavioural characteristics.

By incorporating physics relationships, these digital twins demonstrate real-life representations of environmental conditions. An example of such a process is the use of computational fluid dynamics (CFD) modelling. Although CFD modelling has been used since the early 1930s, the technology and evolution of CFD software is increasing exponentially. As advances occur in the understanding of flow field physics, more complex relationships are being incorporated into the fluid flow prediction analysis method based on Navier-Stokes equations.

Recent model validations prove that carefully built and solved models may portray close-to-exact environmental conditions of fluid flows in complex environments. Although CFD has long been used as a tool in aerospace modelling, the cost and hardware requirements did not previously validate use in open channel water flow fields. However, the overall cost of computing is decreasing as readily available computers become more and more powerful. Thus, numerical analysis in water flows is becoming a more feasible and attractive option in complex water flow field research.

Recently, the Hydro Research Group in the University's Department of Civil Engineering found a use for this powerful software within small-scale hydropower systems, specifically hydrokinetic (HK) systems. With the global focus on the Sustainable Development Goals (SDGs), and increasing renewable energy resources, the research team has been further developing and optimising small-scale HK energy systems.

Although HK renewable energy potential is – in itself – abundant in nature, it is lacking in maturity and does not reach the energy production potential of which it is capable. Ideally, a renewable source should have minimum environmental impact with maximum power output. Small-scale renewable technologies generally have lower environmental influence due to the partial extraction of the available energy.



Recent model validations prove that carefully built and solved models may portray close-to-exact environmental conditions of fluid flows in complex environments. The overall cost of computing is decreasing as readily available computers become more and more powerful.

For power supply near flowing water, micro-hydro systems, such as HK schemes, have – in many cases – been estimated to be the most economical and reliable generation option. However, the interaction of the micro-hydro scheme and the infrastructure itself are often overlooked and not well understood. This may lead to HK schemes influencing the supply of water (which is the primary purpose of conveyance infrastructure) and degrading the cross-sectional properties due to turbulence.

The HK schemes may be simply defined as a wind turbine placed under water. The energy source makes use of the kinetic energy in flowing water rather than the more traditionally used potential energy. Developing this source of energy will open a window to what was previously considered to be low potential sites, where turbines may be placed at any site at which cross-sectional and flow-velocity requirements are met.

After the Hydro Research Group had installed the first HK scheme in South Africa in the form of a set of devices in the Boegoeberg irrigation canal, two important factors were found to be crucial to the efficient functioning of these installations. The first was the downstream wake length and disturbance intensity produced by the placement of the HK device. The second was the blockage and thus upstream damming caused by placing the device in a subcritical flow environment. Although the worst-case scenario of complete turbine blockage can be simply modelled, the day-to-day functioning and thus permanent damming effect it might have may affect the functioning of the infrastructure in which it is placed. Due to the relatively flat slopes and long lengths of these canal systems, damming may occur kilometres upstream. Aspects such as the available freeboard and operation of spillways along the route therefore need to be predicted. This behaviour is not easy to understand and model in simplified backwater calculations due to the complex rotational flow disturbance.

Hydrokinetic application

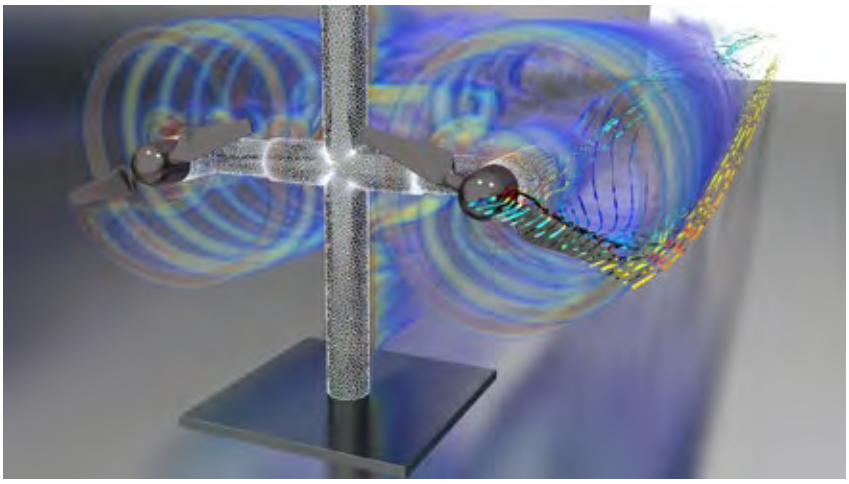


Figure 1: Reference Model 1 HK turbine modelled as a reference study in the Siemens Simcenter ATAR-CCM+ at UP.

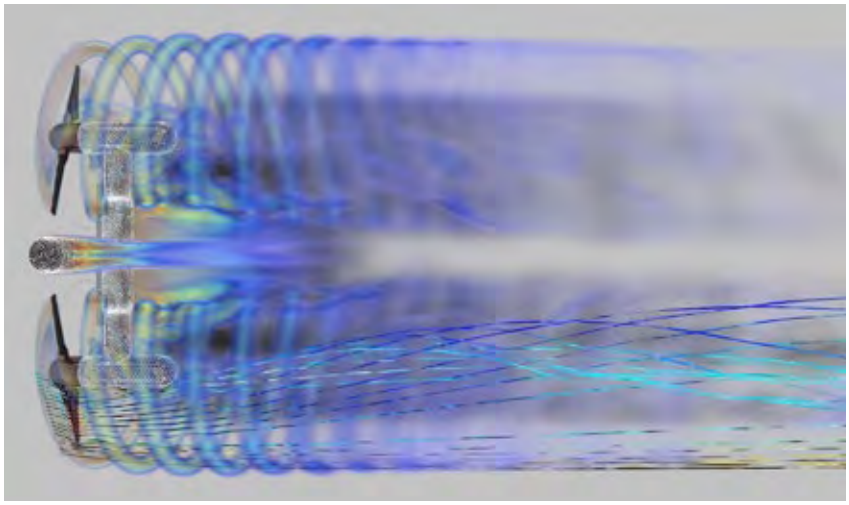


Figure 2: Reference Model 1 turbine wake analysis.

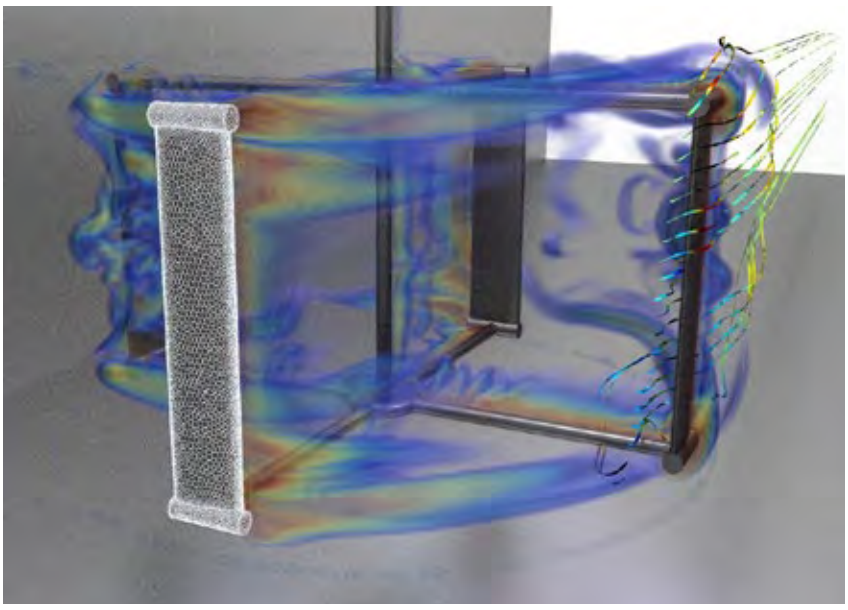


Figure 3: The CFD digital twin for the darrieus-type turbine developed by UP for canal installation.

Figure 4: Showcasing other applications of water engineering applications modelled in the Siemens Simcenter STAR-CCM+.

To allow prediction of the wake and damming behaviour, the flow was analysed using a full-scale model. However, site testing provided limited insight, thus CFD modelling was incorporated. By model validation with the available site data, the CFD model provided a broader picture of the complex flow environment, allowing in-depth analysis of the influences of these systems within a cross-sectional area. The accuracies of these models are in many cases overlooked. However, model validation provides a basis for comparison and ensures the correct use of the software. Once the model has been validated, flow and input scenarios may be varied to provide an indication of what may be anticipated in the flow fields, additional to details about the turbulence effects, damming, wall influence or erosion.

The analysis of the flow behaviour opens doors to optimal design with a full system understanding.

Although CFD software may be misunderstood as a simplified "black box"-type software tool, it is not. Training in and the study of flow behaviour and the physics models used is needed, together with a deep understanding of turbulence models.

The future of CFD in water engineering research fields

Integrating CFD modelling into future research gives researchers in UP's Water Engineering Division – who have recently started incorporating this modelling method into active projects – a feel of the validity and accuracy of these models when comparing them to the laboratory or full-scale models used in testing. This opens doors to incorporate the "digital twin" and provide a digital version of the investigated process or system with visualisation of flow and a deeper understanding of the behaviour around the design.

Becoming comfortable with a simulation environment, and most importantly understanding its limitations, will allow maximum exploitation of this incredibly powerful tool. It allows researchers to apply it where possible to save time, avoid unnecessary and expensive laboratory or site tests, and gain a deeper understanding to prevent the many misconceptions that occur in the very complex water flow testing environment.

Although these models are extremely complex and may require large domain sizes – and thus long solving times – UP has incredible resources for this, given that the Department of Civil Engineering recently obtained its own full-version Siemens Simcenter STAR-CCM+ licences. The Department also receives incredible support from Aerotherm Computational Dynamics (Pty) Ltd, which provides assistance and training in the use of the software. Furthermore, the Centre for High Performance Computing (CHPC) allows UP the generous use of its Lengau Cluster, allowing solving possibilities of up to 2 400 cores. This gives UP's Water Engineering Division a huge advantage to become a leader in CFD modelling-based research in a civil engineering context.

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Modelling cave mining in the geotechnical centrifuge

Prof SW Jacobsz

Cave mining involves the controlled undermining of ore bodies in deep mines by drilling and blasting, allowing the rock mass to fracture under its own weight. Once a sufficiently large area has been undermined, continuous caving initiates and propagates throughout the ore body. As fractured material is removed, a zone of influence propagates upwards through the rock mass.

Block cave mining is an efficient mining method as no overburden needs to be removed and material can be selectively mined, thus limiting the volume of material to be processed. Once caving is initiated, the need for blasting is minimal. The shape and size of the cave that forms is dependent on the size of the void formed under the ore body, the composition of the ore body and the strength of the abutment zone formed around the caving area. Due to the lack of access inside the caving rock mass, direct observation of the cave propagation process is not possible.

It is generally assumed that the damage ahead of the cave back in block cave mines decreases with increasing distance from the cave back, and caving takes place as a result of slip along pre-existing discontinuities. This model, proposed by Duplancic (2001), has been generally accepted within the mining industry, but has not been rigorously scrutinised and verified. The model describes the zone of influence affected by cave mining, which is divided into a number of sub-zones, depending on the process governing rock behaviour in each particular zone. The respective zones are illustrated in Figure 1.

The first zone is the caved zone: a zone of caved material that has fallen from the cave back, providing some support to the walls. The second zone comprises an air gap between the cave back and the caved zone. The next zone is a zone of loosening, comprising loose rock not supporting the overlying rock mass, which represents a zone where disintegration occurs. The fourth zone is referred to as the seismogenic zone, a stressed front ahead of the cave back where seismic fracture of the rock mass occurs by means of slip via pre-existing discontinuities. The final zone is a pseudo-continuous domain: the rock mass ahead of the seismogenic zone where only elastic deformations occur.

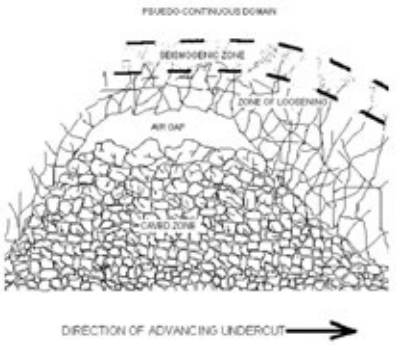

Figure 1: Conceptual model for cave mining by Duplancic (2001).

A few researchers have attempted physical model studies to understand draw control, i.e. how the removal of fractured material from the base of the caved zone affects movement within the fractured rock mass. The authors are aware of only one study examining the process of cave propagation itself, i.e. McNearny and Abel (1993), who used a two-dimensional model of layers of bricks to examine the effect of drawpoint spacing on cave propagation. There were, however, certain shortcomings associated with this model, such as the absence of a realistic horizontal stress field and a joint pattern dictated by the brick geometry, which was not necessarily representative of an actual rock mass.

During cave mining, cave propagation is generally monitored by means of acoustic detection and modelling, and is analysed using numerical methods. However, due to the mining process being hidden below the ground, opportunities that allow for models to be calibrated are rare. Due to complexities modelling fracture processes theoretically, physical model studies are an attractive means to investigate this type of mining problem.

A physical model study of cave mining by Prof SW Jacobsz and Prof Elsabé Kearsley of the Department of Civil Engineering at the University of Pretoria, and Prof Johan Wesseloo of the Australian Centre for Geomechanics at the University of Western Australia in Perth, is underway to investigate factors affecting cave mining by means of physical modelling in UP's geotechnical centrifuge. The study is currently being funded by two Australian mining houses.

There are very few centrifuge model studies described in the literature that investigate mining problems. Prof Evert Hoek, then Head of the Rock Mechanics Division of the National Mechanical Engineering Research Institute at the South African Council for Scientific and Industrial Research (CSIR) during the early 1960s, designed and supervised the construction of a centrifuge with a diameter of 9 foot (2.74 m), capable of accelerating models weighing up to 100 lb (45.4 kg) to 1 000 g (1 000 times the earth's gravity, giving the centrifuge a capacity of 45 g-ton). The centrifuge was used to simulate gravitational force fields in mine models.

Prof Hoek's models generally involved photo-elastic materials that were "stress frozen" at high acceleration by means of heating elements so that the models could be studied after the tests (Hoek, 1965). Hoek demonstrated the need to simulate gravitational body forces when investigating the stress and fracture of a rock mass around mine excavations. Although the equipment Hoek used at the CSIR has been obsolete for decades, the scaling laws he published provide a starting point for the development of scaling law refinement to study cave propagation in the centrifuge.

The first phase of the study comprised the design of a centrifuge model that allowed the controlled removal of support from an artificial rock mass to allow fracturing and the observation of the caving process. To allow visual observation of the caving process, a purpose-built two-dimensional model frame was constructed from aluminium. The test frame is illustrated in Figure 2.

The cave mining process was modelled using a bank of 5 x 50 mm wide trapdoors next to each other, supporting a model rock mass (caving medium). The trapdoors were mounted on pistons that could be individually retracted to lower the trapdoors and remove support from the caving medium by releasing fluid via solenoid valves. The rate of settlement was limited by using a flow restrictor set to the desired flow rate. The model also included a glass window to allow the caving process to be observed to enable image analysis.

A sample space 500 mm high, 450 mm wide and 50 mm deep was developed to allow plane-strain modelling of the mining process. Fluid-filled rubber bladders on the sides of the model rock mass were used to apply the desired horizontal stress by varying the density of the fluid used. A standpipe, in which a constant fluid level is maintained, allows further control of the horizontal pressure exerted by the fluid-filled bladders. Weights placed on top of the caving medium were used to provide additional overburden stress if required. Substantial improvements have subsequently been made to the model by significantly stiffening the frame, by using thicker glass and by replacing the pistons controlling the support of the model rock mass by electric actuators.

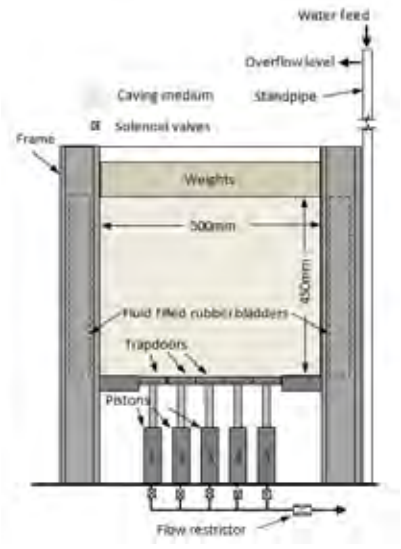

Figure 2: Centrifuge model developed to study cave mining in the geotechnical centrifuge.

Researchers in the Department of Civil Engineering are undertaking a physical model study to investigate factors affecting cave mining using the University's geotechnical centrifuge.

Prof Hoek recommended the use of accelerations as high as practically possible to study mining problems in a centrifuge in order to replicate the high stresses present in deep mines. In South Africa, the deepest mines have now advanced to depths in excess of 4 km, implying rock stresses well above 100 MPa. Even with the use of powerful centrifuges, these stresses are not practically achievable in model studies. It was therefore necessary to develop a material that could be used to model caving at accelerations that could be achieved in the centrifuge. Due to constraints imposed by the monitoring equipment – predominantly the cameras – the model study is carried out at 80 g.

Initially, a cementitious material comprising sand, fly ash, cement and water was developed to provide a material that would cave in a brittle fashion under its own weight at the test acceleration. This material was not sufficiently brittle and its properties changed significantly over time as the cement in the material continued to undergo hydration. The material was subsequently replaced by a mixture of kaolin, fly ash and water cast in moulds 500 x 450 x 50 mm deep to produce flat slabs suitable for testing. This material is also much more brittle, better resembling the properties of actual rock.

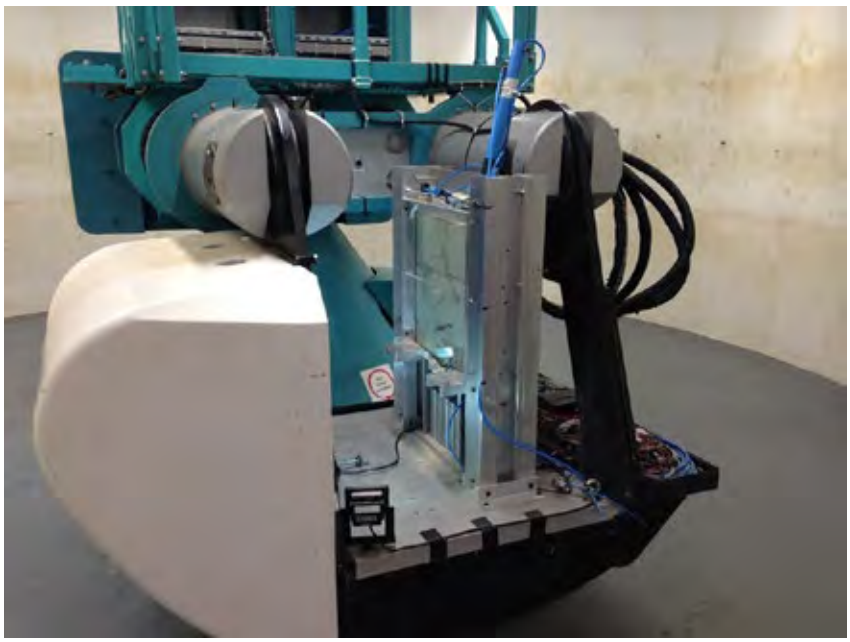

Figure 3: The physical model on the geotechnical centrifuge after a test.

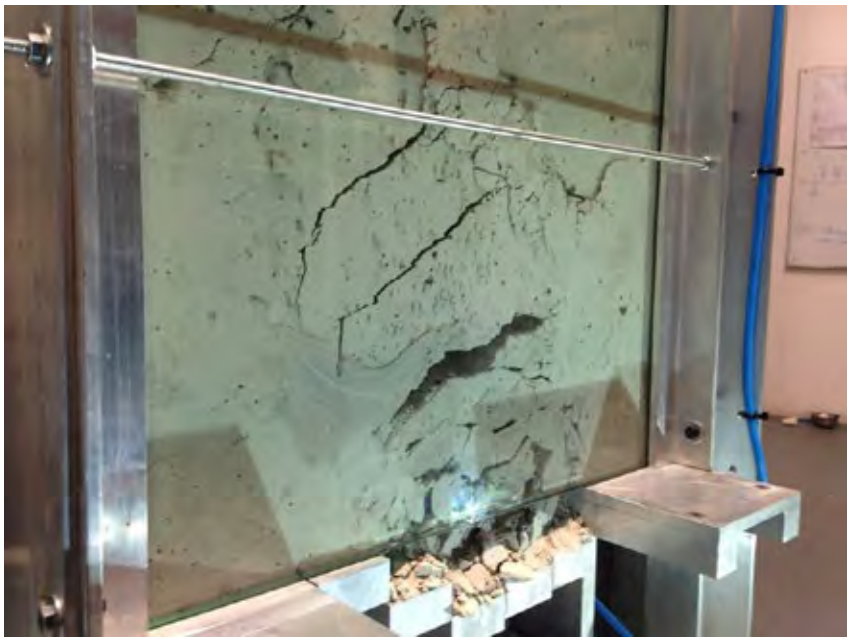

Figure 4: The fractured artificial rock mass after a caving test at 80 g.

Prior to each test, a caving medium panel was placed in the model frame and the glass window was bolted into position. The model on the centrifuge is shown in Figure 3. The rubber bladders were filled with water and the standpipe was filled to the overflow level, which was set to exert the desired horizontal stress. The standpipe water level was maintained at the overflow level for the entire test duration by continuously adding water and allowing the excess to spill.

Once the test acceleration of 80 g was reached, the pistons supporting the trapdoors were retracted in approximately 1 mm increments in a special sequence to model progressive undermining of the caving medium. The process was monitored by taking photographs every six seconds using a high-quality DSLR camera and a webcam. A high-speed camera capable of recording approximately 180 frames per second was added. The fractured artificial rock mass shortly after a test is shown in Figure 4.

Results from the first phases of the study challenged some of the concepts proposed by the widely used Duplancic model referred to above, suggesting that extensional failure is an important mechanism, which plays a role in the caving process in the presence of elevated horizontal stresses. The presence of substantial and widely spaced near-horizontal cracking in Figure 4 is indicative of this mechanism. The team was awarded the Gold Medal of the Southern African Institute for Mining and Metallurgy (SAIMM) for this work.

The work is currently being expanded to study the effects of the caving zone advancing into a previous cave rock mass above the area currently being mined. Work is also in progress to implement acoustic emission detection in the centrifuge model to observe acoustic signals generated by the curing fracturing of the rock mass. This requires the impressive logging capabilities of the centrifuge data acquisition system to be well utilised, which includes recording 14 channels of acoustic sensors each at 200 kHz and high-speed photography recording 160 frames per second. Two high-end solid-state computers mounted on the centrifuge and controlled through its fibre optic network are used for this purpose.

This project is a good example of how physical modelling at elevated stresses in the geotechnical centrifuge not only finds application in geotechnical or civil engineering, but also stimulates research in mining engineering applications. It is believed that the availability of this unique facility will continue to enable state-of-the-art research to be conducted in the Department of Civil Engineering, and will attract further international research collaboration.

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Determining safe clearance distances during mine blasting operations

Jennifer van der Walt and Prof William Spiteri

During blasting operations on surface mines, the rock that is ejected from the blast is known as flyrock, and is often categorised as normal flyrock (the expected movement of the material) and wild flyrock (rock fragments projected beyond an acceptable perimeter). Historically, flyrock has caused injury to people and damaged property. The consequences can result in significant financial and reputational penalties.

Determining safe blast clearance radii for blasting operations is a topic of particular concern for a number of collieries in and around the Emalahleni area of Mpumalanga. The senior management of some of these mines approached researchers at the AEL Mining Services Chair for Innovative Rock Breaking in the University's Department of Mining Engineering in 2017 to review the existing clearance distances implemented. Since no specific legislation is in place as a guideline, if the mine's management cannot validate the clearance distance implemented, the mines risk legal prosecution in the case of a flyrock incident.

The main objective of the investigation in 2017 was to review the current clearance distances and make recommendations following a literature review and field investigation. The available literature reviewed during the study yielded significant evidence that insufficient practical scientific work had been conducted on flyrock and that the overall concept was rarely fully understood. One main concern was that there were significant gaps between the theoretical causative factors of flyrock and the factors considered in predictive models.

In the literature study, the causative factors of flyrock that were identified were the geology of the rock mass and surrounding area and blast design parameters, namely the burden, stemming length and material, the amount of explosives charged per hole, blast design layout or pattern and the timing sequence. The existing empirical models for flyrock prediction that were identified mostly depended on the depth of burial of the explosive charge, which only considers one of the three mechanisms of flyrock.

Therefore, after comparing the causative factors to the factors of the predictive models, an obvious disconnect was observed, resulting in the conclusion that additional research and investigation was necessary.

The field investigation and gap analysis that was conducted yielded evidence that blast parameters were not always designed according to accepted rules-of-thumb. This could potentially result in flyrock, but the risk cannot be quantified since the exact influence of these deviations is unknown. Stemming was identified as the most significant parameter that is often manipulated in blast designs. A lack of confinement of the explosive charge will significantly influence the risk of flyrock. Blasters should, therefore, adjust the calculated clearance distance.

Methods of reducing and managing flyrock have yielded mixed and inconclusive results. The main reason is that flyrock is dependent on a vast number of elements, which make the phenomenon quite random. Flyrock, therefore, remains a significant side effect of surface blasting practices, even with recent research and prediction efforts.

To improve on existing prediction models, a method of quantifying the trajectory of (random) flyrock, other than the inadequate traditional physical observation of the final resting place of rocks, had to be developed. This would entail finding a way to accurately measure and record the flight path of flyrock during a blast in order to gain a sufficient sample size or data set to make additional and more reliable recommendations to the mine. If the trajectory of flyrock can be quantified, it would be possible to determine the final landing point of the flyrock and

Figure 1: An example of the images taken during the initial concept tests, proving that a projectile can be captured and positional measurements taken.

its origin from the blast design. This would allow investigators to study the influence of specific environmental and blast design parameters on the overall risk of flyrock.

Following additional research and consultations with experts in various technological fields, it was decided that photogrammetry would be the approach that presented the highest probability of success. Therefore, the implementation of photogrammetric methods to capture the position of flyrock fragments in their flight path were pursued.

High-resolution cameras, that are commercially available, were used in the initial tests to capture the position of a projectile per unit of time as it moves across the field of view of the camera's lens. Typically, photogrammetry is implemented in one of two ways. The first method is a single camera system that is moved around the target, taking sufficient overlapping images to recreate the object or scene in a three-dimensional space. The second method is using a multi-camera system that surrounds a moving object or person.

For the purpose of this investigation, a compromise was required. Since the conditions on a mine site are far from the ideal conditions in a studio environment, fewer cameras are used to simplify the system.

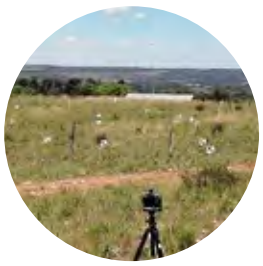
However, a single camera system is also not possible since the target objects of interest are moving in a random way. Therefore, it was determined that at least three cameras should be used, with the respective fields of view parallel to one another, creating the overlap of the images based on the angle of view of the lenses.

Proof of concept tests using a clay pigeon catapult in a controlled environment formed an essential component of the research and proved the concept's success. Promising results were obtained. Existing stereo-mapping software was used to confirm that the position of a projectile could be measured.

An essential part of the research was to investigate and solve the key elements of the system. These key elements are the timing of the images and synchronisation between cameras to achieve a multi-camera view of the exact position of each fragment at a specific point in time.

The other challenge was triggering the cameras from a distance, since the operator must be positioned at a safe distance from the blast, generally at least 500 m.

Further research indicated that the mathematical analysis of the data



Proof of concept tests using a clay pigeon catapult in a controlled environment formed an essential component of the research. Existing stereo-mapping software was used to confirm that the position of a projectile could be measured.

using projectile physics or ballistics principles and differential equations was possible. This was proven by an independent research team from Serbia in 2011 to 2015.

The next phase of the project was to test this concept on a relatively small mine site (quarry) and to apply the entire process in realistic field conditions to identify new bottlenecks and challenges in the system.

The first small-scale test was conducted on an aggregate quarry between Pretoria and Johannesburg. Some of the resulting images are shown in Figure 2. The analysis and interpretation of these images are still in progress.

Figure 2: Small-scale field test image data. Images taken at 0.17 second (or 170 millisecond) intervals.

Assembled and reassembled public spaces in South Africa

Prof Karina Landman

South African cities are rapidly changing to accommodate many new inhabitants from rural areas and the rest of Africa, as well as new preferences of old and new residents. On a micro scale, public spaces are both the container and reflector of these fluctuations. Consequently, public spaces in South Africa are constantly being remade to accommodate and represent these changes. Understanding the assemblage of public space not only offers insight into current urban practices, but also provides guidance to built environment professionals on the value of these spaces and the needs of their users.

Assemblage thinking is concerned with the making and remaking of various objects in the city; in other words, the process of assembly that happens in various places and moments across the city as a result of interactions between human and non-human components (McFarlane, 2011). It therefore allows us to unpack the current nature of these objects (public spaces in this case) through an understanding of the entire assembly line, for example, why public space is changing, how it is modified and the impact and implications of these transitions. This article focuses on how the spaces are changing; in other words, the spatial manifestation of the production and reproduction of public space in the country.

Research in the Department of Town and Regional Planning has indicated that public spaces are assembled and reassembled in four different ways: through privatisation, celebration, revitalisation and informalisation. Privatisation refers to the partial or complete privatisation of open space through pseudo-public spaces linked to shopping centres or common open spaces in gated communities. Through gates and/or strict security measures, use is selective and restrictive, and behaviour is carefully controlled. Yet, the spaces are well maintained and often reflect many characteristics of well-performing public spaces.

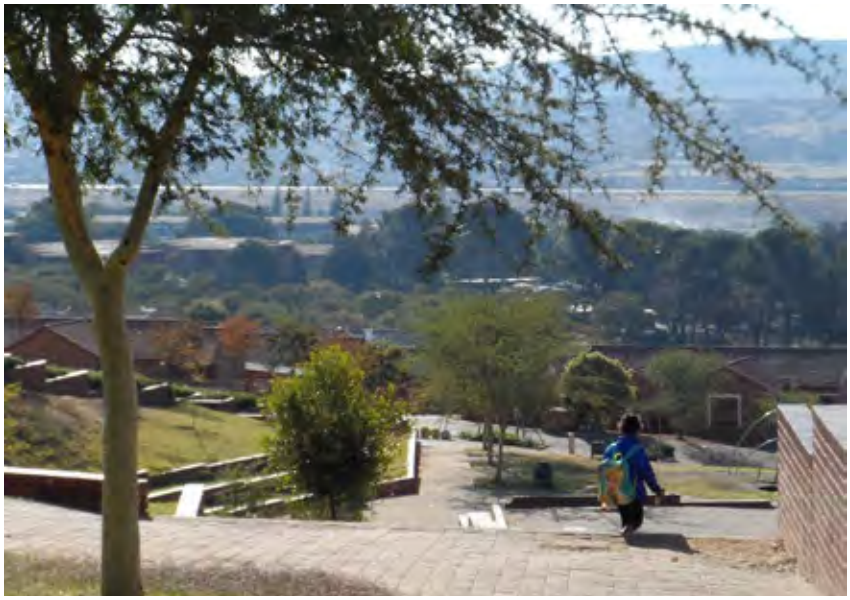
For example, Irene Mall offers an inviting environment based on a typical village setting with restaurants lining the central square, benches and trees flanking the water fountain and sculptures, which add to the identity of the space. Similarly, the clubhouse and sports facilities, including the magnificent golf course, as well as many smaller play areas in Silver Lakes Estate, offer residents a plethora of well-developed common open spaces within a safe and well-maintained environment.

The second trend, celebration, is connected to the creation of new historically or ideologically significant spaces linked to the acknowledgment of important historical figures or places, for example, Lilian Ngoyi Square and Solomon Mahlangu Square in Pretoria, Gandhi Square in Johannesburg and Vuyisle Square in Port Elizabeth. While Lilian Ngoyi Square was reconceptualised to celebrate the 1956 Women's March to the Union Buildings against pass laws, Vuyisle Square was reassembled to commemorate Vuyisle Mini – an anti-apartheid activist killed by the apartheid government. This trend, however, also reflects the celebration of community life and open access to the new South African public, for example in Jan Cilliers Park (Pretoria), Bulwer Park (Durban) and Green Point Park (Cape Town).

Thirdly, many post-apartheid spaces are reassembled through revitalisation. In many cities, a deliberate attempt has been made to improve conditions in the inner cities and the former marginalised areas through the revitalisation of public space. Examples are Church Square (Pretoria), Freedom Square (Pietermaritzburg), Market Square (Mahikeng), Harbour Park (Durban) and Joubert Park (Johannesburg), which are all linked to inner-city upgrading, as well as Kalafong Fitness Park (Pretoria), Tokoza Park (Johannesburg) and Mdantsane N2 Park (Buffalo City Municipality) in former township areas. Kalefong Fitness Park, located in Atteridgeville, is a great example of how a well-designed space that makes provision for a range of activities through beautiful gardens, an amphitheatre, an outdoor gym and a play area for children can significantly enhance the

The central space in Irene Village Mall.

The recently redeveloped Lilian Ngoyi Square with the Woman's Museum in the background.



The Kalafong Fitness Park, with stairs leading down the slope and a view of the city in the background.

quality of life of its users and those residing around the space.

However, despite many good efforts, poverty and unemployment remain a huge challenge that contributes to the growing number of informal settlements in many cities and towns. Consequently, gathering spaces have emerged in many of these settlements to accommodate the needs of their residents, reflecting the informalisation of public space. Examples include the Gomora Market, the Soshanguwe Ext 13 Market, the Iterileng Market and the Pomelong trading space. In addition, trends of informalisation are evident in the more traditional public spaces with the growth of informal traders frequenting these spaces.

Public spaces are part of a continuous process of change related to need, order, form, function, meaning and response, which in turn creates new needs. The entire story of transformation can be read in a book that has just been published by Routledge, entitled *Evolving public space in South Africa: towards regenerative spaces in the post-apartheid city.*

Suffice it to say that the lessons learned from the research not only highlight the important role that built environment practitioners can play in the conceptualisation and actualisation of well-performing public spaces in South Africa, but also how essential it is to take cognisance of the real needs of those who are using or not using public space in our cities.

The form and function of public spaces are constantly being produced and reproduced, while at the same time they are being interrogated, appropriated and revisioned, influencing the parts that are assembled and reassembled on the assembly line of constantly changing cities.

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Spatial Revolution 4.0: A vehicle towards the realisation of spatial justice in contemporary African cities

Kundani Makakavhule and Danielle Hill

African cities are framed by multi-layered transformations. As a result, urbanisation within the continent is happening at an increasingly rapid rate, from a population of 395 million in 2010 to a predicted 1.339 billion in 2050. This will signify a tripling of the population over 40 years.

Africa is currently characterised by unique colonial histories, socio-economic landscapes and, in some cases, volatile political dynamics. Africa's history has depicted a disparate emphasis on the spatial, social, economic and geographical aspects of justice. These disparate attempts vary in intensity per country and per megacity.

The most influential megacities in Africa resemble complex diversities and pluralities in their histories, as influenced by the French and Belgians in Kinshasa, the administrations of the British in Johannesburg-Pretoria, Nairobi, Lagos and Accra, and the Portuguese, Omani Arabs and German influences in Dar es Salaam. These complexities result in realities that have been seen as "problematic" and need "fixing" as planners seek to conform to Eurocentric replications of plans and practices to reconcile past, present and future injustices that are embedded between space and society.

African planners are challenged first by how they perceive African realities; second, by how they apply planning knowledge and solutions to their African context in pursuit of spatial justice, and third by how they are able to situate or locate African realities in planning theory and practice. As such, one may begin to think of the conversations around the subjectivity of planning knowledge, notions of spatial justice in different African megacities, and how different encounters or experiences in history may have shaped the production of knowledge and moral virtues within these cities; moreover, how planners have been able to read situated differences within African megacities.

Africa's unfolding urban growth is characterised by the "self-constructed city" or slums, increase in migration, rapid transformation, political unrest, corrupt management systems, gender inequality, violence, bureaucratic inefficiency, structural and spatial disorder, and xenophobia. Planning practice has sought to address these symptomatic "stubborn realities" that are perpetuated by spatial injustices. Even though there has been a southern turn in planning literature, the ambition to solve problems is deeply embedded in concepts, models and approaches of spatial justice from the global north, which still persists in the planning practice and curriculum today. The deep difference experienced within African contexts is demanding and taxing as structural processes do not equal the rapid speed of urban growth and transformation. Moreover, the need for the planning profession's ability to adapt to evolving diverse African contexts is imperative in moving forward.

African planners are challenged with how they perceive African realities, how they apply planning knowledge and solutions to their African context in pursuit of spatial justice, and how they are able to situate or locate African realities in planning theory and practice.

An informal settlement in Asazani, Mossel Bay. (Photo: Danielle Hill, 2019)

In South Africa, in particular, the concept of spatial justice has evolved from notions of equality and struggle against racial division to more plural and contested definitions that encompass elements of economic and social impartiality. Due to this plurality in views of spatial justice, we find ourselves in an era in which spatial justice is pursued in different ways and by different actors.

In post-apartheid South Africa, the pursuit of spatial justice by urban planners focused on spatial reconstructions and infrastructural interventions – and more recently technological interventions. The abovementioned reiterates the emphasis on fixing the "problem", whereas the new research focus on Spatial Revolution 4.0 in the Department of Town and Regional Planning involves the move towards a more holistic approach that encapsulates the socio-economic and political understanding of cities and their dynamics.

Despite the challenging relationship between planning practice and urban growth, understanding planning practice is rooted in how planners are trained to "think about what they think".

A departure from traditional approaches to planners' education and training is required to come to grips with functional, structural and spatial conditions within Africa. Planning education often makes the mistake of generalising the African context, without being cognisant of work done by African scholars. This, in turn, replicates "northern" visions of the south, which translates into an incongruent relationship between spatial plans and African realities. Moreover, this disjuncture deepens the gap between African planners and planning interventions, particularly in planning knowledge and education. The role of civil society is growing in its importance and relevance in planning practice. Planning knowledge needs to evolve in spatial imagination and provide

The concept of spatial justice has evolved from notions of equality and struggle against racial division to definitions that encompass elements of economic and social impartiality. In post-apartheid South Africa, the pursuit of spatial justice focused on spatial reconstructions and infrastructural interventions – and more recently technological interventions.

Social housing protest in Kwanonkaba, Mossel Bay. (Photo: Danielle Hill, 2019)

the necessary tools for planners to negotiate and better understand differentiated space, situated differences, various actors and lived realities that encompass the planning process and the realisation of spatial justice.

The concept of spatial justice plays an integral role in an effort to navigate the pathology of change in how we address the African context, more crucially in the era of the Fourth Industrial Revolution (4IR).

The 18th and 19th centuries saw the beginning of the contestation regarding the concept of justice, which resulted in the formation of other forms of justice and different interpretations. This is witnessed in the emergence of other kinds of "justice" (redistributive, distributive and restitution) that have been conceptualised as a response to emerging societal needs and context. Subsequently, Africa needs its own interpretation of the concept of spatial justice that is not tainted by construed notions of power, capital and politics. Cities are fluid, in constant revolution and transformation. Therefore, new knowledge should be developed by redefining traditional concepts, while simultaneously forming new concepts that address existing and newly discovered societal issues and dilemmas.

The increasing advancement of network, digital information and communication technologies, smart buildings, smart transportation and mobility in the global arena and its filtration into the African landscape brings about intended and unintended consequences that may suggest an opportunity to rethink the relationship between technologies and cities, i.e. how do we think about technology, data and its fair access and distribution, and distance. As a result, the definition of spatial justice needs to evolve with the changing times and will require constant (re)alignment with society's understanding and context.

The Department of Town and Regional Planning seeks to address these controversies through the adoption of a new research focus, Spatial Revolution 4.0, which is geared towards producing credible knowledge that will assist those in the built environment who are involved in and seeking to "create just spaces that can enable and elicit viable, life-enhancing and sustainable responses in urban and rural settlements". The 4IR and the challenges it will bring amid existing challenges will require a revolution in how planners produce and use knowledge in accordance with the multiple ways of knowing and sense-making.

There is a need to investigate ways in which urban spatial planners can use the Spatial Revolution 4.0 to activate the stimulation, realisation and response to the concept of spatial justice. The proposition is that African cities are not merely spaces of disruption, illegality and hopelessness. Alternatively, they are spaces of economic opportunities, public participation, spirituality and political expression. Lastly, they are spaces that can be emancipated from homogenous autonomy.

The current contestations on the plurality of the concept of spatial justice and the actions by different actors in pursuit of this ideal provide an exciting opportunity to explore the role that the Spatial Revolution 4.0 can play in activating the concept of spatial justice, training future planners and ensuring a seamless embrace of the 4IR, while bringing about its realisation in progressive African cities.

How does consumer personality and architecture affect the retail trade?

Prof Hoffie Cruywagen

The world is entering a new era, with cities growing at a rapid pace as people flock to urban areas to improve their living conditions and socio-economic prosperity. In order to keep up with urbanisation and population growth, urban, town and regional planners, and architects need to change the way they develop cities.

Globalisation and the technological advancements of the Fourth Industrial Revolution (4IR) give developing countries the opportunity to catch up to or even leapfrog First World countries by learning from the mistakes that these countries have made with the use of modern technology. Even though there are major technological advances in the way cities are designed to keep evolving, some of the basic principles seem to remain the same. One thing that is apparent is that certain personality types experience specific buildings or environments in a certain way, while others might experience them differently.

How retail development evolved

Research that formed part of the MSc (Real Estate) study of Jaco Reynecke in the Department of Construction Economics revealed that retail has always been part of society. As society changes and evolves, the type and form of trading also changes. In the past 100 years, the development of retail destinations has gone through three major stages: mass consumption, market consumption and Mind16 consumption[1] (Heiberg, 2016). Each of these stages is influenced by four factors: world view, society, technology and consumption.

With the advent of globalisation, consumers are becoming more aware of world-class retail destinations. Developers have therefore had to start improving their offering as retail destinations are starting to be compared to the best retail developments in the world. This has brought about a diverse store mix, where improved technology has opened new doors in terms of personalised marketing. This gives consumers a choice of where and when they would like to shop.

Today, retailers do not only have to cater to a particular social group. They need to consider each individual when it comes to the products being sold and the way products are advertised. The challenge for developers, therefore, is that shopping centres also need to cater to the individual and not only to a certain group of people, as consumers now have a variety of retail destinations from which to choose

Retailers need to consider each individual when it comes to the products being sold and the way products are advertised. The challenge is that shopping centres also need to cater to the individual and not only to a certain group of people.

1 Mind16 consumption is based on the Myers Briggs personality types. It was developed to determine to what extent each personality type will feel more at home in a certain retail environment.

The Reteamgroup approach

With the change in the retail market, it became necessary to change the way architects look at retail developments. Reteamgroup, a company based in Denmark, subsequently developed three tools to help architects and developers design new retail destinations or refurbish existing ones. These tools are retail mapping, replace making and Mind16.

Retail mapping is a process where all the shops in a case study, as well as all the shops in five competing shopping centres, are rated according to 20 different categories. The respective stores are then not only compared to the same store on a national level (in the case of a national chain), but also with the competing stores surrounding it on a local level. Once this data has been captured, it is easy to compare each store with its surrounding competitors (Börden, 2017). This gives developers an idea of what stores to add to the store mix and which stores need to be removed. Store owners also know what improvements they need to make to compete better in the market (Lasse, 2017).

In the case of replace making, it is recognised that shoppers go to a retail destination for one of three reasons: to buy something specific; to meet someone in a safe environment and engage in a social activity; or to make purchases or conduct other business if they are on the move between work and home. It is important that a shopping destination should include these three aspects and give consumers the opportunity to do any of them (Börden, 2017).

The Mind16 tool was developed to determine how people of different personality types will feel more at home in a certain retail environment. Questionnaires of between 15 and 20 questions are distributed to determine the personality types of potential consumers in the area (Börden, 2017). Four personality types were identified: intellectual, emotional, practical and sensual. Each individual has a primary and a secondary personality. For example, one can primarily have an intellectual personality, but have sensual qualities as a secondary personality (Lasse, 2017).

Most architects and developers are intellectuals. Therefore, most shopping centres are developed for intellectual personality types. That is why most shopping centres seem to look the same and to be built with the same building material (steel and glass) (Lasse, 2017). Depending on the personality type of the consumers using a specific mall, the Mind16 test enables architects to improve shopping centres to such an extent that most of the people using them feel at home on a subconscious level (Lasse, 2017).

Once all the data has been collected, and the main personality types have been identified, architects can develop a public space that is unique to the consumers and the public living in that area.

→ *Two impressions of the same shopping centre: an intellectual design (left) and a practical design (right).*

Relevance to city development

City development has a much larger demographic footprint than the construction of a single shopping centre, and it is difficult to determine the most common personality type and what architectural language should be used for an entire city. However, as soon as a building or public space has been developed according to the architectural language of a certain personality type, that space tends to attract more people of that particular personality type.

Within a city district, it is important that different personality types do not clash with each other, but rather that there is a transition from one area to the next. Large-scale developments normally have one common theme, identified as a different mind or personality type, which can function as a common denominator throughout the city district. Different areas are identified according to the results of the interviews conducted to collect data for a particular area. Even though each area might have a different result in terms of the most common personality type in the area, the areas still have a sense of unity due to the theme of the city district.

→ *Site for Ezibeleni Mall. (Drone image, 2016)*

Ezibeleni as a case study

Ezibeleni is a small, vibrant town 10 km from Queenstown in the Eastern Cape. In 1974, the government declared it part of the Transkei, one of 10 fragmented homelands. Ezibeleni therefore developed as a segregated town with very little retail development. Nevertheless, the population has expanded and residential development has taken place over the last few years. Today, the town boasts 12 schools and the Ikhala Technical and Vocational Education and Training (TVET) College. The households are in the lower income category, receiving an average of between R3 500 and R7 499 per month. Ezibeleni is a community of approximately 7 700 households living in a relatively dense area. A large portion of the population is relatively young and attends schools and the TVET College. For basic shopping and business activities, most of the people commute to Queenstown.

The municipality is situated between Queenstown and Ezibeleni, and employs many of the people staying in the town. There are only spaza (informal) shops in Ezibeleni. All formal shopping centres and services are found in Queenstown. Houses vary from small shacks to large houses. People with established jobs tend to stay in the town.

The Ezibeleni Mall will change that situation. People in the town will have a modern mall with an offering that will cover 100% of their everyday shopping needs. To design a mall that responds to the needs of the people living in this small town, the Reteamgroup first got an idea of what such a mall should look like.

Commercial concept

Reteamgroup conducted 150 random interviews in the town to determine the required store and brand mix. The first questions they asked were: "What is your favourite store?" and "What is your favourite brand?". The favourite stores had a lower price level than the favourite brands. However, people in the town did not only favour discount stores. In fact, Mr Price only came sixth. Pep and Jet (two discount stores) were number 10 and 11. The main national chains and department stores topped the list of favourite stores. Similar to the rest of the world, the people loved strong brands, and there was a focus on sports brands.

It is of the utmost importance to make a good offer in food retail. The top four stores currently missing in that area are all supermarkets: Boxer Superstore, Checkers, Pick n Pay and Spar. When one looks at the categories, the people in the town would like to have supermarkets, as well as fashion stores and some restaurants and cafés, which helps when it comes to the tenant mix. When asked about the most important considerations when they go shopping, 64% of the respondents indicated that they would like a variety of stores. They favoured national chain stores and well-known supermarkets.

The mall would respond to all these needs and wants. The master plan would be designed in such a way that major chains could have well-located and visible stores as they are the backbone of the mall. To offer a larger variety of stores than normally seen in a project of 6 000 m^2, many small stores are included in order to offer local retailers a suitable and financially sound platform on which to grow their business.

Included in the contracts with the smaller entrepreneurs is a "retail, design, decoration or service school" to ease the transformation from an informal retail to a professional retail environment. The aim is to cover 100% of the shopping needs of the people living in the town.

Another interesting question was: "What would you do if you were responsible for building the mall in Ezibeleni?" Even though people were missing the most basic retail offers, it was not the store offer that was the most important consideration. The residents were longing for things to do together: a physical frame for having a good time. A mall is the perfect place for delivering entertainment. If a creative and stimulating environment is created for people to come together, people will "produce" the entertainment just by being there.

The best form of entertainment is other people, looking at them and interacting with each other. The entertainment offering in the town would be significant. Firstly, an art playground would be installed for children. A café would be provided next to the art area so that parents could watch their children.

Secondly, a cinema would be provided by changing the indoor aisle into a cinema once a week. A cinema is always an attraction, and there is currently no cinema either in the town or in Queenstown. The cinema would also be used for the Ezibeleni Film Festival once a year. This project would be done in collaboration with the schools and the TVET College in the town. The mall would therefore transform into a cinema once a week when the stores are closed. A large screen hidden in the ceiling structure would appear and the indoor square would become the seating area. Surround sound would be incorporated into the design above the stores' façades.

Children's play area.

An artist's impression of a cinema in another shopping centre.

Permanent table tennis tables.

Permanent chess tables.

Finally, to keep the teenagers and older children busy, the mall would have a permanent installation of fixed table tennis tables, as well as permanent chess tables. Research has indicated that there is a great need for entertainment in the town.

With all the schools surrounding the community centre and the number of young people staying in the town, it is important to create a safe environment for the youth where they can relax or play while their parents are shopping or watching them from a local café and talking to friends. A playground for children and table tennis facilities will be important factors in developing the social heart of Ezibeleni.

Although these findings are very logical and do not seem like innovative ideas, the ideas come from the questionnaires completed by the town's community. These proposals, together with the new architectural designs using the results from the Mind16 test, generated an idea that makes it easier to present this development to potential tenants, government officials and investors.

The proposals and architectural designs that emanated from the results of the Mind16 test generated an idea that makes it easier to present the development to stakeholders.

Conclusion

After Reteamgroup had conducted its research, it could develop a strategy where one would enter the mall with the idea of only making a quick purchase, but one would stay for an hour or two, meeting neighbours, browsing and enjoying lunch. It would also be possible to make a quick stop on the way home from work, as the parking and master plan would be designed for commuters. At the same time, the cafés, stores and common areas would make it a pleasant experience to stay longer.

It is envisaged that the products for sale would be a mix of local fare and well-known brands, while the price level would be spread across a good selection of value-for-money brands to more expensive, contemporary fashion items.

The mall aims to be the heart of the community. The scale is human, and the planning of common areas makes the urban activity visible to everyone, creating a vibrant atmosphere.

People belong there and will be proud to show it to outside visitors. The mall will make a difference to the community. Technology is also used to enhance service and communication.

The internet is the perfect partner as it is a link to the rest of the world. There will be public internet in the mall, not only to learn what is happening around the globe, but also to tell the world about the mall.

According to Charles Darwin, "It is not the strongest species that survives, nor the most intelligent. It is the one who is most adaptive to change who will survive." This is also true for shopping centres, and property managers need to be able to adapt to global changes and implement these changes for properties to achieve their maximum potential.

Shopping centres and the way they are currently designed are under threat, and people may see some drastic changes in the way they shop in the future. However, people will always look for a social gathering place, and property managers need to change properties in such a way to fulfill this need in future smart cities.

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Building a data science competency model for organisations

Rennie Naidoo, Marlene Holmner, Linda Marshall and Marie Hattingh

The Data Science Competency Research Group (DSCRG) in the University's School of Information Technology (SIT) was established to conduct research into data science competency. The group was formed after the School's inaugural interdepartmental Research Day held on 22 June 2018, which focused on improving collaborative research between the departments of Computer Science, Informatics and Information Science. The focus of this particular collaborative research project is to understand the competencies that organisations require of their data science employees.

The broader aim of this research group is to develop a Data Science Competency Model (DSCM) to inform government policy makers to develop a high-quality competitive data science workforce, to assist education institutions with the development of credible curricula in data science, to enable employers to select, recruit and train competent data scientists, and to prepare students for the data-intensive workplace of the Fourth Industrial Revolution (4IR).

Organisations use competency models to identify and describe the competencies that are required for an employee to work in a specific job. A competency model typically depicts a group of seven to nine total competencies. Some models break these competency groups down further into sub-competencies to provide more focus and specifics about a job in a particular industry. A competency model is a valuable tool for providing a more holistic assessment of the competencies that a data scientist should possess. The assessment information can then be used by human resources development (HRD) professionals in competency-based hiring practices, education and training, and in the career planning of data scientists.

There is currently a lack of sufficient understanding of competencies that are essential to educating and training a globally competitive workforce in the field of data science. A data science competency model can be beneficial for educators, government agencies, students, employers, employees and HRD professionals. This is especially relevant because of the implication of the technologies associated with the 4IR, such as data science analytical tools and machine learning. It is necessary to understand what competencies are needed by a data scientist. A model grounded in theory

Organisations use competency models to identify and describe the competencies that are required for an employee to work in a specific job.

and supported by empirical evidence is crucial in closing the skills gap, thereby improving the quality and competitiveness of the South African workforce in the rapidly growing global data market.

A number of organisational theories explain the general importance of competency in the performance of organisations. The resource-based view (RBV) of the firm acknowledges the role of human capital resources in generating superior performance and competitive advantage. The dynamic capabilities perspective also acknowledges the crucial role of human capital resources in rapidly changing and uncertain contexts. The knowledge-based perspective views scientific and specialised knowledge as the most strategic resource in improving organisational performance and competitive advantage.

As an extension of the knowledge-based view, organisational learning theories emphasise the importance of knowledge in organisational and individual performance.

The human resource management literature explains the importance of competency in job analysis. Furthermore, the importance of competency in information technology (IT) is acknowledged by the strategic information systems literature. The emphasis here is on "core competence" as a key organisational resource that could be exploited to gain a competitive advantage.

These competencies are unique and specific to an organisation. The IT literature has also been interested in generic competencies that are required for particular IT-related occupations or job roles. Researchers have studied the business competence of IT professionals in improving IT and business relations. IT researchers also recently developed a data analytics competency model to examine decision-making and organisational performance.

The research conducted in the School of Information Technology is one of the first of its kind to make use of the KSAO model to understand the competencies of a data scientist. The acronym KSAO stands for knowledge, skills, abilities and other personal characteristics that an individual requires to perform a job. Data science competency is defined as a collection of knowledge, skills, abilities and other personal characteristics that are required by an individual or team when using insights that are systematically extracted from data to solve a problem in a given context.

To develop this model, the researchers conducted a systematic literature review of the competencies that are essential to develop a globally competitive workforce in the field of data science. The systematic review covered a wide range of literature, but focused primarily, yet not exclusively, on the computing, information systems, management and organisation science literature. This research used a broad search strategy covering four separate electronic databases. The search strategy led the researchers to scan 139 titles, abstracts and keywords.

Sixty potentially relevant articles were identified, of which 42 met the quality criteria and contributed to the analysis.

The analysis revealed six competencies and seven disciplines. The six competencies include technical, organisational, analytical, ethical and regulatory, cognitive and social competencies. The seven disciplines include business management, computer science, information science, information systems, mathematics, statistics and natural science.

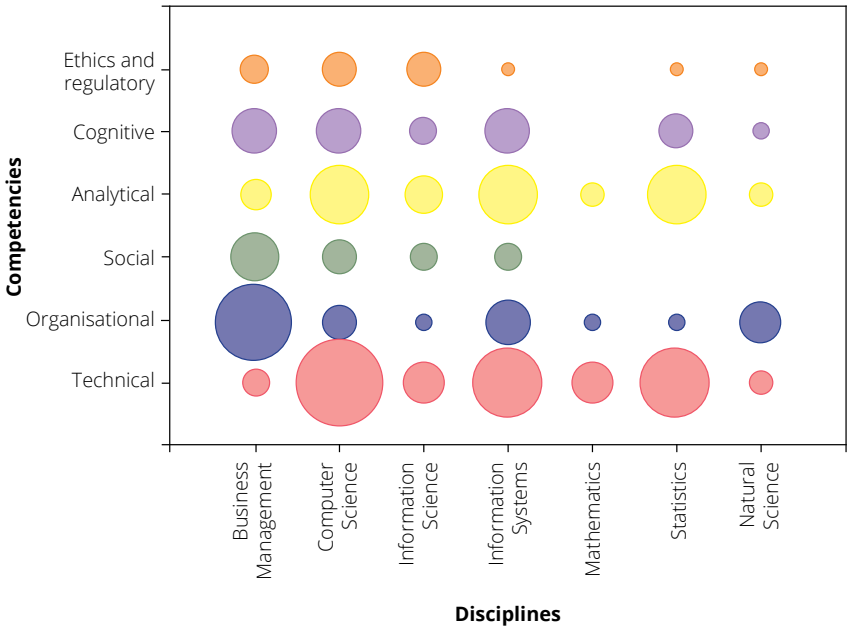


Figure 1: Disciplines vs competencies

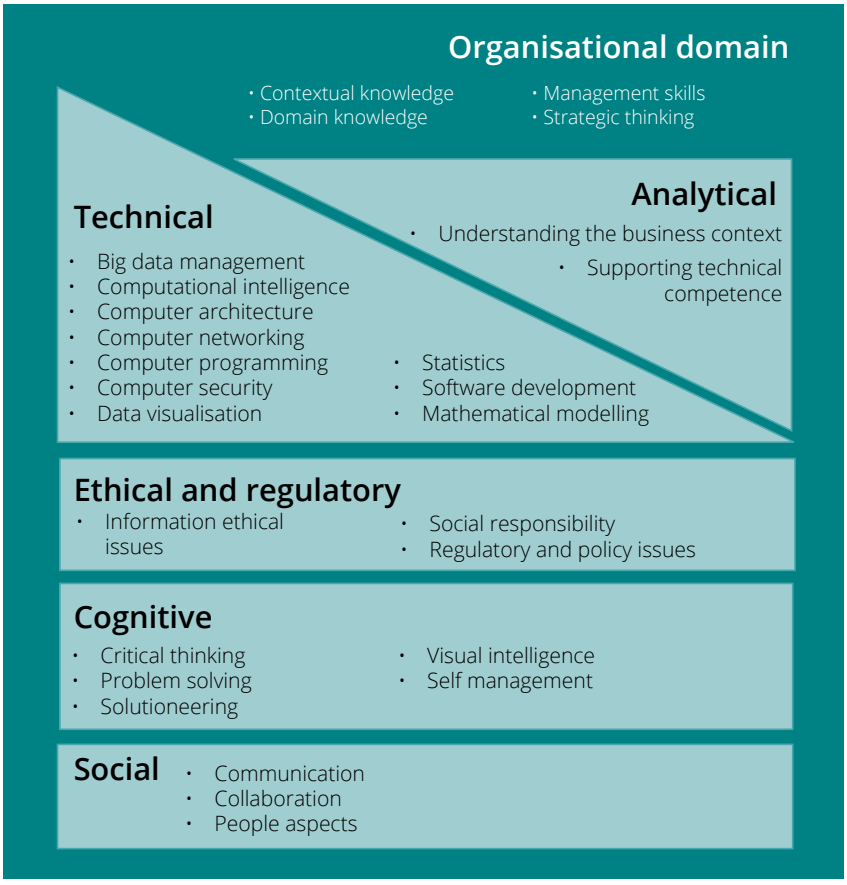


Figure 2: Unified data science competency model

The results of this study identified six key data science competencies with associated sub-competencies: organisational, technical, analytical, ethical and regulatory, cognitive and social competencies. These competencies are multidisciplinary in nature and require varying levels of expertise.

Figure 1 illustrates the representation of papers per competency and discipline. The size of the bubble proportionally represents the number of papers that address the competence per discipline. Figure 2 shows that the most prominent relationship exists between the technical competencies in computer science, followed by organisational competency in business management. The least prominent relationships exist between ethics and regulatory competencies and the disciplines of information systems, statistics and natural science, and the organisational competency and the disciplines of information science, mathematics and statistics. Six categories of knowledge, skills, abilities and other characteristics were identified that data scientists required to perform their work effectively: organisational, social, analytical, technical, ethical and regulatory, and cognitive competencies.

Figure 2 illustrates the comprehensive and unified data science competency model.

Each category in Figure 2 is proportioned to show the relative occurrences of the specific competency. For example, almost double the number of references to the cognitive competency were identified than for the social competency. All competencies fall within the organisational domain for data scientists, emphasising the role of the data science professional in the organisational context.

The results of this study identified six key data science competencies with associated sub-competencies: organisational (contextual knowledge, domain knowledge, management skills and strategic thinking), technical (big data management, computational intelligence, computer architecture, computer networking, computer programming, computer security, data visualisation, statistics, software development and mathematical modelling), analytical (understanding the business context and supporting the technical competence), ethical and regulatory (information ethical issues, social responsibility, regulatory and policy issues), cognitive (critical thinking, problem solving, solutioneering, visual intelligence and self-management) and social (communication, collaboration and people aspects) competencies. These competencies are multidisciplinary in nature and require varying levels of expertise.

These competencies are crucial to improve data scientists' performance in the workplace so as to develop a competitive workforce that is equipped to participate in the rapidly growing global data market. However, the competencies in this study require additional research that examines levels of competencies, ranging from novice to expert. For example, a data scientist can have an advanced statistical competency with a novice programming competency level. It is not expected (and is unlikely) that a data scientist can be an expert in all disciplines.

Therefore, a team of data scientists that complements each other's competencies is more likely to generate superior performance and competitive advantage in the organisation. This is crucial, given the shortage of data scientists. While it is understandable that researchers have focused their efforts in the past on technical, analytical and cognitive competencies, this model suggests that more attention needs to be paid to the ethical and regulatory, and social competencies.

This study has focused on the important competencies that contribute to the skilful performance of data scientists in organisations. One area that requires more attention in future research is the investigation of the competency process: how do data scientists or data science teams go about enacting competent performance in their jobs? In order to answer this question, the researchers intend to apply their initial model to case studies and survey research in future studies.

Evaluating the effectiveness of knowledge visualisation using eye tracking

Hanlie Smuts

The world is seeing revolutionary advances in science and technology, labelled the Fourth Industrial Revolution (4IR) or Industry 4.0. With the evolution of digital technologies, many new opportunities are being realised. Some of these include cyber-physical systems where control and monitoring are done by computer-based algorithms, such as autonomous vehicles; the internet of things, which creates a connected world by enabling smart cities; cloud computing, which provides for the on-demand availability of data storage; and computing power and cognitive computing, such as artificial intelligence.

The ability of organisations to apply and optimise Industry 4.0 technologies requires digital citizens to have the knowledge and skills to effectively use and apply digital technologies. Both from a commercial, and from a knowledge and skills perspective, digital technologies enable two options: they enable an organisation to embrace digital transformation, and they enable a world of visual and experiential learning to enhance skills and knowledge.

Whether an organisation addresses smart offerings for customers or digital skills for employees, the transfer and creation of knowledge may be achieved more effectively through knowledge visualisation. The aim of this research is to evaluate the impact that knowledge visualisation has on knowledge conversion and recall. By presenting a knowledge visualisation framework, educational institutions and organisations may optimise learning, and improve knowledge and skills.

The role of teaching and learning – whether in an educational institution or an organisation – includes the development of cross-boundary knowledge and requires new approaches to knowledge generation and transmission as students and employees are required to apply knowledge in and outside work structures.

Knowledge visualisation can be described as the use of visual representations to improve the creation and transfer of knowledge, using available visual resources to create, integrate and administer knowledge. It differs from information visualisation, which aims to explore large amounts of abstract (often numeric) data to derive new insights or make the stored data more accessible.

In the EDUCAUSE 2019 Horizon Report Preview, six key trends are highlighted that accelerate the adoption of technology in higher education. The two short-term trends that were presented focused on the redesign of learning spaces and blended learning designs. A focus on virtual learning spaces is required as many online platforms have bundled solutions to facilitate team-based learning and synchronous meeting spaces, yet emerging learning spaces programmed in extended reality (XR) have the potential to create more engaging and personal experiences for learners than any current online course design developments.

Blended learning designs are defined by the proportions of face-to-face versus online coursework, including media-rich elements. The requirement is to scale blended learning and to design learning experiences that take full advantage of digital platforms.

The question now is: what are the key knowledge visualisation considerations when applying this approach in order to optimise knowledge recall and how successful are they when applied?

The following are some key considerations for knowledge visualisation:

- Meet the audience need by considering for whom the visualisation is intended
- Facilitate audience engagement
- Strive for graphic excellence by focusing on usability and avoiding decorations as the use of irrelevant elements may distract

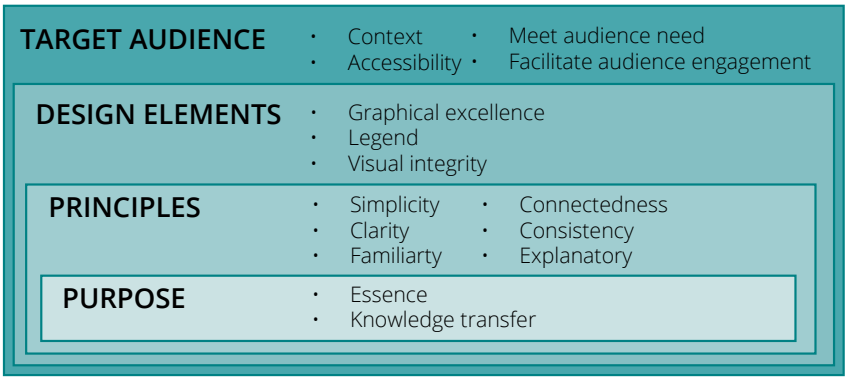
→ *A heat map.*

→ *A gaze plot.*

Images courtesy of Tobii Pro.

the audience from the content of the topic

- Only extract the essential components and their relationships from a body of knowledge
- Ensure that the level of abstraction is aligned to the audience's prior knowledge of the knowledge subject area
- Strive for simplicity by minimising the number of concepts in each level of visualisation
- Strive for clarity by ensuring that the visualisation is not ambiguous
- Strive for consistency by ensuring that visual elements such as colour, symbols and shapes are the same for similar kinds of information
- Present the overview and detail (the boundaries around elements and the connections to other elements should be clear)
- Clearly show the relationship between concepts
- Visualisation must have explanatory power and not merely descriptive value
- Associate with familiarity: establish a recognition-based approach to interpreting images by associating visualisation with the real world, instead of one that requires recall
- Ensure that there is an accompanying legend to provide detailed explanations of the symbols used



→ *Figure 1: The knowledge visualisation framework*

- Strive for visual integrity by ensuring that the representation does not distort the underlying data or create a false impression or interpretation of that data

In order to inform the evaluation, a four-layer nested knowledge visualisation framework was developed.

Researchers in the University's Department of Informatics use a technique known as eye-tracking to evaluate the knowledge visualisation framework as a means of optimising knowledge recall.

Knowledge visualisation is measured against a control group of existing knowledge visualisations found in handbooks, module materials or the internet. The eye-tracking evaluation fundamentally evaluates the three outer layers of the knowledge visualisation framework. The inner-most layer is assessed by retrieving related details from memory in a free recall setting.

Eye-tracking provides rich data about where one is visually focused, whether it is on a mobile phone, tablet or web interface. Gaze plots are graphs that show a user's sequence of fixation and how long a user was fixated on one point. Gaze videos show an animated view of the gazing pattern. Heat maps indicate which parts of an object users looked at and how intensely they looked at them. Data for multiple users may be overlaid to compare the experience of different users or different user groups.

The transfer of knowledge is a core process in knowledge management. Making knowledge visible so that it can be better accessed, discussed, valued and managed is a key objective.

Knowledge visualisation furthermore aims to transfer insights, experiences, attitudes, values, expectations, perspectives, opinions and predictions. It enables people to reconstruct, remember and apply insights gained.

Teaching and the Fourth Industrial Revolution

Dr Riana Steyn and Sean Kruger

When one thinks about the Industrial Revolution, an image that might come to mind is that of a big factory with black smoke coming from the chimneys, and a young Oliver Twist asking: "Please sir, can I have some more".

Fast forward to the 21st century. The Industrial Revolution of the 18th and 19th centuries has long gone, and information is everywhere. Most of the world's population is connected to at least one device at any given moment and most of us have asked: "Please, smart phone, do some more."

Nowadays, students who enrol for study programmes at universities are no different. Generation Z, as they are known, are clip-thinkers and process data at enormous speeds. They regularly face the choice of deciding what information is relevant to their situation. They will Google until they find that "something more", whether their lecturers give it to them or not.

As the Fourth Industrial Revolution (4IR) repaints the picture of society in its entirety, South African universities have to adapt their teaching and learning strategies. The rapid changes in our environment challenge lecturers to use new technologies to their advantage.

For instance, the use of 3D printers, also known as additive manufacturing, is becoming more widespread. This phenomenon makes the manufacture of unique items as easy as sending a file to a computer and printing it. Students can rapidly ideate, create, test and improve physical objects like never before. This process allows assessments that require actual physical products from students,

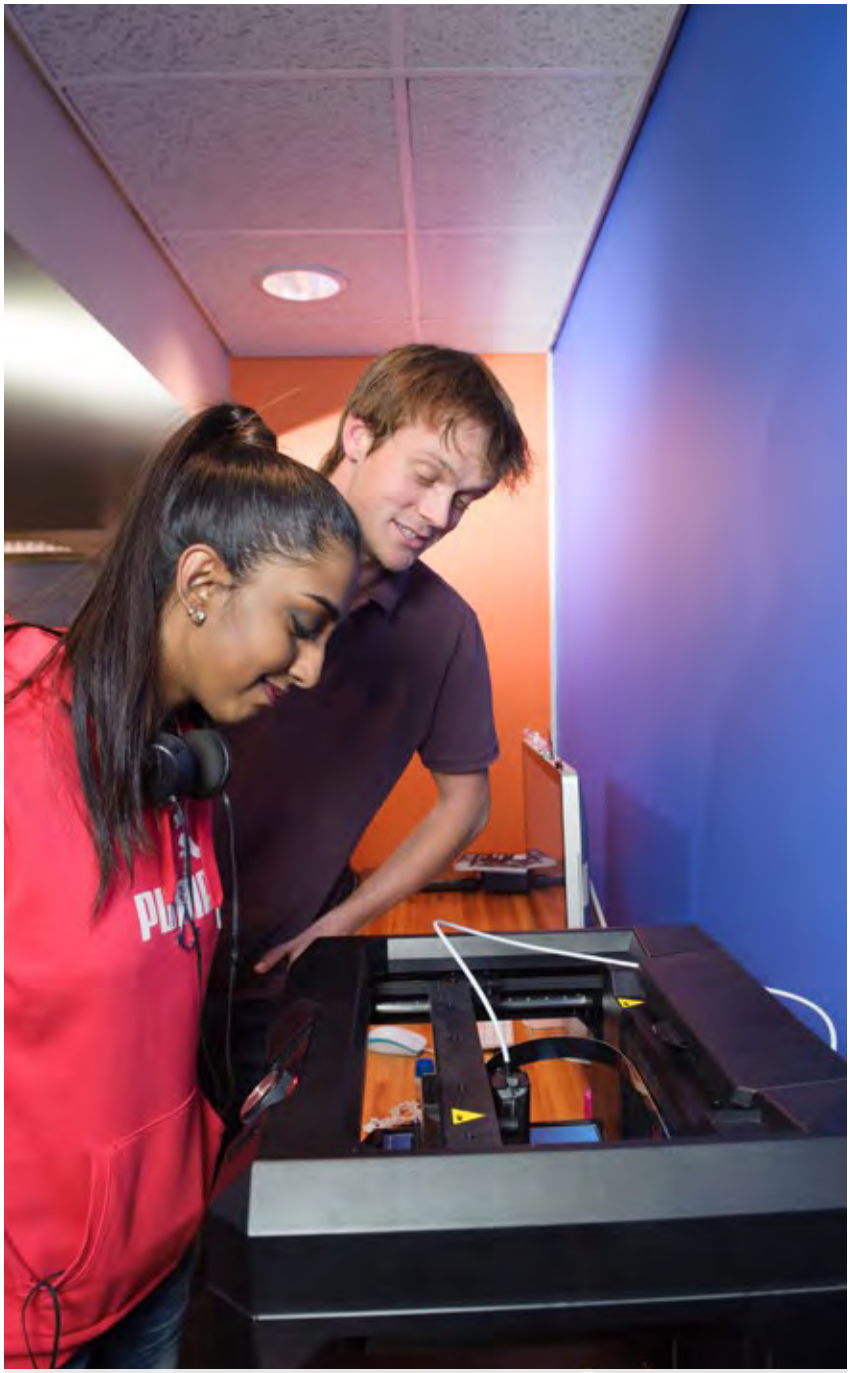
showing the entire journey from concept to delivery. The use of such assessments has not been restricted to one discipline, and despite being technically sophisticated, students can create something that is genuinely at the centre of their learning, whether they are novices or experts. This phenomenon has allowed modules to have a more hands-on approach through the visual creation of physical objects from digital files to stimulate interest, which makes the content relatable and more memorable.

The University of Pretoria understands the importance of these technologies in teaching and learning. In 2015, the Department of Library Services became the first library in South Africa to open a library MakerSpace. The MakerSpace is equipped with soldering benches, 3D printers and computers on which to design and render models. This creative space enables students to fulfil their creative potential by giving them access to specialised equipment and collaborative space in which to work.

Additive manufacturing is not limited to the classroom. For example, veterinary dentists can print patient-specific models to help students work out how to approach each procedure. This not only enhances the teaching and learning experience, but also reduces the duration of actual procedures.

In terms of the internet of things, lecturers have a myriad of technologies, such as Arduino and M5Stack, at their disposal. Arduino is an open-source electronics platform that is popular in the prototyping of digital devices. It is based on easy-to-use hardware and software. Arduino boards can read inputs and turn them into outputs.

A simple example of such a device is a weather display system that receives temperature input and displays it on a small LED screen. An M5Stack is a robust, Arduino-compatible open-source development kit with stackable modules and a user-friendly, integrated development environment, among other things.



The MakerSpace in the University's library allows students to experiment with additive manufacturing.

Arduino kits and M5Stacks are used to create customised solutions, from making products smarter to creating devices that track relevant data.

These technologies are also used to make everyday items much more interactive and connected to meet people's need for instant feedback. For example, one can build a chess-playing robot with feedback and data points within a few hours. The learning outcomes that these technologies can help achieve are only limited to what students can imagine.

Ultimately, students will never stop asking for more; they will never be satisfied with enough. As educators, we need to take advantage of this fact and allow these students to grow and help us shape the 4IR. We need to answer students' most pertinent question: "Please, can I learn some more".

They are here: What Generation Z is trying to tell us

Dr Riana Steyn

Nowadays, educators have to teach Generation Z, a digitally connected generation of clip-thinkers and information seekers. Educators need to evolve with their students to keep them engaged with learning content. They need to be creative and willing to change the way they do things, even if they think they know what works. Some people doubt whether Generation Z truly exists. Others believe that they have already been "defined" through the Millennial Generation. Millennials started seeing technology in shops, in some businesses, and a lucky few even had a computer when they were in high school. Unlike Millennials, members of Generation Z do not know what it feels like to go through an entire day without receiving a single text message or "liking" something on some or other social media platform.

They are the only generation so far that does not know a world without modern technology. With all the technology at their disposal, it is no surprise that this generation responds positively to learning experiences that use technology to engage them in exciting ways.

Whether you agree with the term "Generation Z" or not, the fact remains that students who enrol in universities today can find something on Google within a few seconds. What does that mean for educators?

Educators in various settings have been playing catchup. For many years, they knew that this tech-savvy generation was on its way, and they thought that they were adequately prepared for them. They thought they knew how to keep these youngsters engaged with content and connect with their world. Now that they are here, are educators really prepared?

Educators should ask themselves if they are prepared to be challenged in classroom situations where students can Google the course content in real time and ask questions that Google cannot answer. Educators should also be prepared to forego traditional curriculum design and provide students with content to see if they can figure out the course's structure.

Re-evaluating their assessment methods could help educators to focus on achieving the outcomes and helping students to understand concepts. This is preferred to repeating phrases and techniques during tests and examinations. Many educators feel that they must provide students with what they need to know. Instead, the educator's role could be to facilitate the process of learning in a more practical way that involves all the students' senses.

If educators change the way they approach their classrooms, there is

There is an exciting array of tools available to facilitate learning for Generation Z.

an exciting array of tools available to facilitate learning. Students could lead a class discussion of definitions they have to find on Google. Educators can provide students with an outline for an assignment, and let them structure the content, write the case study and create a video or blog that shows how they would teach the content. The content that was created during this process could be used to teach the next group of students.

Escape rooms represent an engaging tool that could be used for class tests. An escape room or game is a mental and physical adventure game in which students solve a series of puzzles and riddles using clues, hints and strategies to open a locked box or escape from a locked room. Students can work together to get clues, and as they find clues, their marks accumulate. If they discuss the challenge with fellow students in the process, let them. At least they are discussing your content, and if not, they are wasting their own time.

The bottom line is that academics need to move away from doing everything for students. Engaging students by keeping their generation's habits and priorities in mind is a sure-fire way to ensure that learning takes place while students have fun.

Turning teaching philosophies into learning experiences

Prof Alta van der Merwe

Dr Riana Steyn, a lecturer in the Department of Informatics, augments teaching and learning in her field through innovative projects and research studies that outline her teaching philosophies. She is not only the recipient of the Faculty's Teaching and Learning Award for 2018, but also of the UP Teaching Excellence Laureate Award for 2018/19 and the Award for Innovation in Teaching of the Association for Information Systems (AIS).

Dr Steyn believes that students can realise their full potential if they have the relevant access to learning opportunities. "They learn best when they are presented with challenges that relate to their experiences," she says.

For Dr Steyn, these philosophies underpin the business analysis and design modules that she teaches. Students acquire creative problem-solving skills that they can use to design effective software solutions in order to analyse real-life business problems.

One of the challenges of the INF 171 module that she teaches is the lack of an appropriate textbook that focuses on all aspects of the modules.

In 2015, Dr Steyn considered using the entire class as a talent pool to contribute to the development of a cost-effective textbook. She launched the project by giving the students an assignment based on use cases to see if one could develop student-created content that speaks to the average Millennial.

Dr Riana Steyn embraces the challenges of teaching to a new generation of learners.

The first draft was published in July 2018 and students had to complete an assignment while using it as an additional resource.

Dr Steyn is collaborating with an educational technology developer to create an interactive textbook that will be adapted annually to accommodate the rapidly changing technological environment.

Developing social responsibility skills for the future workplace

Martina Jordaan and Dolf Jordaan

The concept of Industry 4.0 was explored by Klaus Schwab, Founder and Executive Chairman of the World Economic Forum (WEF), in 2016 during the Forum's Annual Meeting, which focused on the theme "Mastering the Fourth Industrial Revolution (4IR)". This term relates, in particular, to integrated technological developments where automation impacts on industry products and services. Although it may increase economic inequality, it also presents an opportunity to empower people and create a shared vision for a better future.

Hatfield Community Park, restored by the University's Department of Facilities Management and students enrolled in the JCP module. The park was previously owned by the City of Tshwane Metropolitan Municipality, but is now the property of the University of Pretoria following a land swap agreement for a property in Hammanskraal.

The relevance of this debate in the context of higher education in South Africa relates to current and future strategic goals. While higher education in South Africa is entangled in debates about its history, macro trends, such as the 4IR, necessitate a critical reflection of existing curricula to ensure the relevance of students' qualifications through the integration of necessary and cross-functional skills for the 21st century.

The anticipated demands of the future workplace require higher education to cultivate innovative talent that is trained in an interdisciplinary and digitised environment. It will entail substantial changes to the science, technology, engineering and mathematics (STEM) curricula with the subsequent convergence of the so-called hard sciences, social sciences and humanities. The medium of delivering teaching in the 4IR will build upon existing hybrid teaching models, but with higher levels of attention to its implications at a socioeconomic level. Catalysing new cross-disciplinary curricula must therefore develop students with an agile mindset to function in an intercultural context through self-directed learning and critical thinking. Curriculum designers therefore need to identify the specific skills anticipated in the 4IR.

Research presented at the WEF's Annual Meeting of 2016 revealed 10 critical skills that are required for the modern workforce. This skills list was updated in the WEF's Future of Jobs report of 2018.

It provides a set of 21st-century skills that serve as a forward-looking measurement framework to evaluate the current skills mastered by students enrolled in service-based modules, such as Community-based Project (Code: JCP), which forms part of the curriculum of all undergraduate students in the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria.

These top 10 critical skills can be translated into module objectives and outcomes of the JCP module to ensure that students have the necessary skills to navigate an unknown future.

Translating the top 10 critical global skills into module objectives and outcomes

Global skills	Future job requirements	Module objectives and outcomes
Analytical thinking and innovation	Analysing information and using logic to address work-related problems.	Carry out a project related to community service that is aimed at achieving a beneficial impact on a chosen section of society.
	Creativity and alternative thinking to develop new ideas for and answers to work-related problems.	
Complex problem-solving	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.	Demonstrate that learning outcomes relevant to the project have been achieved.
Critical thinking and analysis	Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.	
Active learning and learning strategies	Understanding the implications of new information for both current and future problem solving and decision making.	Demonstrate that learning outcomes relevant to the project have been achieved.
	Selecting and using training or instructional methods and procedures appropriate to the situation when learning or teaching new things.	
Creativity, originality and initiative	The ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem.	Carry out a project related to community service and aimed at achieving a beneficial impact on a chosen section of society.
	The willingness to take on responsibilities and challenges.	
Attention to detail, trustworthiness	Attention to detail and being thorough in completing work tasks.	Achieve a comprehensive understanding of the social issues relevant to the project.
	Being reliable, responsible and dependable, and fulfilling obligations.	
Emotional intelligence	Being sensitive to others' needs and feelings, and understanding and being helpful on the job.	Develop an awareness of personal, social and cultural values, an attitude that shows a willingness to serve, and a deep understanding of social issues; develop essential multidisciplinary and life skills, such as communication; and develop interpersonal and leadership skills.
	Being pleasant with others on the job and displaying a good-natured, cooperative attitude.	
	Preferring to work with others rather than alone, and being personally connected with others on the job.	
	Being aware of others' reactions, and understanding why they react as they do.	
Reasoning, problem-solving and ideation	Abilities that influence the application and manipulation of information in problem solving.	Able to work effectively in a multidisciplinary environment and to perform critical functions.
	Abilities that influence the solution of problems involving mathematical relationships.	
Leadership and social influence	A willingness to lead, take charge and offer opinions and direction.	Develop important multidisciplinary and life skills, such as communication, interpersonal and leadership skills.
	Having an impact on others in the organisation, and displaying energy and leadership.	
Coordination and time management	Adjusting actions in relation to others' actions.	Able to work effectively in a multidisciplinary environment and to perform critical functions.
	Managing one's own time and the time of others.	

The 4IR necessitates a critical reflection of existing curricula to ensure the relevance of students' qualifications through the integration of necessary and cross-functional skills for the 21st century.

The 10 critical global skills identified by the WEF need to be interpreted in the context of a shift of focus in the industry for human resource skills requirements, as well as a reskilling and upskilling imperative, taking cognisance of South Africa's emerging skills demand. These global skills can be applied to the skills required to operate in the 4IR. A comparison of the WEF's critical global skills and the emerging skills required for South Africa in the 4IR reveal an 80% similarity. The only difference lies in the inclusion of "attention to detail and trustworthiness" as a critical global skill, and "resilience, stress tolerance and flexibility" as an emerging skill that is required for the future job market in South Africa.

Although no formal, universally agreed set of soft skills exists, most of the WEF's skills are a cluster of personality traits that have an interactive effect on personal and professional efficiency. These include our attitude towards each other, how we approach others, and how we adapt and interact with each other in the professional environment. According to Prof Ronny Webber-Youngman, Head of the Department of Mining Engineering at the University of Pretoria, more than half of the skills identified as being necessary for the 4IR can be classified as people skills and emotional intelligence.

For the past two decades, service-learning and community engagement modules in higher education programmes have created the opportunity to address and develop students' soft skills, enabling them to be engaged citizens who are ready for the world of work. The ability to understand the needs of others, as well as the broader social issues and the desire to make a difference in the community is a positive attribute that is developed through service-learning.

Service-learning modules develop specific skills such as written and verbal communication skills, leadership skills and teamwork skills. Problem solving, critical thinking, and administrative and organisation skills are also frequently associated with community engagement projects. These projects also give students the opportunity to address challenging tasks in an authentic environment similar to that which they will encounter in a professional consulting practice.

Solving a unique challenge often includes conflict management between group members, managing the time available for the task, and working within the limits of inadequate or unobtainable information. Subsequently, service-learning skills can be correlated with the skills required for the 4IR. The engineering workforce of the future needs to understand its social responsibility and the need to be collectively responsible for improving the lives of the broader community.

Disrupting the higher education curriculum

The technological developments that form part of the 4IR bring about a dissolution of the boundaries between the physical, biological and digital domains. The result is a disruption of the higher education curriculum by ensuring that students have the skills required to navigate an unknown future.

To be competitive in the 4IR, students need to understand the importance of digital literacy in an increasingly integrated digital world. Of particular concern to students involved in community engagement projects is the impact of an increase in the digital divide as a result of the 4IR and the value of creating social awareness as a student attribute in a fast-changing world. The relevance of community service in this new curriculum relates to ensuring that students understand the value of social responsibility as a curriculum outcome, as well as the need for lifelong learners who are able to master the necessary skills to succeed in their future careers.

It is with these changes in mind that the Faculty implements its compulsory undergraduate Community-based Project module. This module is aligned to the University's strategic goal of social responsiveness, and integrates service-learning projects in all the Faculty's undergraduate programmes.

More than 1 600 students register for this macro service-learning module annually, with an average completion rate of 95%. Each year, the students work in approximately 450 groups to help more than 350 different campus-community partners. They have to spend at least 40 hours working in the community. In the process, they not only apply their knowledge to solve a specific need in the community, but also acquire new skills, or improve existing ones. Students undertake a variety of projects within a set of guidelines, and each project provides unique learning experiences. The most successful projects for the 2019 cohort were basic renovation and building projects. This included building jungle gyms, and benches for communities. They also developed a community park in Hatfield, and taught Mathematics and Science to secondary school learners, and computer skills to community members.

The students' exposure to authentic challenges through these projects allows them to increase their awareness of social responsibility.

The anticipated demands of the future workplace require higher education to cultivate innovative talent that is trained in an interdisciplinary and digitised environment.

It also encourages them to collaborate in a multidisciplinary and multilingual environment to apply communication, interpersonal, technological and leadership skills. Continuous critical reflection and the students' feedback inform the module's efficiency and are part of a necessary process that contributes to its development and quality assurance. This reflection has revealed that more than half of the students had never been involved in a community outreach project before undertaking the module. Many of those who had claimed to have participated in some form of community service had misconceptions about what community service and personal social responsibility entail.

Prior to commencing with their community engagement projects, students were asked about their expectations of the module. Their responses generally indicated that they would like to be more aware of how broader society functions and to develop a new skill. Other expectations included enhancing their CVs to increase their employability prospects, being exposed to people from different backgrounds, and developing an awareness of social responsibility.

Upon conclusion of the module, students were required to reflect on how they had benefitted personally from their involvement in a community engagement project. The feedback received indicated that the skills the students had mastered or applied during their community service projects correlated with the skills required for the challenges in the workplace, and for the 4IR.

Although the skills students acquire in each project are different, the generic skills identified by JCP students compare positively with both the WEF's global skills and the emerging South African skills for the 4IR, and are either directly or indirectly embedded in the achievement of the module's goals and objectives. The skills students identified as having acquired include creative thinking, groupwork and teamwork, communication and interpersonal skills, time management, project management, and working with people from diverse cultures and backgrounds.

The module also plays a valuable role in preparing students for numerous realities in the South African workplace; something that is seldom included in the curricula of subjects in the hard sciences. This reinforces the Faculty's decision to embed the JCP module in the curriculum of all undergraduate students in engineering, built environment and information technology at the University of Pretoria.

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Using virtual reality applications in the Civil Engineering laboratory

Prof Wynand Steyn and Koos de Beer

Virtual reality (VR) technology has advanced rapidly in the last 10 years and has become adopted commercially. A range of options exists regarding the use of the available systems. The combination of these systems, with appropriate software, is required to ensure that VR applications can support training and education in a productive way. The University's Engineering 4.0 facility is a joint development supported by the South African National Roads Agency Limited (SANRAL) and the University of Pretoria and provides a new laboratory facility for training, reference testing and concrete research.

The training laboratory focuses on the training and certification of laboratory technicians focusing on road construction materials. This vital skill is essential for the accurate evaluation of the properties of road materials to ensure correct decisions regarding appropriate materials to be used in road provision.

The use of VR has proven effective in rehabilitation and training. As an immersive technology, VR can be used to train kinaesthetic memory, while engaging the cognitive aspect of the training content. As part of the training facility, the University's Department of Civil Engineering, together with the Department of Information Science, has embarked on the development of a VR application that focuses on typical laboratory tests used for road materials.

One of the challenges for training laboratory technicians is that they are widely distributed in the country, and often originate from rural areas. The cost of travelling to the new training facility and accommodation for potential technicians to be trained in the various laboratory tests is prohibitive.

As an alternative option, VR applications provide an opportunity for VR headsets to be distributed to training facilities in rural areas. Aspiring technicians can then use the VR system to conduct the training in virtual space until they understand the techniques required, and build up muscle memory in terms of conducting the testing in this environment. Once such an aspiring technician is competent in the basic test, they can go to the Engineering 4.0 training facility for a short certification process in a real environment.

The VR application has been developed with the same layout and environment as inside the training laboratory, with the benefit that trainees will be familiar with the environment once they arrive for certification.

The project uses a standalone VR headset and the Unreal engine to immerse the trainee in the laboratory environment. The trainee is taught to do a specific test through a guided series of steps, following the standard procedure for the specific test by interacting with a complete virtual environment.

The development thus provides for a combination of virtual and real-world reality to provide road materials laboratory technicians an additional route to becoming competent in their chosen field, supporting the broader provision of roads in South Africa.

Educating and leading mining engineers to become imagineers

Prof Ronny Webber-Youngman

The Department of Mining Engineering at the University of Pretoria plays a significant role in mining teaching, learning and research in the Faculty of Engineering, Built Environment and Information Technology. Its mission is to educate and lead mining engineers to become Imagineers by empowering them with technical and non-technical skills through the use of world-class education, research, leadership and related technology interventions.

As a leading department in this discipline in South Africa, it realises that the challenges pertaining to the Fourth Industrial Revolution (4IR) need to be dealt with in a very different way than has been done in the past. The ability to deal with up to five different generations in the workforce also requires special skills. The Department is therefore embracing this challenge by equipping its students with various non-technical skills, which will enhance their ability to deal with the complexities that are inherent in the mining industry.

The mining industry is one of the largest industries in South Africa, producing more than 60 different minerals in over a thousand mines and quarries throughout the country. Graduates from the Department can be employed in a wide range of companies both locally and internationally. Potential careers include those of rock engineer, mine ventilation engineer, rock breaking engineer, drill and blast engineer, project engineer, mine planner and environmental engineer.

Approximately 95% of the Department's graduates from 2017 and 2018 are currently employed in various fields in the minerals sector, as well as in consultancies and financial institutions. The leading edge that it has over other tertiary institutions in South Africa is its focus on developing leadership skills, as well as its initiative to improve students' English literacy.

Mining Engineering Leadership Academy

More than a decade ago, the Department established the Mining Engineering Leadership Academy (MELA) in an attempt to prepare graduates for the challenges they face when they transition from student to manager and leader. This is particularly relevant in the complex, rapidly changing world of cyber technology, the internet of things and Industry 4.0.

The Department is embracing the 4IR challenge by equipping its students with both technical and non-technical skills.

The MELA programme focuses particularly on nurturing self-awareness, interpersonal and communication skills in graduates, as well as the ability to work in multidisciplinary settings and in diverse groups spanning many generations. All final-year Mining Engineering students attend this programme at the start of each year. It then extends to the second half of the year, when students are divided into teams of four students each for their Mine Design course.

The MELA programme is structured to better prepare students for their careers in the mining industry by creating an awareness of the stewardship of being a Tukkie and a future mining engineering leader.

The teams are selected based on psychometric assessments obtained from the DiSC profile (based on determining the personality traits of dominance, influence, steadiness and conscientiousness) and the Myers-Briggs personality profiles. In conjunction with academic performance, commodity and biographic profiles, teams should be as diverse as possible.

The programme concludes in July with a Leadership Week in which students are introduced to the 4.0D™ Leadership Model for Industry 4.0, developed by Dr Johann Uys, a senior lecturer in the Department.

In the context of teamwork in the Mine Design course, MELA focuses on working in teams, emotional intelligence and conflict management. At the end of the week, the teams embark on an outward-bound experiential and action learning team-building day to tackle challenges similar to those they may experience in the world of work first-hand. In 2019, the students attended the day in a bush setting east of Pretoria.

Under the guidance of Dr Uys, seasoned team building facilitators and MELA staff accompanied students to hone their skills. They were constantly made aware of experiential learning applications in the academic programme, as well as vocational preparation and implementation.

The final phase of the leadership programme incorporates contemporary topics relevant to mine design with specific reference to mine closure design, as well as community awareness and responsibility.

Four major focus areas in mine design with regard to communities are highlighted: potential resettlement strategies, current town and settlement expansion plans, the balance between re-skilling local residents and importing skills in the form of migrant labour, and ramping up communities for viable post-mining activity.

Guest speakers who were invited to address the students included Dr George Maluleka, General Manager: Projects at Kumba Iron Ore, who delivered a presentation on the Dingleton resettlement project, and Mr Jan Nel, Director at Shangoni Management Services, who enlightened the students about mine closure, as well as post-mining activities and the rehabilitation of mining sites.

English literacy initiative

The Department acknowledges the fact that good language skills are essential for its students to succeed, both in their studies and in their careers. Despite the fact that English is not the first language of the majority of the students in the Department, they still need to attend classes, read articles and write reports in English.

An inadequate grasp of the English language will therefore lead to poor results, no matter how gifted a student is otherwise.

For this reason, the Department has instituted an English language intervention programme over the past five years, which runs concurrently with the mining engineering classes from the first to the final year of study, providing students with the opportunity to improve their English skills.

Students attend presentations, writing workshops, online

→ *The University's mining engineering students are prepared for the world of work.*

programmes and private consultations, which are aimed at helping them improve their writing, reading and speaking skills. In 2019, the Department appointed three additional postgraduate English tutors to accommodate all the year groups.

The outcome of this intervention is to empower students to produce well-written dissertations and presentations. In the process, they will also have acquired a skill that will be of immense value to them throughout their professional lives.

Industry collaboration

The Department of Mining Engineering encourages collaboration with industry, and with the other South African tertiary institutions who train mining engineers. As such, it participates in Mining Engineering Education South Africa (MEESA), a forum with representation by the deans of Mining Engineering at the University of Pretoria, the University of the Witwatersrand, the University of Johannesburg and the University of South Africa (Unisa).

Members of Mining Engineering Education South Africa (MEESA) (from left): Mr Lucky Maseko (Unisa), Prof Cuthbert Musingwini (Wits University), Prof Ronny Webber-Youngman (University of Pretoria) and Prof Hennie Grobler (University of Johannesburg).

Harmony Gold's graduates of the Leadership Capacity-building short course presented by the Department of Mining Engineering.

The vision of MEESA is to establish a uniform platform for the four mining schools in South Africa to engage and discuss challenges and solutions related to mining education and research, and to foster a spirit of collaboration in this regard so as to benefit the mining industry in South Africa as a whole. Future plans include formalising research exchange programmes in the context of internationalisation, with a specific emphasis on research and co-publication with international partners, as well as collaboration on projects of the Mandela Mining Precinct.

The Department also supports industry through the presentation of short courses in collaboration with Enterprises University of Pretoria. These short courses not only contribute to the Department's third-stream income activities, but also elevate its visibility in the mining industry. They make the expertise of the Department available to members of industry for purposes of skills development and capacity building.

They also enable individuals in the mining sector to become more effective in the development of smart, long-lasting solutions for society. An example of this is the Department's establishment of the Leadership Capacity-building short course for Harmony Gold, which includes participants at executive level, senior staff members, as well as junior staff members.

The Department's footprint extends across each of the University's nine faculties by means of cross-disciplinary and inter-disciplinary research. This has contributed to the University of Pretoria being rated in the top 100 universities in the world for mining and mineral engineering in the 2019 Academic Ranking of World Universities (ARWU) subject rankings.

Virtual reality provides an "explosive" teaching experience

Wolter de Graaf

The implementation of safe and efficient blasting practices in an underground mining environment contributes to safer working conditions and increased productivity. Training learners in a real production mining environment is often inefficient with associated safety concerns. The University of Pretoria has therefore embraced digital technology to provide training in a "practical" environment through the use of virtual reality (VR).

The establishment of the VR blast training wall in the Department of Mining Engineering enables learners to plan and execute the blasting of a rock face in a controlled and safe environment. By means of VR and augmented reality, they are able to design the blast, mark the blast holes and blast hole timing sequence activities, and actually execute the blast and experience the "explosion" on an interactive screen.

This has the advantage over teaching in a traditional classroom environment, as the learners are able to visualise and fully comprehend the concepts being taught, while gaining practical experience in a user-friendly, safe and erasable environment, where mistakes can be made without any consequences.

The blast wall is projected on a screen, and the learners focus on the marking of grade lines, direction lines and grid lines on the virtual wall, using a computer mouse shaped like a paint brush (again portraying the real-life environment).

It is important for the learners to draw the grade and direction lines accurately, as this will determine the blast hole positions, and ultimately the direction of advance of the tunnel. At this point, they can either proceed to the next step, or delete the lines and start again. The intersection points of the horizontal and vertical grid lines represent the drill hole positions. After marking the drill hole positions, detonator delay numbers are assigned to the drill hole positions.

Once the students are satisfied with the marking and timing of the round, they can watch the simulated blast sequence in real time or slow motion.

The hardware that forms part of this training exercise comprises a personal computer, overhead projector, stereo sound, infrared receivers and an infrared paint brush.

The VR blast training wall can also be used to train newly appointed mine workers to effectively master the skills of marking and timing blast rounds in a controlled and "real" environment, and is the perfect tool to give workers refresher training at regular intervals, thereby enhancing their skills and improving the quality of tasks to be performed underground for safe and efficient blast outcomes.

The virtual reality blast wall enables learners to plan and execute the blasting of a rock wall in a controlled and safe environment.

Graphical communication intervention project prepares students for success

Dr Lelanie Smith

The University of Pretoria recognises the importance of adequately preparing first-year engineering students with technical drawing and computer literacy skills to ensure their academic success.

Having identified a lack of these skills in some of its first-year students, the Faculty's School of Engineering has implemented an intervention plan to better prepare these students for the challenges they may experience in the Graphical Communication (MGC) module. All first-year engineering students have to complete this module to progress to their second year of study in the various fields of engineering that the School offers.

The intervention takes the form of a self-driven, hands-on e-learning programme that focuses on computer literacy and technical drawing. It also includes a component that provides new insights from the latest brain research that helps students learn new study techniques to learn more effectively. An existing computer application, miEBooks provides a platform for a e-books and resources linked to topics in the book. These resources include automated assessments, study material, videos and links to articles and other relevant sites.

The project was piloted in January 2018, when new first-year students were introduced to it during Orientation Week. After a call for volunteers, 38 students actively participated. Following their successful completion of the course, the e-learning programme was introduced as a compulsory component of the MGC 110 curriculum in 2019.

In the past, new first-year students did not always have the necessary basic computer literacy or technical drawing experience when they enrolled for engineering study programmes. As a result, they struggled to adjust to the module's pace, which meant that they could not always understand important concepts.

The Graphical Communication module incorporates a self-driven, hands-on e-learning programme that focuses on computer literacy and technical drawing.

Owing to time and resource constraints, lecturers could not teach these skills in class.

Students can now use this self-driven, self-paced intervention to overcome this challenge in their own time before they commence with their studies or at the latest within the first couple of weeks of the first semester.

The benefit of this support tool for teaching staff is that it is a standalone introductory intervention that requires little supervision and can be run in the University's existing computer laboratories or on students' own electronic devices. It includes practical, hands-on work and automated assessments, and student activities can be tracked to actively measure the intervention's impact after the first round of implementation.

An advantage of the programme is that students who have not mastered a particular skill can repeat the assessments until they have mastered the skills they need to progress to the next level.

Students who used this tool found it easy to use and self-explanatory. They remarked that the course made them consider their study methods, and they liked the fact that the course was self-paced. The feedback also revealed that the course improved students' understanding of the material that is covered in the module.

Upon completion of the course, the academic performance of the students who had actively participated in the programme was compared to that of students who had been invited to participate in the course based on their lack of computer literacy and technical drawing skills but did not actively engage with the material.

On average, an improvement of 5% was observed in the performance of the students who had actively participated in the programme.

The pilot project revealed that the course has immense potential for preparing first-year engineering students for the MGC 110 module and providing them with essential computer literacy and study skills. The programme thus eases the transition from school to university.

It is anticipated that a vast improvement in students' performance in this module will be noted at the end of 2019 following the entire first-year group's participation.

ClickUP Goals tool measures alignment with programme outcomes

Adriana Botha

The University of Pretoria is at the forefront of tertiary education in South Africa and collaborates with world-class partners to ensure continued excellence in teaching and learning. Blended and inquiry-based learning, assessment and accreditation, and learning analytics are just some of the areas in which the University has improved in recent years to promote higher levels of student success.

"The implementation of the University's learning management system (LMS), clickUP, in 1998, laid the foundation for the current level of maturity in the use of educational technology at the University. In 2018, we celebrated two decades of partnership with Blackboard, the developer of clickUP," says Mr Dolf Jordaan, Deputy Director of E-Learning and Media Development at the University.

While clickUP has become a way of life for students and staff, Ms Adriana Botha, education consultant for the Faculty of Engineering, Built Environment and Information Technology, is examining some of clickUP's innovative applications that have not been utilised to their full potential.

An important consideration in achieving the University's strategic goal of enhancing access to education and successful student learning is the promotion of best practice approaches in assessment and accreditation. This entails employing constructive course design and programme alignment to ensure that one's efforts reflect how teaching and assessment affect programme outcomes.

The University realises that if it can get all its academic staff to use the LMS to its full potential, the Goals tools can allow it to link all learning outcomes to course activities, including formative and summative assessments. In this way, student performance can be monitored with regard to these learning outcomes as students progress through their qualification. The tool can report on areas in which students perform well in their academic career path, and areas in which they experience academic challenges. This will result in a more constructive alignment of students' hybrid learning experience.

The Goals tool, together with its reporting functionalities, is not only a tool for compliance, but also assists lecturers to monitor student learning and success against set outcomes. Struggling students can be identified early, and interventions for support, based on clean and quality-assured data, can be implemented. "We strongly believe that the Goals functionality is one of the building blocks to support effective learning design," says Mr Jordaan. "Learning design affects student engagement, which affects the value of data from the LMS to support student success," he concludes.

Assessment and accreditation

In South Africa, the Council on Higher Education (CHE) is an independent statutory body for quality assurance in the higher education sector in terms of the National Qualifications Framework Act, Act No. 67 of 2008. Through its permanent Higher Education Quality Committee (HEQC), the CHE is responsible for quality assurance and the promotion in higher education.

According to Mr Jordaan and Ms Botha, the Quality Unit in the University's Department of Institutional Planning manages the institution's external evaluation and professional body accreditation. The accreditation of academic programmes, both nationally and internationally, plays a crucial role in affirming the quality of an institution's programmes. The evaluation and accreditation of the University's programmes involve the formation of panels, self-evaluation reports, site visits and formal reporting. Faculties, departments and

Adriana Botha (left) explains the use of the Goals tool to Prof Carina de Villiers of the Department of Informatics.

programmes are expected to develop improvement plans and progress reports for the external evaluation process. At present, each programme follows a unique method of developing self-assessment reports for external evaluation.

The University is currently working towards a process of internal review that is more effective and meaningful to faculties and the programmes they offer. This review process will allow departments to capture data for critical dialogue on student learning performance and continuous programme improvement that can manifest itself through planned interventions and accountable actions, according to Ms Botha.

Over the years, many departments have developed initiatives to manage and report on programme review and assessment. Although these departments have the technology available to ease this critical process, such as the Goals tool, it has not been centrally institutionalised thus far.

In an endeavour to streamline the accreditation process, Ms Botha recommended the use of the Goals tool as part of a pilot project in the School of Information Technology. This will form part of the School's assessment for accreditation with the Accreditation Board for Engineering and Technology for Informatics (ABET).

Developed in collaboration with the Department for Education Innovation, the pilot project will help the University decide on the future implementation and roll-out of the Goals tool across the University as part of an institutional assessment and accreditation solution. The Department of Mining Engineering is also using this tool for its assessment with the Engineering Council of South Africa (ECSA).

Assessment workshop

To assist lecturers in the School of Information Technology to meet their assurance-of-learning requirements using the Goals tool, Blackboard presented a three-day workshop. One of the key outcomes of this workshop was the development of a practical goals structure for efficient and effective assessment reporting. It also enabled lecturers to reflect on their teaching, learning and assessment practices, and empowered them to improve current practices based on quality-assured data that is derived from Blackboard Learn.

Through this tool, academics can develop a systematic process for compiling a programme-level accreditation review. They can also align programmes' learning outcomes with institutional learning outcomes to provide a holistic view of student performance.

This collected data will inform the steps to be taken to improve the educational offering to students, which will subsequently manifest in enhanced student learning and success. According to Ms Botha, the University has the technology available, but still lacks the institutional framework for its implementation. Blackboard is assisting the Department for Education Innovation to facilitate programme assessment with technology. In this regard, the University has to realise that 80% is about academic decisions, processes and structures, and only 20% is about the technology.

From a programme assessment point of view, if the University wants to see

a return on investment of its LMS features, it should first ensure that institutional policies and guidelines are available. Secondly, the basic framework structures and resources should be in place to assist academic staff. It is also essential that lecturers embrace the pedagogically sound use of the LMS to gather the necessary data within the system beliefs.

Fostering the use of learning management systems

Given Blackboard's potential as a useful tool for programme assessment, the e-Education Group in the University's Department for Education Innovation decided to drastically change its training strategy by transforming teaching and learning through the promotion of the pedagogically sound use of the digital learning environment. Ms Detken Scheepers, Head of e-Learning at the University, explains that lecturers are encouraged to discuss the educational aspects of the learning material before they consider the functionalities within the digital learning environment to meet students' educational needs. This process shifts their thinking to first evaluate students' educational needs before considering the technology.

Since the implementation of this training strategy in 2011, the use of clickUP by lecturers has increased from 68% to 94.1%. According to Ms Scheepers, the University's hybrid learning strategy was put to the test in the second semester of 2016, when violent campus disruptions forced the institution to implement alternatives to on-campus lectures from October 2016 so that students could finish their academic year. She said that this option was implemented at the time because 83.7% of undergraduate modules included an active course on clickUP. This use of blended learning to complete the academic year was an institutional success story that allowed 83.18% of the students to finish their modules, and 89.74% of students to pass their examinations in 2016. This experience led to an increase in the use of digital tools at the University.

→ *The strategic goals of the University of Pretoria leading up to 2021.*

Quick tips: best practice in assessment and accreditation

1. **Ensure a clear and mutual understanding** of the objectives and aims of and for programme assessment. Governance and workflow structures for assessment should be reviewed and, if not in place, be implemented.
2. **Create a culture of curriculum dialogue** among academics and collaboratively reflect across programmes on teaching, learning and assessment practices, and the challenges and opportunities for programme assessment.
3. **Get a clear understanding between assessment versus grading** and the tools that are used to measure it. Investigate the current role of your digital learning environment and invest time to explore how LMS tools for assessment can be utilised.
4. **Employ proper constructive alignment and course design to** ensure that your efforts in the LMS reflect how your teaching and assessment address your outcomes.

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Developing work-ready graduates

Prof Alta van der Merwe

The groundbreaking Vertically Integrated Projects (VIP) programme of the Faculty of Engineering, Built Environment and Information Technology implemented outstanding teaching and learning methods to produce work-ready graduates in 2019.

Dr Nadia Trent, a lecturer in the Department of Industrial and Systems Engineering, coordinates the programme, a joint initiative with the top-ranking Georgia Institute of Technology. In this programme, students solve real problems for real clients. They practice professional skills and contribute to multidisciplinary design projects in the School of Engineering.

The VIP programme extends the design experience beyond a single semester, with students from all disciplines and at different academic levels participating for up to three years. When students join a team, they spend much of the first semester getting up to speed. They make their most substantial contributions in subsequent semesters, both in terms of technical contributions and team leadership. Students have to ensure the project's continuity when team members change.

The long-term VIP programme creates an environment where faculty members supervise teams and new members are mentored by experienced students. Faculty engagement is crucial to the programme's success and projects must align with the supervisors' research interests to be sustainable.

Supervisors and peers evaluate students' work and the students have the opportunity to improve. They receive a participation certificate to improve their employment prospects.

The teams participated in the following projects in 2019:

- Campus mobility
- Multi-agent transport simulation
- Nutridoctor
- Reliable systems
- Renewable energy systems
- Sensors and systems for unmanned aerial vehicles

With the establishment of its VIP programme, the University has joined the VIP Consortium, which includes more than 30 institutions worldwide. UP is currently the only partner institution in Africa. The University's teams are increasingly using this platform to collaborate on projects and have expanded to include postgraduate students. Dr Trent's dream is to get many more teams involved and for the programme to gain traction in other faculties at UP.

Learning by doing is crucial for developing work-ready graduates. The VIP programme accomplishes this by teaching students to tackle real-world problems.

Prof Johan Joubert (front centre) with one of the first groups of students to participate in the Faculty's VIP programme.

GSTM empowers students with project management skills

Dr Taryn Bond-Barnard

The University of Pretoria is well positioned to respond to the Sustainable Development Goals (SDGs) of the United Nations (UN). The Faculty of Engineering, Built Environment and Information Technology realises the importance of service learning and involves students in community engagement experiences to teach them the valuable skills they need to succeed in their studies, while allowing them to make a tangible difference in many communities.

The Graduate School of Technology Management (GSTM) has partnered with the Department of Business Management in the Faculty of Economic and Management Sciences in a joint initiative to work towards achieving the SDGs.

Since 2017, students of the BCom Business Management Foundation Programme at the University of Pretoria's Mamelodi Campus have formed groups to identify, plan and execute a community-based project in Mamelodi. These projects encourage students to conceptualise novel ways to address at least one of the SDGs in their immediate community.

This initiative also equips students with project management skills and provides mentorship. In 2018 alone, 56 groups of first-year BCom students initiated, planned and executed projects at various early childhood development (ECD) centres in Mamelodi.

The GSTM's involvement in these projects came about after Dr Taryn Bond-Barnard from the Department of Technology Management, Ms Salomé Pretorius from the Department of Business Management and Dr Ilse Fouche, a former lecturer in the Foundation Programme's Language and Study Skills module, identified an opportunity for multidisciplinary research following the collaboration opportunities that the 2017 Tuks Young Research Leader Programme (TYRLP) afforded them.

The application of project management skills plays an important role in any successful project. Through its South African chapter, the Project Management Institute Educational Foundation (PMIEF) provides each group of students with five hours' project management training.

During this training, volunteers show students how project managers and teams should define projects, organise work, create plans and implement their ideas successfully.

In addition to the project management training, several students who are studying towards a Master's in Project Management (MPM) degree at the GSTM and members of the South African Chapter of the Project Management Institute (PMI) volunteer to act as project mentors.

The mentors help their groups to improve the planning and execution of their projects, which increases the projects' impact in the community. In 2018, 34 groups benefitted from the guidance and input of project mentors.

Through their projects, students can see the inter- and transdisciplinary links between their subjects and contribute to solving real-world problems in the Mamelodi community by applying their academic knowledge and the resources at their disposal.

Because students only engage in one project for three of their modules, they have fewer assignments to complete during the year, giving them a chance to interact more meaningfully with the content and experience deeper learning.

This assignment accounts for a significant proportion of students' marks in both the Business Management and Language and Study Skills modules. This approach to learning is a notable example of how students from multiple disciplines and various levels can collaborate on projects that can solidify student knowledge and make an important social impact in the immediate community.

Through their projects, students can see the inter- and transdisciplinary links between their subjects and contribute to solving real-world problems in the Mamelodi community by applying their academic knowledge and the resources at their disposal.

The projects that the students undertake do not only have social and educational value. They also create unique research opportunities. The academics who are involved in this initiative have already identified several opportunities for multidisciplinary research.

Furthermore, several of the MPM students will be conducting research on the effectiveness of the project management interventions in transferring project management skills and knowledge for their mini dissertations.

This will hopefully increase the GSTM's research output and further the PMI chapter's mandate to serve its strong local membership base and support the promotion and advancement of art and science, to the benefit of project management professions.

The programme is now in its third year. The following cohort of 318 first-year students addressed food security and the sourcing, construction and utilisation of EcoBricks in Mamelodi in 2019.

Creating a yearning for learning: initiatives for increasing student engagement

Prof Alta van der Merwe

The University of Pretoria's approach to teaching and learning is based on inquiry-based learning, hybrid learning and community-based learning. Its Teaching and Learning Plan is focused on a number of strategies to enhance access and successful student learning. Key drivers to achieving its institutional goals related to teaching and learning include the centrality of the academic mission and the student-centredness of its offerings.

The Faculty of Engineering, Built Environment and Information Technology is committed to student success and achieving world-class teaching and learning outcomes. It has a progressive strategy in place to address several key priorities. These include increasing the Faculty's overall module success rates, increasing minimum-time completion rates, transforming the curriculum, bringing about transformation through the curriculum, systematically monitoring the implementation of the hybrid model of teaching and learning, and improving the Faculty's international ranking through teaching and learning practices.

The Faculty hosts an annual Teaching and Learning Seminar, where lecturers in the Faculty can share initiatives for increasing student success – some which worked, and can be emulated by other staff members; and others that were not as successful, but could be used by other colleagues in different situations, having learned from shared past experiences. The theme of the Faculty's fifth seminar, held at the University's Future Africa Campus on 30 October 2019, was "Creating a yearning for learning: initiatives for increasing student engagement".

The Dean, Prof Sunil Maharaj, welcomed delegates from all four schools in the Faculty. He declared that he was invigorated to see the innovations in teaching and learning taking place in the Faculty.

Prof Norman Duncan, Vice-Principal: Academic delivered the opening address. He commended the Faculty for foregrounding teaching and learning. He stated that the Faculty is setting the trend for teaching and learning at the University, and its initiatives are impacting on what other faculties are doing in the teaching and learning space. He ascribes this to the excellent leadership in the Faculty, as well as the institutional culture that encourages student engagement.

Personalised adaptive learning

The keynote address was delivered by Dr Nathalie Charlier from the Katholieke Universiteit Leuven (KU Leuven) in Belgium. Dr Charlier is an associate professor in the Faculty of Pharmaceutical Sciences and programme director of the Educational Master's degree in Health Sciences. She has participated in several national and international research projects in educational technology and game-based learning and assessment. One of her research interests is the use of new technologies in education. Her address focused on personalised learning through interactive video. She discussed trends in e-learning, particularly as they relate to the Fourth Industrial Revolution (4IR), and disruptive technologies.

Through personalised adaptive learning, game-based learning allows students to choose what they wish to learn on an e-learning platform. Students who require background information have access to it, while students with prior knowledge can go straight into the acquisition of new information. She provided delegates with some advice when using multimedia learning, such as avoiding cognitive overload and presenting new knowledge in small bite-sized chunks. She emphasised the need to manage students' essential processing of new information to ensure that it is retained in their long-term memory.

Dr Charlier went on to discuss the advantages and disadvantages of interactive video as a teaching and learning tool. Advantages include the fact that it is self-paced, sustainable, convenient and standardised. Disadvantages include aspects such as cost, connectivity, instructor effort and learner isolation. She concluded her presentation by elaborating on the key challenges of interactive learning. These include incorporating flexibility, stimulating interaction, facilitating students' learning processes and fostering an effective learning climate.

Planned changes in teaching

Following the keynote address, Dr Helen Inglis of the Department of Mechanical and Aeronautical Engineering and Carl Sandrock of the Department of Chemical Engineering presented the preliminary results of a survey of planned changes in teaching that they had conducted in the Faculty. The purpose of this survey was to create a culture of sharing and support, and to spark more conversations around teaching, as they believed that reflecting on teaching contributes to enhancing teaching and learning in the Faculty. The conclusion they reached was that teaching staff in the Faculty are serious about teaching, and are making a significant effort to help students to learn, understand and succeed.

The Faculty has a progressive strategy in place to address its overall module success rates, increase minimum-time completion rates, transform the curriculum, bring about transformation through the curriculum, systematically monitor the implementation of the hybrid model of teaching and learning, and improve the Faculty's international ranking through teaching and learning practices.

Assessment and feedback

The seminar featured two presentations on assessment and feedback.

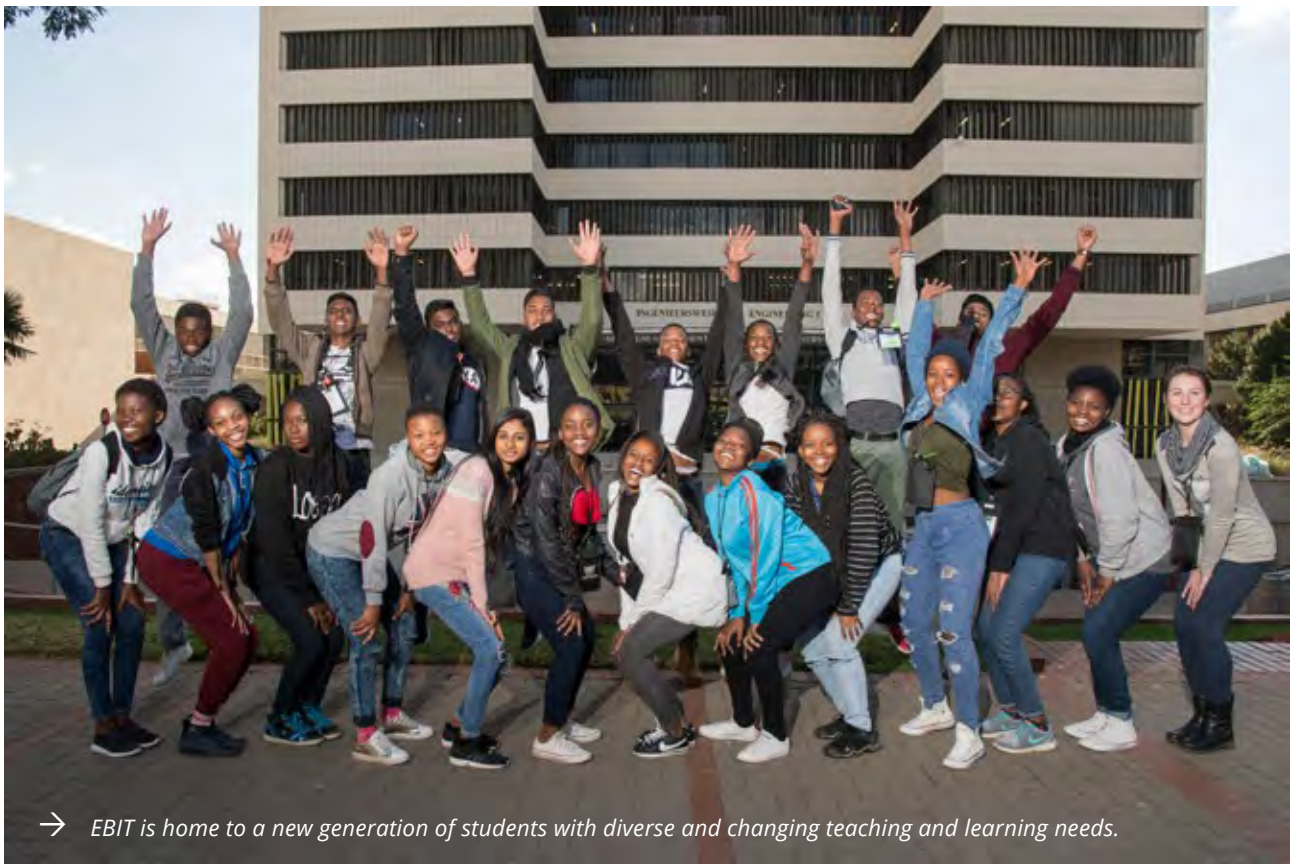
Annique Smith of the Department of Information Science shared her experience on formative feedback through two-stage submissions, where students had two deadlines: the first to receive formative feedback regarding the project deliverables, and the second for assessment purposes. This gave students the opportunity to process and incorporate the feedback received in order to improve their work for final assessment. She found that the students engaged with these optional deadlines to deliver better outcomes.

Prof Willie Nicol of the Department of Chemical Engineering presented a recipe for harvesting more productive student hours. The recipe entails various online preparation tools like Youtube lectures and Perusall annotation that are linked to 20 three-hour work sessions. Randomly assigned groups of three students each complete the session tutorial together and then rate each other's work. Each work session was concluded with a 30-minute individual semester test in order to assess preparation and class participation. It was argued that the recipe resulted in improved understanding of the subject given a fixed time investment, thus increasing productivity.

Student reflection

Three presentations were delivered on student reflection.

Prof Nico Wilke of the Department of Mechanical and Aeronautical Engineering discussed the important role of reflection in learning. This essential ingredient of learning is often overlooked, as true learning only takes place once one reflects on what one has learned. This shift in focus places emphasis on the conceptual understanding of the curriculum content, which leads to critical thinking and actual learning.



EBIT is home to a new generation of students with diverse and changing teaching and learning needs.

This requires crafted assignments, where each question has a clear purpose and meaning. This drives the learning momentum towards reflection. He concluded his presentation by reminding delegates that learning is not about finding the right answers, but about asking the right questions.

Prof David Walwyn of the Graduate School of Technology Management reflected on developing an awareness of a personal epistemology in a cohort of technology management research students. This entailed considering how students' personal beliefs impact on their cognitive thinking and reasoning. The challenge was to encourage a level of ontological self-reflection, within which students could be made aware of the limitations of positivism in the analysis of management problems. Changes in his teaching method included the use of an awareness questionnaire and more time for class discussion, which resulted in an improvement in the quality of students' research proposals.

Prof Warren du Plessis of the Department of Electrical, Electronic and Computer Engineering asked the question: Why do students realise I care? He focused on the importance of developing a nurturing relationship with students. He described some of the approaches he uses to make students realise that he cares about both the course and the students themselves. This included listening to students' suggestions and providing feedback, developing mutual respect and trust, breaking down the barriers that exist between the lecturer and the student, and encouraging interaction. While he does not consider any of his approaches to be significant in themselves, he concludes that everything lecturers do contributes to students' impression of them as lecturers.

Active learning

The theme of the last five presentations of the day was active learning.

The presentation of Dr Marie Hattingh of the Department of Informatics explored bridging the gap between theory and practice. In the Systems Analysis and Design module, students often struggle to relate the theory of modelling with its practice. The presentation of theory, tutorial and practical classes in this module was restructured to optimise students' learning experience. This intervention resulted in teaching being concentrated on the modelling tool instead of on aspects related to understanding the theory, which resulted in increased student engagement. Targeted discussion classes based on the concepts taught previously allowed students to reflect on what they had learned, and allowed them to ask pertinent questions on areas with which they experience difficulty.

Dr Nadia Trent of the Department of Industrial and Systems Engineering presented the case of active learning in engineering economics: making money move. She decided to change her approach to teaching the subject of engineering economics by incorporating aspects of active learning. She combined elements of collaborative, experiential and self-

guided learning with gamification in order to emphasise the relevance of financial management to students who are on the threshold of their working lives. She also resocialised her classroom for increased student engagement by changing the way she related to her students. This led to them becoming co-conspirators in discovery.

Carl Sandrock of the Department of Chemical Engineering explained how he made use of hands-on activities as an aid to understanding dynamics and control. The material presented in the modules of Process Dynamics and Control is often abstract with no real-world value. He therefore restructured his course by focusing on small-scale real systems that students can touch and interact with during the tutorials. This provided a more cohesive underpinning to the examples of abstract manipulation by relating the content to students' personal experience rather than theory. This allowed for a more immediate, shared experience of abstract concepts, and resulted in positive feedback from the students.

Prof Tania Hanekom of the Department of Electrical, Electronic and Computer Engineering introduced delegates to the MARVelous Micros Project. This formed part of teaching related to the microcontroller-based autonomous robotics vehicle (MARV), presented in the Microprocessors module. In an attempt to increase student engagement, she developed an online textbook, which was aligned to the development of a practical project involving robotic vehicles. It was specifically focused on addressing issues at a basic level that students struggle to understand. The textbook was made available in Google Docs, and included the option for live updates based on student feedback. It also introduced a flipped classroom strategy. The approach seemed to have the highest impact on the middle-level students, while the performance of the top students was slightly improved. Unfortunately, the performance of the poor students did not show any noticeable improvement.

The key challenges of interactive learning include incorporating flexibility, stimulating interaction, facilitating students' learning processes and fostering an effective learning climate.

Prof Christo Venter of the Department of Civil Engineering discussed interactive learning through gaming simulation in a cross-disciplinary course. The Infrastructure Planning module entails integrated land-use transport planning, and is taught in conjunction with the Department of Town and Regional Planning. A game, called UPTown, was developed as a bespoke application that integrates commercial software with a locally developed interface to simulate the development of a hypothetical town over a 30-year timeframe. Students take on specific roles of either public sector planners or private sector real estate developers. This allows them to explore the problems of conflicting objectives and discover the value of cooperative planning in land use and transport development. An assessment of student performance showed that the game significantly enhanced the achievement of learning outcomes.

Conclusion

The seminar was concluded with a discussion on teaching and learning initiatives, led by the Faculty's Deputy-Dean: Teaching and Learning. The value of the presentations in starting a conversation about teaching and learning was commended, and several suggestions were made, which will be incorporated in the development of future initiatives to enhance teaching and learning in the Faculty.

Dean of the Faculty, Prof Sunil Maharaj, keynote speaker, Dr Nathalie Charlier, Deputy Dean: Teaching and Learning, Prof Alta van der Merwe, and University of Pretoria Vice-Principal: Academic, Prof Norman Duncan.

Celebrating the Faculty's exceptional achievers

The University of Pretoria's Academic Achiever Awards is an annual event that celebrates the institution's exceptional achievers. The event was held at Union Caterers in Pretoria on 21 May 2019. At this event, awards were made to the recipients of the Chancellor's Award: Research, the Exceptional Academic Achievers, the Exceptional Young Researchers, the Teaching Excellence Laureate Award and the Community Engagement Award. The new National Research Foundation (NRF) ratings for 2019 were also announced.

→ *Prof Josua Meyer.*

Chancellor's Award: Research

The Faculty of Engineering, Built Environment and Information Technology takes pride in the fact that, in 2019, one of the top prizes at the Exceptional Achiever Awards function, the Chancellor's Award: Research, was awarded to one of its prestigious researchers: Prof Josua Meyer.

This award is made in recognition of exceptional achievement in the field of research, aimed at the advancement of science, and the associated promotion of the interests of UP. Prof Meyer is Head of the Department of Mechanical and Aeronautical Engineering, and Chair of the School of Engineering. His research focus is on thermal sciences and fluid flow, as well as on heat exchangers.

His heat exchanger work is focused on the transitional flow regime, nanofluids and condensation at a fundamental level, while at an applications level, it is focused on the investigation of thermal, solar, wind and nuclear energy.

His research group conducts joint research and published with scholars from L'Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland, Massachusetts Institute of Technology (MIT), Massachusetts, USA, Ghent University, Belgium, Duke University, North Carolina, USA, the University of Edinburgh, Scotland, and the Institut National des Sciences Appliquées de Toulouse (INSA), France. He is a member, fellow or honorary fellow of various professional institutes and societies, and holds an A2 rating from the NRF.

Exceptional Academic Achiever

The Faculty also congratulates Prof Walter Focke, Director of the Institute of Applied Materials and a full professor in the Department of Chemical Engineering, for his recognition as an Exceptional Academic Achiever. This award is made annually to senior academics who have already received the status of professor, are highly regarded by their peers, and have consistently excelled in the areas of undergraduate and postgraduate teaching and learning, research, community service and administration over a period of time.

His core research is in chemical product design with an emphasis on carbon materials, polymer additive technology, pyrotechnics and malaria vector control. His research on carbon technology focuses on the use of expandable graphite in thermal energy applications and as conductive and flame-retardant additive in polymers. A highlight of his research was the development of an elegant method for making medium-density graphite foams with high thermal conductivity.

His clay and polymer additive technology research is aimed at functional applications in polymers to improve thermo-oxidative stability and flame retardancy. In the field of pyrotechnics, he successfully developed a range of "green" compositions for use as time delays and initiating compositions in chemical mine detonators.

He is also a member of the UP Institute for Sustainable Malaria Control, which won a National Science and Technology Forum (NSTF) Award in 2018. His achievements in malaria vector control relate to the controlled delivery of the following repellents and insecticides: a particle-stabilised insecticide for an indoor residual spray that outlasted DDT in laboratory trials, a patented low-cost wall lining that has successfully completed a five-year field trial in Limpopo, a mosquito-repellent textile based on bicomponent fibres that are currently in an industrial scale-up trial phase, and a particularly effective topical mosquito repellent that also acts as an insecticide. He holds a B3 rating from the NRF.

The Exceptional Academic Achiever Award is made annually to senior academics who are highly regarded by their peers, and have consistently excelled in the areas of teaching and learning, research, community service and administration over a period of time.

→ *Prof Walter Focke.*

Exceptional Young Researcher

The Faculty also featured in the Exceptional Young Researcher Awards. This award is given to exceptional young achievers in the field of research, as seen against the University's strategic goals of achieving academic excellence, international competitiveness and local relevance. Two of its young researchers received this award.

Dr Deon Brink is a senior lecturer in the Water Utilisation and Environmental Engineering Division of the Department of Chemical Engineering. He is currently leading several projects that involve diverse research, with a particular interest in resource recovery from waste. This approach is imperative for sustainable development and for catalysing a circular economy.

Prof Nico Wilke is an associate professor in the Department of Mechanical and Aeronautical Engineering, where he heads up the Gradient-only Research Group, while also contributing to the activities of the Centre for Asset and Integrity Management (C-AIM). Over the past decade, he has developed a new

Dr Deon Brink.

Prof Nico Wilke.

optimisation paradigm that presents a solution to discontinuous optimisation problems, rather than conventional mathematical programming approaches that often fall short of providing solutions to discontinuous problems.

Prof Wilke also received recognition as an academic author by receiving the Vice-Chancellor's Scholarly Book Award. This was awarded for his publication, together with the late Prof Jan Snyman (formerly also from the Department of Mechanical and Aeronautical Engineering), of the second edition of the publication *Practical mathematical optimisation – basic optimisation theory and gradient-based algorithms.*

The Exceptional Young Researcher Award is given to young achievers in the field of research, as seen against the University's strategic goals.

Teaching Excellence Laureate Award

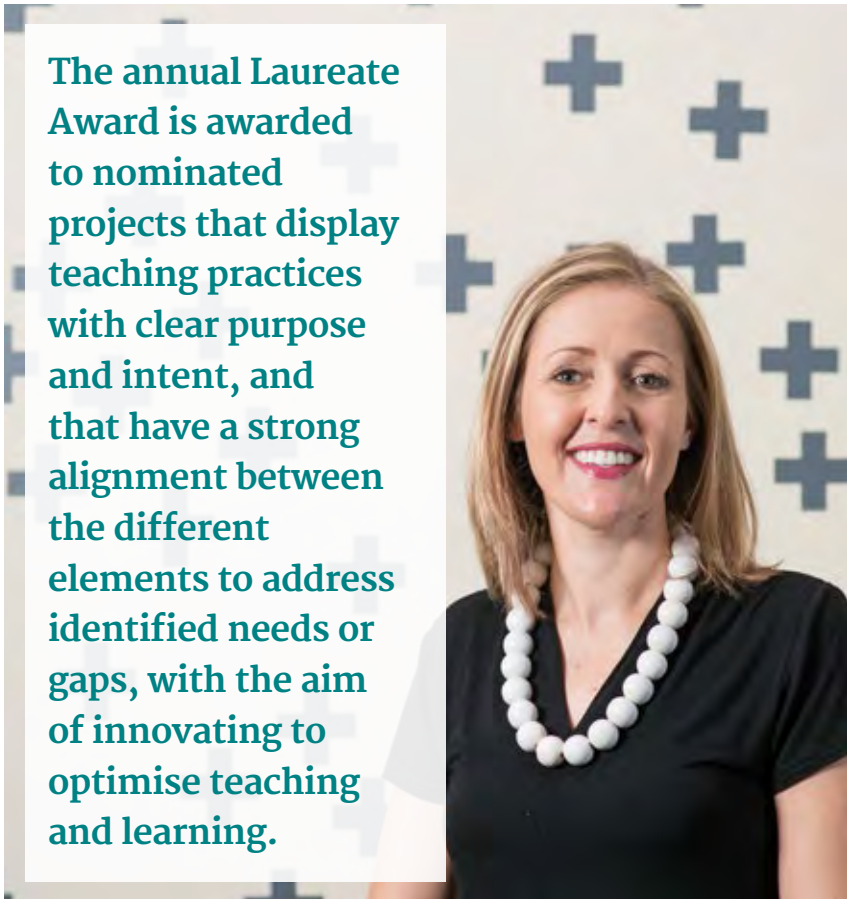
The annual Laureate Award is awarded to nominated projects that display teaching practices with clear purpose and intent, and that have a strong alignment between the different elements, in the broader context, to address identified needs or gaps, with the aim of innovating to optimise teaching and learning.

Recipients display significant evidence of impact on student learning. The projects in which they are involved should be sustainable, and it should be possible to replicate them in other contexts. They should also contribute to best practice in teaching, and should display significant evidence of innovation that addresses the identified challenges.

This award was presented to Dr Riana Steyn, a lecturer in the Department of Informatics. She describes her teaching style as characterising a similar mindset as that required of an entrepreneur: having an appetite for risk-taking, passion, self-efficacy, proactiveness, innovation and perseverance.

This allows her to shape her students' way of thinking in order to enable them to survive in the modern world. As academics teach in an ever-changing university landscape, in which students' needs are constantly changing, she realised the need to adapt her teaching approach to include the adoption of technologies for learning.

The main focus of her research is on how she can adopt innovative teaching styles, technologies and techniques to ensure that students remember what they need to remember. This led to the development of an interactive textbook using strategies that are focused on research and understanding why it is necessary to approach educational research in a different way to the way it has been done in the past.



→ *Dr Riana Steyn.*

Community Engagement Award

The Community Engagement Award is awarded annually to an individual to recognise community engagement as a long-standing and valued tradition in higher education and an extensive, high-impact practice in teaching at UP.

This award was presented to Dr Carin Combrinck, Director of the Unit for Urban Citizenship and a senior lecturer in the Department of Architecture. Her field of interest is the role of architecture in community development, with an interdisciplinary view towards social innovation and urban citizenship. A highlight of her work is the Mamelodi Community Learning Collaborative, a formal undertaking between UP's Mamelodi Campus and Rutgers University, Newark, USA.

Her contributions to this endeavour focus on the educational ecosystem, with a specific view to the spatial conditions required for safe and secure neighbourhoods. To this end, her current cohort of honours students is engaged with Tsako Thabo High School, one of the participants in the Mamelodi Collaborative.

→ *Dr Carin Combrinck.*

NRF-rated researchers

The event also celebrated the University's NRF-rated researchers for 2019, several of whom share their expertise in the Faculty of Engineering, Built Environment and Information Technology. These include the following:

- Prof Jan Eloff, Deputy-Dean: Research and Postgraduate Studies (B2 rating)
- Prof Schalk Els, Department of Mechanical and Aeronautical Engineering (B2 rating)
- Prof Hannes Gräbe, Department of Civil Engineering (B3 rating)
- Prof Hein Venter, Department of Computer Science (B3 rating)
- Prof Warren du Plessis, Department of Electrical, Electronic and Computer Engineering (C2 rating)
- Prof Michael Gitau, Department of Electrical, Electronic and Computer Engineering (C2 rating)
- Prof SW Jacobsz, Department of Civil Engineering (C2 rating)
- Prof Machdel Matthee, Department of Informatics (C2 rating)
- Prof Tinus Pretorius, Graduate School of Technology Management (C2 rating)
- Dr Uche Chude-Okonkwo, Department of Electrical, Electronic and Computer Engineering (C3 rating)
- Dr George Thopil, Graduate School of Technology Management (Y2 rating)
- Dr Xianming Ye, Department of Electrical, Electronic and Computer Engineering (Y2 rating)

International young researcher award for EBIT hydropower researcher

Chantel Niebuhr from the Department of Civil Engineering received the International Hydropower Association (IHA) Young Researcher Award for 2019.

As part of the award, she was granted attendance to the World Hydropower Congress in Paris during May 2019. The Congress focused on the power of water in a sustainable, interconnected world – specifically the role of hydropower in delivering on the Paris Agreement and the Sustainable Development Goals.

The awards granted during the Congress recognise relevant work done globally in the hydropower field. The IHA Young Researcher Award recognises emerging talent in the hydropower sector.

Chantel Niebuhr.

Exceptional female scientist

Dr Marilize Everts, a postdoctoral fellow in the Department of Mechanical and Aeronautical Engineering, was awarded the 2018 L'Oréal-UNESCO Women in Science for Sub-Saharan Africa Postdoctoral Award. This award recognises and rewards talented young female scientists in the field of life sciences and physical sciences. As part of the award, Dr Everts attended a leadership training course in Kenya, hosted by the L'Oreal-UNESCO Foundation.

The purpose of the course was to strengthen the award recipient's career and connect her with scientific women all over the continent.

Dr Everts's research focuses on improving the fundamental understanding of mixed convection in laminar and transitional flows. For her postdoctoral research, she is primarily focusing on the heat transfer and pressure drop of high viscosity fluids. The resulting correlations will enable engineers to design heat exchangers that operate in the transitional flow regime, as well as to optimise the design of heat exchangers that operate in the laminar flow regime. The applications of this fundamental research are very wide and range from domestic systems such as air-conditioners in cars and buildings to renewable energy systems.

Dr Everts has received over 20 awards, including the TATA Africa Scholarship for Women in Science, Engineering and Technology (in both 2015 and 2017), the S^2A^3 Medal for Original Research at master's degree level, and the Eskom Chairman's

Dr Marilize Everts.

University Award for the best final-year engineering student in 2012. She is currently involved in the ThermaSmart Horizon 2020 project that involves 18 universities across five continents. It focuses on the phase-change cooling of high-powered electronic devices, as well as a Royal Society-funded collaboration between Imperial College London and the universities of Pretoria, Nigeria and Mauritius that focuses on unsteady boiling in solar power plants that typically occurs when the sun is blocked by clouds.

Chinese Government Friendship Award

Prof Ian Craig from the Department of Electrical, Electronic and Computer Engineering has been awarded a 2019 Chinese Government Friendship Award.

The award is the highest honour given to foreign experts who have made outstanding contributions to the country's economic and social progress. Prof Craig's relationship with the Chinese control systems community started about 20 years ago. In particular, he supported this community in its efforts to increase international participation as President of the International Federation of Automatic Control (IFAC) from 2011 to 2014. He was also appointed Chief Academic Master of the Chinese Government's 111 Project on intelligent control and decision optimisation for manufacturing processes at the Central South University in Changsha, China, in 2017.

In this role, he acts as advisor to the School of Automation at the Central South University. There have also been a number of exchanges between UP and the Central South University, which have led to joint research projects in which he has been involved.

Prof Ian Craig.

IEOM Society International Fellowship

Prof Sarma Yadavalli, Head of the Department of Industrial and Systems Engineering, has been selected as a Fellow of the Industrial Engineering and Operations Management Society International

The Fellow distinction is the highest level of membership in the organisation. This prestigious award recognises an individual researcher's contribution to the industrial engineering and operations management profession. Fellows have distinguished themselves by conducting theoretical and applied research.

Prof Sarma Yadavalli .

Data science student wins international professional award

Patrick Sekgoka, a PhD student who focuses on data science in the Department of Industrial and Systems Engineering, received an International Professional Award at the SAS Global Forum 2019.

The SAS Global Forum is a learning-focused conference that features over 5 000 of the brightest SAS users and experts in the world. It is an excellent forum for knowledge expansion and networking with other users at all skills levels. Patrick was honoured at this event, along with 14 other SAS professionals from Brazil, Canada, India, Japan, Poland and the United Kingdom.

Patrick Sekgoka.

EBIT researchers honoured in NSTF-South32 Awards

The exceptional work of two EBIT researchers has been recognised by the National Science and Technology Forum (NSTF) through the organisation's awards programme this year.

Prof Xiaohua Xia.

The NSTF is the largest and most representative non-profit body in the fields of science, engineering and technology (SET) and innovation in South Africa, and is recognised by government for the purposes of consultation. The NSTF's vision is a transformed country where SET and innovation contribute to attaining a high quality of life for all who live here. The profile of SET professionals is representative of the population profile in areas where education is effective, particularly in terms of performance in SET subjects and the promotion of innovation. Through the NSTF-South32 Awards, the NSTF has, since 1998, recognised and celebrated individuals and teams for innovation and outstanding contributions in the SET fields.

Prof Xiaohua Xia from the Department of Electrical, Electronic and Computer Engineering was nominated for consideration of a 2018/19 NSTF-South32 Award in the category Lifetime Awards. Being nominated means that he has made an outstanding contribution to SET and innovation in South Africa.

In his invitation to Prof Xia to attend the Award Gala Dinner, the Chairman of the NSTF Adjudication Panel, Mr Denis Hunt, congratulated both him and the University of Pretoria on his nomination for this prestigious award.

Dr Mardé Helbig.

The NSTF Emerging Researcher Award was conferred to Dr Mardé Helbig, a senior lecturer in the Department of Computer Science. The award recognises a researcher's outstanding contribution to SET and innovation through their research outputs over a period of up to six years in research, predominantly in South Africa. It is an honour to be nominated for an NTSF Award, and to reach the finals is an exceptional milestone. The NSTF Award Gala Dinner is the organisation's flagship celebration of South African research excellence. The outstanding research output of the winners year after year is indicative of South Africa's advancement, economic growth and social upliftment projects.

The NSTF's vision is a transformed country where SET and innovation contribute to attaining a high quality of life for all who live here.

Top industry awards for Mining Engineering researchers

Two of the Department of Mining Engineering's researchers have been honoured by industry organisations for their exceptional contributions to their respective fields.

Prof Francois Malan (left) and Prof John Napier with Mr Alistair Macfarlane (right), President of SAIMM.

Prof Francois Malan and Prof John Napier were awarded the Silver Medal of the Southern African Institute of Mining and Metallurgy (SAIMM) for their joint publication in *Journal of the Southern African Institute of Mining and Metallurgy* of an article titled "Reassessing continuous stope closure data using a limit equilibrium displacement discontinuity model".

The SAIMM Silver Medal is awarded annually to researchers who have published papers that make a major contribution to the professions of mining and metallurgy and to the prestige of the Institute.

In addition to this achievement, Prof Napier, who serves as an extraordinary professor in the Department, received the inaugural Napier Award in recognition of his enormous contribution to the field of rock engineering over many decades. This award was launched at the first annual banquet of the South African National Institute of Rock Engineering (SANIRE).

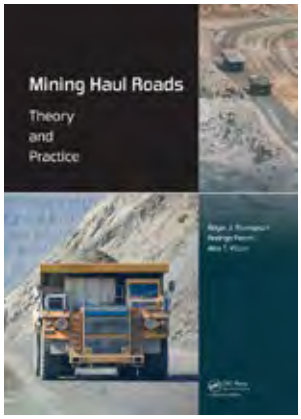
Prof Napier is world-renowned for the development of a displacement discontinuity computational method to simulate three-dimensional fracture growth with application to hydraulic fracturing, mixed mode fracture propagation and dynamic rock fracture processes near mine excavations. As supervisor and advisor of many PhD students, his guidance has led to the incredible achievement of four candidates being awarded the prestigious Rocha Medal of the International Society for Rock Mechanics for the best PhD thesis in the world. This record is unmatched in any country.

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

The Napier Award will, in future, be awarded in recognition of distinguished contributions to the field of rock engineering. The criteria will include conducting world-class research in rock mechanics over many years, as well as recognised publication in local and international journals.

EBIT researchers launch award-winning professional title

In February 2019, Prof Alex Visser, Prof Roger Thompson and Prof Rodrigo Peroni from the Department of Civil Engineering launched their book, titled *Mining haul roads – theory and practice*. The title was chosen as the Taylor & Francis Outstanding Professional Title in Engineering for 2018.



Authors (from left): Prof Roger Thompson, Prof Rodrigo Peroni and Prof Alex Visser.

Mining haul roads are a critical component of surface mining infrastructure and the performance of these roads has a direct impact on operational efficiency, costs and safety. A significant proportion of a mine's cost is associated with material haulage, and well-designed and managed roads contribute directly to reductions in cycle times, fuel burn, tyre costs and overall cost per tonne hauled, and critically underpin a safe transport system.

New partnership between UP and the CBE

The University of Pretoria, through the School for the Built Environment, signed a Memorandum of Understanding with the Council for the Built Environment (CBE). This partnership will enhance the recruitment of high school learners into careers in the built environment and emphasise the importance of mathematics and science for the Fourth Industrial Revolution in schools.

The following goals will be pursued:

- The Faculty will be the link to the South African Universities' Deans Forum, which is a network for all tertiary institutions' faculties for engineering and the built environment.
- The Faculty, together with other relevant faculties at UP, will embrace the support of the CBE in driving the transformation agenda through the CBE National Transformation Indaba.
- The Faculty and the CBE will share resources to successfully deliver the CBE National Transformation Indaba and develop skills and graduates needed for the built environment.
- The CBE will assist to solicit funding to support female and black students to pursue undergraduate and postgraduate studies in construction, town and regional planning, quantity surveying and other related built environment degree programmes offered in the School for the Built Environment.
- UP will assist the CBE on specific research projects and the training of industry personnel as identified and required by the CBE.

Priscilla Mdlalose, CEO of the CBE (left) and Prof Tawana Kupe, Vice-Chancellor and Principal of UP, during the signing of the Memorandum of Understanding.

Signing the collaboration agreement: (back from left): Dean of the Faculty of Engineering, Built Environment and Information Technology, Prof Sunil Maharaj, and UP Vice-Principal: Research and Postgraduate Education, Prof Stephanie Burton; (front from left): UP Vice-Chancellor and Principal, Prof Tawana Kupe, Ambassador of Italy, Paolo Cuculi, and Unimore Vice-Chancellor, Prof Sergio Ferrari.

Collaboration in car manufacturing and transport industries

The University of Pretoria signed a collaboration agreement with the University of Modena and Reggio Emilia (Unimore) to promote learning and research in the car manufacturing and transport industries in South Africa. Other Gauteng-based partner universities include the University of the Witwatersrand and the Tshwane University of Technology.

The agreement will ensure that the institutions work together by developing programmes designed to promote and facilitate the international exchange of ideas and research. It addresses the United Nations Sustainable Development Goal (SDG) 9 (to build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation); SDG 11 (to make cities and human settlements inclusive, safe, resilient and sustainable) and SDG 17 (to strengthen the means of implementation and revitalise the global partnership for sustainable development). Programmes of particular interest are the Erasmus Plus programmes for student and staff exchanges and the Horizon 2020 programmes for collaborative research. Horizon 2020 is the biggest European Union (EU) Research and Innovation programme that takes innovative ideas from the laboratory to the marketplace and stimulates economic growth and job creation.

Unimore has taken advantage of its position in the heart of the "Motor Valley" in northern Italy to build excellent collaboration with global leaders in supercar and related automotive engineering and manufacturing, such as Ferrari, Maserati and Lamborghini. It also has a proven record of success in obtaining EU funding for student and staff exchanges and for collaborative research with universities in other countries and with industry.

The automotive manufacturing industry is important, because it is the largest sector of the manufacturing industry in South Africa. Mobility engineering is growing massively in importance as pressures on society increase due to rapid urbanisation and due to the environmental impact of mobility.

Engineering 4.0 is set to take transportation into the future

The University of Pretoria's state-of-the-art Engineering 4.0 Building, which is nearing completion, will host Africa's first independent transport reference and testing facility. It will also be a research and training hub for smart transport systems, said Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology.

Prof Maharaj was speaking at a recent roof-wetting function that was attended by the UP Executive, architects, representatives of the South African National Roads Agency Limited (SANRAL) and the Council for Scientific and Industrial Research (CSIR). The building, which is close to UP's Future Africa Campus in Hillcrest, is the result of a partnership with SANRAL and the CSIR.

In terms of the United Nations' 17 Sustainable Development Goals (SDGs), innovation, infrastructure, and sustainable cities and communities are critical for developing any economy. This new hub is aimed at installing UP as a leader in this field and making a distinct contribution to these goals.

"It aims to be a transportation research hub, which will foster interdisciplinary research in the wake of the Fourth Industrial Revolution," said Prof Maharaj. Beyond its academic mandate, Engineering 4.0 will function as a hub for smart cities and transport. It will share its vast resources in technology and data sciences with all faculties via the Future Africa Campus, which is a platform for developing interdisciplinary and transdisciplinary research networks within the university and the global research community.

Prof Maharaj explained that the structure is built in three parts. SANRAL's National Roads Materials Reference Laboratory will be the site for the independent reference testing of materials for the road construction industry. Such testing will characterise materials for appropriate construction. The independent materials reference and testing facility will be the first in Africa.

There is also a laboratory for the training and certification of laboratory technicians and engineering students. The objective is to ensure that materials testing in the field is up to standard and that the technicians who conduct the testing are capable and certified to do such tests with a high degree of accuracy, explained Prof Maharaj.

Prof Wynand Steyn, Head of the Department of Civil Engineering, indicated that students will be exposed to hands-on research activities in these laboratories, supporting theoretical teaching. This will enable a deeper understanding of the civil engineering curriculum in preparation for students' working lives as civil engineers. "The new laboratory supersedes the existing one with a modern facility that is much larger and better laid out for optimal working conditions. The location inside a natural forest on campus supports a positive learning environment."

The new hub is aimed at installing UP as a leader in the field of innovation, infrastructure, and sustainable cities and communities, and at making a distinct contribution to this Sustainable Development Goal.

The Engineering 4.0 Campus also has an Accelerated Pavement Testing (APT) facility and active traffic track for real-traffic testing. This unique facility allows one to characterise pavement design and construction while using data obtained from the active traffic lane to model many aspects in transportation systems. "The proximity of this hub to the N1/N4 highway is unique as, adjacent to the facility, we have an active test lane on the highway, which is a first for Africa, where we will collect real-time data to measure and model transport systems, and design and test internet of things sensors and devices," said Prof Steyn. Such data and models will support the planning and design of future transportation systems, and support cost-effective and innovative pavement engineering for Africa's infrastructure development.

SANRAL decided to initiate and support the project, as it allows for research, as well as the training and education of road pavement specialists on all levels (technicians to engineers with PhDs), and combines the talent of UP's students and staff with that of the CSIR. It also brings researchers from South Africa and across Africa together in a collaborative and interdisciplinary work approach. This will support the economic growth of South Africa through improved understanding of vehicle-pavement interaction, explained Prof Maharaj.

Vice-Chancellor and Principal, Prof Tawana Kupe, said: "We are not talking about anticipating the Fourth Industrial Revolution, we are living in the Fourth Industrial Revolution, we are talking about anticipating the Fifth Industrial Revolution."

He explained that "infrastructure is fundamental to economic growth. It deals with smart transportation and can be transformative to the country, continent and globally. This will be key to the trans-disciplinary activities of teaching, research, testing and training, and collaboration."

Construction of the building began in August 2018 and completion is expected in February 2020.

Making world-class knowledge accessible to local researchers

The Faculty of Engineering, Built Environment and Information Technology is committed to advancing the principles of the Fourth Industrial Revolution to inspire innovative research. To this end, the Faculty makes an effort to bring world-class knowledge to local researchers.

During 2019, EBIT hosted a range of local and international experts who shared their innovative work.

One of the highlights on the Faculty's calender is the annual Hendrik van der Bijl Memorial Lecture. This year's lecture was delivered by Andrew Kirby, President and CEO of Toyota SA. He presented a case for the South African automotive industry in a time of disruption globally. During his lecture, he discussed whether the South African automotive industry can contribute to the reindustrialisation of the country.

Other insightful lectures were delivered by Prof Norbert Gronau, Chair of Business Informatics, Processes and Systems at the University of Potsdam, Germany, and Prof David Hensher, Founding Director of the Institute of Transport and Logistic Studies at the University of Sydney.

Prof Gronau discussed ways in which workers could be prepared for digital transformation in the Fourth Industrial Revolution by sharing experiences from the European market. Prof Hensher considered the future of transportation by describing the international transition towards smart mobility, and speculating on what this might mean for cities, citizens and transport companies of the future.

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Artificial Intelligence Student Society takes shape

Derrick Beckedahl, Pat Pretorius and Nelishia Pillay

Artificial intelligence (AI) has played an increasing part in students' academic journey as the full-scale Fourth Industrial Revolution (4IR) looms. In light of this, the Artificial Intelligence Student Society (AISS) was established at the University of Pretoria in February 2019. It is a multidisciplinary student society that promotes artificial intelligence literacy and innovation and has more than 200 members from a variety of disciplines.

On 4 April 2019, the AISS hosted its first event, titled "An introduction to artificial intelligence". Prof Nelishia Pillay, Head of the Department of Computer Science, opened the event with a presentation on the impact of AI and its relevance in the context of 4IR. A guided work-through of Andrew Ng's introductory AI course, hosted through the online learning platform Coursera, followed Prof Pillay's introduction.

Another event, which was hosted on 16 May 2019, saw guest speaker Cindy Friedman present her research on the ethics of AI. The presentation was titled "Should artificially intelligent social robots be used as slaves?"

The AISS plans to host many more exciting events, each with a focus on promoting AI literacy and encouraging members to think critically about all the aspects of AI, from implementation to ethical considerations and everything in between.

The Faculty of Engineering, Built Environment and Information Technology wishes the AISS well in its endeavours in promoting AI as it moves into the 4IR. For more information about the AISS or to become a member, send an email to art.int.soc@gmail.com.

"I think the AISS is essential in university spaces. It is important to promote AI literacy and utilise AI and IoT to solve our most fundamental problems."

– Lindokuhle Ngwenya

"The time for 'silo-academia' has long since passed. I look forward to seeing the AISS grow, not only in size, but in the diversity of its members, facilitating the spread of cross-campus AI literacy in the hopes of a student body better equipped for 4IR."

Pat Pretorius, Chairperson, AISS

"With the increasing adoption of AI systems in our everyday lives, it is becoming imperative that society as a whole becomes more AI literate, and that the doomsday stigma that Hollywood has built up around AI is broken down."

Derrick Beckedahl, Vice-Chairperson, AISS

EBIT students fly UP flag high

University of Pretoria students once again demonstrated the ability to translate the knowledge gained in their study programmes into real-world situations during the Aeronautical Society of South Africa Intervarsity Flight Competition.

The annual competition was held in collaboration with the University of the Witwatersrand at the Johannesburg Model Aircraft Club. Thirty final-year mechnaical and aeronautical engineering students from both universities built their own model aircraft and competed in the Balls Speed Race.

The challenge for 2019 was to conceptualise, design and build a radio-controlled model aircraft that was capable of taking off under its own power, while transporting as many tennis balls as possible over a short course in five minutes with an unlimited number of flights.

Each team member had to run, quickly unload and load the balls, and position the plane on the runway to be able to take off again after landing. Teamwork was essential to save time, while the ball-loading strategy was the key to victory. UP teams were awarded the Best University certificate.

TuksBaja is victorious

It was a clean sweep for the TuksBaja team of the University of Pretoria, whose Car 17 emerged the overall winner in this year's action-packed national Baja Competition.

TuksBaja's Car 10 took pole position in the endurance race, while two other UP cars grabbed the second and third spots. The event was hosted by UP, with students from the University of South Africa (Unisa) and Nelson Mandela University also taking part. Eight cars, built by students from the three universities, entered the event.

The objective of the competition is to produce well-rounded engineers with practical experience that is useful in the workplace. Prof Schalk Els, leader of the Vehicle Dynamics Group in the Department of Mechanical and Aeronautical Engineering, explained that, during the endurance race, the UP cars managed to stay on the track for the majority of the race, overcoming rock pits, speed bumps and a number of other obstacles that proved too much for some of the other competitors. The three cars survived 50 laps, 48 laps and 47 laps, respectively.

Baja Society of Automotive Engineers (SAE) is an international engineering design competition in which undergraduate students have to conceptualise, design, manufacture and test an off-road car that complies with strict safety rules. The car is designed to last in a four-hour off-road endurance race every October, as well as compete in a number of other events, including design evaluation, safety, sales and performance. Performance includes acceleration and a sled pull, handling and top speed.

Robot Race Day helps students drive the Fourth Industrial Revolution (4IR)

Prof Tania Hanekom

This year, the Faculty held its seventh annual Robot Car Race Day. This electrifying event marked the end of a semester's hard work, during which students developed their own robot cars in a quest to master the fundamentals of Microcontroller System Design.

Robotics is currently an extremely popular field that allows many young aspiring engineers to experiment with a wide variety of commercially available robot kits. However, while robot kits may satisfy gadgeteers and googleneers, driving the 4IR needs authentic engineers that have the ability to solve real-world problems from a scientific perspective.

Progressing through all the steps to complete a small microcontroller-based autonomous robotics vehicle (MARV) prepares students for the challenges associated with creating novel microcontroller-based solutions to problems that cannot be solved by using hobbyist kits.

www.up.ac.za/eece/article/2669042/annual-robot-car-race

Celebrating World Book Day with a book launch

Samantha Miller and Jana Klingenberg

On 23 April 2019, the Department of Library Services and the Department of Information Science celebrated World Book Day with the launch of *My France: A South African's Guide,* written by Olivia Loots, a student of the University of Pretoria.

Samantha Miller and Jana Klingenberg, lecturers in Publishing Studies at the Department of Information Science, managed the publication's production, which was commissioned by the Embassy of France in 2018.

During the book launch, Olivia shared her thoughts on her travels, as well as the writing and publication process. While taking a gap year after high school, Olivia travelled through France for eight months. This beautifully illustrated guide records her experiences and provides travel tips. It will entice any travel enthusiast. Olivia's deep love for France – its people, language and culture – was clear when she sadly reminisced about her time spent at Notre Dame in 2013. After the talk, guests enjoyed snacks, chatted with Olivia and had their books signed. It was a terrific way to celebrate World Book Day.

These departments will be collaborating on book-related events in future, and are looking forward to collaborating with other disciplines at the University of Pretoria.

"There are pieces of my heart in your church towers with their lively bells, in your boats making their way to our islands, in your boutiques and boulangeries, in your sea and the streets of your cities. My love and gratitude are spread over the kilometres of your land."

– Olivia Loots

The roots of computer engineering

Leibniz: The 17th-century lawyer who helped pave the way for computer engineering

Gottfried Wilhelm Leibniz was, among many other things, an acclaimed German polymath, philosopher, lawyer and political advisor. He is also credited with the development of the "stepped reckoner", a calculating machine that could perform all four arithmetic functions. He made significant contributions to philosophy, engineering, physics, law, politics and theology.

Early life and education

Leibniz was born in Leipzig, Germany, on 1 July 1646 near the end of the Thirty Years' War, which had laid Germany in ruins. His father, Friedrich Leibnütz, was a professor of moral philosophy at the University of Leipzig and his mother, Catherina Schmuck, was the daughter of a wealthy lawyer.

From an early age, it became apparent that Leibniz was extraordinary. His parents were devoted to his education. When he was six years old, Leibnütz passed away, and the young Leibniz inherited his father's well-stocked library, which contained many Latin writings. He became fluent in Latin and had studied the works of Greek scholars by the age of 12.

When he was 14, he enrolled at the University of Leipzig, where he studied philosophy, mathematics and law. Here, he was exposed to the works of Galileo Galilei, Francis Bacon, Thomas Hobbes and René Descartes. He completed his bachelor's degree in Philosophy by the age of 15 and obtained a master's degree a year later. By the age of 17, he had completed an undergraduate degree in law. During early adulthood, he started spelling his name as Leibniz.

After completing his legal studies in 1666, Leibniz applied for a doctoral degree in law. He was deemed too young to obtain this degree, which prompted him to leave Leipzig indefinitely. He submitted his thesis to the University of Altdorf near Nuremberg, where he earned his doctorate in law in five months. He declined an offer of academic appointment at Altdorf.

Career

During his stay in Nuremberg, Leibniz met Johann Christian, Freiherr von Boineburg, one of the most distinguished German statesmen of the day. Von Boineburg took him into his service and introduced him to the court of the Prince Elector, the archbishop of Mainz, Johann Philipp von Schönborn, who appointed him as a legal and political advisor.

Von Boineburg fervently promoted Leibniz's reputation, and his service to the Elector soon included a diplomatic component. During Leibniz's adult life, the central European geopolitical reality was King Louis XIV's ambition, which was backed by French military and economic might. In 1672, Leibniz went to Paris to present a plan that would distract the French king and protect German-speaking Europe.

As a result of this trip, Leibniz stayed in Paris for several years, during which time he expanded his knowledge of mathematics and physics, and began coming into his own on both fronts. During this time,

he met Nicolas Malebranche and Antoine Arnauld, the leading French philosophers of the day. He also studied the writings of Descartes and Blaise Pascal, and befriended a German mathematician, Ehrenfried Walther von Tschirnhaus.

Leibniz also met the Dutch physicist and mathematician, Christiaan Huygens, who was active in Paris at the time. Leibniz realised, to his dismay, that his knowledge of mathematics and physics was insufficient. Huygens mentored him as he began a programme of self-study. Soon Leibniz started to make significant contributions to both subjects.

In 1673, Leibniz briefly went to London, where he met Henry Oldenburg. Oldenburg was the secretary of the Royal Society. The calculating machine Leibniz had invented particularly impressed him. This new machine could perform all four arithmetical operations, instead of merely adding and subtracting like Pascal's Pascaline. The Royal Society elected Leibniz as a fellow that same year.

While Leibniz was in Paris, both Von Boineburg and Von Schönborn had died and he was now unemployed. He had set his sights on employment by the Paris Academy, but this did not materialise. (He was finally accepted in 1700.) He reluctantly took a position as a councillor at the Court of Hanover for Duke Johann Friedrich of Brunswick-Lüneburg.

Leibniz arrived in Hanover at the end of 1676, after passing through London. On the way to Hanover, he stopped in The Hague, where he met Anton van Leeuwenhoek, who discovered microorganisms. He also engaged in intense discussion with Baruch Spinoza, who had just completed his masterwork, the *Ethics*. Leibniz respected Spinoza's powerful intellect, but he was disillusioned by his contemporary's conclusions that contradicted Christian orthodoxy.

In the House of Brunswick, Leibniz was involved in numerous projects, and he began writing the first mature expressions of his philosophy, which started with meditations on knowledge, truth and ideas of 1684, during this time.

For the rest of his life, he was occupied with various tasks associated with Hanover. He travelled to various courts throughout Europe. Despite many municipal and legal projects, he maintained an extensive correspondence with over 600 correspondents on nearly every topic imaginable, and around 15 000 of his letters survive. Leibniz never married.

→ *The statue of Gottfried Wilhelm Leibniz in Leipzig, Saxony, Germany.*

"I have so many ideas that may perhaps be of some use in time if others more penetrating than I go deeply into them someday and join the beauty of their minds to the labour of mine."

Work on the binary system and the "stepped reckoner"

Leibniz has been credited as the inventor of the binary system, the coding system that uses the binary digits 0 and 1 to represent letters, digits or other characters in electronic devices. Some scholars, such as Shirley (1951), have refuted this claim and attribute the binary system's conceptualisation to Thomas Harriot, an English astronomer, physicist and mathematician who died in 1621.

Leibniz documented the modern binary system in his article *Explication de l'Arithmétique Binaire* (explanation of binary arithmetic) in 1705. His exploration of this system was inspired by the *I Ching*, a 5 000-year-old divination text. He realised that the *I Ching*'s hexagrams correspond to the binary numbers from 0 to 111111. Leibniz's work on the binary system paved the way for its use in computers in later centuries. Today, almost nothing in the world can run smoothly without the aid of computers.

Despite seeing the value of the binary system in machines, Leibniz did not use it in the calculating machine that he presented to the Royal Society. Instead, his machine represented numbers in decimal format. Leibniz called it the *Instrumentum Arithmeticum*, and it was later named the "stepped reckoner".

The idea of a calculating machine came to Leibniz at the end of the 1660s. At the beginning of the design process, he realised that he would need to design a new mechanism if he wanted it to perform all four arithmetic functions. This meant that using a design similar to Pascal's Pascaline, which could only add and subtract, would not be sufficient. To solve this problem, he created the stepped-drum mechanism that allowed multiplication and division.

Leibniz managed to develop a successful machine that improved on the Pascaline, and it was easier to operate.

In 1764, 48 years after Leibniz's death, a "stepped reckoner" was given to a clockmaker in Göttingen to repair. The clockmaker did not repair it, and the machine wound up in the attic of the University of Göttingen. It was discovered in 1879 when a leaky roof needed repairs. Some 14 years later, the University sent the machine to the Arthur Burkhardt Company, one of the country's leading calculator manufacturers for analysis and repair.

The calculus debate

Both Isaac Newton and Leibniz are credited with inventing infinitesimal calculus, a mathematical device that deals with quantities that continually vary. There has been fierce debate as to which one of them conceptualised it first. The argument in Leibniz's favour is that he was the first to publish his work in 1684, but Newton had already started his work on calculus in 1665. Some scholars concede that they co-discovered the method, while some favour one over the other. Nevertheless, Leibniz's work on calculus helped make modern calculus possible.

For years, Leibniz was embroiled in a lengthy debate with Newton and others about who the rightful inventor of calculus was, and by the time he died in November 1716, his reputation had been in decline. Much of Europe doubted his role in the development of calculus and one of his books, *Théodicée*, was seen as a ploy to ridicule Voltaire's *Candide*, which contained a parody character of Leibniz.

After his death, his grave went unmarked for more than 50 years. His posthumous reputation recovered as his writings became more publicly available and were read by scholars such as Immanuel Kant, a reputable German philosopher and scientist. In 1985, the Leibniz Prize was instituted in his name in Germany to support the research of scientists and academics.

Conclusion

Leibniz not only made game-changing contributions to mathematics, but also to metaphysics, symbolic logic and philosophy. His works are so numerous that a definite expression of his main philosophical thought is difficult to pinpoint, but his influence on subsequent philosophers is unmistakable.

Leibniz was indeed one of the great polymaths in history, despite the fact that his peers might have disagreed. Although he was buried unceremoniously in an unmarked grave, he is recognised today for his accomplishments. His work on the binary system paved the way for modern computer technology, and his works remain influential in many disciplines.

"It is unworthy of excellent men to lose hours like slaves in the labour of calculation, which could safely be relegated to anyone else if machines were used."

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The Faculty of Engineering, Built Environment and Information Technology (EBIT) at the University of Pretoria presents locally relevant and internationally competitive academic programmes and produces novel research in its three specialist fields.

EBIT is committed to future-focused research and innovation in its efforts to propel the country into embracing the Fourth Industrial Revolution (4IR). In order to do this, its teaching, learning and research initiatives address the 4IR skills challenge, particularly in the exciting fields of virtual reality, additive manufacturing, big data, machine learning, internet of things and artificial intelligence.

The Faculty enjoys high institutional rankings on the world stage and maintains close ties with industry to support its cutting-edge programmes and facilities. Opportunities for industry-relevant collaborative research are constantly investigated to ensure that the Faculty is ready to embrace and overcome future challenges.

In its efforts to embrace the 4IR, EBIT dedicates itself to cross-disciplinary projects and interventions aimed at consolidating the knowledge and skills required to thrive in this exciting new world. The current challenges faced by both industry and society require researchers to break away from working in discipline-specific silos, and cross academic boundaries to approach challenges from different perspectives. The Faculty is home to a unique combination of academic disciplines, which encourages the incorporation of multiple approaches to research problems, and allows for vivid cross-disciplinary work.

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