Innovate:

Issue 05 2010

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Innovate:

Issue 05 2010

Innovate 5: 2010
ISSN 1814-443X
GTIN (9771818443006)

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

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University of Pretoria
Pretoria 0002
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On the cover:

Injection-enhanced silicon in avalanche (INSiAVA) is an innovation of the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) at the University of Pretoria that is set to solve a looming industry dilemma. Employing photons moving at the speed of light could potentially increase bandwidth and data transmission speed, thereby solving the computing industry's interconnect problem.

Full story on p6

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LAST WORD

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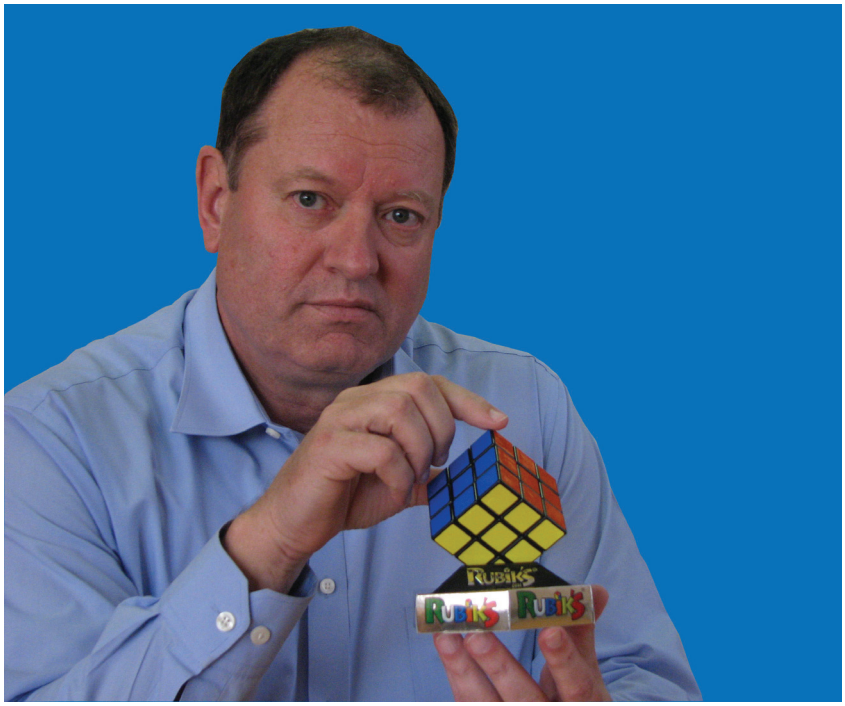
Thinking out of the “cube”



It has been 30 years since the first magic Rubik cube was exported from Hungary – its country of origin – to the rest of the world. During this period, the Rubik cube became one of the world’s favourite toys, with hundreds of millions being sold and enjoyed by old and young.

There is certainly a lot to learn from this success story, for example, how creativity can “overwhelm” the market and its customers, or how to keep the market alive and customers interested.

For me, the most interesting aspect of this invention is the fact that Ernó Rubik, the creator of the Rubik cube, was an architect by profession, and not an engineer or a mathematician as would have been expected.

I am often asked whether the content of *Innovate* does not span too broad a field of academic interest. The answer to that question is that the content of this publication has to represent the creativity and innovation within the broader Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria. My personal view, however, is that it is exactly the integration of all the skills and knowledge from these different disciplines that can lead to novel ideas and innovations.

This view is perfectly illustrated by the architect who came up with the radical idea of a magic cube and who (probably with the support of skills and knowledge from engineers, marketing specialists and other colleagues) turned it into a fantastic success story.

In this edition of *Innovate,* you will once again find a variety of interesting contributions from the researchers, academics and students of the faculty.

The Department of Chemical Engineering celebrates its 50th anniversary in 2010 and shares some of its leading research. You can also read about the leading new technology that is being developed for low-cost, efficient and fast-switching silicon light-emitting devices in photonic integrated circuits.

This edition contains a special feature on the outstanding work students are doing in serving the community, while gaining valuable practical experience. Other interesting contributions include articles on energy studies, informatics and cancer research, as well as advanced computing.

This only provides a glimpse of the challenging and very interesting research and education activities in the faculty, which give an indication of why the faculty is recognised as one of the leading faculties of its kind on the continent. Perhaps the title of the contribution by Michael Neale says it all: The sky is the limit!

I trust you will enjoy this edition of *Innovate.*

Editor
Tinus Pretorius

INSiAVA comes to light

The story of INSiAVA (injection-enhanced silicon in avalanche) started with a vision in the early 1990s. It is a story interwoven with foresight, flawless timing, a methodological approach to both business and research, and – above all – discipline.

The computer industry is faced with the so-called interconnect dilemma, a challenge that was predicted decades ago by the co-founder of Intel, Gordon Moore.

In its quest to solve the chip-to-chip interconnect problem, INSiAVA (Pty) Ltd, a privately owned company established by the University of Pretoria as the commercialisation vehicle of its silicon electroluminescent technology (the generation of light from an electrical current), recently achieved another critical milestone.

Farsighted thinking

As early as 1990, Prof Monuko du Plessis, Director of the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) at the University of Pretoria, spearheaded CEFIM's research efforts to focus on optical communication as the way to solve the chip-to-chip and on-chip interconnect problem. This prophetic insight turned out to be immensely accurate in terms of the way in which the industry unfolded.

As a result, Prof Du Plessis focused CEFIM's research efforts on the generation of light in silicon, in particular. Why silicon? Because 99% of the world's computer chips are created in silicon. The US$100-billion industry, dominated by industry giants such as Intel, ST Microelectronics and Mitsubishi, is based on the production of silicon chips in extremely controlled, maximum-purity silicon wafer plants – operating under the most highly restrictive contamination requirements.

Grasping the implication of this, Prof Du Plessis purposefully steered the microelectronic research at the University of Pretoria towards light generation from silicon, as opposed to any other medium, in order to find synergies with the industry's existing mega-billion dollar investment in silicon plants.

The innovation race to solve the chip-to-chip interconnect dilemma continues within a chequered environment. So-called "breakthrough" technologies are announced almost on a daily basis that claim to turn around the interconnect problem.

However, INSiAVA's competitive and strategic advantage lies in the fact that most chip-to-chip interconnect "solutions" are not compatible with CMOS (complementary metal-oxide-semiconductor) standards, which means that they cannot be used in the industry's mega-billion dollar silicon-based plants.

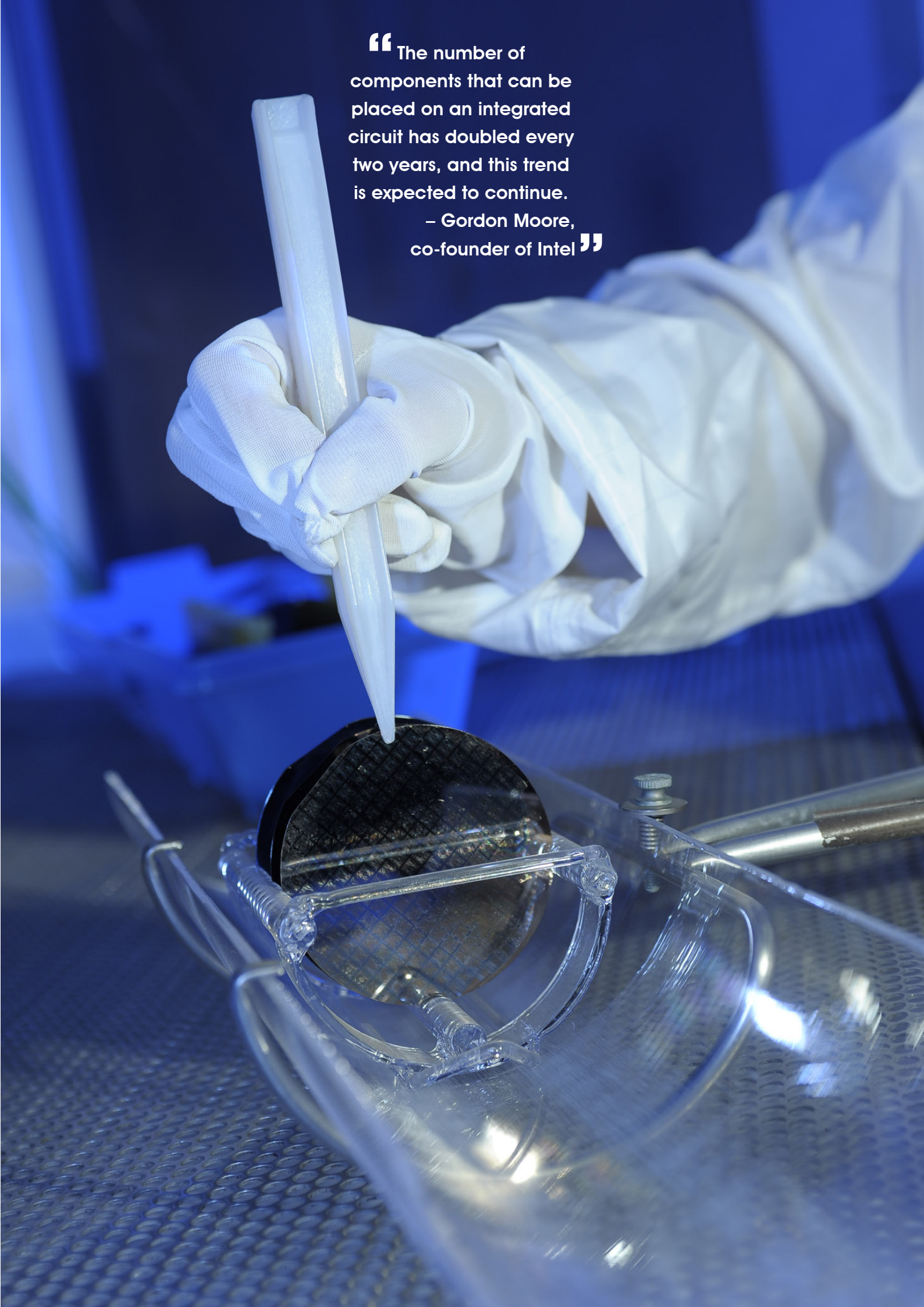
Prof Du Plessis' vision to use silicon-based optical technology is therefore one of the computing industry's potentially most sought-after new technologies.

A phased process

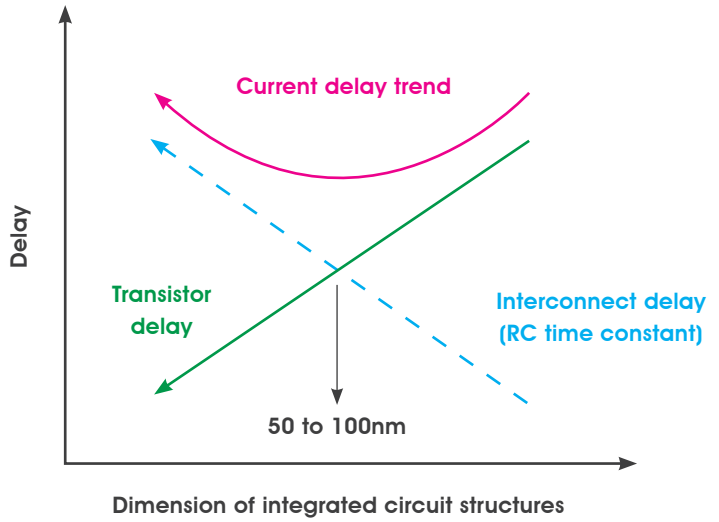
According to Gerrie Mostert, who is responsible for operationalising the start-up venture, INSiAVA (Pty) Ltd, and building its intellectual property (IP) portfolio, the project has been conducted in phases since it kicked off in the early 1990s.

A balance between the registration of international patents and the publication of more than 50 local and international peer-reviewed articles in accredited scientific journals has been a critical balancing act that the team has managed to achieve successfully.

"In the process, publications were often delayed due to first patenting key aspects of the technology. Without the first two granted USA patents on the silicon light-emitting technology, no investor would have been interested in the technology. The discipline to delay publications and to file patents at the right time has been crucial in our journey thus far," says Mostert.


“The number of components that can be placed on an integrated circuit has doubled every two years, and this trend is expected to continue.
– Gordon Moore, co-founder of Intel”

Moore's Law:
how it created the interconnect dilemma



1. Moore's Law and circuit delay.

In 1965, Gordon E Moore, co-founder of Intel, noted that the number of transistors in integrated circuits has doubled every two years since the first integrated circuit was invented in 1958. He predicted that this trend was set to continue. This phenomenon is popularly known as Moore's Law. The driving forces behind Moore's Law were increased processing speed and increased functionality, while cost remained low by having it all available on a single chip. The interconnect lines (copper wires) between transistors on chips and between chips have become thinner, increasingly affecting the processing speed.

This reduction in size of the transistors and their interconnecting copper wires meant increased interconnect delays. When the transistor size reaches about 100 or 90 nanometer, the resulting delay is such that it offsets the gain of going smaller. This affects the reliability and overall performance of the circuit.

This phenomenon is widely known as "the interconnect dilemma".

One approach to resolve the interconnect dilemma is to communicate optically (by means of light) between and on computer chips instead of through metal wires.

Long-distance optical fibre communication is not a new technology. The challenge of long-distance optical data transfer was solved many years ago. The current challenge is to resolve this between and on computer chips. An economically viable solution to this challenge has been evading the computing industry for years.

To date, INSiAVA has filed patent applications for a suite of 12 different inventions, which all underpin vital breakthroughs and/or technological building blocks along the INSiAVA research path.

Phase I and Phase II of the project focused on creating and developing the silicon light source.

Phase III focused on making the silicon light source more efficient, while identifying a range of potential applications. It was underpinned by the key research objective to improve the external quantum efficiency of the light source from 0.01% to 0.1%. This objective was achieved in November 2009.

"Getting the power efficiency right remains a critical aspect and will continue to form the focus for the fourth phase of development," says Mostert. Power efficiency refers to the fraction of the electrical power input that converts to usable optical power output.

Phase IV is primarily aimed at improving the power efficiency, as well as commercialising the technology. It will culminate in the first niche applications once the technology meets industry specifications for each potential application.

"Research priorities include improving the power efficiency ratio by experimenting with device structure and device design, as well as integrated circuit design.

The development programme will also explore surface effects and a silicon germanium (Si-Ge) heterojunction as techniques to improve the power efficiency," notes Mostert.

The ultimate objective is to achieve a data transmission rate of 10 Gb/s (gigabits per second) within the next three years.

According to Mostert, the industry would not be able to ignore such transmission rates in a fully CMOS-compatible technology. “High-speed data communication is a killer application and will remain our highest priority for the next few years,” he says. “But there might also be other attractive applications that can be developed and commercialised in parallel by teams dedicated to those applications.”

The road to commercialisation

A paramount aspect of the commercialisation process is to consult and engage with industry to get advice on how to approach the research and development within the commercial requirements of the industry.

“With R3.6 million in our back pockets at the start of Phase II, we travelled overseas to meet with key role-players in the computer and venture capital industries to get advice on how to approach this project,” tells Mostert. This, coupled with Prof Du Plessis’ far-sighted vision to narrow down research efforts to silicon-based optical solutions in the early 1990s and the discipline of filing patent applications at the right time, made a significant difference to INSiAVA’s significant progress to date.

According to the August 2002 issue of *IEEE Spectrum*, the scientific journal of the International Institute of Electrical and Electronic Engineers, short-range optical data communication was likely to unfold as follows:

2002: computer to computer
2004–2007: board to board
2007–2012: chip to chip
2013: on-chip optical interconnects

The industry has fallen behind on the chip-to-chip solution due to the sheer technical challenge thereof. “After three to four years of lower budgets for research efforts, optical data transfer is regaining the interest of industry. There is a revitalised sense of urgency to find a chip-to-chip solution, not only promising research results,” says Mostert.

Phase IV of the research and the funding that has recently been secured mark the start of another exciting phase in INSiAVA’s history that will eventually solve the interconnect dilemma.

The solution for the chip-to-chip optical interconnect might come from South Africa – an achievement that would be remarkable by any standard. “We are at least a front-runner in the race,” concluded Mostert. “That, in itself, is already an achievement of note.”

Project profile

On 25 October 2010, the Chairperson of INSiAVA (Pty) Ltd, Prof Robin Crewe, announced the approval of a R30 million investment in the company over three years by its current shareholders, the University of Pretoria and the South African Intellectual Property Fund (SAIP Fund), managed by Triumph Venture Capital (Pty) Ltd. This marks the imminent launch of Phase IV of the development of the INSiAVA silicon-based light source technology. The project has proceeded according to the following course since 1990:

Phase I (1990–2004)

The University of Pretoria, with funding received from the Carl and Emily Fuchs Foundation, made a substantial investment of several million rand into the project.

Phase II (2004–2006)

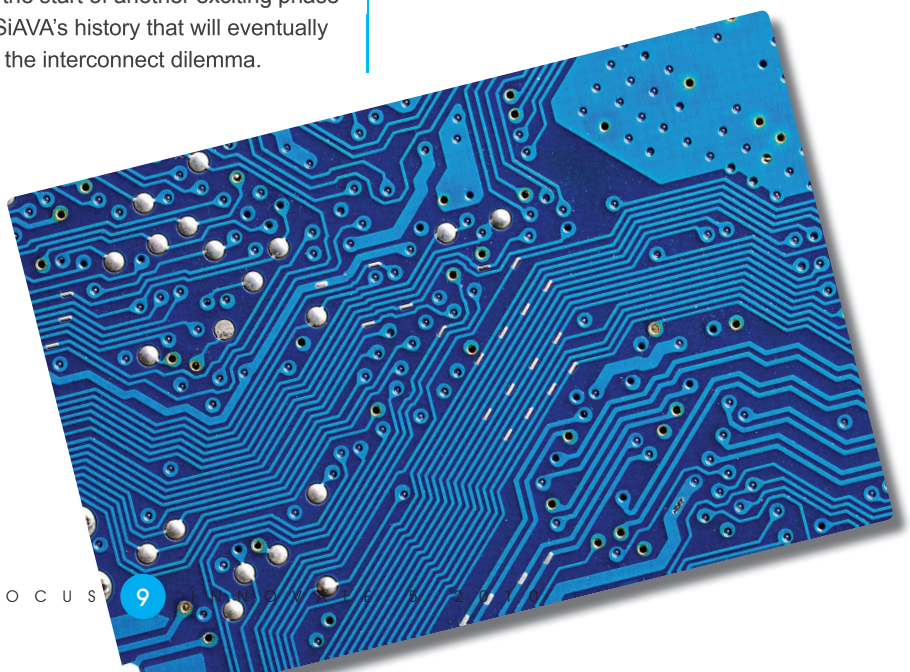
The project received joint funding from the University of Pretoria and the Innovation Fund of the Department of Science and Technology.

Phase III (2007–2010)

The SAIP Fund invested R15 million in the project.

Phase IV (2011–2013)

An investment of R30 million over three years in INSiAVA (Pty) Ltd was approved by the shareholders, the SAIP Fund and the University of Pretoria, in October 2010.



Enhanced silicon light-emission for optical data communication

A new technological innovation by the University of Pretoria aims to develop low-cost, efficient and fast-switching silicon light-emitting devices in photonic integrated circuits.

The exponential growth of global data volumes and associated data centres is outpacing the industry's ability to efficiently produce more powerful data processing integrated circuits in accordance with Moore's Law. The modern trend of deploying more parallel computers with higher capacity data storage solves the problem of lagging microprocessor speeds, but the resultant significant proliferation of separate data computing equipment in turn leads to a growing need for faster and more efficient communication between computers and data storage.

Science meets art

According to Laurie Olivier, convenor of the international advisory board, the beauty of the injection-enhanced silicon in avalanche (INSiAVA) innovation is what happens when science meets art. This is clearly illustrated in the work of Prof Monuko du Plessis, who has instinctively conceived solutions that had been considered impossible when he initiated his research close to two decades ago.

The quest is to overcome the "interconnect dilemma" and to achieve enhanced interconnection performance by replacing electrical conductors with photonic interconnects. An initial patent that was filed more than a decade ago provided the fundamental basis for the subsequent research, development and associated investment.

INSiAVA's novel technologies

Complementary metal-oxide-semiconductor (CMOS), with its presence in almost every modern electronic device, is the most widespread semiconductor technology. This is largely due to its tight integration ability and considerable manufacturing ease when compared to other mainstream semiconductor materials. The result is a technology that is highly optimised for mass production. It has also become by far the least expensive semiconductor platform. Unfortunately, CMOS is based on silicon, an indirect band-gap material, which leads to poor performance

→ Prof Monuko du Plessis is the key inventor of INSiAVA technology and the principal research engineer leading the ongoing development work to refine INSiAVA technology to be suitable for widespread use in industry.

when generating light from the material. This creates difficulty when integrating optical circuitry, especially light emitters. It would, therefore, be very practical if one could combine the extensive reach of CMOS technology with the extreme functionality of optics.

INSiAVA's CMOS-compatible silicon-based light-emission technology has the potential to induce the new technological breakthrough that is needed over the next five years to solve the interconnect dilemma of electronic data transmission. This technology has the following key characteristics:

- It uses photonic devices to perform fast signal transmission among integrated circuits.
- The use of all-silicon light sources allows easy integration with associated circuitry.
- Full integration in standard CMOS and BiCMOS manufacturing technologies implies that integrated circuit development and manufacturing costs can be kept low.
- The technology allows switching frequencies in excess of 10 GHz.

INSiAVA's optical source features novel device physics and architecture.The basic device comprises a reverse-biased pn-junction at or very close to avalanche breakdown. Various techniques enhance the emission of light by injecting carriers into the avalanche region. This can, for example, be achieved by closely placing forward-biased injection junctions. Through impact ionisation, the injected carriers multiply in the avalanche field, which provide more carriers for radiative recombination. The resulting radiative recombination of hot and cold carriers improves the electro-optical conversion efficiency and the switching speed, which then enhance the signal transmission capability.

In addition, INSiAVA employs several novel geometric-optical device structure innovations to not only enhance the extraction of the generated light, but also to direct the emerging light beams into a useful direction.

INSiAVA has the following competitive advantages:

- Full compatibility with the CMOS integrated circuit manufacturing technology.
- Wide-band light emission spectrum ranging from 450 nm to 850 nm, peaking around 650 nm.
- Proven switching speed in excess of 10 GHz.
- An external quantum efficiency target of 1% (technology applications become feasible above 0.1%).

The optical solution

In order to increase bandwidth and data transmission speeds and solve the interconnect problem, the industry is increasingly considering optical signalling to replace the current industry standard slow electric connections.

Employing photons travelling at the speed of light, instead of electrons, increases the possible transmission speed of interconnect.

Opto-electronic interconnects are expected to significantly increase overall computing power in applications where large amounts of data are exchanged at ultra-high data rates. Most connections between data centres already employ optical communication. The next step is to expand the use of optical interconnects to include rack-to-rack back plane, board-to-board and ultimately chip-to-chip interconnects on motherboards. Current optical links require expensive discrete optical modulators to modulate light from large-chip external continuous-wave lasers with data.

INSiAVA sees an opportunity to eliminate the need for separate lasers and modulators by integrating optical light emitters and receivers into integrated circuits. This would allow direct fibre-optic data transmission between microchips. To realise inter-chip optical signalling, a fast-switching and efficient optical source that integrates easily into the existing state-of-art silicon CMOS-integrated circuit manufacturing technology is desirable. The innovative INSiAVA light source aims to fulfil these requirements.

Application of the technology

According to Prof Roelf van den Heever, CEO of INSiAVA (Pty) Ltd, an important aspect of the commercialisation of this technology, which is one of the outcomes of Phase IV of research and development, is the identification of products with "killer application" potential.

The technical team of Prof Monuko du Plessis at CEFIM has identified a number of technology demonstrators to illustrate the feasibility of the patented INSiAVA silicon light source technology in various application fields.

Optical communication

The potential of combining a complete optical transceiver on a single chip presents a very attractive opportunity. This may, for example, enable optical links between computers, while doing so at reasonable cost. This is what INSiAVA aims for with its drive to develop an optical data communication link.

The research team has demonstrated practical optical links, based

completely on silicon, with transmission rates reaching multiple Mb/s, manufactured in the same type of process used for making computer CPUs. The main limitation is the efficiency of the electrical to optical conversion. The research emphasis is placed on improving the efficiency of the integrated light source in an attempt to create an all-silicon optical link with data rates exceeding hundreds of Mb/s or even into the Gb/s regime, all based on CMOS-compatible technologies. With such potential, it might even be plausible to expect optical ports on mass-produced devices such as cellular phones and portable electronic devices.

Lab-on-chip sensor

In the medical field, the chemical analysis of various samples is usually a slow process by dedicated specialists with expensive equipment in large laboratories. Small, inexpensive and disposable diagnostic devices are desirable as they can be operated by inexperienced persons and can yield fast and reliable results.

A lab-on-chip (LOC) system is therefore a miniature implementation of one or several processes that would traditionally be performed on a larger scale in a laboratory.

LOC devices are advantageous as they can be mass produced in mature, standard technologies. The resultant unit cost would be low enough to render disposable devices. Due to the small scale of such systems, only very small sample and reagent quantities are required for operation and results can usually be attained faster.

INSiAVA's CMOS-compatible light sources can integrate with the electronic circuitry that forms part of an LOC system, eliminating the need for external light sources in LOC implementations where samples need to be illuminated. INSiAVA is combining its novel sources and expertise with the microfluidic capability and expertise of the Materials Science and Manufacturing Group at the Council for Scientific and Industrial Research (CSIR) to develop an optical LOC. A very promising possibility is the development of an inexpensive, rapid diagnostic point-of-care system for the detection of certain infectious diseases that currently take months to diagnose. All chemical processing of a sample will occur on-chip and even the diagnosis will be performed and displayed by the system, eliminating the need for skilled personnel and complex analysis equipment.

Near-to-eye displays

Near-to-eye displays find increasing implementation in a wide range of industrial, medical and military applications where products like microscopes, binocular rangefinders, electronic viewfinders, telescopes and head-mounted displays enhance situational awareness, surveillance, thermal imaging, training, simulation, surgery, optometric diagnosis and reconnaissance through the display of superimposed information, augmented reality or substitutional imaging. In contrast to conventional displays, near-to-eye displays enable longer viewing times with less stress on the eye. They also offer mobility, privacy and three-dimensional imaging. Compared to competing liquid crystal (LCD) and organic light-emitting diode (OLED) micro-displays, INSiAVA's CMOS near-to-eye display technology offers several advantages.

CMOS micro-displays can be located on the same integrated circuit with associated digital electronics, deliver higher resolution displays with pixel dimensions down to five by five micrometers and have a wider operating temperature range than LCDs and OLEDs, which usually perform poorly or not at all below freezing point. Furthermore, CMOS micro-displays exhibit a longer lifetime than OLEDs, which degrade over time and typically lose half their brightness after about 50 000 operating hours.

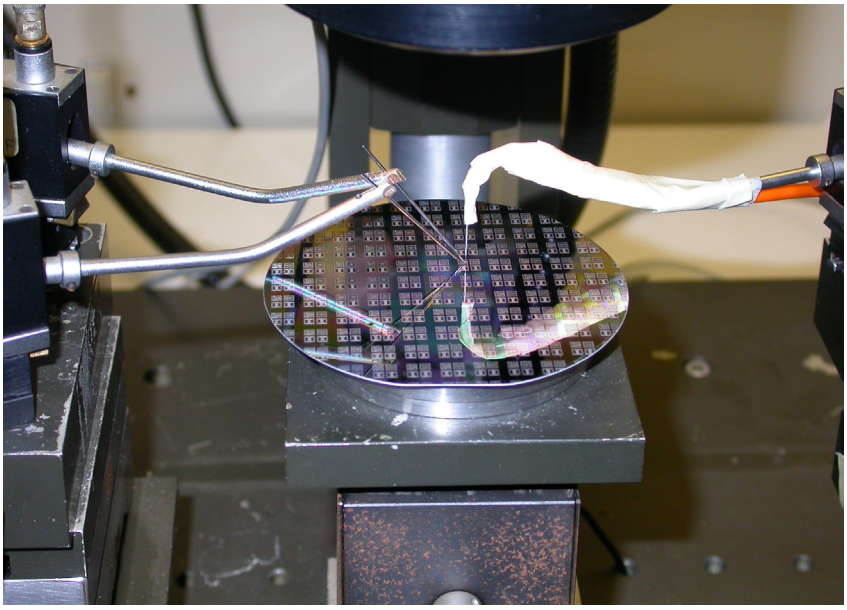
In contrast to LCD's maximum switching frequency of about 240 Hz, the much higher intrinsic switching speed of silicon light sources makes CMOS displays blur-free. In contrast to commercial OLEDs and LCDs that are usually only available in fixed sizes and custom-made displays, and are prohibitively expensive, CMOS displays offer lower non-recurring engineering (NRE) and production costs to implement customised display sizes, shapes, pixel dimensions and resolutions. INSiAVA's integrated CMOS reflector technology allows a customisable viewing angle up to 180º.

Technical team

Prof Monuko du Plessis is the key inventor of the INSiAVA technology and the principal research engineer leading the ongoing development work to refine INSiAVA technology to be suitable for widespread industrial and commercial use. Other research engineering team members are Jannes Venter and Alfons Bogalecki, who are responsible for the design, processing and characterisation of INSiAVA microchips, Hannetjie Nell, who is responsible for the lab-on-chip research and development, and Marius Goosen, who is responsible for the development of digital and analogue optical communication links. Dr Pieter Rademeyer, co-founder and former director of CEFIM, has been appointed to perform market research, and to direct the development of technology demonstrators of INSiAVA's intellectual property.

Commercialising the INSiAVA intellectual property

Market leaders in chip manufacture, such as Intel Corporation, have comprehensive research initiatives focused on solving the interconnect dilemma (the need for faster and smaller semiconductor products with greater functionality). The research team at the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) at the University of Pretoria (UP) is pushing the boundaries and is close to a technological breakthrough that could solve this dilemma.



→ The optical performance of new INSiAVA silicon light sources is characterised by a fibre-optic measurement probe on a micro-manipulator.

It is envisaged that the most significant applications of the injection-enhanced silicon in avalanche (INSiAVA) technology will be in products that rely on a high switching speed. These include video applications, for instance, in the entertainment and security industry, and imaging, such as medical imaging or geographic information systems (GIS). The potential advantage of chip-to-chip optical interconnects, which could send data a thousand times faster than copper wire, potentially has a huge market in all computing applications, making it a truly "billion unit" application.

Establishment of INSiAVA (Pty) Ltd

Investor interest was sparked with the registration of a USA patent in 2000 by Prof Monuko du Plessis, Director of CEFIM, together with his erstwhile colleagues, Prof Lukas Snyman and Prof Herzl Aharoni. Subsequently, INSiAVA (Pty) Ltd was established in 2005 as a privately owned start-up company of the University of Pretoria. The South African Intellectual Property Fund (SAIP Fund), managed by Triumph Venture Capital (Pty) Ltd, became a shareholder upon its investment in Phase III of the technology development. It is the sole owner of the valuable portfolio of intellectual property rights that would protect the technology in the world's major economies once those rights have been granted.

The company is also the exclusive licensee of the applicable background intellectual property of the University of Pretoria. The company uses the bulk of its investment capital to contract the University of Pretoria to conduct the technology development programme, aimed at improving the technology to industry specifications for a range of applications.

INSiAVA Inc was established in 2010 as a USA-based subsidiary of INSiAVA (Pty) Ltd, incorporated in Delaware, USA, with an executive office in Atlanta. INSiAVA Inc will be the vehicle through which the international commercialisation of the company's light-from-silicon technology will be undertaken. A European subsidiary might follow.

The International Advisory Board (IAB) will play a key role in directing the development programme and commercialise the INSiAVA technology portfolio. The key roleplayers in this regard are Laurie Olivier, convenor of the IAB, Prof Philippe M Fauchet, the first international specialist appointed to the IAB, who will serve as an anchor member, and Prof Roelf van den Heever, CEO of INSiAVA (Pty) Ltd.

Laurie Olivier is the Atlanta-based partner of Veritas Venture Partners, the oldest existing Israeli venture capital company. His involvement in venture capital commenced in 1989 when he represented the venture capital interests of Anglo-American Corporation. He represented Anglo-American on an East Asian private equity fund and a South African venture capital fund. Since being established as Veritas' USA-based partner in Atlanta, Georgia, Laurie has been Chairperson of the American-Israel Chamber of Commerce (Southeast Region) from 2007 to 2009. He has been retained by the Southern Education and Research Alliance (SERA) as a commercialisation advisor, is a venturing advisor to UP, and has served as an advisor to the VentureLab of the Georgia Institute of Technology in Atlanta. He holds a BEng (Electronics) degree from the University of Pretoria and a BCom (Hons) and Diploma in Datametrics from the University of South Africa.

Prof Philippe M Fauchet is a distinguished professor in Electrical and Computer Engineering at the University of Rochester, New York. He is also a professor at the Institute of Optics, Biomedical Engineering, Materials Science and Physics, and a senior scientist in the Laboratory for Laser Energetics at the same institution. He has more than 25 years of experience in silicon photonics, nanoscience and nanotechnology with silicon quantum dots, biosensors, electroluminescent materials and devices, and optical diagnostics. Over the past five years he has been working on the development of silicon-based lasers and silicon photonic components such as modulators and switches for use in optical interconnects.

Prof Roelf van den Heever is chief executive officer (CEO) of INSiAVA (Pty) Ltd. He has extensive business experience, with the added advantage of understanding the academic environment, having served as head of the Department of Computer Science at the University of Pretoria from 1969 to 1997. He established the EPI-USE Group of Companies, which operates in 10 countries and employs in excess of 800 people. This group grew out of a high-tech software development initiative that was started at UP in 1982. He is therefore well acquainted with business planning, international business matters, the startup of companies, and supporting corporate governance considerations due to his responsibilities in this group. He can thus make an important contribution to the management of the company at a strategic level.

While the current phase of research and development is being conducted by the University of Pretoria under contract of INSiAVA (Pty) Ltd, the company has started concentrating on the specification of the technology for prospective applications and the development of demonstrators that would underpin commercialisation of the technology for various applications.

The shareholders have appointed a board of directors to oversee the company's strategy and operationalisation, as well as the commercialisation of its intellectual property portfolio. The chairperson of the board is Prof Robin Crewe, Vice-Principal (Research and Postgraduate Studies) at the University of Pretoria. Prof Roelf van den Heever, co-founder and chairperson of the EPI-USE group of companies, is chief executive officer of INSiAVA. The other directors are Wellington Chadehumbe, CEO of Triumph Venture Capital, an internationally trained investment banker and venture capitalist, Prof Roelf Sandenbergh, dean of the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria, and Mark Eccles, a corporate lawyer and partner in Triumph Venture Capital.

International Advisory Board – preparing for global success

An international advisory board (IAB) is being established by the board of INSiAVA The IAB will play a key role in directing the development programme and to commercialise the INSiAVA technology portfolio.

The IAB is convened by Laurie Olivier, an alumnus of the University of Pretoria. He is the globalisation advisor of a number of South African technology startup companies, including INSiAVA (Pty) Ltd. His extensive experience in venture capital investments and private equity will play a crucial role in nurturing the available expertise that might ensure INSiAVA's ultimate success.

Olivier has been involved in INSiAVA since the founding of the company in 2005. He has played an important role in introducing representatives from the University of Pretoria to eminent venture capital funding institutions in the USA. With his understanding of the venture capital environment both locally and internationally, he will continue to play an invaluable role in the commercialisation of the University's intellectual property, particularly the portfolio assigned and/or licensed to INSiAVA (Pty) Ltd. He is particularly knowledgeable about applying a trans-Atlantic venture capital investment model, resulting in a public offering of shares, a private sale of a technology or a company, particularly when dealing with high-technology innovations such as the INSiAVA technology. Having facilitated the growth of start-up companies on both sides of the Atlantic Ocean, he is keenly aware of the importance of keeping technology ownership close to its research and development base, while commercialising it in the USA to provide an optimal return on investment.

According to Olivier, INSiAVA fits this trans-Atlantic venture capital model perfectly. An added advantage is the fact that the direct benefits of commercialising the technology will flow back to South Africa. "As it is a fundamental technology, it represents a potential global breakthrough in an important market," says Olivier. "By developing competency around this venture, the University of Pretoria will be positioned as a world leader in silicon photonics."

The role of the IAB is to develop strategies that will pave the road for future international commercialisation of the INSiAVA technology. The members of the IAB will accumulate as much international expertise as possible in the venture in order to develop a global network of excellence. "As we enter the final research phases, we need a combination of world-class researchers and individuals who are experienced in the commercialisation of intellectual property," adds Olivier.

> **"This is fundamental technology that represents a potential global breakthrough in an important market."**

The IAB is expected to provide guidance on the research endeavours of the University of Pretoria, which will, in turn, develop technological depth at the University. An important objective is to develop a centre of excellence in silicon photonics at the University of Pretoria, recognised internationally among the best in the world in this field.

"This initiative has the commitment and support of the University at executive level," says Olivier. "Following INSiAVA's success, the way will be paved for other research initiatives at the University with commercial potential to follow a similar route."

With the investment of a further R30 million in funding in October 2010, the technology can enter the final phase of its research and development, preparing it for commercialisation within the next three to five years. "During this phase, the IAB will play an important role in developing business relationships overseas so that the company can be in a position to raise international venture capital by 2013," explains Olivier.

"Once the viability of the technology has been demonstrated for selected applications, the company will consider various commercialisation avenues based on the advice of the IAB. This could include options such as developing a fab-less company (subcontracting microchip production), engaging in a joint venture with an industrial partner, or licensing the intellectual property."

When fully constituted, the IAB will comprise a combination of scientifically and commercially orientated members who are world leaders in their fields. The commercial members would comprise a combination of representatives from leading companies, smaller silicon photonics-focused entities and start-up companies, as well as industry and academic representatives. It will also have a balanced geographic representation.

The first international specialist appointed to the IAB was Prof Philippe Fauchet, who will serve as an anchor member of the IAB. "Prof Fauchet is one of the top three researchers in the world in the field of silicon photonics," says Olivier.

The executive management of INSiAVA (Pty) Ltd can now proceed with the recruitment of additional IAB members. Negotiations are ongoing with a number of eminent international scientists and entrepreneurs.

Contemplating the fate of African honey bee populations

The University of Pretoria (UP) is recognised as one of South Africa's leading research universities. It is the top ranking University in terms of the number of accredited publication units. The number of researchers with National Research Foundation (NRF) ratings is increasing annually, as is UP's visibility in ISI indicators. At the helm of the University's research function is Prof Robin Crewe, Vice-Principal: Research and Postgraduate Studies.

Prof Crewe is more than just a member of the University's executive. He is also an active researcher in his own right, who holds a B1 rating from the NRF.

In addition to his management functions, he is also professor of Entomology and leader of the Social Insects Research Group in the University's Department of Zoology and Entomology. He is also President of the Academy of Science of South Africa.

Among the many honours he has received in his scientific career are the gold medal of the Zoological Society of South Africa, honorary member of the International Federation of Beekeepers' Associations (Apimondia), fellow of the Royal Entomological Society and Chevalier: L'Ordre Nationale du Mérite. He is also a fellow of the Academy of Science of the Developing World (TWAS) and of the Royal Society of South Africa.

He obtained his PhD in Entomology from the University of Georgia, where he developed an interest in chemical communication and social organisation in insects.

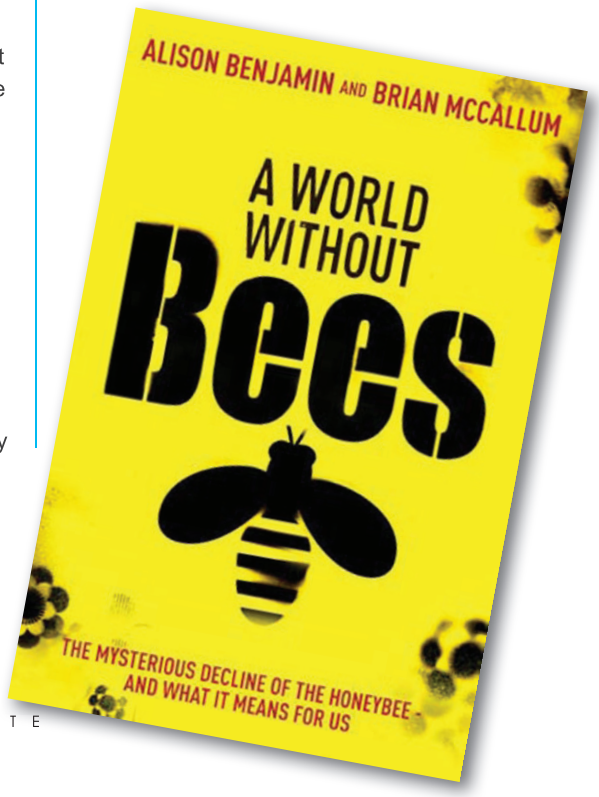
During a recent expert lecture held at the University of Pretoria, Prof Crewe presented what he calls "doomsday scenarios" related to the fate of African honey bee populations.

Doomsday scenarios

Recent media attention has been focused on the perceived worldwide plight of honey bee populations with predictions about the drastic ecological effects of the loss of honey bees as pollinators. Alison Benjamin and Brian McCallum published a review of this position in their book, *A world without bees: the mysterious decline of the honeybee – and what it means for us.*

Prof Robin Crew

The scientific journal Apidologie has published a special issue on bee health to address "the large-scale loss of honey bee colonies (which) has come into focus under a worldwide spotlight. Colony collapse disorder, winter losses and weak bee colonies are pervasive in many apiaries leading to a serious situation for beekeepers and pollination."



→ *African honey bees could supply the raw material to recolonise the world.*

These doomsday scenarios arise from research in the USA, Europe and Latin America, and suggest that we should be concerned by this apparently global pandemic affecting honey bee populations.

However, very little is said about honey bee populations in Africa, and nothing is said about the "plight" of African populations of honey bees. Furthermore, there is very little recognition of the significance of Africa honey bee populations for this story.

As with human populations, the origin of all honey bee populations is the African continent and an exploration of the impact of African, and particularly southern African, honey bees on global honey bee populations needs to be understood in order to provide solutions to the regional crises in the USA, Europe and Latin America occasioned by honey bee colony losses over the last three or four years.

His lecture explored the evolution of honey bees in Africa, their expansion to Europe and the Middle, followed by their anthropogenic transmission to other continents where they became classic invasion species.

He went on to explore the role of southern African populations of honey bees in this unfolding drama in depth, both to describe one of the most extraordinary invasions of a continent by an organism and to understand the interaction between honey bee populations from the extremes of the species distribution.

The discovery of social parasitism in honey bee colonies has lead to a much better understanding of plasticity of honey bee social organisation.

Among the findings of his research is the fact that Africa has the largest number of wild honey bee swarms in the world. A substantial proportion of honey bee genetic diversity is therefore located in Africa. Populations in Africa are not as severley affected by diseases and the impact of industrialised apiculture.

Prof Crewe concludes that the insights gained from African honey bees can be used to indicate that the threats to honey bee populations in the northern hemisphere and Latin America may be resolved by recolonisation of these areas using populations of African honey bees.

Students gain practical experience while serving the community

by Dr Martina Jordaan

In 2005, the Faculty of Engineering, Built Environment and Information Technology (EBIT) at the University of Pretoria introduced the community-based project as a compulsory module in the students' undergraduate curriculum. This initiative was a new endeavour for the faculty and the first of its kind for students in the disciplines of engineering, the built environment and information technology in South Africa.

Since community-based learning was not included in existing modules at the time, it was necessary to establish a separate new module to cover this field. One of the complicating factors in developing such a module was the demanding time schedules of EBIT students.

The Community-based Project (JCP) module is offered on an open-ended and project-orientated basis. Students have the option of attempting the eight-credit (40 hours) module in any one of their undergraduate years of study, but preferably not during their final year.

Depending on the specific nature of the project, it can be attempted during the course of a semester or during vacation time. Projects can be done by students individually or in teams. The faculty encourages multidisciplinary project teams that consist of team members from different schools and departments in the faculty.

Students choose projects in an area they feel passionate about, while also considering the needs of the community. Popular projects include computer training for community members, designing and uploading websites for non-profit organisations, assisting secondary school learners with Mathematics and Science, renovating rooms in orphanages, and designing and building jungle gyms.

This module was formally accredited by the Engineering Council of South Africa (ECSA) in 2006. Since its inception, the number of students enrolled for the module has grown from 238 in 2005 to 1 459 in 2010. The number of projects undertaken in the various communities increased from 47 in 2005 to 445 in 2009.

Objectives, outcomes and assessment

Some of the critical cross-field outcomes stipulated by the South African Qualifications Authority (SAQA) are that students should be encouraged to think for themselves and be able to work in teams. Importance is attached to the acquisition of general intellectual skills, communication skills, time management skills, and attitudes and values. The Community-based Project module tries to accommodate these issues as reflected in its objectives and learning outcomes.

The main objectives of the module are as follows:

- The execution of a community service-related project, aimed at achieving a beneficial impact on a chosen section of society, preferably, but not exclusively, by engagement with a section of society that is different from the student's own social background.
- The development of an awareness of personal, social and cultural values, an attitude to be of service and a deep understanding of social issues.
- The development of important multidisciplinary and life skills, such as communication, interpersonal and leadership skills.

Depending on the nature of the project chosen by the student, the main learning outcomes of the module are demonstrated when the student exhibits the following:

- A deep and broad understanding of the social issues relevant to the project
- The ability to communicate effectively with the community at large

→ *Students who have completed the Community-based Project module can enter the world of work with a better understanding of the needs of the community.*

- The ability to communicate effectively through writing and presentations
- The ability to perform leadership functions
- The ability to work effectively in a multidisciplinary environment and to perform critical functions

In assessing a student's project work, the mark allocation is based on what the student has learned and the extent to which the learning outcomes have been achieved. The final mark earned is a reflection of the quality of learning achieved rather than the nature of the service provided.

Structure of the module

Although the main focus of a community-based module is service to the community, students are required to complete assignments and reflect on their experiences. Assessment includes the attendance of compulsory contact sessions, evaluation and approval of the project proposal, self-assessment, peer assessment and assessment by a supervisor from the community, as well as the community-based lecturer, during the execution of the project.

It also includes three reflections written during the project, a report in the form of a blog, and a presentation to the project coordinator, peers and the community in which the student was involved.

Ensuring sustainability

One of the greatest challenges of the module is to ensure the sustainability of the module, as well as the sustainability of the projects done in the community and with the community partners. At the end of the project, the students' participation may end, but the communities' realities remain.

Giving students a say in the different phases of the community projects has a strong influence on the academic and civic engagement that follows, and allows students to engage in problem-solving, decision-making, planning, goal-setting and helping others. Students who are dedicated to their projects develop a sense of social awareness and usually feel responsible for the continuation of their project and the partnership with the communities.

To ensure the sustainability of projects and students' involvement in the communities, a mentorship programme has been established where students who have completed the module become mentors to the following year's cohort.

These mentors ensure the continuation of their projects by assisting the new entrants to the module in executing their projects and assessing them upon completion of their projects.

→ *Participating in the Community-based Project module helps develop a sense of unity between the students.*

Attitude change

Community-based learning shows students that they can make a difference. It increases their confidence as citizens. Although the students' collective actions are not always successful, it teaches them to learn from their mistakes by engaging in a continuous sequence of action and reflection.

Community engagement is viewed as valuable, useful, relevant and interesting. Students become more engaged and acquire greater knowledge and skills. It also becomes more meaningful for students when they choose the issue to address, when the issue requires analysis and problem-solving, and when there is a personal connection with the community to the task at hand. Community engagement only becomes meaningful for students when the service actually meets an important need in the community.

It provides students with opportunities for meaningful involvement with the local community. As they implement service projects, students usually develop greater awareness of social issues and the need for civic responsibility.

They often learn leadership, teamwork and social skills, and improve their critical thinking and analytical abilities. In the process, they tend to increase their self-confidence and self-efficacy. Feedback from students is very positive.

Campus community partners

A list of more than 500 community partners has been compiled where students may do their projects. These community partners identify their specific needs and submit them to the University each year.

New community partners are visited or invited to discuss possible new projects and developmental needs. Many community partners contact the University and request assistance. Students also identify possible new partners and projects.

To ensure ongoing engagement with the community partners, it is important to establish a good relationship with a contact person at an institution or non-governmental organisation (NGO) where the students will be doing their field work. An empathetic and dedicated supervisor or contact person on site ensures the successful execution of a project and positive feedback from the students.

The community partners assist in assessing the students on their project outcomes. This assistance is acknowledged in the blog reports of the students. Feedback with regard to module outcomes and possible new projects is requested from the community partners.

Funding

Most of the funding received for the implementation of the community-based projects is used for the transportation of the students to and from the communities. Some corporate sponsors have come forward to address this problem. These companies take responsibility for certain projects that are identified by the company. They then use the outcomes of the projects to meet their social responsibility targets. Such agreements are in place with Exxaro and Kumba Iron Ore.

Junior primary learners enjoy their *cosy* reading corners

The vision of three students to create reading corners for learners became a reality when they carpeted the cement reading corners in three classrooms at the Irene Middle Farm School as part of their community project. These reading corners are now warm spaces where the learners can retreat into the worlds of their books and participate in other activities there.

The learners of the Irene Middle Farm School benefited from the students' work.

The students carpeted the reading corners in three junior phase classes. Each corner was 3 m^2 in size and allowed sufficient space to seat the whole class. As none of the students had ever laid carpets before, they had to plan their project really well in advance in terms of measuring, marking up the floor and applying glue to the carpet. This proved to be much easier on paper than in practice. The students had to do a lot of brainstorming as they went along, and succeeded admirably in creating warm spaces where the learners could sit, especially on cold winter days.

The unforeseen practicalities included surveying the three classrooms to decide on the location of each reading corner and clearing out these corners. This included moving shelves, cabinets, files and desks. The other big job was cleaning the floor in preparation for laying the carpets. Preparation included sweeping the area, scrubbing the floor (to allow the adhesive to bond), washing the allocated area (to ensure that no dust was left behind), and finally applying the adhesive.

On the last day, there was a great bonus: a donation of books for the school! The books were all brand new, and added to the excitement of finalising the reading corners. The three students kept their tools so that they could maintain the carpets. In their words, "Mission accomplished: we came, we saw and we conquered those reading corners."

The learners received a donation of books as well.

LOVING restoration brings new life to an old military vehicle

"She was missing a carburettor when we first met." With these words, David Toma, leader of this Community-based Project (JCP) group, expressed just how involved 15 second-year civil engineering students had become with their community project: the restoration of a 1942 Marmon Herrington MKIV at the Swartkop Air Force Base (SAFB), the oldest operational air force base in the world.

These civil engineering students spent over 200 hours restoring an old military vehicle.

The vehicle had been left out in the open for many years in Cape Town. It was sent to the SAFB where it was provided with covered parking. The group's goal was to get back to the way it had been in its glory days and to get it running like it used to. They kept all the original parts or replaced them either with identical parts or similar parts without changing any of the mechanical properties (such as the six-volt system on which it operated, which was replaced with a generator, not an alternator).

At their project presentation for assessment, David regaled the audience with a magnificent slide show of the project since its inception, with a hugely entertaining and informative commentary, and humorous anecdotes. Watching a four-ton armoured truck being towed uphill by a Nissan Micra was truly something to behold!

Walter Moll, vice-person of the Friends of the South African Air Force Museum Society (FSAAFMS), considered the students' contribution to be significant and was impressed by the fact that the students wanted to be involved in a project of this nature. The FSAAFMS is involved in raising funds and restoring old aircraft and other old military items based at the SAFB, and supported the project all the way, providing advice and raising funds to help with the restoration.

The group has spent over 200 hours on the restoration so far. This restoration not only saved a forgotten classic, but also contributed to preserving a part of the country's heritage.

David says the group will continue cooperating with the SAFM and the FSAAFMS to help restore various aircraft, weapons, anti-aircraft vehicles and other ground support and military vehicles, as part of sustaining the impetus they created. They will also act as mentors to the 2011 student group.

Tiny tots become TECH SAVVY

Eight enthusiastic students from the University of Pretoria were met with great excitement when they arrived at Sunnyside Preprimary School – not least of all because of the soccer fever that had gripped this school! The students had planned to present ten days of hands-on mathematics, science and technology lessons for the little ones in the form of the Tekki Tots programme, which was developed by the Meraka Institute.

Learners at Sunnyside Preprimary School discovered that technology can be fun.

When the innovative group of students finally got started, they used brightly coloured jelly tots to determine the preschoolers' different levels of learning. The children went on to make necklaces to learn about patterns and to learn to cut in straight lines, they performed "magic tricks" using cabbages and different solutions to learn about acids and bases, and explored the wonderful world of sounds and vibrations. This culminated in the children creating their own special musical instruments and even forming a band, singing favourite songs like Old McDonald and Big Fat Mama. Other fun activities included organising data using smarties (and, of course, eating them at the end of the lesson!) and mixing and separating colours, which led to much experimentation, not to mention the fascination at seeing the colours separating before their eyes.

Shapes take on a new meaning.

This is the fifth year that students from the University of Pretoria have taken the Tekki Tots programme to this school. Other projects that are being undertaken at the school include revamping the sandpit and building a roof for the school's entrance.

Headmistress Marietjie Engelbrecht commended the students and the University for initiating the JCP programme. She said that the Tekki Tots lessons encourage Grade R learners to think "outside the box" and that the one-on-one interaction with the students is invaluable. She looks forward to ongoing engagement with students from the University of Pretoria.

Fresh, FUNKY space

where youngsters can eat and learn

The Thembisa after-school day-care centre takes care of 30 primary school children in the afternoons and during the holidays. This centre was established to provide the learners with lunch and help them with their homework. There are also volunteers who help the children with their mathematics homework, in particular.

→ *The students get hands-on experience in transforming the Thembisa day-care centre.*

Four civil and mechanical engineering students from the University of Pretoria decided to revamp the kitchen and dining hall of the centre during their July holidays as part of their JCP module. They happened to have chosen one of the coldest weeks of the year, and worked in freezing weather to finish their project in the allotted five days. They were lucky to have Pastor and Mrs Vilakazi who provided many delicious meals during the week.

The students received many donations for their project, for example, a school donated 30 table frames, a plumbing supplier donated a geyser, and a hardware supply company donated a whole range of fastening equipment and hundreds of litres of paint.

The space was transformed from an empty shell to a warm, friendly room, with freshly painted walls, a desk for each child, pigeon holes, cupboards and bookshelves. Almost everything was made from scratch, including the desks that were built and the pigeon holes that were constructed.

Youth Day on 16 June was freezing, but the students kept warm by giving the dining hall its final coat of pink paint and tiling the kitchen. The final day saw a lot of scurrying around to get everything finalised and the place cleaned up. Only the four students were allowed inside the building until the “big reveal”. Pastor and Mrs Vilakazi were amazed at the transformation.

Alerna Möller, a third-year civil engineering student, said the group was grateful for this opportunity to help the children, and to see how such a seemingly small endeavour could bring such happiness and joy to so many people.

New basking space for big cats at the zoo

Everyone enjoys a visit to the zoo, especially to one of the world's top ten zoos. The National Zoological Gardens, located in Pretoria, was founded in 1899 and established as a national zoo in 1916. It receives in excess of 600 000 visitors annually. A group of seven construction management and industrial engineering students decided that building platforms in the tiger enclosure would not only provide these big cats with a comfortable place to eat, sleep and bask in the sun, but would also create a better viewing experience for the public.

→ The tiger enclosure at the National Zoological Gardens in Pretoria is transformed.

During the July holidays, the pretty ordinary tiger enclosure was transformed into a much more interesting and engaging space with three platforms. This was quite a hefty task at times, not just because of the heavy materials that were needed to build the platforms, but also because these materials had to be transported by hand from the lower level of the zoo to the higher level where the tiger enclosure is situated.

Digging huge holes, pouring cement, drilling and hammering in the tiger enclosure under the watchful eyes of the striped carnivores was quite a chilling experience, but luckily a ten-foot fence and a huge ditch separated the students from the ferocious beasts.

The construction was concluded relatively quickly, thanks to the hard work of the group, and the three platforms were completed in just four days. The students used big, juicy steaks to lure the tigers onto the platforms, but as tempting as the meat was, the tigers were still wary and took their time reclaiming their territory.

Industrial engineering student Christiaan Ehlers says, "Our JCP project was an awesome learning experience. It was a wonderful opportunity to give back to the community. It was jam-packed with hard work and fun. We helped the community by using our time to build something useful and beneficial."

This project is just one of the many and varied projects the students of the University's Faculty of Engineering, Built Environment and Information Technology have been involved in at the zoo. Other projects have included building hammocks for the gorillas, renovating the suricate camp, and building mufflers for the noisy machinery.

Robynn Ingle-Moller, project coordinator at the National Zoological Gardens, says, "The students are a huge benefit to the zoo, as they provide refreshing support to the zoo's often overtaxed Civil Works Department. The students are not the only ones to benefit. The staff also gains insight and knowledge on how to manage the students, while the students in turn become tutors and mentors. In so doing, they gain important professional development skills that promote learning."

Venda Secondary School library is upgraded

A library that no one could use, with books in tatters and in complete disarray, stacked in dishevelled piles on shelves groaning under their unkempt load, prompted ten students from the University of Pretoria to jump in and transform this chaos into a true place of information. After the project had been concluded, the pupils of Tshilavhutume Secondary School in Mapate village in Thohoyandou, Limpopo, were able to easily access the books they wanted to use.

→ The disorganised library at the Tshilavhutume Secondary School is turned into an organised space.

The team was hoping to obtain sponsors for their project, which was executed over four days during the July holidays, but did not have much luck. The only sponsor was the University of Limpopo/Venda, which donated shelves, tables, a television set and microscopes, and provided them with transport. The lack of sponsorship did not deter this committed, enthusiastic team in their orange overalls. They tackled this gigantic task with gusto, cleaning out the entire library so that they could paint it and start stocking it from scratch. It took them two full days to sort out the books, working right through the night.

Despite the lack of sleep and very hard physical work, the students found time on the last day to have a career guidance session with the Grade 12 learners.

Their hard work paid off, as the school now has a library it can be proud of. It can now be fully utilised by the learners, who love their new library. The whole community was really excited about the new library, to the extent that even the primary school learners came to see the library on the last day.

The principal, MP Mathoma, says the school "now has a library." He was amazed at the transformation of the previously unused, dirty space into this new, clean, organised space. He says learners now frequently use the library. The school is very grateful for this intervention.

Vinolia Teffo, a metallurgical engineering student, said that she wouldn't trade this experience for anything. "JCP is really a good platform for students to be proactive in touching communities. I have learned that when people work together as a unit they can achieve a lot and make a tremendous difference in the lives of those they serve. The highlight of my experience was when the community expressed their gratitude," she said.

CONSTRUCTING

a better community

Students in Construction Economics, various role-players from the construction industry and the Berakah Educational Foundation are currently involved in a community engagement project in Mamelodi East.

This project, under the leadership of Riaan Jansen, a full-time lecturer in the Department of Construction Economics, was acknowledged as an exceptional innovation to improve teaching and learning. Jansen received a certificate at the biannual Education Innovation Awards for "learning by doing" for the impact this project has on student learning and student engagement.

→ *Construction Economics students gain practical experience while serving the community.*

The departments in the School for the Built Environment are among the many departments at the University of Pretoria whose students are involved in this large-scale project. Instead of each group undertaking individual projects, students work together to gain practical construction management experience at two sites in Mamelodi.

Viva Village houses orphaned and vulnerable children, while the Berakah site comprises a multifunctional building that will be used as a preprimary school, a training facility, community hall, clinic and church. It will also include a feeding scheme. The project is linked to the learning outcomes of construction economics subjects such as Construction Management, Building Science and Quantity Surveying Practice.

The first phase of the project was completed just before the construction industry closed for its annual December break in 2009. The second phase commenced in February 2010 and was spread over 14 weeks during the first semester. One day per week was allocated to the project so as to ensure that the construction practice and theory were integrated over this time.

Work during the second semester was mainly done by Quantity Surveying students, as most of the Construction Economics students had almost completed their required 40 hours of community work.

The University's close relationship with the construction industry creates the opportunity for contract research and the employment of students, and enables the department to keep abreast of developments in the construction industry to ensure better student education. Apart from coordinating and providing student labour for the Berakah and Viva Village sites, the Department of Construction Economics also procured services and material for the projects.

The project is a high-impact project and the first of its kind where suppliers, contractors, lecturers and students combine forces to make it successful. While practical work is usually reserved for fourth- and fifth-year students, third-year students now get an early introduction to site work as the project involves the disciplines of both quantity surveying and construction management. The value of the knowledge transfer between students, lecturers and the community is immeasurable.

Initiative develops skills in the field of informatics

by Kirstin Krauss

The Department of Informatics at the University of Pretoria was involved in a number of initiatives to combine information and communication technology (ICT) research and teaching to support community development.

This forms part of a special community development project in the department, known as the Informatics Initiative. This project was launched when the department noticed that so many academically disadvantaged students experience difficulty in coming to terms with studies in a technological and business-orientated discipline such as informatics. The department also came to realise that academically successful students tend to move into lucrative positions in industry, and are "lost" to the academic world.

The aim of this initiative was to enable students to complete their studies successfully, and to encourage them to continue with postgraduate study and eventually become lecturers in the Department of Informatics.

The initiative therefore has the following aims:

- To identify and help undergraduate students who experience difficulties in adapting to studies in informatics
- To identify and encourage undergraduate students who may wish to continue with postgraduate studies and eventually embark on an academic career
- To inform students and staff about what is happening in the information technology (IT) industry
- To reach out to disadvantaged schools and communities, and inform and support them with regard to the impact and role of IT in their communities and in their personal lives

To achieve these objectives, the department offers special tuition classes to students who experience problems with the subject, and exposes students to lectures by academic visitors to the department.

Building capacity in Zithobeni

Following a special teacher training initiative that was launched with funding from the United Nations Educational, Scientific and Cultural Organisation (UNESCO) in rural KwaZulu-Natal in 2008, UNESCO has provided the Informatics Initiative with another grant of US$8 000 for teacher training at Kgoro Primary School in Bronkhorstspruit.

With this initiative, the Department of Information Science will partner with the Department of Informatics to present information and communication technology (ICT) literacy and information literacy teacher training. So far, 43 teachers from both the primary and the secondary schools at Zithobeni have attended two courses at the University's Mamelodi Campus.

UNESCO has also requested the department's assistance with the testing of a draft media and information literacy curriculum in the Zithobeni community. This curriculum, proposed by UNESCO, is not yet available in the public sphere. Therefore, the University of Pretoria and the Zithobeni community have the opportunity of being the first to engage with it. The teachers from Zithobeni receive this training free of charge.

This is an exciting opportunity for the community and, as far as ICT for development research is concerned, it is hoped that some useful results will be generated and published from the experiences gained in engaging with the community.

According to the headmistress of Kgoro Primary School, Mrs Phoofolo, the school is situated in the township of Zithobeni, 7 km north of Bronkhorstspruit and 60 km east of Pretoria. It has 1 215 pupils, 27 teachers and eight administrative staff members.

The Zithobeni community is disadvantaged in terms of social and economic life. Most people stay in informal settlements and are unemployed, making it difficult for the parents to pay school fees. There is a high level of illiteracy in the community. This makes it difficult for parents to be involved in the economic and academic matters of their children. The school has programmes on HIV/AIDS and presents regular awareness activities. The teachers try to make their learners and the community aware of the extent of this epidemic. The high number of orphans among the learners (41) is a further challenge for the school.

Over the years, the Department of Informatics assisted the school by donating ten desktop PCs. This has enabled the school to create a computer room that is used by teachers to prepare their lessons and to compile tests, examinations and learners' reports.

Continuing the teacher training project in Tugela Ferry

The department's involvement with a local school in Tugela Ferry, a small rural village in KwaZulu-Natal, was launched in 2008, when 24 teachers from Lobethal Independent School received training in practical ICT literacy. This village was identified as one of the most economically disadvantaged communities in South Africa, and was in dire need of various forms of development and support.

During 2010, PhD research in Tugela Ferry formed part of the Informatics Initiative. The first community engagement endeavour for 2010 was a teacher training project from 6 to 10 April, where the teachers received training in MS Word and MS Excel. The revision and training was finalised in July 2010, and the community-owned course was also completed. The Tugela Ferry community is now ready to take over the ICT initiative that was started with them. The success of the training is reflected in the fact that the teachers who successfully completed their training have gone on to successfully teach nurses in Philanjalo to use MS Word.

→ Buzwe Gxulwana, a master's student in Informatics, assists the teachers from Zithobeni.

In addition, Dr Liana le Roux and one of her master's students from the Department of Social Work and Criminology at UP will collaborate with the Khayelisha Orphan Care Centre in Tugela Ferry to support the caregivers and to facilitate training on child therapy for molested and mistreated children. Through continuing the friendships made, more ICT training courses were planned for the remainder of the year.

In April 2010, eight Grade 11 learners and two teachers from Lobethal Independent School in Tugela Ferry had the opportunity to visit the University of Pretoria.

During the campus trip, the learners were invited to attend a dinner with Prof Trish Alexander and Zodwa Mahlangu from the Siyabuswa community. The Siyabuswa Education Improvement and Development Trust (SEIDET) and the Department of Informatics have had a long relationship in terms of research and community development projects that are related to a socio-technical view of information technology.

The following day, the learners from Tugela Ferry were introduced to Dr Jackie Phahlamohlaka. Dr Phahlamohlaka is a subject of the late King Mayisha III of the Ndzundza Ndebele people in Mpumalanga and is a systems modelling expert at the Council for Scientific and Industrial Research (CSIR). He has been involved, together with the University of Pretoria, in teaching the community of Siyabuswa that tradition and science do mix.

The success story of SEIDET and meeting Mahlangu and Dr Phahlamohlaka really inspired the learners from Tugela Ferry.

Department of Chemical Engineering celebrates its 50th anniversary

by Prof Philip de Vaal

The University of Pretoria has the biggest school of engineering in the country and offers tuition in the widest range of engineering disciplines. In 2010, the Department of Chemical Engineering celebrates its 50th anniversary. Its establishment and growth reflects the changing role of chemical engineering in society as a whole.

Wherever industrial processes are required to convert raw materials into products with a higher monetary value through physical, chemical thermal, biochemical and mechanical changes, the importance of chemical engineering to the country's economy becomes evident. The role of chemical engineering is vast, and its impact can be felt in a variety of process industries, ranging from the oil, coal, fuel, paper, food and textile industries to mineral processing, water and effluent treatment, air pollution control, polymer production and processing, the nuclear fuels industry and power generation.

The department's main focus is to use effective education and relevant research to produce graduates who will use their ability to think independently and generate new knowledge to the benefit of the broader South African society. Since the establishment of a fully fledged Department of Chemical Engineering in 1960, the University of Pretoria has been delivering chemical engineers who can be involved in any stage of a process engineering project, from the generation of an idea to the sale of the final product. This includes aspects such as fundamental and applied research, techno-economic evaluations, and plant design and optimisation.

With the increasing awareness of the need to protect the environment against pollution and the development of biotechnology on an industrial scale and in medical applications of engineering, the role of the chemical engineer is increasing in global importance. The department's research focus areas have subsequently developed to meet national and international needs. These include process modelling and control, applied materials, environmental engineering, water utilisation, reaction engineering, biochemical engineering and sustainable process systems engineering.

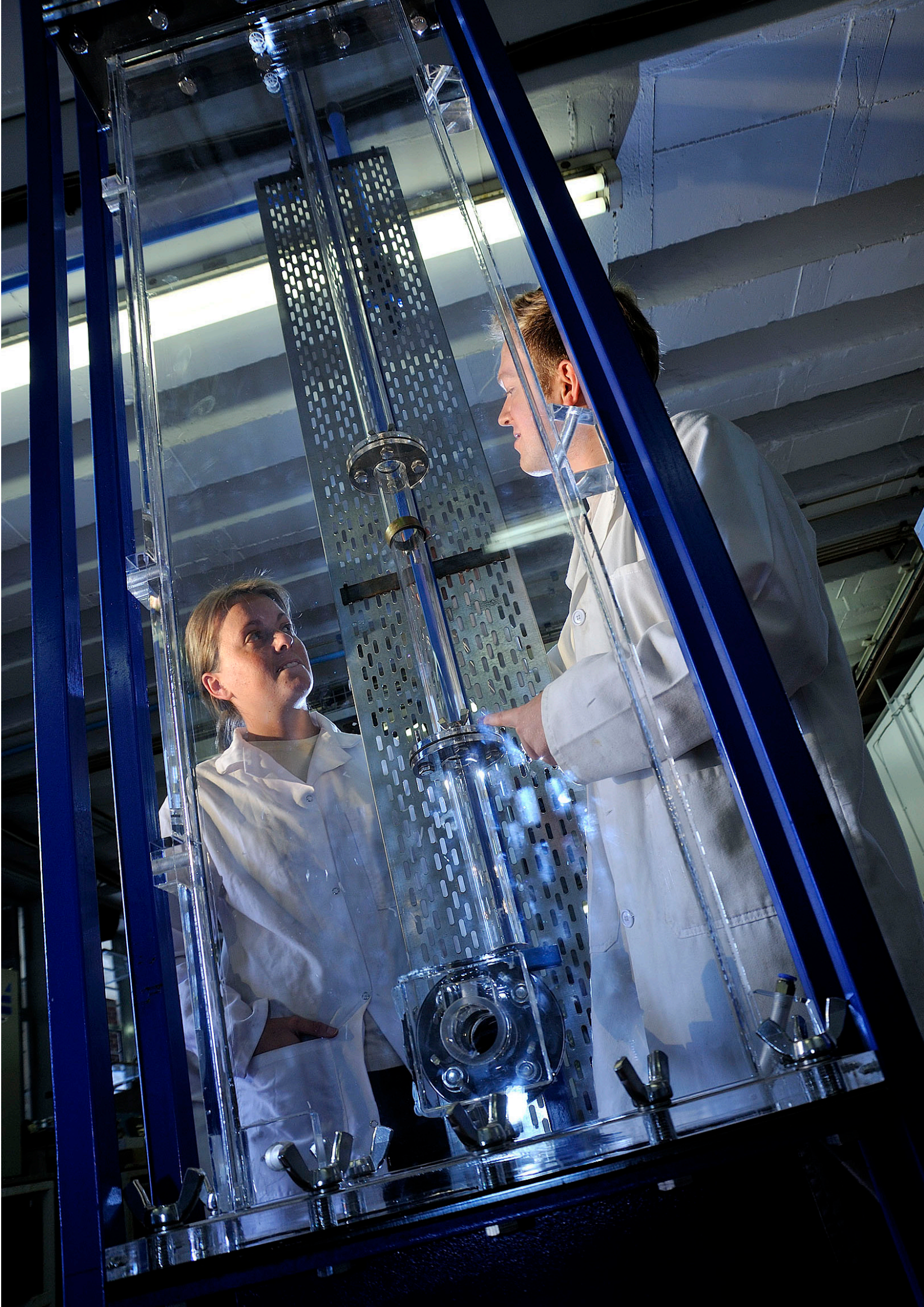
The Department of Chemical Engineering will also play an increasingly important role in the future to ensure the sustainable utilisation of South Africa's valuable non-renewable natural resources, which include scarce metals like platinum, chromium, vanadium and gold, as well as the country's large coal reserves. It is important to treat coal as a valuable resource for the production of chemicals, rather than as a cheap source of energy. Alternative sources of energy therefore need to be found, and this will of necessity include renewable resources and nuclear power.

> **"There is an increasing demand for engineers (including chemical engineers) in South Africa and the School of Engineering intends doubling the number of engineering graduates over the next 10 years."**

Historical perspective

Although the establishment of a faculty of engineering at the University of Pretoria was approved in 1954, it was only in 1960 that the founding three departments in the faculty (civil, mechanical and electrical

→ *The Department of Chemical Engineering will play an increasingly important role in ensuring the sustainable utilisation of South Africa's valuable resources.*



→ *The annual number of graduates increases steadily.*

engineering) were expanded to include a fourth department to cater for the students in chemical engineering that had enrolled in 1959. Prof Dawie Schoeman was appointed as the first head of department in 1960 and the first graduates completed their studies in 1962. When Prof Schoeman became dean of the faculty in 1980, Prof Uys Grimsehl took over as head of department. He was succeeded by Prof Philip de Vaal in 2004.

The first-year enrolment for the first 15 years of the department's existence was fairly stable at between 20 and 30 students per annum. By the early 1990s, this had increased to about 70 students per annum. By 2009, about 140 prospective chemical engineers were choosing to enrol at the University of Pretoria. The annual number of graduates has shown a steady increase from seven in 1962 to between 40 and 50 in the period 2002–2008.

About 70 to 80 students are expected to graduate between 2010 and 2012. The growth in postgraduate student numbers is equally encouraging: from 30 in 1985 to 65 in 1992 and 154 in 2009. The increase in the number of students enrolled for master's and doctoral degrees bodes well for the University's plan to develop into one of the country's top research universities.

There is an increasing demand for engineers (including chemical engineers) in South Africa, and the School of Engineering intends doubling the number of engineering graduates over the next ten years. To accommodate this growth, support has been obtained from government and the University Council to significantly expand the University's engineering facilities through the construction of additional lecture halls, as well as teaching and research laboratories.

Research achievements

High-quality research outputs can only be achieved with high-quality human resources, supported by adequate, state-of-the-art equipment and laboratories. To this end, the Department of Chemical Engineering has been highly successful in attracting funds to complement internal resources. Since 1960, a total of four endowed chairs have been adding value to the activities of the department:

- The Rand Water Chair in Water Utilisation Engineering
- The East Rand Water Care Company (ERWAT) Chair in Waste Water Management
- The Department of Science and Technology (DST) Chair in Carbon Technology and Materials
- The DST Chair in Fluoromaterial Science and Process Integration

→ *Third-year students regularly gain practical experience in the laboratories of the Department of Chemical Engineering.*

Several members of the department have been honoured for their outstanding research achievements. Earlier in 2010, Prof Walter Focke, Director of the Institute of Applied Materials, received the Technology and Human Resources for Industry Programme (THRIP) Award in the category Competitiveness of Industry Partner. This was for work done on the characterisation of carbon materials for use in a pebble-bed nuclear reactor. He received an allocation of $100 000 from the Bill and Melinda Gates Foundation for the development of an indoor spray to control malaria transmission. He has also developed a method to impregnate mosquito nets with insecticide where the rate of release conforms to the stringent requirements of the World Health Organization (WHO). Prof Thokozani Majozi was appointed as a research fellow of the CSIR in 2009. In 2008, he received the Silver Medal of the British Association, awarded by the Southern African Society for the Advancement of Science (S_2A_3). He is also the 2010 recipient of the South African Institution of Chemical Engineers (SAIChE) Bill Neal-May Gold Medal Award for Outstanding Achievement and International Recognition.

In 2008, the University of Pretoria honoured the 100 leading minds of the past century. Three of these scientists come from the Department of Chemical Engineering. They are Prof Walter Focke, Prof Thokozani Majozi and Dr Henk Viljoen.
The faculty also boasts several researchers with ratings from the National Research Foundation (NRF), including one of only two researchers in the School of Engineering with an A-rating. This prestigious honour goes to Prof Brian Rand, who is the incumbent of the DST Chair in Carbon Technology and Materials in the Institute of Applied Materials.

Student achievements

Students of the department are regularly recognised for their contributions at a national and an international level.

- **Edrich Malan** received the national Sasol Chemical Industries (Sastech) prize for the best vacation training report in 2006 with a project entitled *Energy balance and mineral dissolution kinetics for copper bioleaching systems*.
- **Tobi Louw** received the first prize in the Chemical Innovation Award of SAIChE in 2007 with a project entitled *Rheological behaviour of synovial fluid: effects on joint lubrication*, while **Jacqueline Barnard** came second with her project *Stabilisation of nano-emulsions against Ostwald ripening by adding Inutec SP1 polymeric surfactant*.

- **Devon Clack** was the runner-up in the Honeywell Users Group International UniSim Student Competition in 2008 for the development of a dynamic simulation of a Lurgi-gasifier and improving the accuracy of data accumulated from the Sasol gasifiers. As part of his prize, he had the opportunity to present his work at the annual Honeywell Users Group Conference for Europe, the Middle East and Africa (EMEA) in Berlin, where his project was one of the top five projects internationally.
- **Ria Muller** won the Sastech Prize in 2008 for the best vacation training report, with a report entitled *A study of the catalytic minimisation of the yield of perfluoro-isobutylene*.
- **Kersch Naidoo**, a postgraduate student, won the SAIChE Award in 2009 for the best postgraduate report with a dissertation entitled *Preparation for novel microporous polymeric hemi-shells*.
- Three students in the Department of Chemical Engineering were recognised in different categories of the 2009 Chemical Technology Award. **Ria Muller** won the CSIR Undergraduate Student of the Year Award, **Vutshilo Madzivhandhila** won the Anglo Research Postgraduate Research Paper of the Year Award and **Puxley Mashele** won the Special Environmental Award.

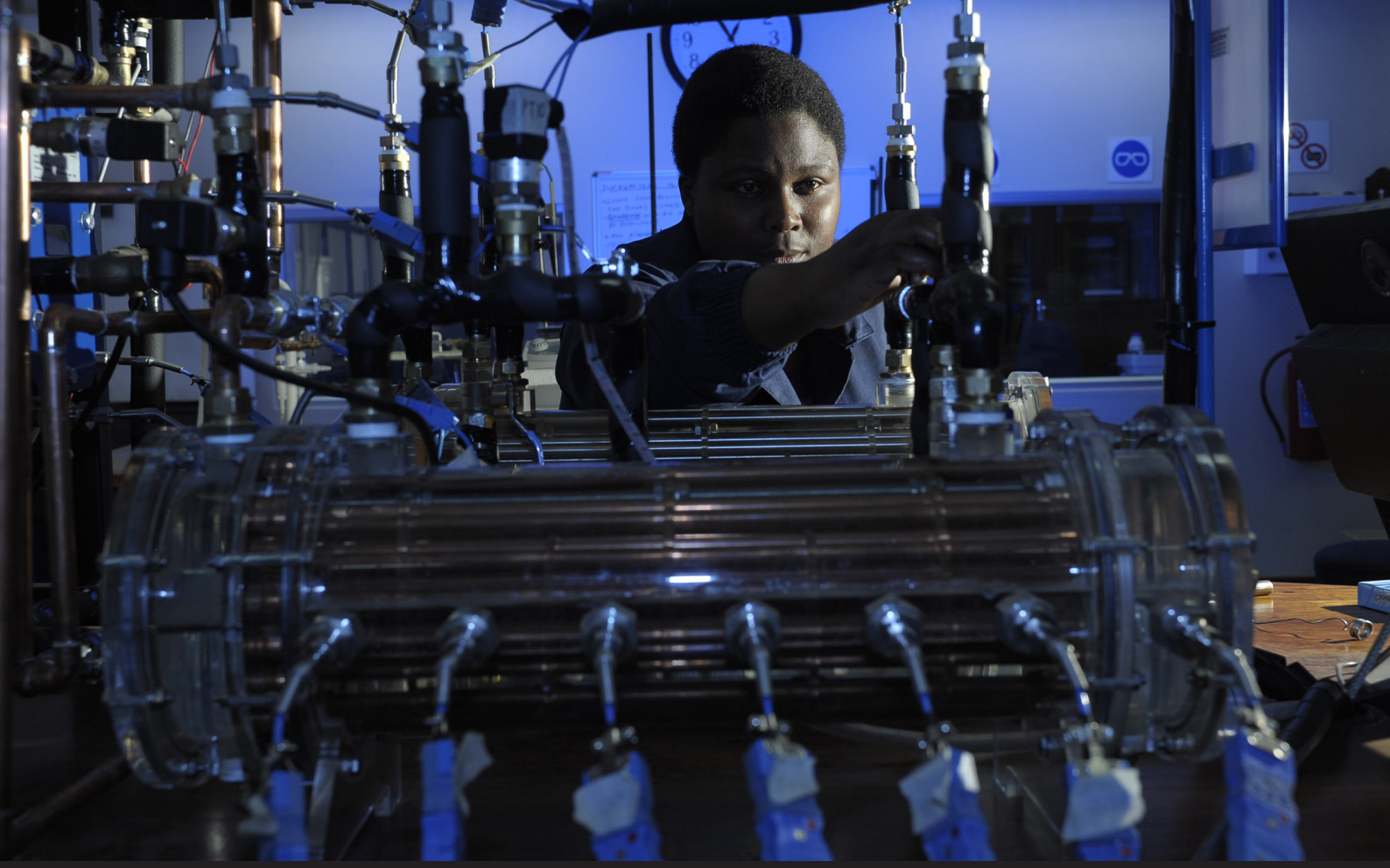
Prof Philip de Vaal, Head of the Department of Chemical Engineering.

Prominent alumni

Alumni of the Department of Chemical Engineering have a proud record of local and international performance:

- **Marius Kloppers**, who graduated from the department in 1986, was appointed chief executive of BHP Billiton in 2006.
- **Ralph Havenstein**, who obtained the BEng(Chem) and MEng(Chem) degrees in 1977 and 1979 respectively, was the executive director of Sasol from 1998 to 2003 and chief executive officer of Anglo Platinum from 2003 to 2007.
- **Dr Henk Viljoen**, who obtained the BEng(Chem) and MEng(Chem) degrees in 1979 and 1981 respectively, is currently professor at the University of Nebraska-Lincoln in the USA.
- **Hans van Leeuwen**, who graduated from the department in 1972, is a professor in the Department of Civil, Construction and Environmental Engineering at Iowa State University and was recently named as one of the top 100 innovators by the American National Science Foundation. He was also named as the *R&D Magazine*'s innovator of the year in 2009 for his research on the use of fungi for the production of biofuels.

The Department of Chemical Engineering at the University of Pretoria has certainly come a long way over the past fifty years to become one of the country's leading providers of chemical engineering skills and innovative, cutting-edge research in its various focus areas. It is with anticipation that it looks forward to playing an even greater role in promoting the economic prosperity of the country and improving the lives of communities, not only in South Africa, but in Africa as a whole.



New high-tech lab to test performance of synthetic diesel

High-technology equipment, which is being installed at the University of Pretoria, will provide better insight into the properties and performance of synthetic diesel fuels and the application of such fuels in engines, turbines and other devices.

A research collaboration between petrochemicals giant Sasol and the departments of Chemistry (Faculty of Natural and Agricultural Sciences) and Chemical Engineering (Faculty of Engineering, Built Environment and Information Technology) at the University of Pretoria has resulted in the commissioning of a new LECO Pegasus 4 comprehensive two-dimensional gas chromatograph, combined with a time-of-flight mass spectrometer (GCxGC-TOFMS). The acquisition of this equipment was made possible by financial support from Sasol Technology through joint research interest in the chemistry that underpins the physical properties of diesel fuels.

Sasol reports that the study of the flow of substances under various conditions and the physical behaviour of synthetic fuels are important areas related to the company's fuels and lubricants research. The LECO Pegasus 4 GCxGC-TOFMS will enable scientists to make a more detailed analysis of how the more than 100 compounds that make up synthetic diesel fuel contribute to the performance, viscosity and lubricity of these fuels.

The ability to obtain such chemical insight only became feasible through the extreme analytical power of the GCxGC-TOFMS instrument, allowing for the identification and classification of literally thousands of compounds. The initiative forms part of Sasol's university collaboration initiative, a long-term programme that supports the aims of world-class teaching and research capacity in chemistry and chemical engineering at selected local universities.

The ability to identify specific chemical compounds in complicated mixtures will help the University of Pretoria in other non-petrochemicals research fields, including air and water pollution, forensic toxicology and aroma analysis. In all these areas, the LECO GCxGC-TOFMS will be used in combination with other unique analytical instrumentation and techniques developed at the University's separation science laboratories.

(extracted from *Engineering News*, 4 June 2010)

Marius Kloppers – an alumnus rises to the top

When you hear the name Marius Kloppers, you instinctively think BHP Billiton, superpower executive, ambitious risk-taker and family man. Marius is an alumnus of the University of Pretoria who graduated with a Bachelor of Chemical Engineering in 1986. In 2007, when he took over the reins as chief executive officer of BHP Billiton, he was awarded a TuksAlumni Laureate Award for his steamrolling professional career and exceptional rise to the top of the world's single largest mineral resources group. With the celebration of the Department of Chemical Engineering's 50th anniversary in 2010, *Innovate* found it fit to profile this remarkable mining man.

→ *Marius Kloppers.*

Marius J Kloppers was born on 26 August 1962 and grew up in Johannesburg. He graduated from Helpmekaar Kollege and completed his BEng at the University of Pretoria. He went on to receive a PhD in the same subject at the Massachusetts Institute of Technology (MIT) in the United States. He also graduated with an MBA from INSEAD in France, an experience that he has described as "incredibly rewarding" for the open, cross-cultural debates it stimulated with people around the globe and the grounding experience it gave him in commerce.

Marius worked in petrochemicals at Sasol and as an engineer in materials research with Mintek in South Africa. Following the completion of his MBA at INSEAD, he went to work for McKinsey & Co in the Netherlands. It was here that his interest in the aluminium industry was sparked, paving the way for his future at BHP Billiton. In 1993, Marius left McKinsey & Co to join Gencor, which later became Billiton.

Marius has been progressively active in the mining and resources industry since 1993. He was appointed chief commercial officer of BHP Billiton in December 2003. Previously he held the roles of chief marketing officer, group executive of Billiton Plc, and chief executive of Samancor Manganese, as well as holding several other positions at Billiton Aluminium, including those of chief operating officer and general manager of Hillside Aluminium.

In 2007, at the age of 45, he was appointed CEO of the largest resource company in the world. He officially assumed the position of CEO on 1 October 2007. He has been a director of BHP Billiton Limited and of BHP Billiton Plc since January 2006 and executive director of BHP Billiton Plc since 1 January 2006. He also serves as a director of the BHP Billiton Group.

Fortune 500 voted Marius as one of the world's 25 most powerful people in business. "Talk about being in a hurry," wrote Brian O'Keefe on the *Fortune* website. "Kloppers took over as chief executive of the world's biggest mining company by market capitalisation (some $200 billion) on 1 October 2007. One month later he launched a $150-billion takeover bid for rival Anglo-Australian mining giant Rio Tinto."

Mining insiders weren't too surprised by Kloppers' bold takeover move, writes O'Keefe, as he has a reputation as "an aggressive executive with superior intellectual bandwidth." Today his quick-thinking, yet humble management style continues to steer BHP Billiton to success.

Marius is married to Carin, whom he met in high school. They live in Melbourne, Australia, with their three children, Noni, Reuben and Gabrielle.

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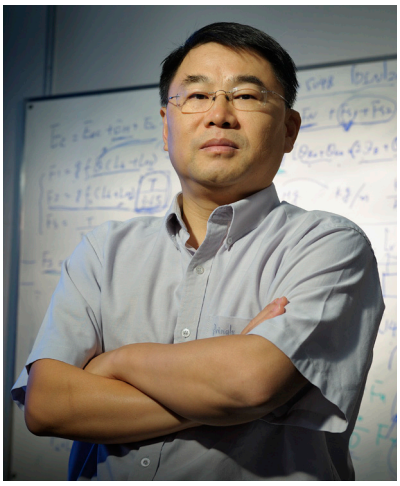
Focused energy-efficiency research – addressing the gap

The University of Pretoria's Hub for Energy Efficiency and Demand-side Management is at the cutting edge of innovation and research in energy-saving engineering.

Energy efficiency remains an abstract academic topic, underpinned by an endless set of definitions and an alarming shortage of technical and academic skills. In June 2008, the University of Pretoria launched the Hub for Energy Efficiency and Demand-side Management in an attempt to shed more light on these topics through focused research and to provide a general pool of high-level expertise in energy efficiency at tertiary level. At the forefront of this innovative and much-needed postgraduate programme is Prof Xiaohua Xia, a lecturer in the University's Department of Electrical, Electronic and Computer Engineering. He is also the director of the hub.

Prof Xia notes that the objective of the hub is threefold: to train students, to trade knowledge and to develop technology in the focus areas of energy efficiency and demand-side management. The hub is a five-year initiative that will put its efforts into bursary management and the training of postgraduate students. Although it is a virtual hub by nature, comprising intellectual capital, it is administratively hosted at the Centre of New Energy Systems (CNES) on the University's Hatfield Campus.

The initiative came about when the South African National Energy Research Institute (SANERI) issued a tender for the establishment of a centre to host postgraduate programmes in energy efficiency and demand-side management in an attempt to meet SANERI's human capital growth objectives as stipulated by the Energy Research and Development Strategy. SANERI is a subsidiary of the Central Energy Fund (CEF) and a joint initiative between the Department of Science and Technology and the Department of Energy. Six academic institutions submitted proposals to host the programme and the University of Pretoria's Faculty of Engineering,



→ *Prof Xiaohua Xia.*

Built Environment and Information Technology was awarded first prize. By winning the bid, it was selected by the SANERI Board to host the centre.

Diverse expertise

The hub's research topics are clustered around different research groups and in various departments of the University of Pretoria. These research topics include energy-efficient drives and power electronics, energy-efficient housing, fuel and process efficiency, energy-efficient power integration with renewable and alternative energy, energy optimisation and standardisation tools and applications in industries, energy-efficient lighting, energy efficiency in heat transfer and energy efficiency in transport. These research topics are covered by the Department of Electrical, Electronic and Computer Engineering, the Department of Chemical Engineering, the Department of Mechanical and Aeronautical Engineering, the Department of Civil Engineering and the Department of Architecture.

The hub's core staff members comprise six full professors, three associate professors and two senior lecturers, five of whom have National Research Foundation (NRF) ratings.

Vast progress has been made since the launch of the hub. In 2009, the centre funded 25 honours and master's degree students in engineering, as well as two doctoral students. The total number of students undertaking courses has grown from 27 in 2008 to 61 in 2009. Six short courses have been developed, 25 research topics have been identified and 33 research papers have been completed.

"From an academic point of view, there is excellent expertise in energy efficiency across the country, but the mobilisation of that research is often missing. In terms of human resources, there is a shortage of high-level technical people in energy efficiency, which results in research efforts that are more scattered rather than focused. However, it must be said that there is strong expertise across the country, with some specialists in leading international positions," comments Prof Xia.

The hub therefore aims to grow and develop focused skills at PhD level and to connect professional and academic expertise in energy efficiency and demand-side management so that it can be collectively addressed at academic level and filtered through to industry. The hub aims to include and liaise with various academic institutions across the country and provides bursaries to students from several tertiary institutions in South Africa. The objective is also to obtain a more even gender representation in the fields of energy-efficient engineering. The hub therefore invites participation from female students in particular.

The annual budget received from SANERI, including bursaries, amounts to R4.5 million. Additional funds are secured from Eskom and the NRF. Other interdepartmental funding is also obtained.

Pioneering research

Although there are several research groups within the hub, Prof Xia highlights some pioneering work that has been conducted by the Industrial Energy Optimisation Group. He is personally involved with this group and can therefore cite direct information, but qualifies that dynamic research is being conducted by all the focus groups across the various departments in the School of Engineering at the University of Pretoria.

The Industrial Energy Optimisation Group has conducted significant studies on the optimisation of conveyor belts and material-handling systems. Broad-based studies have been conducted on a national basis and several papers on this topic have been published.

According to research conducted, there are approximately 50 000 conveyor belts in South Africa. Conveyor belts are responsible for about 16% of the total energy consumption by industrial users. "If we can save only 10% of the energy consumed by all conveyor belts and material handling systems in South Africa, we can save an amount of energy that is equivalent to building a large coal-fired power station with a generation capacity of 1 000 MW," says Prof Xia.

Several energy-consumption models have been developed, and some of these have been translated into commercial products. According to Prof Xia, a number of companies from France are in consultation with the University of Pretoria about intellectual property and the purchasing of these conveyor belt product designs. The work in this regard is continuing.

Prof Xia also highlights the exceptional research that has been conducted to optimise the winder systems of deep-level underground mining operations by managing the winders more effectively in off-peak periods, while not compromising the shafts' production requirements.

According to Prof Xia, the research and training efforts of the Hub for Energy Efficiency and Demand-side Management have already resulted in a significant improvement in energy efficiency knowledge, technology development and skills transfer in South Africa, and will continue to do so in the next years of research action.

→ *Wind turbines generate clean energy.*

Technology road mapping to promote renewable energy – solar as a first step in South Africa

by Prof Alan Brent and Prof Tinus Pretorius

The development and infusion of new technologies into markets are believed to be key long-term drivers for economic development. The result is a sustainable improvement in the quality of life of the beneficiaries of such technologies, whether at organisational or at general society levels. Technology is consequently seen as an important strategic asset for these beneficiaries, and there is an increasing need to include technological considerations in strategy and planning processes.

South Africa's renewable energy strategy has set a target of 10 000 GWh of energy to come from renewable resources by the year 2013. This target is currently being revised. Nevertheless, solar energy technologies are expected to make a considerable contribution to this target. Despite the country having abundant solar resources, the industrial sector is yet to provide appropriate technologies to harness these resources, thereby paving the way for South Africa to become globally competitive and to capture a significant portion of a growing international market.

To facilitate the transition to a knowledge-based economy that focuses on the potential of renewable energy, the Department of Science and Technology aims at creating an enabling environment through a solar energy centre of competence to support an emerging solar industry, and to explore and address the challenges, while also contributing to energy resource diversification.

As part of a larger project to establish such a centre of competence, the Graduate School of Technology Management (GSTM) at the University of Pretoria, in collaboration with the Centre for Renewable and Sustainable Energy Studies (CRSES) at Stellenbosch University, has been tasked to coordinate and develop a national solar energy technology road map through a multistakeholder process.

A technology road map (TRM) is widely considered to be a flexible and powerful technique for supporting technology management and planning and can be adapted to many strategic situations. The flexibility of the method may be considered both a strength and a weakness. Although it can be applied in many contexts, it has to be customised to fit a particular application. The diverse ways of constructing a TRM may be due to a lack of clear and accepted standards or guidelines. Nevertheless, effective road maps have been developed for various sectors, including the solar energy sector.

A TRM offers a solid framework to integrate market, product and technology evolution. A sector can use it to collect information from a wide variety of sources. With this information, dynamic near-, mid- and long-term plans can be developed for research and development (R&D) investments, as well as new product, service and process developments. The tool can integrate what is known at all levels in a sector into a framework that supports strategic initiatives and tactical decisions.

In general, road maps identify technologies that underlie current and planned products and/or services and highlight the known technology developments that are expected, as well as the elements that will be needed to successfully develop these into new products and/or services. In other words, a TRM provides a framework for supporting integrated and aligned multifunctional strategic planning in terms of both "market pull" and "technology push", achieving a balance between market requirements and technological capability.

Additional "pressure" and "support" drivers for the incorporation of sustainability aspects in strategy and planning processes must also be considered when applying the TRM technique. This could address the challenge of forming strategy and policy at corporate and government levels that guide technology development along sustainable paths, as perceived by all stakeholders. To this end, the national solar energy technology road map (SETRM) highlights, among

other things, key strategic focus areas, the required interventions by various role-players, and how South Africa could utilise its comparative advantage of solar irradiation in the best possible way.

Further information on the SETRM can be obtained from
Prof Tinus Pretorius of the GSTM (tinus.pretorius@up.ac.za) and
Prof Alan Brent of the GSTM and the CRSES (acb@sun.ac.za).

→ *Solar energy forms an important part of the country's renewable energy strategy.*

→ *Coal-generated power plants make use of the country's non-renewable resources and are a source of pollution that is to the detriment of both man and the environment.*

The professionalisation of interior design in South Africa

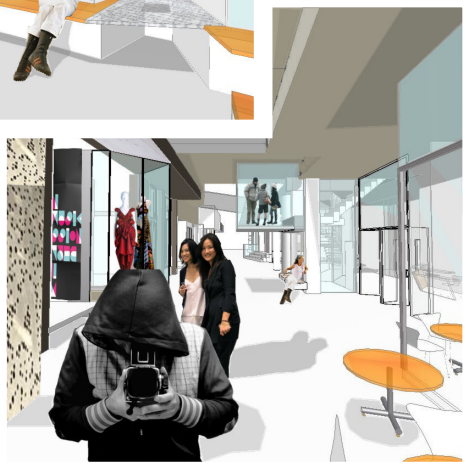
by Raymund Königk

Interior design is a spatial occupation. It entails the design of enclosed interventions in the built environment for which documentation is produced. As such, it is an architectural occupation. At the University of Pretoria (UP), interior design is represented by the Programme for Interior Architecture in the Department of Architecture.

The discipline is the art and science of the design of designated spaces, investigating relationships between user, object and spatial envelope.

The interior design occupation is not given any formal professional recognition in South Africa. The built environment professionals who have achieved occupational closure, as listed by the Council for the Built Environment, are the engineers, architects, landscape architects, property valuers, quantity surveyors, project and construction managers, planners and surveyors. In 2004, interior design was placed under pressure when the South African Council for the Architectural Profession (SACAP) took steps to identify and monopolise architectural work. This served as an incentive for interior design to professionalise the occupation, and led to the establishment of the South African Institute of the Interior Design Professions (IID) in 2006.

This institute is dedicated to establishing, promoting and maintaining expertise, professionalism, sound business practice and high standards throughout the industry. The IID strives to expand the contribution of interior design to society through the exchange and development of knowledge and experience in education, practice and fellowship. The IID was accepted as a voluntary association of the SACAP in April 2009.



In 2009, the Department of Architecture made a proposal to the SACAP to establish interior design as an architectural discipline. This would allow interior designers practising in South Africa to register as professionals with the SACAP. The department is a model of interdisciplinary cooperation, incorporating three architectural disciplines (architecture, landscape architecture and interior architecture). As such, it is in a unique position to assist the IID to achieve one of its key objectives, namely the recognition of the professional status of its members in the interior decorating, interior design and interior architecture sectors. The department entered into a formal relationship with the IID to consolidate their parallel efforts towards professionalisation. The aim of the two institutions was to develop relevant registration categories for the discipline that correlate with the existing registration categories for the architectural profession.

Following research, the Department of Architecture at UP and the IID (with collaboration by the Department of Architectural Technology and Interior Design at the Nelson Mandela Metropolitan University and the Department of Interior Design in the Faculty of Art, Design and Architecture at the University of Johannesburg), finalised the interior design registration categories in 2010. This proposal was submitted to the Council of the SACAP in April 2010.

The department proposed three professional registration categories: professional interior designer, professional senior interior designer and professional interior architect. These categories have been accepted in principle and negotiations between the SACAP, the IID and the department are continuing with regard to the implementation process and time line.

***Raymund Königk** is a lecturer in the University of Pretoria's Department of Architecture and is a national council member of the South African Institute of the Interior Design Professions.*

The South African Institute of the Interior Design Professions

The IID is the only professional body in South Africa representing the local interior design industry. The stated objectives of the Institute include the following:

- To promote excellence in the practice of interior design
- To improve the profession
- To protect the rights of its members
- To grow the organisation
- To expand the contribution of the profession to society at large

Membership of the IID indicates your status as a qualified, experienced and ethical practicing interior design professional.

Membership also provides you with support and networking, as well as access to information and ongoing education, all of which help to improve your professional practice in addition to fostering a wealth of contacts that will help connect you to a host a suppliers and colleagues from across the South African interior design industry.

The IID is a member of the International Federation of Interior Architects / Designers (IFI) and has also been recognised as a Voluntary Association by the South African Council for the Architectural Profession (SACAP).

Who are our Members?

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Students learn to conceive, design, implement and operate

The School of Engineering at the University of Pretoria recently adopted a new approach to engineering education that aims to teach engineering students not only the technical fundamentals of their disciplines, but also non-technical skills. These skills include working in teams, communicating through written or oral presentation, considering their work in the context of society, and professional ethics.

Instead of emphasising analysis and problem-solving in a theoretical realm, students participate in team-based projects where they go through the cycle of conceiving, designing, implementing and operating (CDIO).

The CDIO Initiative is an innovative educational framework that has been adopted by the University of Pretoria to produce the next generation of engineers. The framework provides students with an education that stresses engineering fundamentals set in the context of conceiving, designing, implementing and operating real-world systems and products. Throughout the world, collaborators have adopted CDIO as the framework of their curricular planning and outcomes-based assessment.

CDIO is a return to engineering fundamentals. According to the worldwide CDIO Initiative, engineering education programmes offered students plenty of hands-on practice. Accomplished and experienced engineers taught courses that focused on solving tangible problems. However, as scientific and technical knowledge expanded, engineering education evolved into the teaching of engineering science. Teaching engineering practice received increasingly less emphasis.

Therefore, while graduating students are technically adept, they lack many abilities required in real-world engineering situations. To encourage schools of engineering to meet real-world needs and rethink their educational strategies, the American Accreditation Board of Engineering and Technology identified its expectations for graduating engineers. The resulting international reformation of engineering education has its foundation in the worldwide CDIO Initiative.

Universities throughout the world that implement the CDIO Initiative have adopted 12 standards that serve as guiding principles and create benchmarks and goals with worldwide application. These standards address programme philosophy, curriculum development, design-build experiences and workspaces, new methods of teaching and learning, faculty development, and assessment and evaluation.

The CDIO standards

- Adoption of the principle that product and system life cycle development and deployment (conceiving, designing, implementing and operating) are the context for engineering education.
- Specific, detailed learning outcomes for personal, interpersonal, and product and system building skills, consistent with programme goals and validated by programme stakeholders.
- A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal, interpersonal, and product and system building skills.
- An introductory course that provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills.
- A curriculum that includes two or more design-build experiences, including one at a basic level and one at an advanced level.
- Workspaces and laboratories that support and encourage hands-on learning of product and system building, disciplinary knowledge and social learning.
- Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal, interpersonal, and product and system building skills.

Graduates from the University of Pretoria are better prepared for the world of work.

- Teaching and learning based on active experiential learning methods.
- Actions that enhance faculty competence in personal, interpersonal, and product and system building skills.
- Actions that enhance faculty competence in providing integrated learning experiences, by using active experiential learning methods and assessment of student learning.
- Assessment of student learning in personal, interpersonal, and product and system building skills, as well as in disciplinary knowledge.
- A system that evaluates programmes against these 12 standards, and provides feedback to students, faculty members and other stakeholders for the purposes of continuous improvement.

Aligning the University's undergraduate programmes

When the University of Pretoria's engineering curriculum was evaluated, it was found to meet most of the CDIO standards. The one area in which it was found to be lacking, however, was the development of workspaces and laboratories that support and encourage hands-on learning of product and system building, disciplinary knowledge and social learning.

According to Prof Josua Meyer, chairperson of the University's School of Engineering, it was important to align the University's undergraduate programmes correctly and benchmark them with the best practices internationally. When the new engineering building was therefore planned, a particular instruction to the design team was to develop different study areas where students could work and collaborate informally: some where students could form informal groups between classes, and other quieter workspaces where students could work individually. The idea is to provide engineering students with a home away from home, where they can spend their time in a productive, student-friendly environment.

These workspaces will provide opportunities for students to engage in engineering reasoning and problem-solving through teamwork, with the added advantage that the University of Pretoria will be able to deliver engineering graduates who are better prepared for the world of work.

Reference

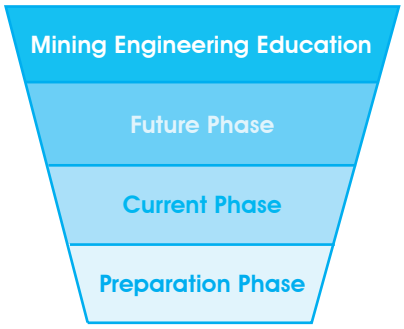
1. www.cdio.org

Real-time mining engineering education for real-time mining engineers

by Prof Ronny Webber-Youngman and Dr Ronel Callaghan

The Department of Mining Engineering accepts that the process of improving teaching and learning is an ongoing exercise with the ultimate aim of delivering well-rounded mining engineering practitioners. Thus, an integrated and innovative process was developed and followed in the department in order to apply holistic teaching approaches and principles. The process includes the introduction of multiple integrated interventions regarding teaching and learning strategies.

This process entailed three phases. Prior to 1999 (Preparation Phase), several teaching and learning challenges were identified. Since then (Current Phase), various interventions have been developed, implemented (and in some cases piloted) and evaluated to address the challenges. The Future Phase will focus on improvement, successes and the full roll-out of current interventions, as well as on training, development and support for all staff members to participate in the process.



→ *1. Phases of progression.*

The process of improving teaching and learning is based on and supported by the prescribed outcomes of the Engineering Council of South Africa (ECSA). These outcomes are also incorporated in the outcomes of the South African Qualifications Authority (SAQA) for the engineering qualification.

The department faces the following main challenges:

- Following the restructuring of the mining engineering qualification prior to 2008, students only specialise in mining engineering from their third year of study. The introduction of basic mining concepts is therefore a challenge, as is progressing to the appropriate high levels of learning in the third and fourth years of study.
- The world of the mining engineer is sometimes not as tangible as that of other engineering disciplines. Students grow up in a "visual era", but are challenged with several scenarios related to mining that do not make sense to them.
- The mining engineer is a manager and a supervisor. Management (planning, organising and control), which includes supervision and interpersonal skills, and teamwork are important aspects of the everyday life of a mining engineer. The teaching of these aspects is not measurable in the traditional context of the engineering curriculum.
- Academic standards are high. The pass requirement of 85% for engineering modules in the Faculty of Engineering, Built Environment and Information Technology is aligned with the University of Pretoria's drive to improve student success and retention. This should be achieved without lowering standards or neglecting the outcomes of ECSA.

Focus areas

These challenges played out practically in five focus areas: content, professional skills, support, communication and teaching.

- **Content:** Because most mining engineering students had never been to a mine (on the surface or underground), it was very difficult for lecturers to make them "see" what they were trying to explain. New concepts and terminology and the work environment of the mining engineer could not be visualised and explained and therefore had a negative impact on students' results. Students specialised in mining engineering from their third year of study without any prior knowledge of the basic concepts.

- **Professional skills:** Management and leadership principles, which are of key importance in the outcomes of becoming a good mining engineer, were not addressed as a critical component in the curriculum. Mining engineering, as a people's profession, was not experienced as such by the students. The perception was created that the department was strict and impersonal.
- **Support:** The mentoring and coaching of individuals and teams was not part of the teaching and learning programme. Problem areas were identified too late, to the detriment of the student and the disappointment of the lecturer. The percentage of mining students that did not pass in certain mining and other modules was quite high (in some modules the failure rate was as high as 50%). The real reason for this had to be identified and rectified.
- **Communication:** The increase in student numbers and subsequent increase in work groups created communication problems (particularly in a multilingual environment and given the realities of students who receive tuition in their second language). Relatively speaking, lecturers had traditionally obtained good feedback reports from students, but a need for improvement was indicated.
- **Teaching:** Class attendance and throughput was poor. A different approach was needed to incorporate larger groups in terms of the teaching and learning strategy. The higher student numbers also made mine visits more difficult due to the logistical challenges associated with these visits. When group work was utilised, the selection and management of groups was not done according to a formal, scientific approach that incorporated management principles. The management and assessment of group work were problematic and were not done professionally. The reason for the failure or success of groups and/or students could also not be measured effectively through conventional assessment strategies.

The department embarked on a process to prove that a holistic multi-intervention approach to improving teaching and learning was, in fact, possible and sustainable through the optimisation of the teaching and learning experience. If the answers to the abovementioned challenges were found, it would be feasible to develop the "ideal" mining engineering student and subsequently a quality mining engineering practitioner.

Interventions

The innovative development process of the qualification links to the five focus areas discussed above. In Figure 2, the focus areas can be represented as arrows to indicate the growth and progression of the intervention process.

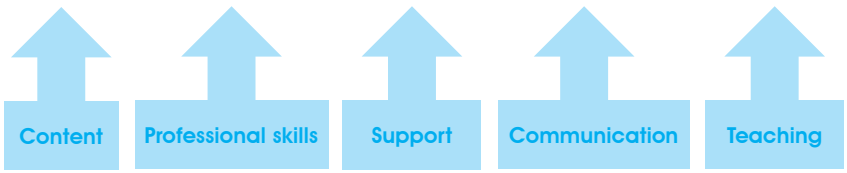
Content

The department employed an instructional designer (sponsored annually by the South African Collieries Managers' Association) to design all mining modules in a format where a one-dimensional script would be enhanced through the inclusion of high-quality pictures and illustrations, simulations of complex mining sequences that had previously not been possible to comprehend without underground visits (and even then they were difficult to comprehend), animations showing difficult concepts in mining, which also included "mouse-overs" to make explanations of mining sketches and descriptions more understandable to the inexperienced mining student, and video material to make "dead" picture images come alive.

A databank of mining industry videos was obtained as part-time viewing material for students to enhance their understanding of difficult mining concepts and procedures. These included reconstructions of typical mine incidents and accidents with 3D animations, for example, accident reconstruction simulations (ARSs) and geological features. These videos have already been introduced in some modules and will further enhance students' comprehension of aspects that had previously only been experienced through on-mine visits. The videos can also be used to introduce students to basic mining concepts.

Professional skills

Several selection procedures were used to identify differences in the personalities and group tendency relationship make-up of individuals. In 2009, the mine design groups were composed using the Myers-Briggs tool, DISC (dominance, influence, steadiness and compliance) analysis, and according



→ *2. Five focus areas in developing "ideal" mining engineering practitioners.*

to gender, race and the commodity type from which a student had a bursary (coal mining, gold mining, platinum, etc).

In 2010, as part of a new approach of identifying a specific student's thinking preference, the Herman Brain Dominance Instrument (HBDI) tool (whole-brain analysis) was introduced to identify the thinking preference of each of the students in the final-year mining engineering class. Figure 3 and Figure 4 depict the different aspects of thinking preferences as identified through HBDI and illustrate the plot summary of the 2010 final-year mining engineering students. Most of the class was grouped in the blue (engineering) quadrant. Their lecturers are also in the process of adapting teaching strategies according to the HBDI approach.

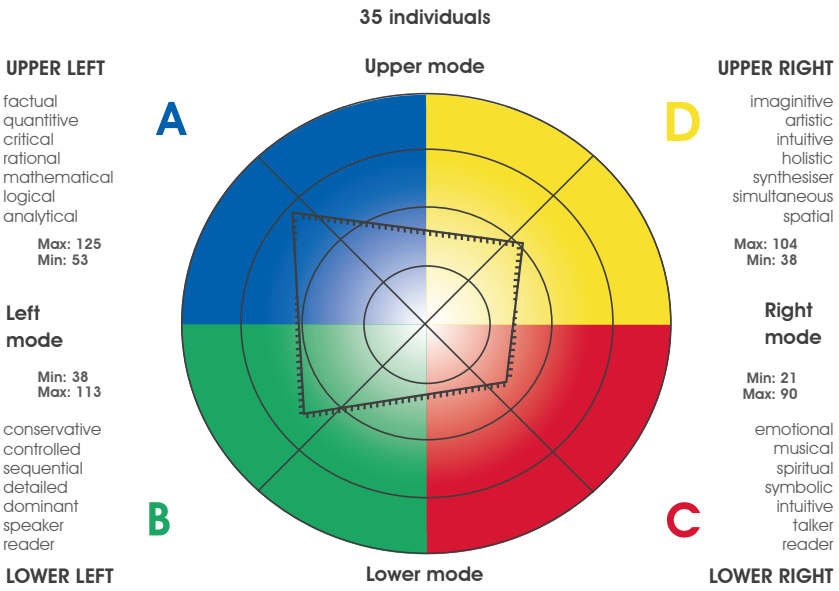
The Shadowmatch tool, which determines dominant habits in an individual, was introduced for the first time in 2010 and will also be included as a way of distinguishing individuals from each other. The habits identified with this tool can be compared to the habits associated with successful mining engineers. This information can also be utilised in future for students' professional development.

Both these tools were sponsored by the Department of Mining Engineering through funds secured from short courses in the safety risk management process (SRMP) that were presented to Anglo-American. The department is investing in the future of quality mining engineers without putting a further financial burden on the students and/or bursary companies.

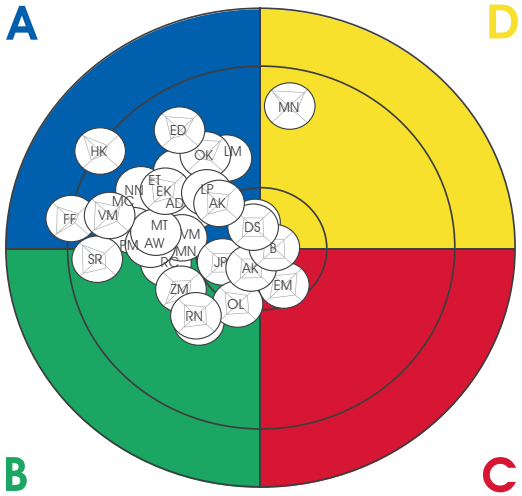
Mentoring and coaching were introduced for the first time in 2009 to develop leadership skills in the mine design groups. Group discussions and gatherings on pre-arranged appointment times led to very important lessons learned.

These included group dynamics, mannerisms and responses to questions under pressure, as well as developing listening and talking skills by all individuals in the group. These sessions were video-taped and played back to the participants to show their responses to certain activities in the group sessions. This process will be continued and further developed in the future.

As part of an assessment procedure, the development of each group was monitored and discussed on an ongoing basis, identifying specific needs proactively. This process amplified the relevance of the continuous monitoring and assessment of the progress of groups and individuals in the groups as part of an improvement strategy, motivated as an ongoing process.



→ *3. HBDI whole-brain explanation.*



→ *4. HBDI whole-brain mining engineering students group plot.*

→ The implementation of a holistic approach of interventions could have an impact on students' results.

Support

The "caring nature" (soft skills) of the mining engineering practitioner (as an addition to a sound technical knowledge base) is developed in lecturers and students. The message is also conveyed that upholding a high standard is not negative, but serves as preparation for the mining industry. Academic support is provided to students in non-compulsory forum information sessions during their first and second years of study to prepare them for their qualification. Personal life skills development programmes, mentoring and peer support (soft skills) are being developed and implemented in collaborative learning sessions.

Support is provided through exposure to material relating to professional certificates by means of the utilisation of practical videos that are made available by the industry and financed by the department (for example, videos on blasting, ventilation and geology). The department acquired its own computer laboratory in the second semester of 2010. This will enable students to explore additional learning material in the secure environment of the Department of Mining Engineering.

Communication

All announcements are communicated to students via the University's learning management system (ClickUP). A big LCD monitor at the entrance to the department also depicts important notices, as well as other newsworthy mining information, on a continuous basis. This is updated weekly to keep the information current. The bulk SMS system that was introduced by the Department of Mining Engineering is successfully used to communicate with students on an ongoing basis.

Teaching

The selection tools for group work are used to improve the efficiency and productivity of groups. It is envisaged that groups made up in this way will be much more efficient and productive than groups composed according to the haphazard approach previously used. Group work discussions and the sharing of ideas on how problems on mines can be solved lead to interactive and high-level discussions and participation where group work is implemented according to professional group work principles.

All the mine design groups attend a weekend session of in-depth team coaching where the different aspects pertaining to group work, including mentorship and coaching, are discussed and dealt with in detail. As part of a strategy to make group discussions more feasible, the mining laboratory area, which had not been used effectively, was converted into discussion rooms for group work activities (incorporating mentoring and coaching sessions to develop leadership skills).

A radio-based Interwrite personal response system (PRS) that allows lecturer and student interaction (clickers), was introduced in 2010. Pre-designed critical concept questions are set as part of a PowerPoint presentation. Once all the students have answered the set question, the lecturer receives immediate feedback in the form of a histogram displayed on his or her computer. In this way, shortcomings on key principles that are embedded in the outcomes for the module at hand are identified much sooner.

Lecture material for the instructionally completed modules is made available on CD at the beginning of the semester, enhancing the knowledge and understanding component of learning for the student, with the lecturer then spending more time on the application and design component of teaching. A system of unannounced class tests has also been partly introduced, which has resulted in better preparedness and improved class attendance. By employing this holistic approach, key elements of the teaching and learning strategy can be monitored on a group and individual basis and has made the learning experience much more rewarding and worthwhile for lecturers and students alike.

Impact on teaching and learning

The interventions that have been implemented thus far have had several impacts. These impacts are strengthened by other interventions, such as strict subject prerequisites. Since the examination in June 2010, there has been a large increase in

the number of students that have passed the fourth-year modules in comparison with the previous year. It is speculated that the implementation of a holistic approach of interventions could also have had an impact on students and their results. This will be monitored on an ongoing basis. The pass rate, as a percentage of the number of students enrolled in all the mining courses, has increased significantly, as is indicated in Table 1.

Table 1. Performance of students in certain modules in 2010 in comparison to 2009

Module code	2009	2010
PEE 410	50%	93%
PMY 410	60%	90%
PSZ 410	80%	88%

In a workshop conducted for third-year mining engineering students during 2009, the reasons for their poor results were discussed. Several personal problems and other areas of concern were identified. This information and will be used on an ongoing basis in future in the development and improvement process. Student engagement, as well as preparedness for class, class attendance and class participation, has improved significantly. The average score in terms of student feedback on the lecturers in the department as a whole has also increased significantly from that of previous years. This process of improvement is sustainable, as it is supported by the head of department and lecturers in the department.

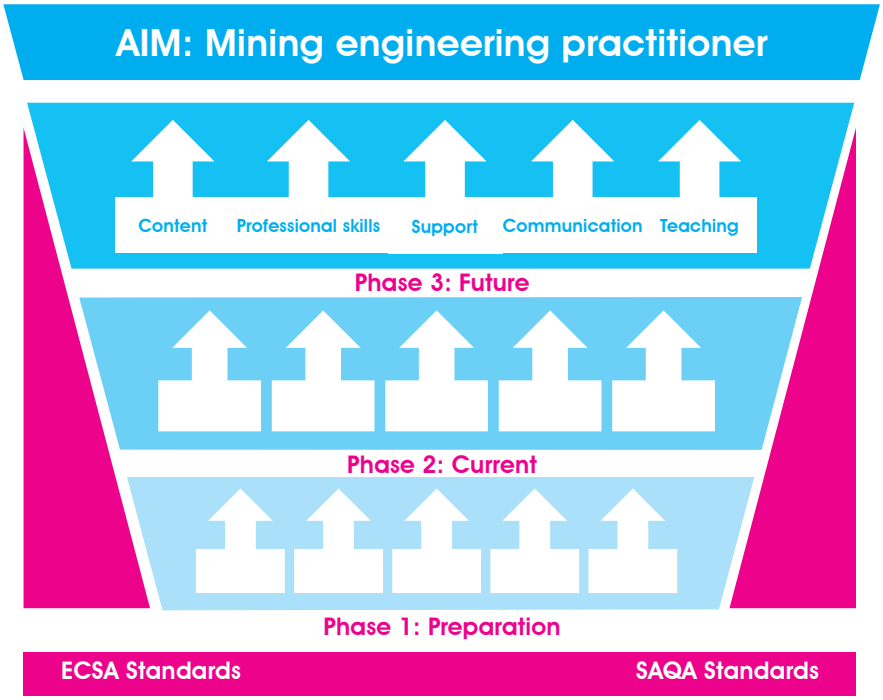
The new holistic interactive multimedia, as well as the group dynamic approach, was presented to the alumni of the Department of Mining Engineering and the Mining Advisory Board in industry and was very well received. It was also complimented by the chairperson of the Minerals Education Trust Fund. Figure 5 illustrates and summarises the teaching and learning development process implemented in the Department of Mining Engineering.

The five main focus areas

The five focus areas that comprise the innovative development process of the qualification are each represented as an arrow to indicate growth and progression. Each arrow increases in size in each phase in a vertical direction to demonstrate how the specific focus area is developing and how more supportive elements are built into the process. The arrows in each band also move closer horizontally to illustrate how elements will eventually be integrated into a holistic learning experience for all students in all modules.

The aim of the intervention is to develop well-rounded mining engineering practitioners who are prepared for the many challenges of their future workplaces through a combination of innovative teaching and learning elements. This process, as well as the mining engineering qualification, is based on and supported by the prescribed outcomes of ECSA and SAQA. The department is also accredited with ECSA.

The figure can also be applied to the development process of a young mining engineering student from his or her first year until he or she has graduated and completed his professional engineering qualification (including the practical part of the programme). As the five components develop in stature (represented upwards and sidewards), the student also gains maturity and experience in the mining industry.



→ *5. The development process of innovative teaching and learning for the mining engineering qualification.*

Developmental phases

The three phases of development are represented as bands on a trapezium. Each phase leads to a broader base on which the next phase can be built. Development entails continuous planning, acting and reflecting. Each new intervention is planned with care, and implemented and reflected on by academic staff, support staff, industry and students. The results are utilised to improve the intervention, or to plan new interventions.

Phase 1: Preparation Phase: Outdated ways of teaching and learning have forced lecturers to think more innovatively about incorporating concepts such as the visualisation of lecture material. Several challenges and potential interventions to improve the situation were identified.

Phase 2: Current Phase: The elements that are being developed and implemented include the use of instructionally designed material, the instructional development of other material, and staff development in and the application of student-centred teaching strategies. This adds a flavour of professionalism and a sense of belonging, and has a major impact on the perception of mining. Plans for improvement are continuously revisited and re-engineered.

Phase 3: Future Phase: Elements are implemented in more modules and staff members are adopting and being trained or educated in the new paradigm. Elements are also integrated into a holistic process of teaching and learning.

The development process is therefore depicted as an ever-growing trapezium to indicate the importance of constant renewal and reflection. This, combined with the collective buy-in of all staff members into the process, ensures the sustainability, not only of the process of development and growth, but also of the implementation of interventions.

There has never been a more in-depth critical evaluation of the teaching and learning strategy of the Department of Mining Engineering to improve mining engineering education than in the last few years. Issues such as integration, diversity, change in the gender composition, literacy and language issues, as well as the quality of education associated with the school system in South Africa, made it clear that a different approach to teaching and learning had to be adopted.

It was also realised that, due to the complexities and specialities associated with mining engineering as a career, various approaches have to be integrated into a holistic approach to mining education. This gave birth to the concept of "real-time mining engineering education for real-time mining engineers". The provisional results from the different aspects that comprise this holistic approach made a positive contribution to the attitudes of the students and lecturers alike. The cognitive level of engagement of students increased considerably and their perception and attitude towards lecturers also changed.

Through the visits by the Mining Advisory Board and the Minerals Education Trust Fund, the Department of Mining Engineering has received several compliments and recognition for this very bold step of introducing a number of innovative teaching and learning strategies to a holistic teaching and learning approach.

Acknowledgements

The Department of Mining Engineering received a Laureate Award at the biannual Education Innovation Awards. This was in recognition of the process on which it has embarked to improve teaching and learning, and to educate the future mining engineering practitioner. This award recognises innovative developments that have resulted in improvements in the quality of the student learning experience or environment. Expected standard of good teaching practice should convincingly be exceeded and evidence of sustainability, positive impact and acceptance should be provided in the form of student feedback or appraisal by peers. Nominations for this award are assessed on evidence provided in relation to clarity of purpose with systematic planning, implementation and evaluation, as well as the impact innovation has on the practice of learning and teaching.

→ Dr Ronel Callaghan, Education Innovation consultant for the School of Engineering (left), and Prof Ronny Webber-Youngman, Head of the Department of Mining Engineering.

Cooperative learning in an engineering context

by Clive Knobbs

In 2009, in my first semester as a lecturer, I was dismayed when one third of the class failed my subject, Underground Mining Methods and Fundamentals of Management and Leadership (PMY 410). This set in motion a process of finding and implementing a turnaround strategy involving cooperative learning, which not only addressed the technical (content) part of the course, but also facilitated the integration of soft skills (process) into engineering education.

When such a large number of students failed, it was tempting to lay the blame on the students, but the old adage states that "if the student hasn't learnt, the teacher hasn't taught". I realised that my aim of imparting an appreciation of the behavioural aspects of the real world and teaching some "people or soft skills" had not succeeded.

Adhering to Einstein's admonition that "insanity is doing the same things over and over and expecting to see different results", I went back to basics and asked a few fundamental questions. Was the course teaching the right material for mining engineers? What aspects of the course were superfluous? How could I teach more effectively, or, more aptly, how could I help the students to learn? What else did they need to know to handle the complexities and challenges of the real world, particularly the people issues?

Objectives

Clearly, the most important objective for the course was the need to improve the pass rate to something close to 85%, a figure 5% higher than the figure of 80% that the dean had set as a target for the Faculty of Engineering, Built Environment and Information Technology. Naturally, the technical and professional standard of the course could not be compromised (if anything, there was room for improvement).

The Fundamentals of Management and Leadership part of PMY 410 had constituted only about 20–30% of the course, but it was theoretical. The new course would concentrate more on emotional intelligence (EQ), subtly enveloping and permeating the technical content. Basic theoretical knowledge of behavioural concepts would be conveyed to students and rudimentary practical skills would be developed, concentrating on those elements that constitute the foundations of effective people management and leadership.

The EQ knowledge and soft skills that had to be included were intrapersonal skills (self-awareness, self-regard, assertiveness and independence), interpersonal skills (empathy, relationships and communication), adaptability (reality testing, conflict-handling and problem-solving) and stress management (tolerance and impulse control). An understanding of group dynamics, particularly in small teams, was also important. The aim was to mimic, as closely as possible, the personal and people issues that graduates would be faced with in the real world and to enable them to understand the situation in order to cope appropriately and adequately. No quantitative objectives were set in this area for obvious reasons. People and their behaviour are highly complex and defy accurate quantification. I also knew what would constitute a "meaningful" change in these multifarious things.

The action plan

I read prolifically (books, papers from luminaries, articles in authoritative publications and the like) – everything I could lay my hands on. I consulted with the cognoscenti at the University of Pretoria who gave unstinting assistance in redesigning the course and the way it was to be presented. In addition, the course that I am attending at the INSEAD Business School in France (Executive Master's degree in Clinical Organisational Psychology) contains many modules that have been invaluable in assisting me to formulate the programme for incorporating some behavioural knowledge and skills into the PMY 410 course. Subjects such as "know thyself" (Plato's dictum), group dynamics, management and leadership, conflict-handling, change management, group coaching,

Soft skills are integrated into engineering education.

and one-on-one coaching for underperformers are among the many topics covered in the INSEAD course.

Armed with this "academic" knowledge, augmented by advice from my mentors, I opted for a cooperative learning approach to teaching. The approach also comes in other names, but essentially it involves the use of small teams to enable effective learning. The discussion and debate in these teams are central to the learning process; not just for technical content, but also for developing soft skills.

For technical content, the international CDIO (conceive, design, implement and operate) model was used. Heavy emphasis was placed on the first three dimensions, as the students would encounter the operate dimension in their mine design course in the second semester. In essence, the goal was to enable students to construct mini-designs of mines by the end of the course. With the content decided, I had to consider the details of the modus operandi for teaching through cooperative learning.

Reading material relating to course content was sent to individuals through ClickUP, the University's online teaching platform. This material consisted of published papers, presentations by experts, lecture notes and references to chapters in a prescribed textbook. Students were expected to prepare themselves for the small-team discussions, where specific questions and points for consideration were posed on the subject matter. Unresolved or unsatisfactorily resolved issues from the small groups, involving understanding or interpretation, were passed on to the full class for later discussion and resolution. Short presentations were made by randomly selected teams.

The big spin-off from this small-group activity of tackling technical issues was the conversation that was taking place inside the group and subsequently in the full class discussions. These discussions were promoting interaction, communication, problem-solving, confidence and a whole array of soft EQ skills.

As part of the soft EQ knowledge and skills and to help construct the small teams that were pivotal for cooperative learning, psychometric tests were employed extensively throughout the semester. Tests were administered that measured brain dominance, habits, learning styles, and character, personality

and behavioural styles. All students wrote a reflection paper at the beginning and in the middle of the course, describing their feelings about cooperative learning. But what was really happening during the course – the hard facts?

Throughout the course, progress was measured. More frequent individual assessments were introduced. Regular short weekly tests were written and three longish assignments were completed in addition to the two standard semester tests. Heavier weighting was given to these semester tests and assignments, which together accounted for 50% of the final mark.

Results

The evaluation of the efficacy of cooperative learning on students' prowess in the hard technical core of the course was measured directly by their final marks. Of the 28 students in the class, 23 passed the course: a pass rate of 80%. Of the five failures, four could rewrite their examinations and one failed outright. On the face of it, the objective was realised. It is impossible to say that cooperative learning was solely responsible for the improved results, but it was an important factor. The students' perceptions might shed some light on the real value of cooperative learning.

Responses to the custom-designed questionnaire administered before the final examination showed that the majority of students found the cooperative learning approach to be helpful or extremely helpful in imparting knowledge and understanding, and in teaching design skills. On the question of enjoyment, the majority of students responded positively; a handful of students disagreed.

What about the effect of cooperative learning on the soft EQ issues? Judging by the responses to the questionnaire, it would appear that the "peripheral" behavioural issues were affected positively. On the main questions of confidence, communication, self-worth, problem-solving, teamwork and interpersonal relationships, understanding of themselves and others, about 80% of the students said that their knowledge and skills had been enhanced or extremely enhanced. This would appear to vindicate the assertion that cooperative learning can have a positive influence on soft EQ issues.

The cooperative learning approach is not new, but to my knowledge it has not been extensively applied in the field of mining engineering. The majority of students have accepted cooperative learning and it has probably contributed to an improved pass rate.

The use of psychometric tests and questionnaires at undergraduate level to help individuals know themselves, understand others and gain an appreciation of behavioural issues in the workplace is innovative. Placing such emphasis on teaching and developing soft skills, and integrating these aspects into the core technical part of the course are certainly new for the Department of Mining Engineering.

Future plans

The class of 2011 could consist of 60 students, double the number of 2010. This poses some logistical problems that would need attention. Refinements to the approach are already being considered. Other workplace skills like written English, project management and ethics can also be integrated into the course. The department is considering the possibility of introducing students to cooperative learning earlier in the degree, perhaps in one of the third-year courses.

A brilliant engineer with no knowledge of himself or herself and the behavioural issues that permeate the workplace is one-dimensional and at a distinct disadvantage relative to his or her counterpart who has acquired even a modicum of EQ knowledge and skills. The introduction of soft EQ knowledge and skills into PMY 410 will enable students to "hit the ground running" in the real world.

Acknowledgements

Prof Diane Grayson, Dr Ronel Callaghan and Ms Erna Gerryts provided ongoing advice and guidance on the cooperative learning technique. Prof Ronny Webber-Youngman, head of the Department of Mining Engineering, gave the project unqualified and unwavering support. Miguel Coelho and Michael Neale, two postgraduate students, assisted admirably with the cooperative learning logistics and were always prepared to enter into a critical review of the programme's progress.

***Clive Knobbs** is a senior lecturer in the Department of Mining Engineering.*

The role of technical standards in engineering, technology and computing curricula

by Dr Saurabh Sinha

Technical standards are established norms or requirements. They are usually available as formal documents that determine uniform engineering, technical, performance and interoperability criteria, methods, processes and practices. Among their uses are the setting of specifications at the onset of a design, defining constraints during the detailed design process, and serving as benchmarks during testing.

Introducing standards in the classroom will augment the learning experience by pointing students to available design tools and to best industry practices. Student knowledge of standards would facilitate the transition from classroom to workplace by aligning educational concepts with real-world applications and market constraints.

General intent

Along with its activities in the area of standard development, the Institute of Electrical and Electronics Engineers (IEEE) is committed to the development and dissemination of educational material about standards.

Recognising that the role of standards in current engineering, technology and computing (ETC) academic curricula is often unclear, and that most graduates of ETC programmes receive little systematic education on standards, the IEEE desires to redefine and enhance the integration of standards in academic education.

The integration of standards in ETC curricula may be achieved in several forms, including the following:

- By reference – indication that a process or a device is covered by a technical standard and a citation of the standard.
- By introducing the principal technical specifications of a standard – an indirect introduction to a technical standard by extraction of principal aspects of the standard and incorporating them in classroom instruction, homework assignments, laboratories or projects.
- By direct use of a published standard (or a significant excerpt of a published standard) in classroom instruction, homework assignments, laboratories or projects.
- By regular use of and reference to technical standards in large-scale projects, especially last-year design or “capstone” projects.

The IEEE makes the following recommendations regarding the role of technical standards in the curriculum of academic programmes in ETC: exposition to standards by reference should be made the norm in all ETC curricula, and the goal should be assisted by increased use of textbooks that review and include references to technical standards.

The IEEE recommends that during their last or next-to-last academic year, ETC undergraduate students in standard curricula should be exposed multiple times to introductions to the principal technical specifications of a standard. Such introductions can be provided through in-classroom instruction, homework assignments, laboratories or projects.

The IEEE recommends that during their last or next-to-last academic year, ETC undergraduate students should be exposed to at least one instance of extensive direct use of a published standard.

The IEEE recommends that, to the extent practicable, last-year design or “capstone” projects should make regular use of technical standards, and that the relevance and applicability of technical standards should be part of progress and final reports on such projects. Among the proposed activities is a “standards search” at the commencement of each project, paralleling the common patent and literature searches.

**The above views were presented as an IEEE position paper by Dr Saurabh Sinha, Chair: IEEE South African Section and member of the IEEE Educational Activities Board (EAB), delivered on behalf of the IEEE Board of Directors.*

Expanding the view of road engineers in training

by Prof Wynand J van der Merwe Steyn

Road pavement engineers are traditionally trained with the emphasis on the materials and processes required to design, construct and maintain roads. The majority of their work focuses on the analysis of traffic loads on roads, the selection of adequate materials to carry these loads, and procedures to ensure that the roads will remain in a serviceable condition for their whole economic life. All of these activities are typically conducted on the assumption that the inputs from the traffic remain relatively constant over the life of the pavement, and with the emphasis on the economic cost of constructing and maintaining the infrastructure.

Although vehicle operating costs (VOCs) have traditionally been incorporated into detailed economic analyses, they were not seen as elements to which road engineers could necessarily make a major contribution. In recent years, the effect that road riding quality (or the unevenness on the surface of the road) has on the experiences of a vehicle (and specifically trucks) travelling on roads, and the contribution of these uneven surfaces to the damage caused to the vehicle and cargo, have been receiving increased attention internationally.

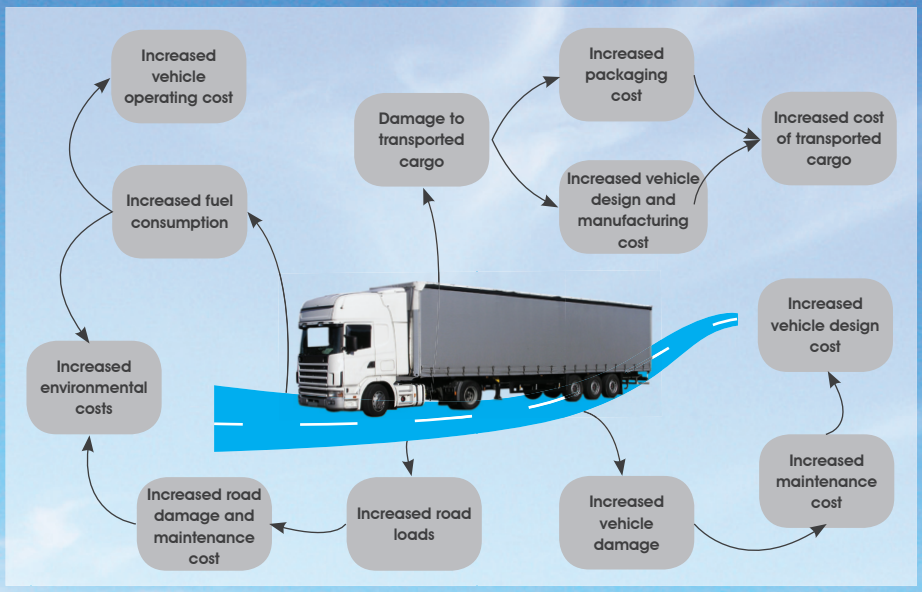
Research into this specific phenomenon is being conducted in a joint project between the University of Pretoria, the Council for Scientific and Industrial Research (CSIR) Built Environment and the University of California at Berkeley and Davis. CSIR Built Environment has, over the past six years, been involved in a state of logistics survey that was conducted to analyse quantitative logistics trends in South Africa and was aimed at informing and assisting public and private sector role-players and decision-makers who operate in the logistics and supply chain management environment. This was done with the support of Imperial Logistics and the University of Stellenbosch. Since 2008, the effects of the worsening riding quality of roads have been included in the survey, with a view to evaluating the ultimate effects of such riding quality on the broader economy.

The specific focus from the road engineering side was to evaluate how the riding quality of specific roads deteriorate over time (with usage by vehicles) and how this deterioration contributes to the damage experienced by the vehicles. The concept and potential effects are illustrated in Figure 1. Changes in the riding quality have a direct influence on a number of non-road-related engineering issues, such as damage to vehicles, damage to cargo, and, ultimately, issues such as the cost of packaging transported cargo. An evaluation of the vibrations caused by vehicles transporting perishable goods on roads has shown that specific locations on the vehicle are specifically prone to larger vibrations. If the riding quality of the road decreases below a certain threshold, improved packaging of perishable goods or improved vehicle components become essential. This adds to the cost of the ultimate product. Current calculations indicate average percentage increases of between 2.5% and 10% as the condition of roads deteriorates from a good to fair and good to bad riding quality.

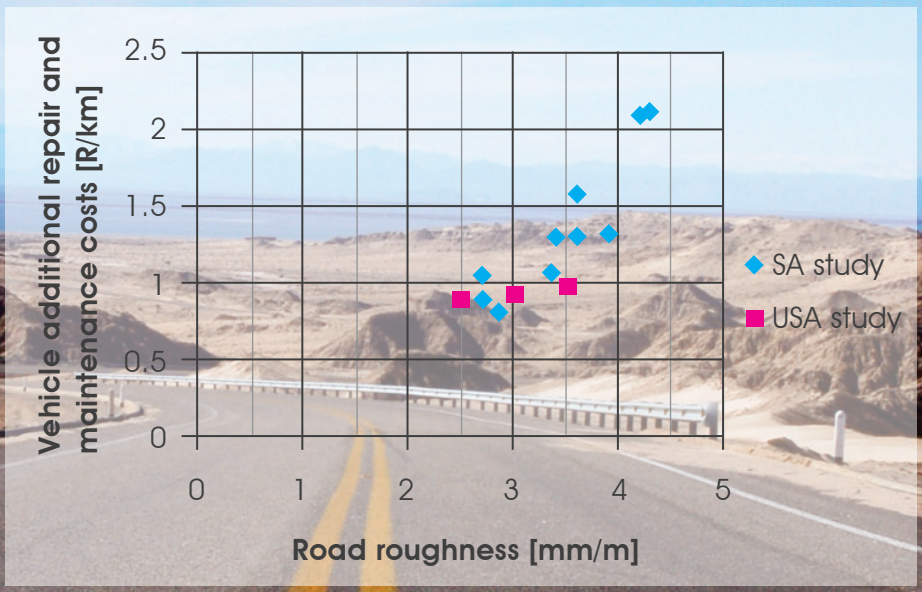
Current research focuses on the comparison between these increased costs and the required cost to perform adequate maintenance on the roads to ensure that they remain in a good ridable condition.

Figure 2 indicates data from a population of real vehicles collected while travelling over a number of roads over a period of six months. It shows the increase in vehicle damage costs due to decreases in riding quality. It also shows data obtained through a study conducted in the USA that compares the conditions in South Africa and the USA. The comparison indicates that similar damage rates are experienced in the two environments.

The information that was collected in these studies is now finding its way into the curriculum of the road engineers at both undergraduate and postgraduate level at the University of Pretoria. The focus of this is to illustrate the broad effect that decisions regarding road maintenance – and specifically, the lack of adequate maintenance – potentially have on the national economy.



→ *1. Conceptual effects of inadequate riding quality on the economy.*



→ *2. Measured vehicle maintenance and repair cost indicating an increase due to deteriorating riding quality.*

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Incorporating international exposure into road engineers' training

by Prof Wynand J van der Merwe Steyn

It is vital to expose students, specifically at postgraduate level, to international viewpoints and opinions about their subject. This is typically done by incorporating international literature into the curriculum, as well as through case studies comparing local and international practice.

The presence of an international specialist on a subject is probably the first prize in this teaching environment, as students then not only obtain their own lecturer's interpretation of international practice, but also get the opportunity to ask specific questions that may not form a part of the existing curriculum. However, the cost and logistics of incorporating a visiting international lecturer into a postgraduate course are quite high, and include travel, accommodation and time costs (current estimates start at R25 000 per week). The dates for the course also need to coincide with the dates when the lecturer can be away from his or her own office for at least a week, and often such dates are not convenient to students who, for instance, attend block weeks.

One way of circumventing this problem is to make use of Internet-based technology. The University of Pretoria has access to the Elluminate system, which enables interactive presentations to be made via the Internet. This includes the simultaneous presentation of a lecture through slides or whiteboards, video and sound while being recorded. The only requirement is an Internet location and a suitable computer. Early in 2010, this system was used to present an international lecture from Seattle, Washington, USA to the Pavement Design postgraduate class. In the process, Prof Joe Mahoney of the University of Washington lectured from his office in Seattle to students at the University of Pretoria on the American Association of State Highway Transportation Officials (AASHTO) Pavement Design method. Prof Mahoney has often visited South Africa and knows the local environment well. However, his visits seldom coincided with postgraduate block weeks, so his input in international lectures could not be used.

The bottom-line benefit of the Elluminate system is financial. Everything that is done with Elluminate can be done with students and a lecturer physically in class. However, Elluminate offers the opportunity to save travel and accommodation costs in the process. There is also a major convenience benefit. With Elluminate, Prof Mahoney could conduct his lecture to students in Pretoria without leaving his office in Seattle. The ten-hour time difference meant that he could start his 90-minute lecture at 05:00 on a Monday morning and finish at 06:30 USA time, and then continue with his normal day of lectures and meetings, with almost no inconvenience.

The system makes provision for four important factors: the presentation itself (by means of PowerPoint), audio feed from the lecturer, video feed between the two locations and discussion by the students, without the lecturer actually being physically present. This makes for a very real experience. The benefit of recording the lecture for later use also gives students the option to replay the whole lecture or even parts of the lecture in their own time to ensure that key concepts are reinforced. This can obviously include discussions and additional examples provided in class, which is not possible if the lecture is not recorded.

The main limitations of the system are Internet access in the venue used for the lecture, the possible time difference and possible technical problems. A moderator is required in the classroom where the students attend the lecture if it takes place in a group environment. As personal contact is important, it should not be used to replace a physical lecturer for a full block week.

Feedback from the group of students through a questionnaire that was distributed to them after the lecture is summarised in Table 1. The feedback

from Prof Mahoney after the lecture was positive, especially regarding the interaction that had taken place. Three professionals linked into the lecture from their home or office computers and provided positive feedback.

Figure 1 shows a potential model for using the technology in short courses, where national and international lecturers can be incorporated into the University of Pretoria's offering. It illustrates how lecturers in different time zones may be incorporated into a teaching programme to ensure that students are exposed to international viewpoints.

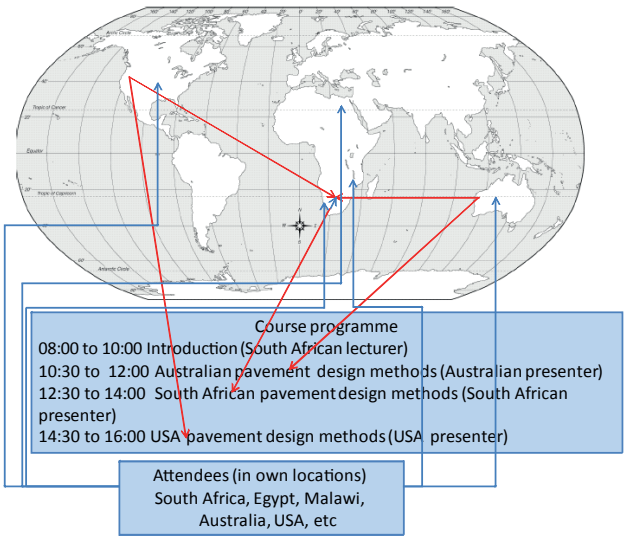
The exercise proved worthwhile in incorporating international viewpoints into a postgraduate lecture, and exposed students to a wider viewpoint and more lecturers during their course. Further engagements are currently being planned for other subjects in the postgraduate programme.

Acknowledgements

The support and encouragement of Dolf Jordaan of the Department of Education Innovation at the University of Pretoria are greatly appreciated.

Table 1: Typical student feedback after an Elluminate lecture (12 out of 24 responses received)

Question	Response count
Do you think that the use of international lecturers in postgraduate courses is important?	Yes: 100%
Did you enjoy the international lecture?	Yes: 90%; Possibly: 10%
Did the international lecture benefit you on a technical or academic level?	Yes: 83%; Possibly: 17%
Would you like more of these lectures in the remainder of the postgraduate lectures?	Yes: 83%; Possibly: 17%
Did the Elluminate system that was used to transmit the international lecture work well, in your opinion?	Yes: 90%; Possibly: 10%
Was the choice of lecturer for the lecture appropriate for the course?	Yes: 100%
Any other comments on the international lecture?	• It was related to required knowledge • The international lecture definitely gives one more confidence in dealings and communication with international counterparts • The lecture was very informative and interesting, especially the comments delivered about advancements in pavement design in South Africa • It was a good experience to hear from international experts as part of the classes



→ *1. Model for the incorporation of international lecturers (and attendees) through courses offered using Elluminate*

Sustainable process systems engineering develops advanced techniques for energy and water optimisation

by Prof Thokozani Majozi

Sustainable process systems engineering (SUSPSE) is one of the research focus areas in the University's Department of Chemical Engineering. This research group focuses on the development of advanced techniques for energy and water optimisation in complex chemical facilities using sustainable process systems engineering. The key dimension of SUSPSE that is embraced in the endeavours of this research group pertains to process integration.

Process integration was established in the late 1970s in response to the energy crisis. At that time, the sole focus was on minimising energy by maximising the process of heat transfer, thereby minimising external utility requirements. By drawing analogies between mass and heat transfer, this concept was expanded in the late 1980s to embed issues of waste management and the reduction of emissions. Recent advances in this field, which evolved as an independent discipline in the early 1990s, involve systems characterised by simultaneous heat and mass transfer, as are commonly encountered in clean coal technologies, such as the integrated gasification combined cycle.

The unique strength of process integration lies in its ability to recognise the unity of the overall process. In practice, unit operations function in unison and not as stand-alone entities. However, most of the developments in published literature tend to address continuous processes at a steady state. The research that is currently underway in the SUSPSE group entails multipurpose batch chemical processes, which are characterised by inherent time-dependent behaviour.

The research group is already conducting advanced research in these areas and has completed a number of projects.

A graphic target and design technique for complex cooling water systems

South Africa is one of the driest countries in the world. Rivers and dams are the main sources of water. The continuous pollution of the country's natural sources, as well as the growing demand for water, has led to stringent environmental regulations to limit consumption and set the acceptable contamination levels before water is discharged into the main water cycle.

Various techniques have been used to address the use and contamination of water in industry. In recent years, pinch analysis has been extended to the design of cooling water systems following its success in heat exchanger networks (HENs) and mass exchanger networks (MENs). One study investigated the consumption of water and effluent reduction opportunities in a nitric acid production plant. This led to the development of a cooling water network design technique for systems with multiple cooling water sources. A cooling tower model was also used to investigate the impact of the new cooling tower design on its performance. The results of this analysis show that the blowdown rate can potentially be reduced by 47%. The cooling water used in the cooling water network could also be reduced by 23% and freshwater makeup by 10%. Moreover, the cooling tower performance was increased.

An automated approach to the development of a unified mass and heat integration framework for sustainable design

The successful industrial applications of pinch analysis techniques in energy optimisation and waste-water minimisation have resulted in recent studies on combined heat and mass integration. Researchers have demonstrated that the operation of cooling water networks in series, rather than the conventional parallel operation of these networks, improves the performance of the cooling tower and the cooling water network in new and retrofit designs. This methodology is extended by utilising a mathematical method to determine the superstructure of the cooling water network supplied by multiple cooling towers, which often occurs in practice. It was further demonstrated that the optimum cooling water supply to a network of heat exchangers supplied by multiple sources is determined by considering the entire system of

→ *The sustainable process systems engineering (SUSPSE) research group (standing from left): Esmael Reshid, Jane Stamp, Knowledge Molokoane, Donald Nonyane and Prof Thokozani Majozi, and (seated from left): Vhutshilo Madzivhandila, Vincent Gololo and Bola Adekola.*

sources (cooling towers) and coolers (heat exchangers). This optimum is less than the sum of the individual minimum cooling water supplies for each subset of coolers and their respective sources. The structure of the model allows the formulation to be cast as a mixed integer linear programming (MILP) problem, for which global optimality is guaranteed.

Developing a new class of batch plants via the exploitation of latent storage capacity

Batch chemical processes are commonly encountered in the production of fine chemicals of a high commercial value, for example, pharmaceuticals and agrochemicals. As with most production facilities, the capital cost of any chemical plant is directly related to its size. Following this argument, it is clearly advantageous to reduce the plant size. In order to reduce the plant size, the intermediate storage is reduced. In most instances, the capacity of intermediate storage is determined heuristically by or using proven rules of thumb. During the operation of batch chemical plants, there is an inherent idleness in the way units are used (they are not used continuously). This idleness can be exploited to reduce the plant size and increase the capital utilisation of process units. A mathematical model was derived and tested in order to take this storage into account using the state sequence network (SSN) process representation in a continuous time framework.

Developing a complete process integration framework for wastewater minimisation in batch processes

The need for industry to produce the smallest possible amount of effluent is greater than ever. This is due to the fact that environmental legislation is becoming even more stringent and freshwater sources are becoming scarcer. This has prompted research into economic means of reducing the amount of wastewater, while still producing the right quality and quantity of the required product. Wastewater minimisation techniques have, in the past, been mainly focused on continuous types of operations. However, due to the nature of the wastewater produced from batch processes, wastewater minimisation cannot be ignored. Relatively few methodologies for wastewater minimisation in batch processes have been presented in the past. Those that have been developed are mainly focused on wastewater characterised by single contaminants and situations where the optimal production schedule is known beforehand. Four novel methodologies have been developed that deal with four different aspects

of wastewater minimisation in batch plants. These are multiple-contaminant wastewater, multiple storage opportunities, zero-effluent operation and inherent storage in a batch plant. These methodologies combine to form a complete framework for wastewater minimisation in batch processes. The effectiveness of the methodologies has been demonstrated through a number of illustrative and practical applications.

Energy optimisation in multipurpose batch plants using heat storage

The concept of heat integration in batch chemical plants has been reported in literature for more than a decade. However, most publications tend to advocate direct rather than indirect heat integration in batch chemical processes. Direct heat integration is encountered when both the source and the sink processes have to be active over a common time interval, assuming that the thermal driving forces allow it. On the other hand, indirect heat integration allows the heat integration of processes regardless of the time interval, as long as the source process takes place before the sink process so as to store energy or heat for later use. Nonetheless, the thermal driving forces must still be obeyed. It is, therefore, evident that direct heat integration is more constrained than indirect heat integration. A research project in this regard entails the development of a mathematically rigorous technique for the optimisation of energy use through the exploitation of heat storage in heat-integrated multipurpose batch plants. The storage of heat is effected through the use of a heat transfer fluid. It is envisioned that the resultant mathematical formulation will exhibit a mixed integer linear programming (MILP) structure, thereby yielding a globally optimal solution for a predefined storage size.

Process integration for efficient utilisation of energy in IGCC plants

Over the years, coal has gained a reputation as an environmentally destructive energy resource, due to the level of CO_2 emissions associated with it. The main sources of these emissions are coal-fired electricity power generation plants. The other significant source is coal-to-liquids technology, which is becoming even more attractive as an alternative source of energy, due to soaring oil prices. Consequently, this form of contribution to CO_2 emissions is likely to be part of humankind for many years to come. However, the abundance of coal in the seams of the planet, combined with its proven fuel capabilities, makes it very difficult (if not impossible) to simply abandon it as a fuel of choice well into the future. It is, therefore, imperative that more environmentally friendly methods of harnessing coal be developed and implemented on a global scale. The integrated gasification combined cycle (IGCC) is a promising technology in this regard. Although not proven in practice, theoretical investigations have shown that it can achieve overall thermal efficiencies in excess of 60% if optimally designed and operated. The main advantage lies in generating electricity from two sources, steam and gas turbines, using the common coal input. Although this framework is inherently integrated, most of the published work tends to analyse it as a combination of discrete unit operations, thereby resulting in sub-optimality. True optimality of this system can be achieved by analysing it as the comprehensive framework that it truly is, hence the choice of process integration as an optimisation tool.

Recently completed work on the steam side has demonstrated that a process integration-based design is capable of increasing the overall thermal efficiency by almost 4%, based on a coal high-heating value (HHV) of 678.5 MW. This improvement is mainly due to the increase in steam flow rate, which consequently improves the steam turbine electric power output by almost 20% from 121 MWe to slightly more than 144 MWe. In the current investigation, the sufficiently detailed performance models for the gasifier and the gas turbine are integrated in an elaborate mathematical structure that describes the gas side performance of the IGCC. The aim of the mathematical model is to determine the operating conditions in both the gasifier and the combustion chamber of the gas turbine to yield optimum thermal efficiency. The analysis is based on the fixed thermodynamic properties of the exhaust gas from the gas turbine so as not to disturb the performance of the heat recovery steam generator (HRSG), which is a crucial component of the IGCC.

A process integration method for the optimisation of steam system networks

The use of steam in heat exchanger networks (HENs) can be considerably reduced by the application of heat integration and optimisation with the intention of debottlenecking the steam boiler and indirectly reducing the water requirement. The reduction of steam flow rate in an HEN affects the operation of the steam boiler. By reducing the steam flow rate, the return condensate temperature to the boiler is compromised, which adversely affects the operation of the boiler. A means of maintaining the efficient operation of the boiler, while still reducing the overall steam flow rate to the heat exchanger network, is to reheat the return flow to the boiler to a sufficiently high temperature. One means of achieving this is by utilising the sensible heat from the superheated steam, leaving the boiler to preheat the boiler feed.

This investigation concerns the optimisation and restructuring of all

Research is conducted in the Reactor Engineering Laboratory in the Department of Chemical Engineering.

steam system heat exchangers using conceptual and mathematical analysis to create a series HEN with the aim of reducing the overall steam flow rate, while maintaining boiler efficiency. Application of this method to a case study involving seven heat exchangers resulted in a 26.3% reduction in steam system flow rate, which renders this a promising concept.

Research collaborations

A number of academic research collaborations are involved in these sustainable process systems engineering projects, including ones with the University of Pannonia, Hungary, the University of Nottingham, Malaysia, the University of Limerick, Ireland, the Universitat Rovira i Virgili, Spain, the De La Salle University, Manilla, Phillipines, the National University of Taiwan, the Indian Institute of Technology, Bombay, India, and the India Institute of Technology, Bombay. Industry partners include African Explosives Limited, Johnson & Johnson (Pty) Ltd, the Council for Scientific and Industrial Research (CSIR), Unilever South Africa and Amalgamated Beverage Industries (ABI).

Research funding has been received from the National Research Foundation (NRF), the Water Research Commission, the CSIR, SANERI: Energy Hub (EEDSM), Johnson & Johnson (Pty) Ltd, SERA, Eskom and the Technology and Human Resources for Industry Programme (THRIP).

Prof Thokozani Majozi *is a full professor in the Department of Chemical Engineering at the University of Pretoria. His main research interest is batch process integration. He also holds an associate professorship at the University of Pannonia in Hungary and was elected Vice-President of the Engineering Council of South Africa (ECSA) in 2009.*

Polypropylene-based long-life insecticide-treated mosquito netting

by Prof Walter Focke and Dr Walter van Pareen

Malaria causes approximately one million deaths a year and more than 300 million cases of severe illness. The World Health Organization (WHO) regards insecticide-treated nets (ITNs) as an important component in its efforts to roll back malaria.

Extensive trials using insecticide-treated nets have established their efficacy to protect against a range of vector-borne diseases. Current efforts focus on making such nets widely available and to popularise their use.

The first mosquito nets were treated with insecticidal formulations by a dipping process. However, long-life nets, treated at factory level, are preferred. ITN programmes in Africa revealed low net retreatment rates because users do not perceive the need for it. The dipping procedure is not simple and the insecticides are either too expensive or not widely available. Treatment centres are not operational or are unsustainable. The treatment of nets at factory level would be restricted to professionals who are better able to control the environmental impact of the effluents.

Netting materials used so far include cotton, nylon, polyester, polyethylene and polypropylene. Multifilament netting has apparently performed better in ITN trials and is also more comfortable. In Africa, where transmission is intense, it has been shown that it is not so much the net, but rather the insecticide in the net that provides protection against malaria vectors. Thus, it is vital to make sure that the net is treated with an effective insecticide. Therefore, this study focused on nets with the insecticide incorporated into the fibre polymer. A key target for the WHO is a product that can resist more than 50 ISO normalised washes at 60°C.

Complex issues, such as safety, efficacy, life span and cost, affect insecticide selection, formulation design and dosage level determination. Synthetic pyrethroids are the only insecticides currently used for treated nets. The WHO sanctions the use of a selected set of insecticides. The pyrethroids are lipophilic compounds that easily pass through cell membranes. They are absorbed through the skin by inhalation or ingestion. Their toxicity is related to their affinity for receptors or targets in the sodium channels essential for nerve conduction. Fortunately, their rapid metabolism greatly lowers the magnitude of the resultant toxicity.

Pyrethroid pesticides combine broad-spectrum insecticidal activity with low mammalian toxicity. Their short persistence in the environmental is a desirable property. The pyrethroids were declared acceptable by the WHO, as the ITNs showed no teratogenic, carcinogenic or mutagenic effects in experimental toxicity studies. Low dosages are used for treatment. They bind strongly to fabrics and have a low volatility. The risk of oral and inhalation toxicity by the users of treated nets is therefore remote.

Developing polypropylene-based nets

Sasol and the University of Pretoria investigated the possibility of making a polypropylene-based net. The ultimate purpose of this project is the development of long-lasting, polypropylene-based mosquito netting, which conforms to WHO specifications.

Initial effectiveness against mosquitoes

Table 1 provides an overview of the efficacy testing results for unwashed insecticide-containing socks and nets. The WHO standards specify >95% knockdown after one hour and >80% mortality after 24 hours. Socks containing any of the six insecticides tested conformed to this requirement at ca. 0.2–0.4% loading.

Effect of washing on net performance

Additives are lost from the surface via sublimation/evaporation or

Table 1: Initial effectiveness against mosquitoes in WHO cone and cylinder tests

Active	Percentage	Knockdown 1 hour	Mortality 24 hours	Method	Format
Alphacypermethrin	0.29	100	100	Cone	Net
Alphacypermethrin	0.38	100	100	Both	Net
Bifenthrin	0.38	100	100	Cone	Net
Cyfluthrin	0.38	100	100	Cone	Net
Betacyfluthrin	0.20	100	100	Cone	Sock
Betacyfluthrin	0.38	100	100	Cone	Sock and net
Deltamethrin	0.19	100	100	Cone	Sock
Deltamethrin	0.46	100	100	Cone	Sock
Deltamethrin	0.72	100	100	Cone	Sock
Lamdacyhalothrin	0.20	98	100	Cone	Sock
Negative	-	0	3	Cone	Sock

Notes: All concentrations are given on a mass basis. All yarn samples were prepared using a draw ratio of 2.37.

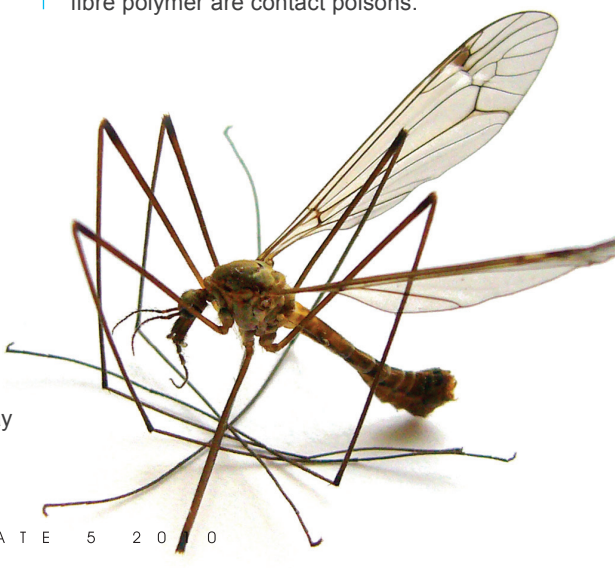
mechanical scuffing. The former rates are very slow for the current set of pyrethroids. They can probably be neglected for net lifetimes of less than five years. However, the latter mechanism also operates when the net is washed. Current WHO standards for long-lasting insecticide-treated nets require that long-lasting nets should retain their efficacy even after 20 ISO standardised washes. According to some sources, every wash removes about 30–50% of deltamethrin deposited on the surface. Other sources suggest that the figure may be as high as 95%. It is clear that the ability of multifilament yarn to retain efficacy beyond a few washes is of paramount importance. Following five washes, nets containing 0.38% betacyfluthrin or 0.29% alphacypermethrin have very high bioactivity when tested six weeks later, but the net containing only 0.19% bifenthrin does not meet the WHO criteria.

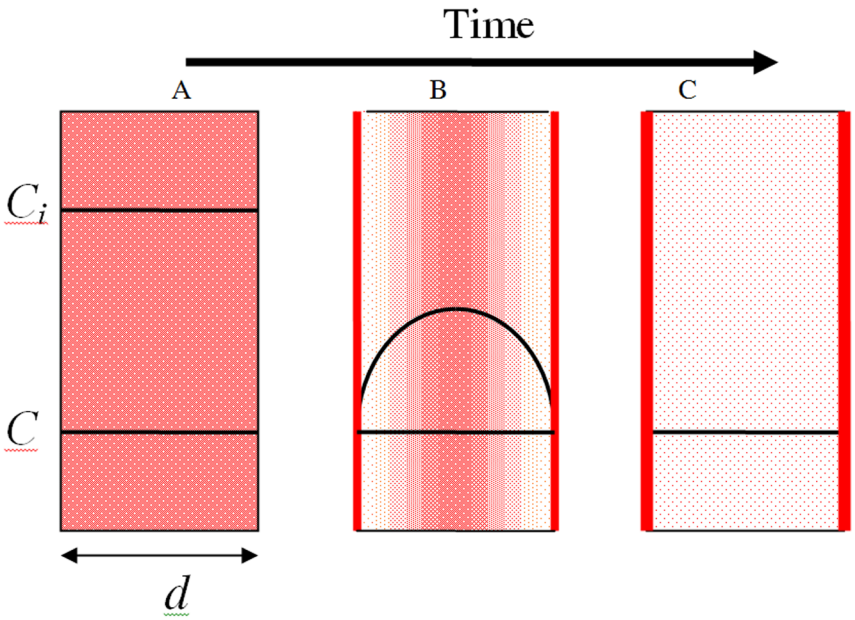
Insecticide solubility in polymers is determined by the temperature and the amount of amorphous phase available. Solubility generally increases with temperature. Polymer additives may dissolve in the amorphous parts of polymer matrices, but are insoluble in crystalline regions. This implies that the insecticide will have a higher solubility in the fully molten polymer than in the drawn fibre at ambient temperature. Full dissolution in the melt is advantageous, as it aids homogeneous dispersion of the solute in the matrix.

During fibre spinning, the melt is cooled, stretched and drawn. The process involves controlled polymer crystallisation. Concomitantly, the fraction amorphous phase available to dissolve the additive is diminished. In practice, the insecticide dosage level exceeds its solubility limit at ambient conditions and it therefore becomes trapped in a supersaturated state inside the polymer. In an effort to return to an equilibrium state, the additive may diffuse to the surface of the fibre. Here it accumulates and may eventually form crystalline deposits.

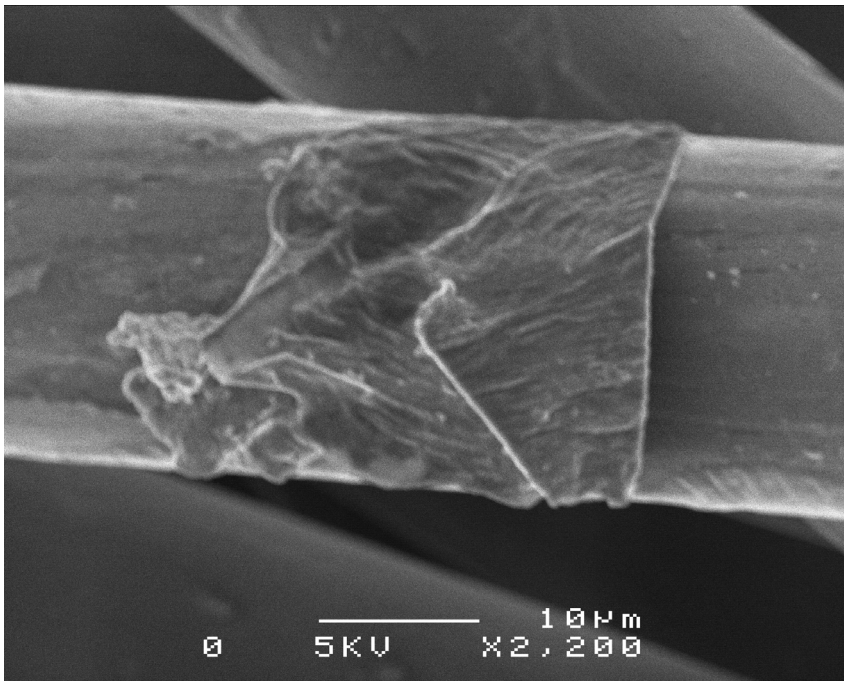
Data obtained during this investigation indicated that the pyrethroid additives stay amorphous when cooled rapidly from their melt. The idealised additive blooming process for an amorphous additive present above its glass transition temperature is illustrated schematically in Figure 1.

Blooming is an undesirable phenomenon when the additive is a stabiliser or colourant. It leads to the effective loss of active from the system and causes surface blights. The insecticides incorporated into the fibre polymer are contact poisons.





→ *1. Schematic representation of the surface blooming mechanism in a fibre with diameter d. The intensity of the red colour scales with the insecticide concentration.*

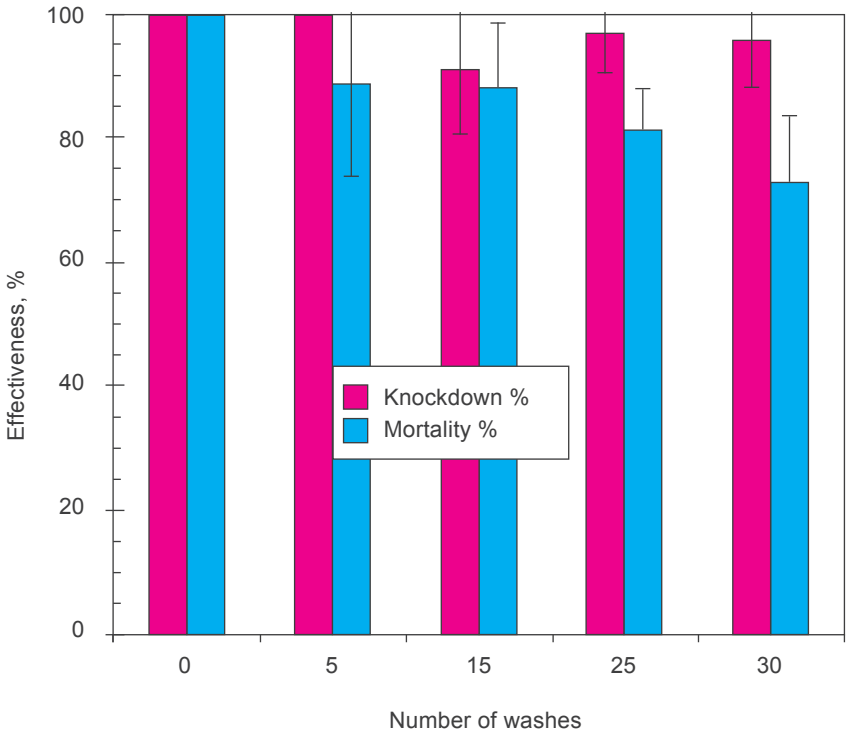


→ *2. SEM picture of a damaged part of a fibre containing 0.57 cyfluthrin that shows the covering "skin".*

To be effective, they have to be available above the minimum effective surface concentration on the outside of the fibre. Thus, in this application, blooming is a desirable process that facilitates additive transport to and accumulation at the fibre surface. The data presented in this research provides evidence that some nets at least retain their bioactivity for several wash cycles. It is, therefore, of interest to determine the actual distribution of the actives in the polymer fibre. Fortunately, some of the actives are fluorescent and this property was exploited through confocal microscopy. This technique facilitates three-dimensional (3-D) visualisation of the additive distribution in the fibre. Visual inspection of the 3-D image revealed the presence of small fluorescent spots throughout the fibre with areas of higher intensity fluorescence near or at the surface of the fibres. The image obtained for the net containing cyfluthrin showed very weak fluorescence, suggesting that virtually all the active was lost after even five washes. In contrast, a net made from deltamethrin still showed comparable fluorescence even after ten washes. This difference may be attributable to the difference in the physical nature of the two additives. Deltamethrin is highly crystalline with a high melting point (>100°C), while cyfluthrin is a viscous liquid at room temperature (it is amorphous and above its glass transition temperature). It is, therefore, easier to remove the cyfluthrin from the fibre through a washing process.

The second assumption made concerning the isotropic nature of the idealised fibre was found to be invalid. Scanning electron microscope (SEM) pictures of the fibres showed the clear presence of a thin skin-like structure that covers the outside of the fibres. It appears that this skin is not strongly bonded to the fibre core. It easily detaches to form blisters when the fibre is severely mechanically stressed.

Figure 2 shows a particularly striking picture of such a piece of skin folded back over the fibre shaft, revealing the structure underneath. Confocal microscopy revealed an intense fluorescence from the underside of this skin. This suggests that the skin may represent a membrane-like barrier to



→ *3. Efficacy testing results for nets containing 0.38% betacyfluthrin.*

outward migration of the actives. Thus, active may be accumulating just below this skin rather than on the outside of the fibre. Clearly, if this were the case, better wash resistance would be the result. The skin morphology was also observed in neat polypropylene fibres. However, SEM pictures suggest that it is more pronounced in fibres containing low-density polyethylene.

Conclusions

Efficacy testing results for unwashed socks showed encouraging results. Most samples containing 0.19% active complied with the WHO requirements (>95% knockdown after 60 minutes and >80% mortality after 24 hours). Analysis reveals that blooming from the thin fibres in the multifilament yarn will be rapid with a time constant of less than one day. Washing is known to remove in excess of 30% active on the fibre surface per wash. This implies that it is unlikely that fibres containing amorphous additives such as cyfluthrin will achieve the minimum of 20 washes stipulated by the WHO. Better results were obtained with the crystalline betacyfluthrin form, as shown in Figure 3.

Multifilament polypropylene yarns that contain WHO-approved insecticides were successfully produced on a production spinning line. The fume generation during extrusion with pyrethroids necessitates superior ventilation, extraction and scrubbing systems.

Prof Walter Focke *is a professor in the University of Pretoria's Department of Chemical Engineering, Director of the Institute of Applied Materials and incumbent of the Chair in Carbon Technology and Materials. He received a grant from the Bill and Melinda Gates Foundation for the development of an indoor spray to control malaria transmission.*

Dr Walter van Pareen *is Business Support Team Manager at Sasol ChemCity. He completed his master's degree in Chemistry in 1991 and joined Sasol, where he gained valuable experience in entrepreneurship, including research and development, international marketing, business management, production management and financial management. He joined Sasol ChemCity in 2005, a Sasol subsidiary with the main focus of SMME development and job creation in the chemical and related industries.*

Acknowledgement

The authors express their gratitude to Sasol ChemCity for its financial support of this project, and to Alan Hall of the Centre for Microscopy for performing the SEM and confocal microscopy work.

Finding patterns in process signals

by Carl Sandrock

Anyone who has tried to understand events at a chemical plant will have spent some time looking at a multitude of process trend graphs. The reason for doing so is often related to process failure. When one is trying to determine why something went wrong, or to establish whether things are likely to go wrong in the near future, it is helpful to build maps of the situations that are related to failures.

Process trends represent the values of measurements taken all over the plant as they change over time. Figure 1 provides an example of a graph to illustrate chemical process data trendlines. There are a couple of ways in which such a graph may be interpreted to understand what the curves on the graph reveal. For example, one may look at the position of all the measurements at a particular time, at how signals are correlated, given some shift in time, and at the patterns that seem to be related, even though they occur at different times.

Classification and clustering

A first approach would be to see the data as clouds of points in a multidimensional space, defined by the different process variables. These points are connected because they take place at the same time. However, time is not taken into account in any other way. Figure 2 shows how one might attempt to classify points using this approach.

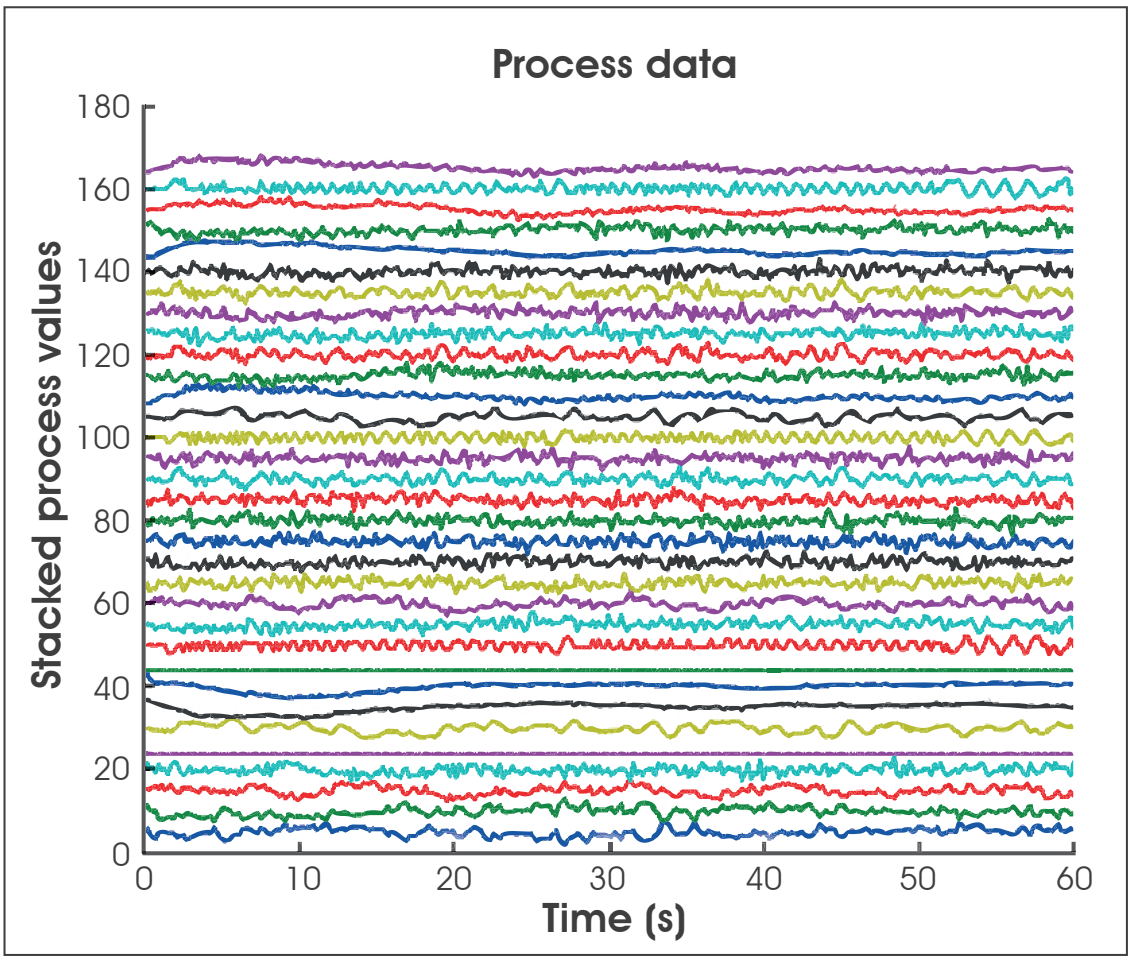
If it were known that the black points were failure points, it would be useful to see the picture in Figure 2, showing how the values of the different variables are related to their status. This problem is known as the classification problem and there are many methods that can be used to build “classifiers” or algorithms for placing a new point in the correct class, based on some known points. But what if the points shown in Figure 2 were all black? Would one be able to figure out that there were two discrete groups? This is the clustering problem: trying to find different clusters of points in this space. There are a similarly large number of clustering algorithms to address this type of problem. Typically, clustering is followed by classification.

The relevance of time

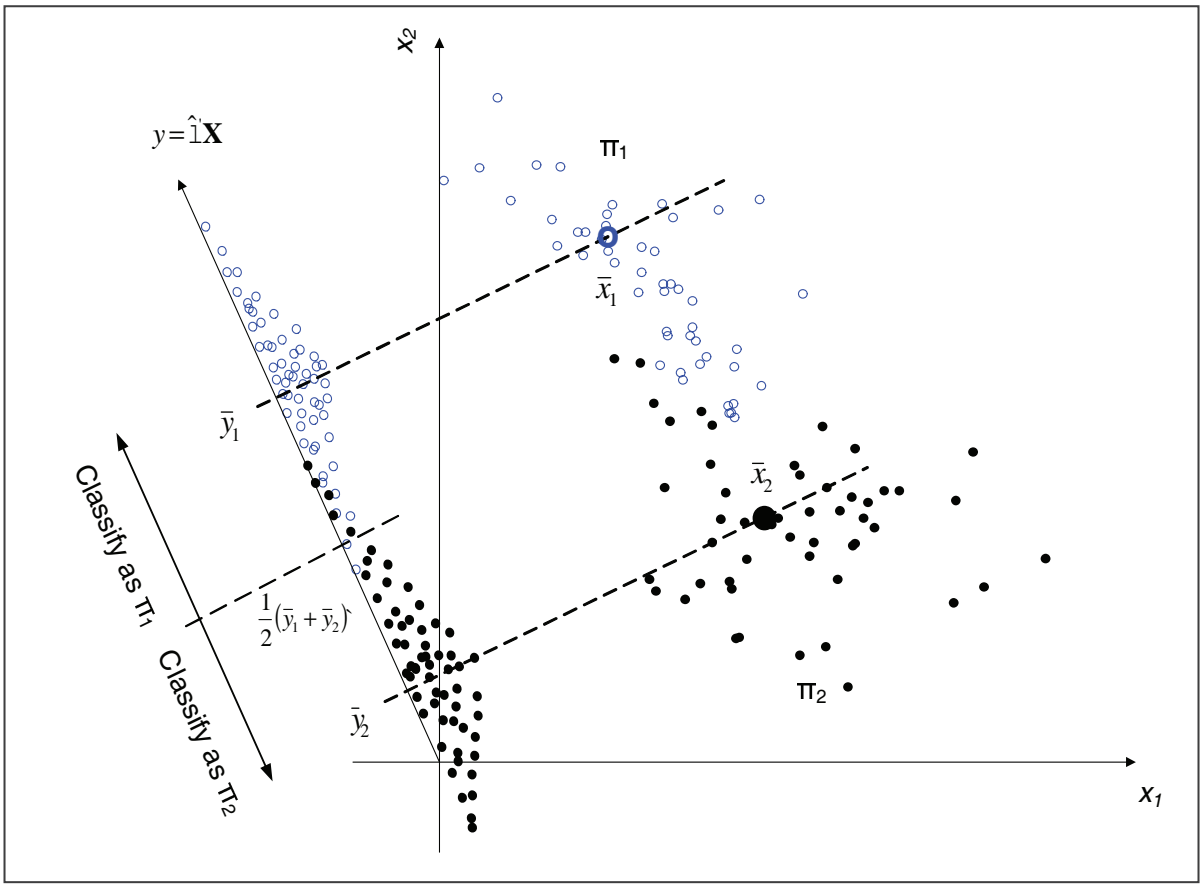
So far, the effect of time has been ignored, except as an index to see which measurements are related to one another. Unfortunately, it may not be the best idea to group the points in this way, as the same event may cause changes at different points in time. The Process Modelling and Control Group in the Department of Chemical Engineering at the University of Pretoria has developed a method of using the correlation between different signals to shift the signals in such a way that the effects all line up, as indicated in Figure 3. Shifting the times in this way allows both clustering and classification to identify single-event causes of failure propagating through the system, rather than just finding out which states are good or bad.

Patterns in time

So far, the patterns formed in the state space of the system have been discussed without looking at the patterns that appear in the signals as they are plotted in Figure 1. The combination of peaks and troughs that is visible on those trends should also be informative. In order to find patterns in this way, it is possible to look at signal processing techniques like spectral or wavelet analysis, but this frequency information is often difficult for plant personnel to interpret. It is also possible to fit simpler patterns to a time series using segmentation algorithms. The result of this is a sequence of particular patterns, like “rising”, “falling” or “steady”. If these are converted to letters in an alphabet (A=rising, B=falling and C=steady), one could search for repeating patterns in sequences like AB**ABC**ABAAA**ABC**. Figure 4 shows another way of assigning letters based on the values of the variable (low, medium or high).



1. Chemical process data trendlines.



2. Classifying data based on their positions in space.

What is the relevance of finding patterns in process signals?

The Process Modelling and Control Group has been finding patterns in process data since 2000. This has yielded several master's dissertations and articles on the subject, working closely with industry to provide methods to learn about the failure modes of processes. By automating the discovery of patterns, the number of variables that can be analysed and the likelihood that patterns will be discovered have increased. Interest in this research is increasing every year, due to the increased availability of measurements and more stringent safety and energy requirements.

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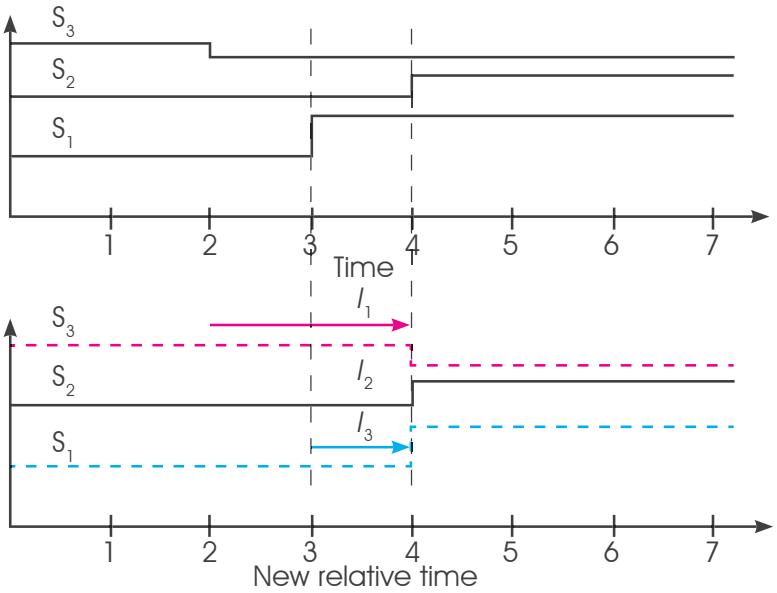
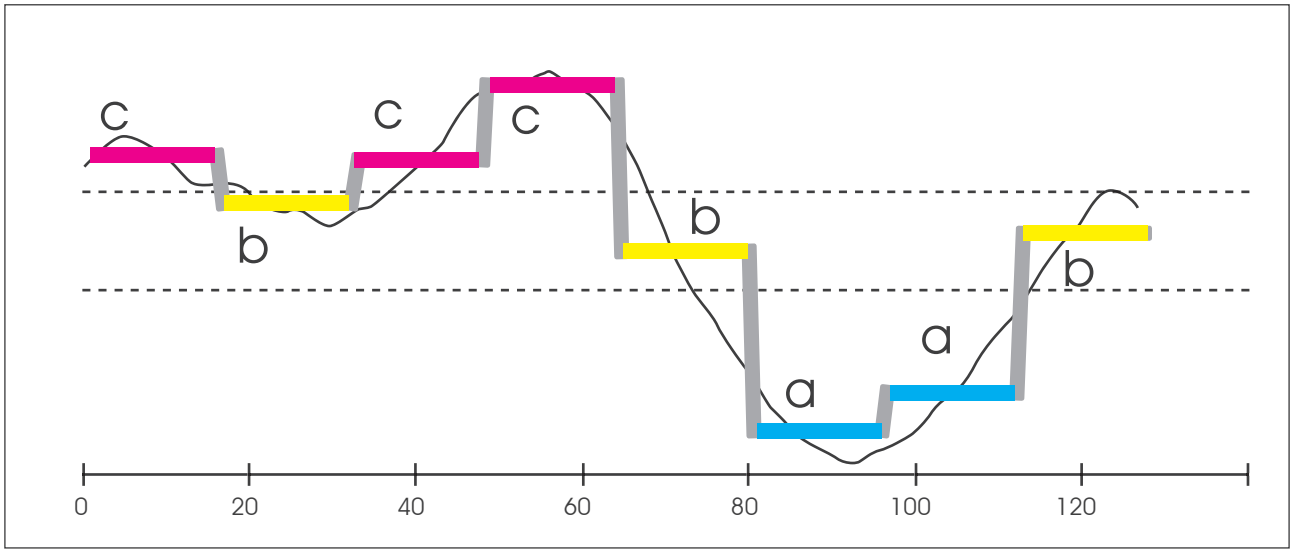


→ *3. Shifting the signals on the original time scale allows the events to line up at the same time on the new time scale.*

***Carl Sandrock** is a full-time lecturer at the University of Pretoria and is currently completing his PhD. His research interests centre around the application of modern computational technology to the modelling and control of chemical engineering processes.*



→ *4. Assigning letters to different values in a time signal for pattern search.*

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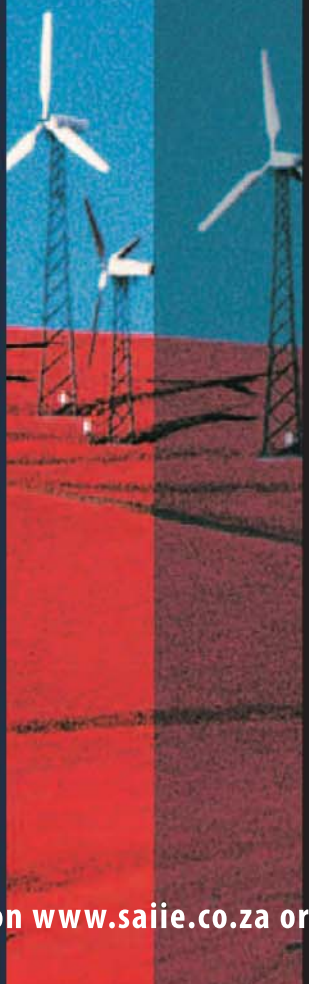

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Reaction Engineering Group constructs a 180" flat screen

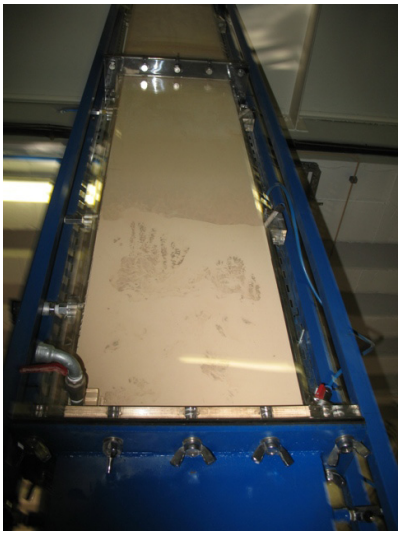
by Prof Willie Nicol, Elizbé du Toit and Jean Saayman

Many people think that large flatscreens are meant for World Cup soccer matches, but the 180" flat screen in the Department of Chemical Engineering delivers even more action than the most exciting football match. Students can now view a chemical reaction in a fluidised bed reactor using a flat screen reactor that is taller than the world's largest flatscreen television.

The complexity of the interaction between fast-flowing gas over a bed of fine particles is hard to capture in a textbook, but unfortunately most chemical engineering students have nothing more than that to grasp the principles of this type of catalytic reactor. The fluidised bed reactor is extensively used in industry, but, due to the tall steel containers used, the internal happenings (where gas and solid meet in intricate contacting patterns) occur in darkness and the engineers can only work with the difference between the gas inlet and the outlet.

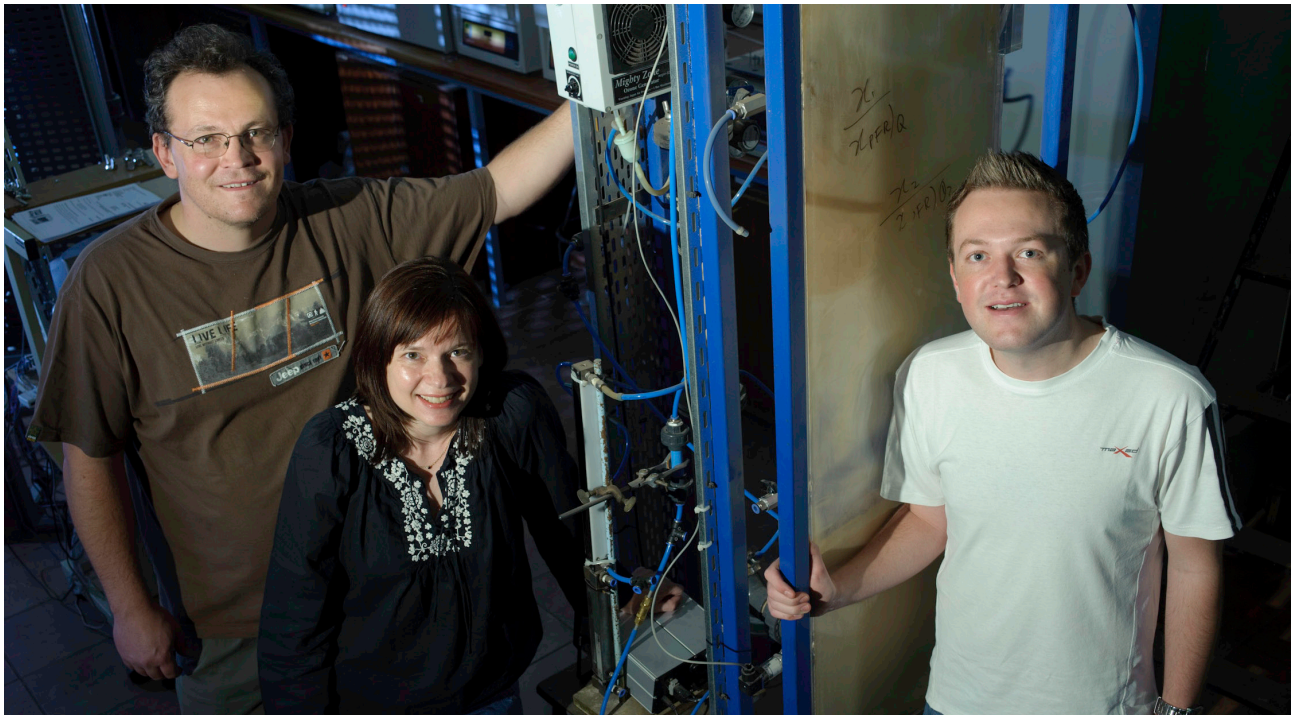
To address this shortcoming, a 4.5 m (180") x 0.4 m x 0.025 m transparent perspex column was constructed to host a chemical reaction at ambient conditions where gaseous ozone gets decomposed over a commercial solid catalyst. This not only enables the solid gas interactions (hydrodynamics) to be viewed, but also allows for simultaneous monitoring of the extent of the reaction in the column via an online ozone concentration display. The link between the hydrodynamics and the extent of the reaction (conversion) provides the opportunity for the "a-ha" moment, where all the textbook theory and models suddenly come to life. If a picture is worth more than a thousand words, then a real-life movie is worth more than a thousand words and fifty equations!

Apart from the display for postgraduate and undergraduate students, the column is also used for research. The column is designed to operate at very high gas velocities, where a significant amount of the catalyst becomes entrained (removed from the dense bed at the bottom). In order to keep all the catalyst in the system, two parallel cyclones are used to separate the solids from the outlet steam and to return the catalyst to the bed. The wider range of possible gas flow rates allows the investigation of the effect of catalyst productivity as a function of the superficial velocity. Governing phenomena like interphase mass transfer and axial dispersion can be explored by using the reaction outcome as measurement.



→ *Dense section of the catalyst bed at intermediate gas velocities.*

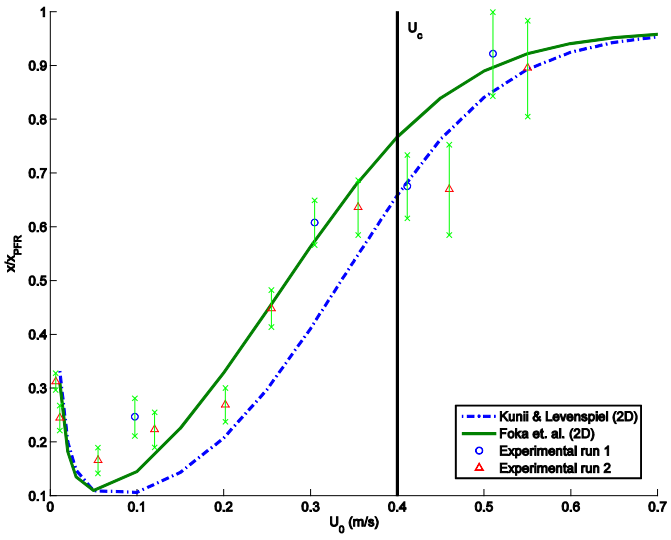
→ *Catalyst circulation above the dense bed section.*



→ *Members of the Reaction Engineering Group in the Department of Chemical Engineering (from left): Prof Willie Nicol, senior lecturer Elizbé du Toit and PhD student Jean Saayman.*

Figure 1 shows the ratio of the measured conversion to the optimum conversion as a function of superficial velocity. From the graph, it is clear that the low-velocity bubble-flow regime exhibits poor productivity characteristics, while the effect diminishes at higher velocities (turbulent regime). This effect can be mimicked by using two-phase models to describe the effect of the hydrodynamics on the reaction.

All in all, the flat sceen reactor is an invaluable tool for chemical reaction engineering, teaching and research.



→ *1. Ozone conversion measurements (as a function of the optimum conversion) with model comparisons.*

Prof Willie Nicol *is a professor in Reaction Engineering in the Department of Chemical Engineering at the University of Pretoria. His research specialisation includes multiphase reactors, with a specific focus on trickle-bed reactors and gas-solid fluidisation.*

Elizbé du Toit *is a senior lecturer in the Department of Chemical Engineering. She is a member of the Reaction Engineering Group where most of the current research focuses on the hydrodynamics and performance of multiphase reactors.*

Jean Saayman *is a PhD student in the Reaction Engineering Group of the Department of Chemical Engineering. His research focuses on mass transfer in a gas-solid fluidised bed reactor in different operating regimes.*

Freedom Park – South Africa's flagship heritage precinct

by Hendrik Prinsloo

In 1999, former President Nelson Mandela said, "the day should not be far off, when we shall have a people's shrine, a Freedom Park, where we shall honour with all the dignity they deserve, those who endured pain so we should experience the joy of freedom."

That day arrived and Freedom Park was born as a national and international icon of humanity and freedom. This memorial site is hailed as the most ambitious heritage project of South Africa's democratic government. It is located on a 52-hectare site on Salvokop in Pretoria, a vantage point that offers visitors a spectacular panorama of the capital city and beyond. The various elements of the park combine to pay tribute to those who have paid the ultimate price for freedom.

The construction process

The site selected for this all-important memorial was a natural hill close to the centre of the capital city. The hill was still in its natural state, which posed major challenges to the design team, who had to put together an urban development framework for the site. Due to the size of the site, it was critical to ensure proper planning from the onset.

The first phase of the project commenced in 2004 to coincide with South Africa's ten-year celebration of democracy. This phase was completed on 8 March 2004 following the appointment of design consultants. In addition to the construction of the infrastructure, the first memorial element, Isivivane, was also completed as part of this phase.

Isivivane is the resting place of the spirits of those who died in the struggle for humanity and freedom. It is situated on the eastern side of the hill. The concept of Isivivane is derived from the word "viva", which means "to come together in a group". It can also be interpreted as "commitment to solidarity" and "unity of purpose". An accumulated heap of stones (beacons), called Isivivane, was believed to bring good fortune to long-distance travellers by paying homage to the landscape and all that it contained.

The idea of an intermediary phase emanated after a visit to Isivivane by former President Thabo Mbeki. He suggested that it was important for the nation to know who the heroes and heroines were who had sacrificed their lives for humanity and freedom. The memorial that commemorates the major conflicts that shaped South Africa's history is known as S'khumbuto and comprises the Wall of Names, the amphitheatre, the sanctuary, the eternal flame and the Gallery of Leaders.

S'khumbuto bears testimony to the various conflicts that have shaped the country and commemorates those who have sacrificed their lives for humanity and freedom. The concept of S'khumbuto is drawn from siSwati nomenclature and signifies a place of remembrance for those who have died and also a place for invoking their assistance in current and future affairs. S'khumbuto is not intended to be a place of grief and mourning, but of celebration. It is a tribute to African and human dignity, and a place for the renewal of the human spirit.

The Wall of Names is an awe-inspiring structure (697 m in length), inscribed with the names of those who died during eight conflicts in South Africa's history: the pre-colonial wars, slavery, genocide, wars of resistance, the South African War, the First World War, the Second World War and the Struggle for Liberation. The physical wall can accommodate 120 000 names. To date, 75 000 names have been verified for inscription. The design allows for future generations to memorialise their heroes and heroines. More names, with additional information, such as biographical data and pictures, will be available on a virtual wall accessible via touch-screen terminals.

The amphitheatre is a terraced space that can seat 2 000 people and serves as a multipurpose venue for

→ *Isivivane, the resting place of the spirits of those who died in the struggle for humanity and freedom.*

major events or celebrations. The sanctuary is a serene environment that is conducive to the outpouring of emotion. Visitors are invited to conduct a ceremony or light a candle in remembrance of the victims in the struggle for freedom, or simply to celebrate the life of a loved one. The eternal flame adjacent to the sanctuary calls on visitors to remember the unknown soldiers – those unsung heroes and heroines who lost their lives without their names being recorded in history. The Gallery of Leaders pays tribute to some of the many people whose leadership qualities and achievements have been pivotal in the struggle for humanity and freedom nationally, continentally and internationally. These leaders have been selected because of the way in which they have brought about change and development and influenced the course of history. They are in the Gallery of Leaders to serve as exemplary role models who are worthy of being emulated.

Significant effort went into the design of the intermediary phase during 2005. Designs were based on historical research. Work on the database for the Wall of Names commenced during this phase. Owing to the sheer scale of the intermediary phase, construction was ongoing for the best part of 2006. On the research side, a vast amount of resources were required to collate and verify the approximately 75 000 names to be inscribed on the wall. Construction was completed in time and S'khumbuto, Moshate and the Wall of Names were introduced to the President and the nation on the Day of Reconciliation, 16 December 2007.

An important element of Phase II was //hapo, the interactive exhibition space where the story of southern Africa will unfold in narrative and visual form. The name //hapo means "dream" and was drawn from a Khoi proverb "//hapo ge //hapo tama /haohasib dis tamas ka i bo", which translates into "A dream is not a dream until it is shared by the entire community." As with the other elements in Freedom Park, //hapo was designed to blend in with the landscape, rather than impose on it. Steel structures, overlaid with copper, were used to sculpt the building frames, and so //hapo was shaped to resemble boulders.

The vision for //hapo was to move away from the historic concept of a museum and to provide an interactive exhibition space that would convey the rich history of southern Africa to visitors. Extensive consultation resulted in detailed guidelines for the design team. It is envisaged that the permanent exhibitions will be structured around social spaces

→ *S'khumbuto bears testimony to the various conflicts that have shaped the country and commemorates those who have sacrificed their lives for humanity and freedom.*

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that allow for live interpretation, performance and storytelling. In future, many of the exhibitions will include a selection of cultural and historical objects that can be handled, discussed or used, transforming the visitor from a spectator to a participant.

The sod-turning ceremony on 23 July 2008 signalled the official launch of Phase IIA. This phase entailed the completion of //hapo, as well as a peaceful garden and walkway that would provide an ideal space for meditation, self-discovery, healing and spiritual contemplation (vhuawelo), additional parking, a restaurant and kiosk, as well as a curio shop.

Phase IIB in the construction process comprises the Pan African Archive, which forms the knowledge base and information storage facility for the park, together with the park's administration building.

The Pan African Archives contain the underlying knowledge base of all the components of Freedom Park. In this space, the park's research data, including printed information and electronic archives of audio, visual and text formats, is stored, conserved and made available to the general public. The archives will be a respected collector of materials on the themes reflected in //hapo, covering the struggles for freedom and humanity. It is envisaged that the archives will play an instrumental role in the development and delivery of national curriculum elements of history: the struggle period, the coming of democracy, the reconciliation process and South Africa's place in serving a global reconciliation agenda.

The final phase of construction (Phase IIC) will comprise Tiva and an access road between the Voortrekker Monument and Freedom Park. Tiva is envisaged to be a large body of water, clearly visible on the slope of the hill, symbolising peace, tranquillity and serenity, as water – the essence of life – features prominently in cleansing and healing rituals. Traditionally, a lake is seen as an area of deep mystery that provides for cleansing and healing, as well as communication with the spiritual world. Visitors to Tiva will be able to relax and enjoy the natural environment, and also find a peaceful place for remembering their ancestors.

The result of this construction process is a unique memorial site that will assist all South Africans in the process of reconciliation and nation-building. It tells the story of our country and its people through the lens of indigenous knowledge systems (IKS), thus showcasing our distinctive history, heritage, spirituality and culture.

→ *Opposite page: The names of those who died during eight conflicts in South Africa's history are inscribed on the Wall of Names.*

Acknowledgements

- Ramzie Abrahams, Departmental Head of Heritage and Knowledge
- Isle Posselt, Public Relations Officer, Freedom Park Trust

***Hendrik Prinsloo** is a registered professional construction project manager who has extensive experience in the construction industry. As project manager, he has been involved in various major fast-track commercial and government projects, including Freedom Park. He is also a senior lecturer in project management in the Graduate School of Technology Management, as well as in the Department of Construction Economics at the University of Pretoria.*

→ *The Pan African Archives contain the underlying knowledge base of all the components of Freedom Park.*

Resort design in Mauritius establishes a benchmark for future development

by Graham A Young and Johan Nel Prinsloo

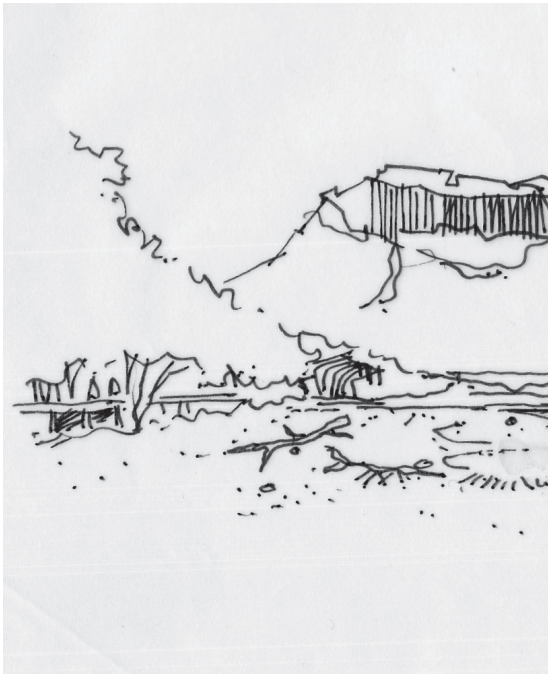
The sustainable approach and contextual sensitivity of the Corniche Bay Integrated Resort Scheme have been cited by the government of Mauritius as a precedent for future hotel developments on the island. The project introduced a botanical paradigm shift with a rigorous zeal towards applying, where possible, an indigenous planting palette. The design also represented a shift from the thematic responses that are most frequently encountered in similar commercial projects and hopes to create a contemporary place rooted in the patterns of the island's ecological, cultural and built environments.

Corniche Bay is situated near the town of La Gaulette on the southwestern coast of Mauritius, bordering the Le Morne World Heritage Site. The scheme comprised 120 hillside villas, a Gary Player signature golf course, and a 150-room beachfront Banyan Tree hotel and spa. Working with the Prizker Prize-winning architectural firm Foster & Partners of London, the landscape architects sought to produce a response that is of an international standard.

Foster & Partners conceived a master plan for the project in collaboration with the engineering firm Arup. The landscape architects were then tasked with reviewing and informing the master plan, conceptualising the landscape design approach and conducting research to establish an on-site indigenous nursery.

Once the home of the extinct dodo, the Republic of Mauritius has become archetypical of the tension between human intervention and the biophysical environment. Since the Portuguese set foot on the island in 1509, it has become a collector of the exotic: less than 2% of the island's vegetation cover can be considered indigenous and the concept of a "first people" is non-existent.

The island is a kaleidoscope of peaceful paradoxes: invasive guava plants that line the roads have become the objects of festive fruit picking outings on public holidays, the clear ocean waters are strewn with beautiful Hindu offerings, Catholic shrines are entombed in mystical Banyan trees from the East, and the biologically competitive *Casuarina* trees along the coastlines leave no room for natural forests, but create high canopies that provide shade for the endless picnic-goers.



It is impossible to imagine and naïve to long for an untouched Mauritius; an island isolated from the world. Working within this context, the formulated design approach was to extract the physical and non-physical layers of the site through research and site analysis and to conceive a landscape design that, as a new layer, critically responds to this depth of context. These layers can loosely be grouped into the biophysical and cultural contexts, and the proposed context of the master plan.

Biophysical context and landscape design response

The 176-hectare site has dramatic views of Le Morne Brabant, Ile aux Bentilier (the coral formations found in the vicinity of the island), the village of La Gaulette and the setting sun over the Indian Ocean. Topographically, the site can be classified as a hillside and a coastal area, separated by National Road B9 running parallel to the coastline.

→ *Sensitively placed boardwalks at the interface between see and land would offer spectacular views of Le Morne Brabant.*

The site's lush green vegetation can easily deceive the onlooker into thinking that it reflects a healthy ecosystem. On the contrary, the hillside area is largely overtaken by invasive species such as *Albizia lebbeck* [fr. *Bois noir*] and star grass. The former is a fast-growing exotic pioneer tree and the latter was planted as grazing for deer when the site was used as a hunting ground after 1993. Prior to this, the site was cleared of its indigenous vegetation for the cultivation of sugar cane.

The lower, coastal part of the site is choked by exotic and invasive eucalyptus and acacia species, but a mangrove forest on the southern edge has significant ecological value. There are two Banyan trees (a fig tree, usually *Ficus benghalensis*, with aerial shoots that descend to the ground to form additional trunks) on the site, which signify gathering places (or places of business) and eternity in Hindu mythology. Another significant characteristic of the site is the presence of various drainage lines that flow down the hillside, transporting storm water run-off to the ocean. These lines are characterised by dense vegetation and smooth rocks and pebbles that line their surfaces. Basaltic boulders are scattered throughout the site.

In spite of the dramatic topography and views, the site is ecologically barren. As a result, rehabilitation of the landscape became a central concept of the design strategy. The complexity of rehabilitation in Mauritius can be understood given that the few nurseries stock a limited palette of indigenous plants and little is known about the “original” island ecologies.

Although the Mauritian Wildlife Foundation (MWF) has done excellent work in collecting and propagating indigenous plants to ensure gene preservation, the project has not yet reached a scale where it can start to feed the commercial nurseries. Exacerbating the problem is the fact that the marketing image of a lush tropical environment has been entrenched in the expectations of visitors to the island, and most hotel developments seek to provide this image through landscaped gardens of exotic tropical vegetation that require extensive irrigation in what is a surprisingly dry climate. The nurseries continue to meet this demand and there is no commitment to “going indigenous”.

The first response to the problem was the proposal of an on-site nursery dedicated to the cultivation of indigenous plants. This was a first for commercial Mauritius. The facility would be established and operated by a local nursery, would employ local labour and would work in close cooperation with the MWF. If successful, the nursery would become a destination in itself and work with other future developments in the Le Morne area to expand this ambitious and necessary project. It is hoped that this will be the beginning of a paradigm shift for the nursery industry in Mauritius.

→ *An image illustrates the shift to an indigenous rather than a "tropical" landscape theme.*

The second response was the development of a strategic, phased approach to the rehabilitation of the site. Phasing is necessitated by the lack of planting stock, the need for an immediate green environment when the development is operational, and budgetary constraints. Briefly, the strategy is to plant all areas disturbed during construction (villa and hotel building sites and road verges) with fast-growing indigenous plants that are more commonly available. Rarer species that would require special cultivation and were not available *en masse* would be planted in spaces that are visually pronounced (for example, pathway crossings and courtyards) to communicate their significance and evoke interest. An understanding of the plants through education was promoted by the design and became an important contributor to the botanic paradigm shift.

Since most indigenous trees, for example, the ebony (*Diospyros tessellaria*; fr. *Bois d' Ebene*), are extremely slow growing, selected exotic trees (for example, the albizias) are kept for their spatial, sculptural and sheltering value until the indigenous trees have grown sufficiently. This is a necessary measure to provide habitable outside spaces when the sweltering sun turns to the west and the Indian Ocean winds thunder against the land. Exotic species such as the eucalyptus will be removed from the outset as they inhibit succession.

Another response to the biophysical context inspired one of the most important concepts of the master plan, namely the idea that the drainage lines become “green fingers” that connect the hillside with the ocean. These lines also become the main structuring device of pedestrian movement from the upper slopes down to the golf course and beachfront hotel.

Visitors are immersed in the landscape (away from the views experienced from the buildings), including dense forests with unexpected bodies of water.

Cultural context and landscape design response

Mauritius, which was known to Arab sailors as long ago as the 10th century, has been inhabited by Portuguese, Dutch, French, British, Indian, African and Chinese farmers, businessmen, aristocrats, slaves and soldiers of Buddhist, Muslim, Hindu and Christian belief. This rich cultural diversity is reflected in the colourful tapestry of celebrations, shrines, building styles, temples, churches, dress, languages, decorated buses and thematic resorts.

Significant to the vicinity of the site is Le Morne Brabant, a mythical volcanic rock that rises from the sea. The almost inaccessible cliffs of the outcrop were frequently occupied by groups of maroons (runaway slaves) in the 18th and 19th centuries to avoid capture. It was granted UNESCO World Heritage Site status in 2008. The Le Morne Brabant peninsula is one of the most striking landscapes of Mauritius.

The cultural diversity and resulting lack of a well-defined architectural vernacular render a thematic response to an existing style problematic. Most hotel developments on Mauritius are stylistically modelled after vague images of sugar plantation mansions or primitive (Polynesian) "island huts". Landscape elements such as street furniture often perpetuate these themes. In contrast, the Corniche Bay landscape design does not attempt to stylistically reflect any one of the many cultures (real and imagined), but rather takes cues from local patterns (such as salt pans), building techniques and materials (for example, basaltic rock walls), and contemporary landscape architecture design ideas.

In responding to the dense meanings of the landscape, it was decided to design spatial interventions that evoke interest and hint at content, rather than to translate ideas literally into form. As with the ecological education, the content (for example, the island's slave history) is to be accessible through a digital field guide.

The most obvious response to the cultural landscape is the layout of the master plan, which is affected by the fact that the site is partially located within the Le Morne World Heritage Site buffer zone. To create a diffused edge (to prevent a definite boundary line in the landscape), landscape "wedges" from the site were allowed to penetrate the heritage site and vice versa.

Master plan and landscape design response

The original master plan, drawn from the natural topography of the site, consists of a road network following the contours of the site, a nine-hole golf course on the hillside area with the gentlest slope, villa sites that are orientated for optimal privacy and views, a beach reclamation strategy, an infrastructural system that promotes sustainability (for example, grey-water harvesting and solar-heated geysers) and an architecture with curving timber constructions that undulate from one building to the next, giving the whole hotel development a bold and unified language that blends with the organic forms of the surrounding gardens.

The landscape architects' first response was to evaluate the original master plan critically to inform the proposed landscape-related concepts. Most importantly, the concept of a lush, tropical environment was questioned in view of the findings concerning the biophysical environment. The complexities of the planting strategy were brought to the master plan and thereby added an important layer to the scheme on a planning (cost estimation and nursery site selection) and conceptual (visualisations of the landscape that departed from the tropical settings of the original marketing images) level. Another area of concern to the landscape architects was the drainage line crossings. The road layout included high-level crossings that required extensive and disrupting earthworks. The landscape architects proposed low-level crossings by means of low-water bridges that would collect pockets of water and immerse the visitor in the landscape in juxtaposition to the general spatial experience on site that is dominated by long-distance views.

Landscape design responses

Landscaping around the hillside villas provides the paradox of privacy and prospect through a grading of vegetation density and height. One approaches the villa through a dense broad-leaf forest, enters the villa and is encouraged to move forward by the linearity of a planted interior wall, moves through the simplistic interior space and is spatially released onto a deck where the dramatic views over low, flowering plants of Le Morne and the ocean are revealed. Framing these views are the sculptural *Bois noirs* (until the indigenous trees are sufficiently mature). Privacy during landscape establishment is ensured by the use of a filigree screen (a repetition of vertical timber poles) that wraps around from the back to the sides of each unit. The screens are positioned to define outdoor shower areas that are linked to the bathrooms. Tall trees contribute to a sense of showering in a forest rain. The *genus loci* of areas on the site that have special qualities are amplified through subtly designed interventions. These places are linked to a digital field guide. The experience of landscape is exalted by the knowledge of landscape. These places include a viewing platform with reference to Le Morne, rest areas in the drainage lines where small pockets of water are collected, a sculptural intervention that alludes to the maroon pathway, sunken walled gardens and Banyan tree clearings.

Whereas the hillside villas are focused on an experience of views and mountainside, the primary concern for the hotel units is the connection with the sea. A patterning of dense vegetation strips that run acutely to the coastline ensures

privacy between the units, with low vegetation in front of the decks that allows visitors to enjoy views of the sun and the sea that touch in the west. These green streaks are contrasted by white sand paths that lead to the beachfront and black strokes of basaltic stones that allude to the dark beaches found naturally in Mauritius. The landscape architects have proposed that the roofs of the units be redesigned to accommodate planting to minimise the visual impact on the landscape and to act as an insolation layer.

The L-shape of the main hotel building forms a central space that can be read as the heart of the resort. The dining areas and individual spa treatment rooms are arranged around this space, giving it additional importance. The space acts as an anchoring point from which a series of lines create a visual and spatial connection to the sea. These lines become the ordering device for pathways and the gardens that celebrate and feature coastal vegetation.

Only the portion of the seafront that is outside the World Heritage Site buffer zone is to be converted into a sandy recreational beach. The area within the buffer zone has been conceptualised to enhance the natural and rugged beauty of the shoreline with sand only being introduced above the high-water mark. A timber boardwalk runs parallel to the coastline and is interrupted by a series of pavilions from which visitors can experience solitude in contrast to the energetic activities of the recreational beach.

In line with the design approach of celebrating and responding to the real contexts of the site, the beachfront is serially interrupted by pockets of basaltic boulders that hold soil for the growth of salt-tolerant coastal vegetation that positively disrupt the marketing images of white sands and palm trees.

Project significance

Although endeavours to design places with meaning are always contentious, it has been attempted (not ignored or prostituted) to design a place where the visitor is immersed in the layers of the landscape through a network of spatial (*in situ*) and informative (*ex situ*) references.

The project intends to not only allow the visitor to enjoy the obvious resort experience, but also to engage the visitor in the historical and contemporary culture of Mauritius and to ground him or her in the landscape of the place.

Although the project was never built, it has set a precedent that is referred to by the authorities as a desirable response to resort development in Mauritius – an example for projects that should enter into dialogue with the culture and environment that they propose to fit.

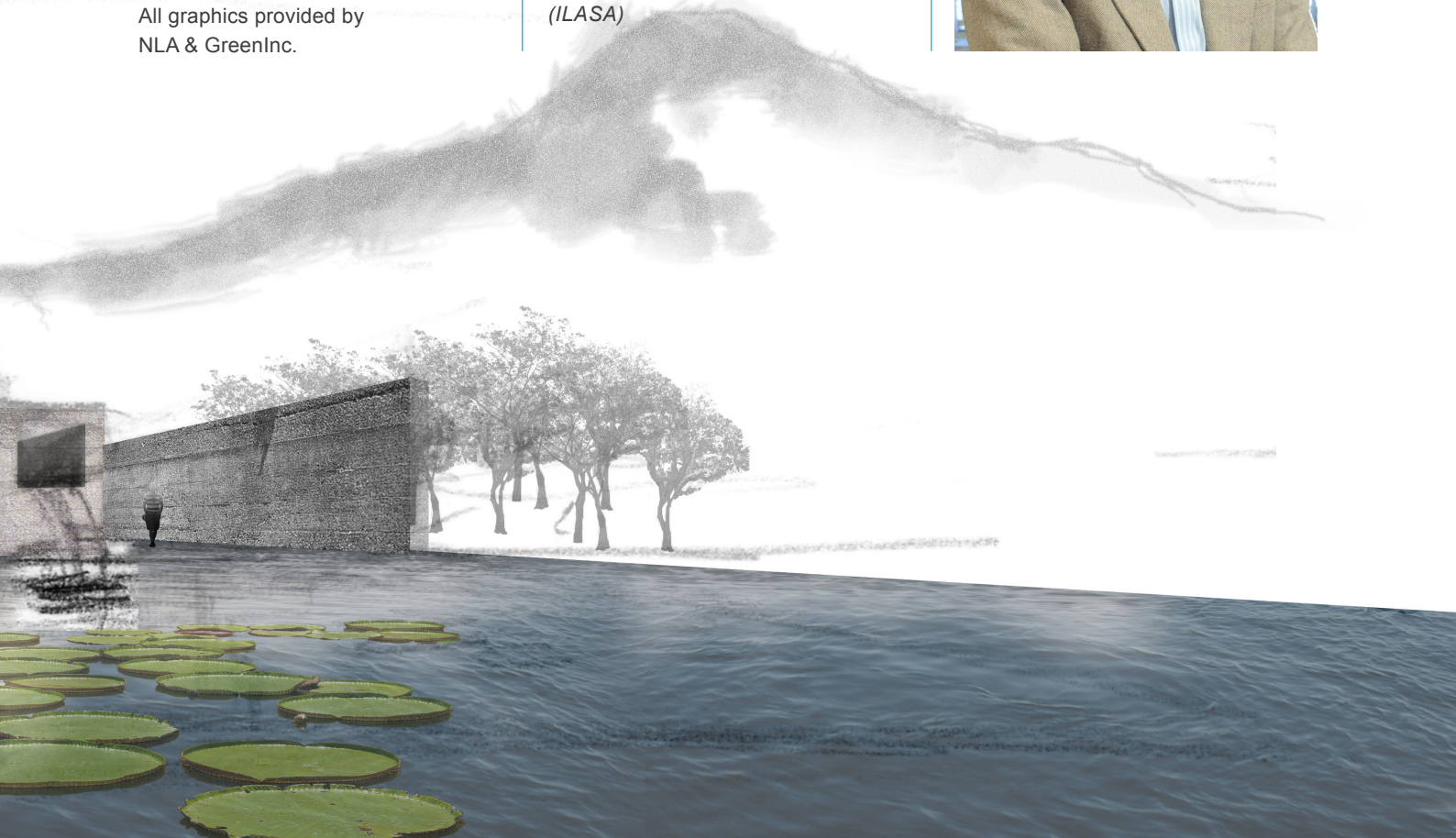
Acknowledgement

All graphics provided by NLA & GreenInc.

Graham Young and Johan Nel Prinsloo *are landscape architects in the Department of Architecture at the University of Pretoria. Through NLA & Green Inc Landscape Architects, they were recently involved in the planning of a resort scheme in Mauritius.*

Their aim was to follow an atypical approach to the planning and layout of the scheme and introduce a new way of thinking about resort development on the island. This was embedded in sustainable thinking and place-making that related to the inherent qualities of the landscape and culture of the island, rather than trying to create another artificial "palms and white sand" scenario, which is so prevalent on Mauritius and favoured by most developers. Fortunately, the client, along with the lead architects, Foster & Partners from London, shared this enlightened view.

In 2009, the project was awarded a merit award by the South African Institute of Landscape Architects (ILASA)



Using a business process management system as an IT tool for corporate governance

by Prof Awie Leonard and Henk Pretorius

In the USA, corporate governance has been heavily criticised because of the failure of companies like Enron, WorldCom, Tyco, Adelphia and Global Crossing. Research[1] has further revealed that industries in the USA lose about $400 billion a year because of unethical and criminal behaviour. Furthermore, the resignation and arrest of top managers in the USA indicate that there is an increasing level of managerial negligence and corporate irresponsibility that has eroded domestic and global trust in USA markets[2].

Examples of corporate misconduct are also found in Europe. Europe's biggest corporate failure is Parmalat. The company collapsed in 2003 with a 14 billion euro hole in its accounts. CEO Calisto Tanzi – once a symbol of unlimited success – was detained hours after the firm was declared insolvent, and charged with financial fraud and money laundering. Hundreds of thousands of investors lost their money and will never recover it.

In South Africa, the corporate governance situation is not much different from the situation in Europe and the USA. IT vendors, for example, are being accused of frequently offering bribes to government employees. According to research[3], suppliers are the root cause of corruption. This research furthermore found that governance and transparency are growing imperatives in the public sector and the researchers urge government IT professionals to get them in place, if only to protect themselves. According to this research, chief information officers (CIOs) fail to report bribery offers from vendors because there are many influences, such as political connections and fear of higher ranking employees. The fight against corruption must therefore start at the top. It must be a collective effort.

The corporate governance problems listed in various sources are in accordance with the findings of Prof Mervyn King, who has done extensive work and research in the field of corporate governance, especially in South Africa. According to King[4]:

> "Good governance is summed up as involving fairness, accountability, responsibility and transparency on a foundation of intellectual honesty."

In March 2002, the King Committee published the King Report on Corporate Governance for South Africa 2002 (also known as the "The King II Report"). This report identified three additional principles of good governance. These are discipline, independence and social responsibility. In more recent times, the King Committee published the King Code of Corporate Governance in South Africa 2009 and the King Report of Corporate Governance in South Africa 2009 (also known as the "The King III Report"). These publications included leadership and sustainability as additional principles of good governance.

> According to the King reports, bad governance is therefore a result of neglecting the good governance principles of fairness, accountability, responsibility, transparency, discipline, independence, social responsibility, leadership and sustainability. Most importantly, the foundation of these concepts are intellectual honesty and acting in good faith and in the best interests of the company.

In response to the USA corporate failures, legislative changes, for example, the Sarbanes-Oxley Act of 2002 (SOX), and regulatory changes, for example, governance guidelines for the New York Stock Exchange (NYSE) and the National Association of Securities Dealers Automated Quotation (NASDAQ), were introduced[5]. Similar acts have been introduced in other countries across the world: Germany introduced the German Corporate Governance Code (Der Deutsche Corporate Governance Kodex), Japan introduced the Japanese equivalent of the Sarbanes-Oxley Act, known as J-SOX, Australia introduced the Corporate Law Economic Reform Programme (Audit Reform and Corporate Disclosure) Act in 2004, known as CLERP9, France

1 Kreitner, R. & Kinicki, A. 2004. *Organisational Behaviour.* 6th edition. New York, NY: McGraw-Hill.
2 Elliott, A.L. & Schroth, R.J. 2002. *How companies lie: Why Enron is just the tip of the iceberg.* New York: Crown Business.

3 Jarvis, K. 2009. IT vendors take rap for corruption. *GovernmentIT*, 1(3):13.
4 King, M. 2006. *The corporate citizen. Governance for all entities.* Johannesburg: Penguin Books.

5 Kaplan, S.N. & Holmstrom, B. 2003. The state of U.S. Corporate governance: What's right and what's wrong? NBER Working Paper No. 9613, April 2003, JEL No. G3, L2. © National Bureau of Economic Research.

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introduced the Financial Security Law of France (Loi sur la Sécurité Financière) and the United Kingdom developed the Combined Code on Corporate Governance (originally derived from the Cadbury Report). However, there are many sceptics. Typical remarks include the following:

> "The cost of compliance is burdensome, both in time and money. Furthermore, the board and the management become focused on compliance rather than the business of the enterprise. It is the duty of the board of a trading enterprise to undertake risk for reward and to try to improve the economic value of the company. If the board follows a narrow focus on compliance, the board's responsibility towards the enterprise and its ultimate responsibility, namely performance, may be diluted." (King III Report, 2009).

> "The cost of compliance by American companies with section 404 of the Sarbanes-Oxley Act, which deals with the verification of internal controls, is estimated at $264 billion since the inception of the act in 2002. The total cost to the American economy of complying with the act is more than the total write-off of Enron, World Com and Tyco combined." (King III Report, 2009).

> "As the second year of Sarbanes-Oxley compliance is completed, there are still many complaints about the costs of compliance and questions about the business value of Sarbanes-Oxley-related investments." (Velichety, S., Park J., Jung, S., Lee, S. & Tanriverdi, H. 2007. *Company perspectives on business value of IT investments in Sarbanes-Oxley compliance*).

It is evident that compliance with legislative and regulatory acts is costly and time-consuming, causes overregulation and does not always provide any value to business. There is also no guarantee that adherence to these measures can be enforced. In fact, the first three years of the Sarbanes-Oxley Act was, at best, an overreaction to Enron and, at worst, ineffective and unnecessary. Researchers in the University of Pretoria's Department of Informatics therefore propose the use of a business process management system (BPMS) for better corporate governance to address the abovementioned lapses of cost, time and business value.

IT for better corporate governance

In *The Corporate Citizen: Governance for all entities*, King states that the use of IT should be increased to achieve better and more effective corporate governance. King believes this to be the ultimate way of achieving good corporate governance for 24 hours a day across the borderless world of today. In his own words:

> "Willingly or unwillingly, we are members of the information age. The ultimate light in regard to transparency and governance has become information technology. The use of IT in the business world is not only an enabler, but has also become of strategic importance. Through this strategic role it has become pervasive."

IT is furthermore a business enabler that has become of strategic importance to a business and, when aligned with the business goals, IT will deliver optimum value to the business. The use of IT in governance is furthermore becoming a popular way to ensure regulatory compliance.

Although compliance with legislative and regulatory acts is costly and time-consuming, causes overregulation and does not always provide any value to business, research[6] has indicated that business processes can easily be adapted (agility) in a BPMS (as an IT tool) to take advantage of new market opportunities. The Australian Community of Practice states that business process management is "…a structured, coherent and consistent way of understanding, documenting, modelling, analysing, simulating, executing and continuously changing end-to-end business processes and all involved resources in the light of their contribution to business improvement."

A BPMS therefore presents the opportunity to meet business and corporate governance objectives in time, as opposed to current mechanisms and measures. It has further been indicated[7] that companies who align their business processes with their organisational strategy and have operationally effective processes will perform better than other companies in taking advantage of new market opportunities. In support of this argument, it has been stated[8] that strategy implicitly or explicitly sets the direction of an enterprise. Strategy lives through processes, people and technology. With these three entities, an organisation can build its core competencies to sustain a competitive market advantage. Therefore, when the core competencies are identified within an organisation, the competencies

6 Silver, B. 2004. *Three Promises of BPM: Agility, Flexibility, Visibility.* © 2004 Bruce Silver Associates.
7 Tallon, P.P., Kraemer, K.L. & Gurbaxani, V. 2001. Executives' Perceptions of the Business Value of Information Technology: A Process-Oriented Approach. *Journal of Management Information Systems.* Spring 2000, 16(4):145-173.
8 Peppard, J. 1995. Broadening Visions of Business Process Re-engineering. *Omega, International. Journal of Management Science, 1996, 24(3): 255-270.*

can be incorporated into a process configuration that can be automated and enforced in a BPMS. In this way, strategy can be delivered through the use of a BPMS as an IT tool to support the business, resulting in increased business value. The Financial Express (2006) reaches the following conclusion:

> "The need of the hour, therefore, is a comprehensive business process management approach. This requires every business process to be documented in detail and with maximum clarity. All possible risks, whether financial, strategic, reputational, or operational, have to be identified, and controls for mitigating these risks have to be established. Processes have to be continually audited to ensure proper implementation and to identify the weakness. Finally, the processes have to be redefined to rectify the identified weaknesses and, thus, continuously improve and refine processes."

When business process management is applied to the domain of corporate governance through the use of a BPMS, business process management will have a dual role, purpose and nature. The first is to improve business performance. The second will be to improve corporate governance. Business process management therefore makes a significant and vital contribution to the field of corporate governance when it is used and applied in the corporate world.

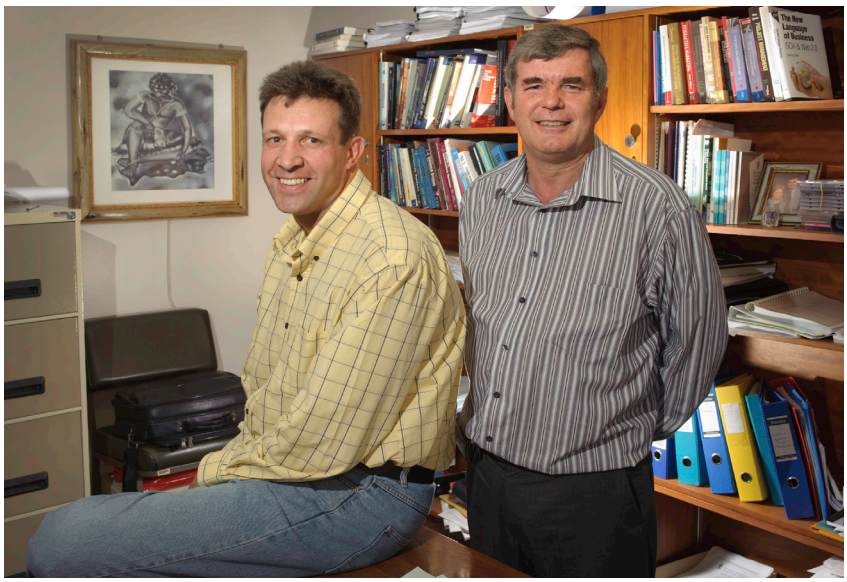
Across the globe, corporate governance has been heavily criticised because of failures of companies such as Enron, WorldCom and Parmalat. Many authors agree that mechanisms that were introduced in response to these failures are costly and time-consuming, cause overregulation and do not always provide any value to business.

King states that the use of IT should be increased to achieve better and more effective corporate governance. A BPMS is an IT tool with the business process management philosophy of continuous improvement behind it. Business process management has a dual role, purpose and nature: to improve business performance and to improve corporate governance.

To improve corporate governance, a BPMS must also support the principles of good governance, although this has not been articulated in current research. The principles of good governance that were introduced by King have specific relevance to the South African context. King's principles of good governance (fairness, accountability, responsibility, transparency, discipline, independence, social responsibility, leadership and sustainability) are based on a foundation of intellectual honesty and integrity, which means that one should act in good faith and in the best interests of the company.

Henk Pretorius *is a lecturer in the Department of Informatics at the University of Pretoria. He is in the process of completing his PhD in information technology on the use of business process management systems to improve corporate governance. He has delivered international and national conference papers on various topics in the field of information technology.*

Prof Awie Leonard *obtained his PhD in Informatics from the University of Pretoria in 1998. His research interests fall in the broad category of information technology (information systems) management. He has contributed several chapters and articles related to IT end-user relationships in prominent books and journals.*



→ *Henk Pretorius (left) and Prof Awie Leonard.*

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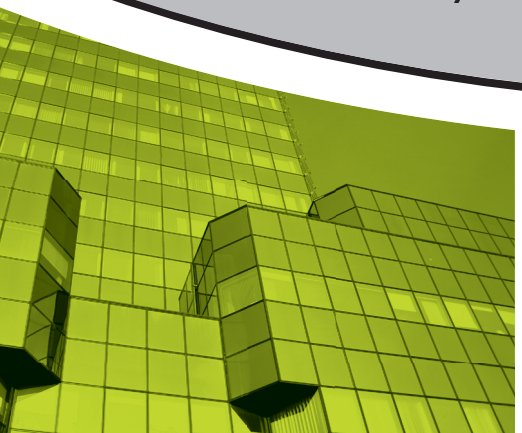

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Rail research at the University of Pretoria

by Prof Hannes Gräbe

The Chair in Railway Engineering in the Department of Civil Engineering at the University of Pretoria was established in 1992 when Spoornet (now Transnet Freight Rail) initiated a partnership between industry and the University. This partnership revolves around three major aspects: graduate training, continuing education courses for industry, and railway research.

Technology development

One of the most basic needs in engineering is to measure the movement of structures and their components. This often has to be done with high accuracy and at a high velocity.

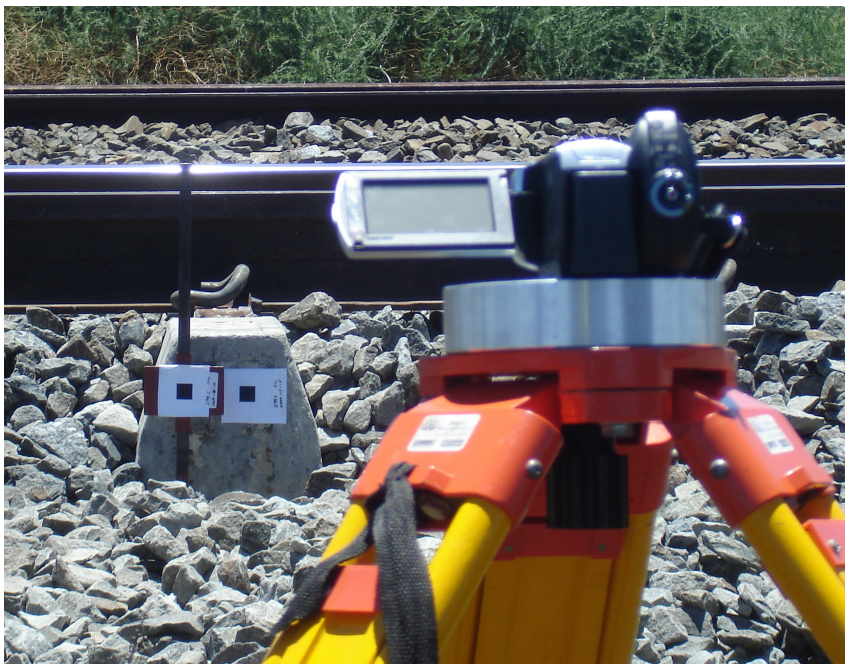
Remote video monitoring (RVM) equipment was developed to address this need and is briefly described. One target, a 2 cm x 2 cm black square on a white background, was fixed to the exposed shoulder of a concrete sleeper in the track. The other target was positioned on a steel rod anchored in the foundation of the track. A video camera was placed three to five metres away from the track where ground vibrations do not influence the measurements. Software was developed that analysed the video recording and produced the horizontal and vertical deflection of the track component. For track applications, the RVM maximum range of deflection measurement was roughly 5 mm with an accuracy of ±10 µm. This cost-effective development enables extremely fast set-up time and solves the problem of finding a stable and immovable reference when doing deflection measurements. Although developed for studying track components, the current RVM equipment that was developed can be applied to any structure where time-dependent measurements are required at frequencies of 1 to 500 Hz. Industry partners for this work are Transnet Freight Rail and TCL Software Solutions.

Another track research focus area is the characterisation of railway foundations. Being a foundation, this vitally important part of a track structure is hidden below the ballast and is therefore not easily accessible. A technology that is already well established in the railway field is ground-penetrating radar (GPR). A GPR antenna transmits a short electromagnetic pulse of radio frequency through the track structure and measures the dielectric constant, the magnetic susceptibility and the electrical conductivity of the medium under consideration. When analysed, this data can be used to detect railway substructures, the degree of fouling of ballast material, the dimensions of subgrade layers and the presence of abnormal moisture accumulation in the track structure.

A video recording of the track and location map, together with GPR results, is a powerful analysis tool in the hands of the rail track maintenance engineer. As the demand on South Africa's rail network increases, Transnet Freight Rail is under pressure to increase the axle load on some of its feeder lines. Future research will use GPR data to classify the substructure based on the stiffness and condition of the subgrade layers, enabling prioritisation of track sections for future rehabilitation. Industry partners for the GPR research are Roadscanners (Finland), Aurecon (SA), E-Logics (SA) and HyGround (USA).

Track research projects

The Chair in Railway Engineering was granted permission to carry out a series of track performance tests on the Gautrain Rapid Rail Link between the Sandton and Marlboro stations. The focus of the research was the transition in track support that occurs when one moves from a rigid, concrete viaduct to a normal track. The same difference in track support is experienced when the train moves out of a tunnel, which is on a slab track, onto normal ballasted track. Differential stiffness at these positions often causes settlement and a characteristic "bump" that develops at the transition zones.



→ *Remote video monitoring is used to measure the horizontal and vertical deflection of a railway sleeper and the foundation below the ballast under train loading.*

→ *Tubular modular track constructed under extreme dessert conditions in Saudi Arabia (photograph courtesy of tubular track).*

A fourth-year Civil Engineering student measured the response of the track at various transitions with RVM equipment. The results quantify the severity of the transition problems and enable track engineers to design mitigation measures for reducing high-track and vehicle dynamics at similar transition zones. The chair has subsequently carried out other field and laboratory tests for the Gautrain on the performance of other track components. Industry partners for Gautrain research are Bombela Concession Company and Isithimela Rail Services.

Although the vast majority of railway tracks in the world are still constructed using ballast, sleepers and rails in the conventional manner, non-conventional track structures are being constructed for specific applications requiring specific performance criteria. Slab track is used in tunnels, on bridges and for high-speed lines that require stable and high-quality track geometry. A South African invention, which falls into the category of non-conventional track structures, is tubular modular track (TMT). The rails are continuously supported on concrete beams, connected to each other by galvanised steel gauge bars. Modules are precast in lengths of six metres and then placed directly on top of a prepared foundation. TMT eliminates the need for ballast and provides a stable track structure with good geometry and low maintenance requirements.

In South Africa, the Chair in Railway Engineering is currently testing and evaluating the performance of TMT installations at Centurion station, Hatfield station, a test section on the Pendoring-Thabazimbi line and a number of TMT turnouts at Ermelo Yard on the coal line. The research focuses on the performance of the system as a whole, but includes detailed investigations on individual components, foundation performance under TMT structures and the transitions between TMT modules. Numerical models are also being developed to broaden the research capabilities of the chair.

Students and staff carry out track performance tests outside Marlboro station on the Gautrain rapid rail link.

As a result of Transnet Freight Rail's support of the Chair in Railway Engineering, a number of research projects are currently being undertaken to investigate specific aspects of railway engineering that require solutions or further development. These research projects form part of a larger project funded by the Technology and Human Resources for Industry Programme (THRIP). One focus is the long-term performance of railway foundations under, among other things, heavy haul loading. A scientific model is being developed to predict the life of a railway foundation based on the details of the foundation design (layerworks and material properties), drainage and environmental conditions, axle load and annual tonnage. This model is especially useful when decisions have to be made regarding increased axle loads and tonnages on existing railway lines. A test site on the coal line was dedicated to the development of this model, and final-year and postgraduate research students in civil engineering visit this site on a yearly basis to accumulate field data and carry out new experiments on the track.

Other research projects for Transnet include the development of a complete formation investigation programme using GPR and other advanced tools, the development of numerical models for enhancing research on conventional and non-conventional track structures and the development of maintenance models for ballast tamping and rail break management. Industry partners for the Transnet research are Transnet Freight Rail, E-Logics and Esteq Engineering.

The Chair in Railway Engineering is honoured to be an active player in the growing railway industry in South Africa. The material and other contributions of industry partners locally and abroad have made it possible for the chair to broaden its research capabilities and make a meaningful contribution to promote the mode of rail transport. It is envisaged that rail will grow and become the preferred mode of transport, not only for passengers, but also for the transportation of bulk, heavy and large-volume commodities.

Prof Hannes Gräbe *is a civil engineer with 16 years' experience in track technology, geotechnology, advanced laboratory testing, field investigations, maintenance models and numerical analysis of track structures. He is an associate professor in the University of Pretoria's Transnet Chair in Railway Engineering.*

Determining the maximum resource utilisation for optimal system profit

by Olufemi Adetunji and Prof Sarma Yadavalli

A major shift in production and supply chain management is that from a predominantly push to a predominantly pull paradigm. However, not many organisations are based entirely on one or the other. The extent to which each paradigm is implemented is usually captured in the decoupling point of the organisation.

In a typical push environment, planning drives the production, and more inventory is allowed to support the production system. A pull environment is more critical of inventory, and management of flow is very important. This is the main thrust of lean principles, theory of constraints (TOC) and the more recent constant work-in-process (CONWIP) systems. Wallace Hopp, a specialist in supply chain science, defined a pull system as a system in which work is released based on the status of the system, thereby placing an inherent limit on the work-in-process (WIP) inventory. This is in contrast to a push system in which work is released based on plan, irrespective of the state of the production system. The magic of pull, he said, is the cap on the WIP in the system. This, in his opinion, is why many pull systems are more profitable than push systems.

However, this WIP cap is implemented differently in the various pull systems, and job scheduling is always implicitly linked to inventory control. Lean uses the Kanban, TOC uses the drum buffer and rope (DBR) and the CONWIP monitors the exit of jobs from the system. One implicit assumption in all such systems, however, is that the demand environment – and by extension, the production system – could be steadied somehow. It is apparent from all these approaches that a key component of every pull technique is the conscious management of the job flow rate through the system and the implicit containment of the level of the WIP in the system.

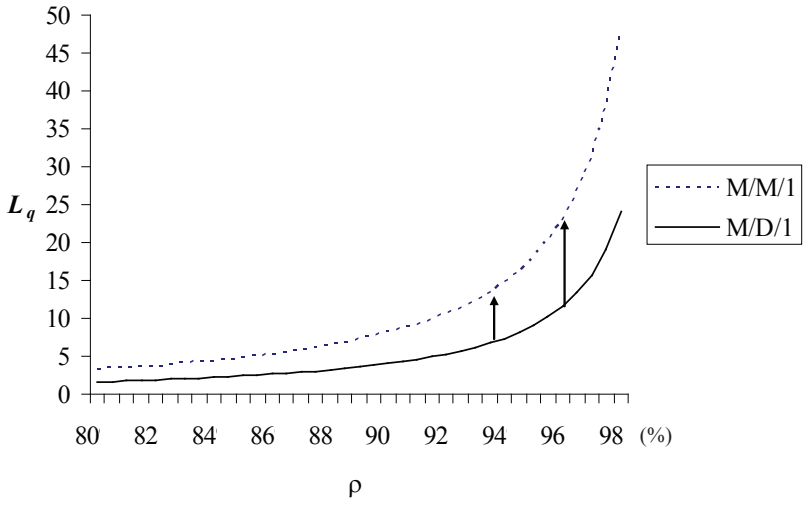
Therefore, an understanding of why WIP grows significantly in every production system (goods or services) would enhance the management of such systems. The interesting thing is that the WIP level is closely related to two main issues: the level of variability in the system and the level of utilisation of the system. The utilisation effect is more easily represented through a simple mathematical relationship called Little's law. Simply put, it states that in any system with variabilities, WIP level = throughput rate x cycle time.

This is similar to most other conservation laws in engineering. It is one of the most fundamental equations of queuing systems. Queues are pervasive models that have been (and are still being) widely researched.

The problem of variability is more intricate than that of utilisation. It is directly dependent on the nature of arrival to the system and that of processing at the resource. It can be captured in simple terms by the coefficient of variation, or in more explicit terms, by the distribution of these variables. Because of the numerous possible combinations of such systems, notations have been developed to manage these systems.

The seminal work in this regard was done by Kendal, who proposed a four-field notation: $A/B/C/D$, where A indicates the nature of variability of arrival pattern, B the nature of variability of processing time, C the number of processing resources available to the input, and D the size of the calling population.

The advantage of the many standard models derived from this classification is that their steady-state solutions are readily available. These steady-state solutions also determine how the system behaves, based on its level of utilisation.



→ *1. Curse of utilisation and variance.*

One of the simplest cases is the Markovian System of ***M/M/1/∞***, where the first ***M*** is Poisson and the second ***M*** is exponential by nature of their distributions. The pattern of WIP builds up as a function of the utilisation and is captured in a term referred to as the curse of utilisation.

This is shown in Figure 1 for the ***M/M/1*** and ***M/D/1*** , where ***ρ*** is the system level of utilisation and L_q is the WIP level (expected queue length). ***D*** means that the processing time is uniform.

From Figure 1, it can be seen that while the WIP level is dependent on the system level of utilisation, its expected value balloons as the utilisation level approaches full resource utilisation. This makes it imperative for a production manager to watch this trade-off as he or she tries to push more and more products through the pipeline to meet more customer demands. There comes a time when it is better to allow customers' demands to go unmet than to increase system throughput, even when it is not yet at full utilisation.

A simple flow model could be built around this characteristic by defining a profit function around the holding cost of the expected WIP that results from the level of utilisation of the system and the profit earned from sale or throughputs from such system.

This is defined as:

$$NP = TH - OE \qquad 1$$

Using the steady-state solution of the ***M/M/1/∞*** queue that the arrival and processing time is assumed to follow, and optimising the utilisation factor relative to this profit function, one can derive an optimal job flow rate to be

$$\rho^{\cdot} = 1 - \sqrt{\frac{C_{OE}}{\mu C_{TH}}} \qquad 2$$

$$NP^{\cdot} = (\sqrt{\mu C_{TH}} - \sqrt{C_{OE}})^2 \qquad 3$$

where ***NP*** is the net profit, ***TH*** is the throughput rate, ***OE*** is the operating expense (incurred during the same time window as the throughput, and assumed here to be made up of only the holding cost), μ is the rate of service at the resource over a stated time interval, C_{TH} is the profit earned from selling a unit of output and C_{OE} is the inventory cost per unit (product-time).

From the model in Equation 2, one can conclude that if the level of utilisation required of the resource by the customer demand exceeds the optimum utilisation level, it is better to allow the customer demand to go unmet. There may, however, be instances when it is important to factor in the cost of not having the product available. Assuming a once-off cost is paid for not having the product available on demand, the equations may be modified as:

$$NP = TH - OE - SH \qquad 4$$

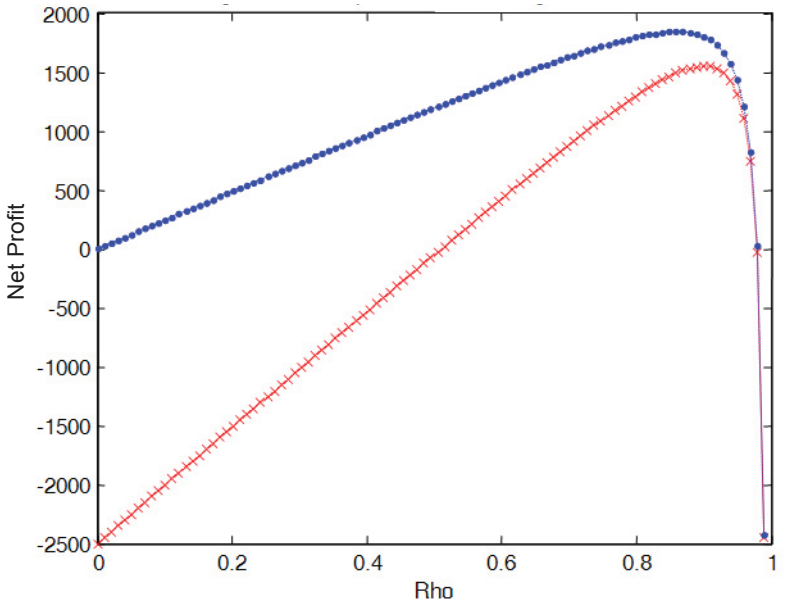
$$\rho^{\cdot} = 1 - \sqrt{\frac{C_{OE}}{\mu(C_{TH} + C_{SH})}} \qquad 5$$

$$NP^{\cdot} = (\sqrt{\mu(C_{TH} + C_{SH})} - \sqrt{C_{OE}})^2 - \mu C_{SH} \qquad 6$$

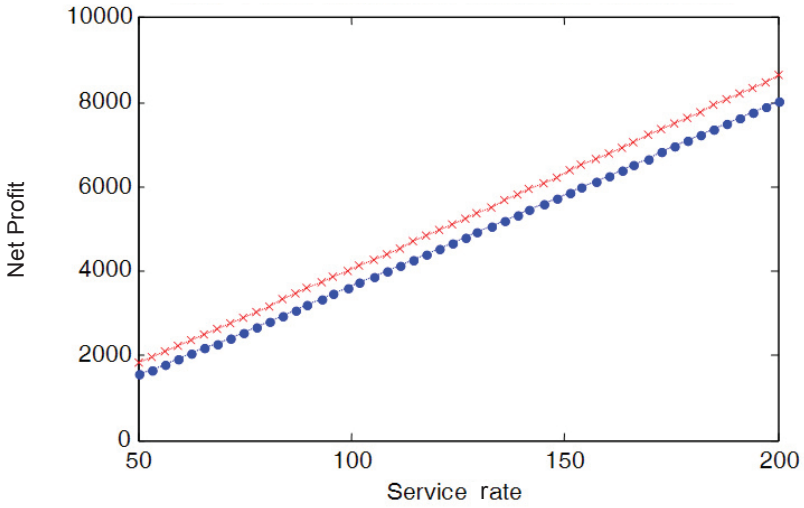
where ***SH*** is the cost of not having the product when demanded (also incurred during the same time window as the throughput), and C_{SH} is a once-off shortage cost charged per unit product for not having the product available for the customer.

To understand why these models are important to the production system, a simple example can be used by initialising all the variables to some values, and the qualitative behaviours of each of the system parameters can be explored. If each of the variables is initialised to 50 units, for instance, and the behaviour of other variables and functions is explored as one of the variables is varied, the following can be observed, starting with the net profit relative to the level of system utilisation:

In Figure 2, the blue-coloured graph is the case where the unit shortage cost is zero, and represents Equation 2. The red-coloured graph represents Equation 5. It can be seen that, in both cases, the net profit declines very rapidly after the optimal



→ *2. Plot of optimal net profit against utilisation.*



→ *3. Plot of optimal net profit against service rate.*

utilisation level. This effect is directly traceable to the rapid non-linear increase in the WIP level as the system gets close to full utilisation, as shown in Figure 1. This shows that it might not be profitable in any way to meet customer demands beyond the optimal utilisation level.

Investigation of the qualitative behaviour of the various input parameters with respect to μ shows, even from the equations, that the optimal utilisation level increases with an increase in the maximum processing capacity, μ, the unit profit rate, C_{TH}, and the unit shortage cost rate, C_{SH}, while it decreases with an increase in the unit holding cost rate, C_{OH}. However, it appears from the diagrammatic plots that the holding cost has a greater effect on the models.

The qualitative behaviour of the net profit pattern is shown in Figure 3. The net profit function for models with shortage cost (Equation 6) is below that of the one without shortage cost (Equation 3). Changes in other input parameters like shortage costs, unit profit and unit holding cost can be plotted in a similar manner to Figure 3, as well, but will be omitted here.

Prof Sarma Yadavalli *is a professor and head of the Department of Industrial and Systems Engineering at the University of Pretoria.*

Olufemi Adetunji *is a lecturer in the Department of Industrial and Systems Engineering at the University of Pretoria.*

ROM-it! Mesh movement made cheap

by Alfred EJ Bogaers, Dr Schalk Kok and Dr Arnaud G Malan

A novel means was recently developed to reduce the computational costs of mesh movement. Mesh movement is a key component in fluid-structure interaction (FSI) simulations. This work was inspired by technology that is being developed by a team of researchers at the Council for Scientific and Industrial Research (CSIR).

Fluid-structure interaction (FSI) is the study of the interaction between fluid flow and deformable structures. Examples of FSI include the flow of air around a flexible aircraft wing, the opening of a parachute, or blood flow through the cardiovascular system. Studying the nature of the FSI of complex systems is a critical component in many engineering fields. It ranges from ensuring that an aircraft wing does not undergo drastic oscillations that will cause it to eventually break off from an aircraft, to understanding the internal mechanics of the human heart. Due to the ever-increasing power of central processing unit (CPU) technologies and the continuing maturity of numerical techniques, it is now possible to perform these simulations accurately using computer-based simulation models.

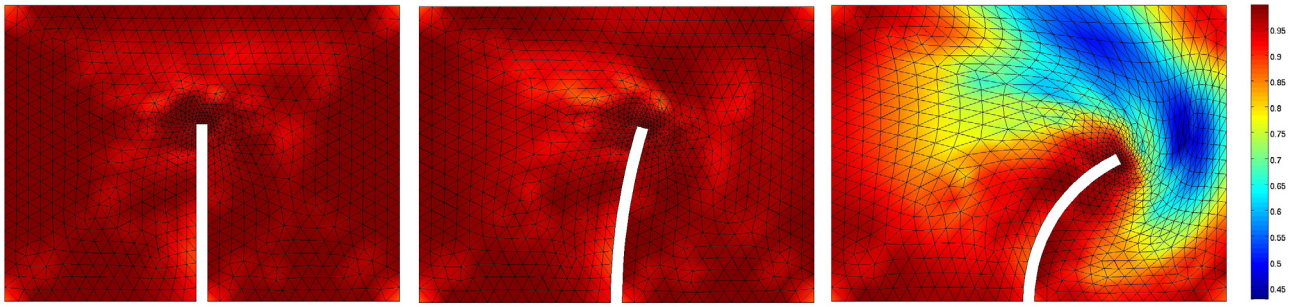
Unfortunately, due to the sheer size and complexity of these simulations, they are, in most cases, unfeasible unless performed on large super-computers or clusters. As such, researchers are continuously striving to decrease the associated cost. The research that was conducted culminated in a generic "black-box" technology that can be applied to essentially trivialise the costs associated with mesh movement. This is one of the critical components of an FSI simulation.

To provide some background – a computational mesh (grid) is the spatial discretisation required by numerical algorithms. The numerical algorithms solve a set of partial differential equations that mathematically describe the predominant physics at play. For example, in fluid flow, these equations may be used to describe and determine the fluid velocity, pressure and density as it is transported through the domain. In order to solve these differential equations, it becomes necessary for the spatial domain to be discretised, or broken into small cells or elements where the combination of these cells is known as the mesh. The numerical algorithm then solves the differential equations over each of the small cells using numerical techniques such as the finite volume or finite element method.

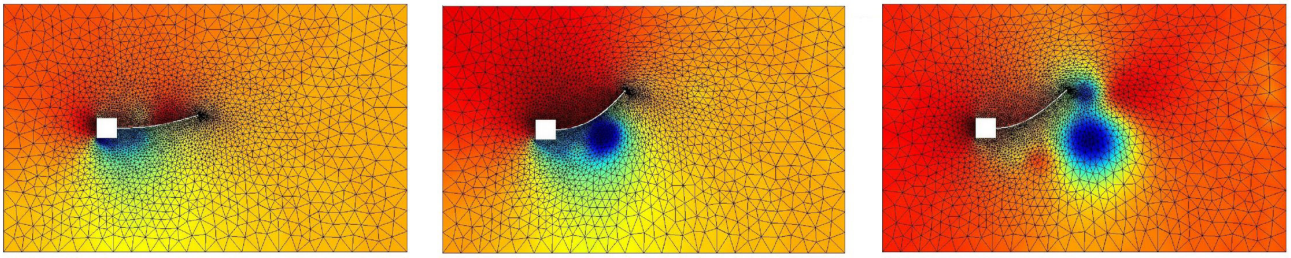
In FSI simulations, as the structure undergoes flow-induced deformations, it becomes necessary for the mesh to conform to the new displaced boundary. This is done either by regenerating the mesh at each instance of boundary deformation, or by moving the mesh itself. Regenerating a mesh presents several complications, including the fact that it is very expensive and that there is a possibility of destroying conservation, which in turn destroys the accuracy and stability of the simulation.

Mesh movement is a technique whereby the internal nodes of vertices of the mesh are relocated to accommodate the structural deformation. Several different mesh movement algorithms have been developed over the years. These are primarily aimed at reducing the frequency and necessity for mesh regeneration. The various techniques vary largely in terms of the associated cost, types and size of the boundary deformations they can support, and the quality of the resulting meshes after deformation. The stability and accuracy of the numerical scheme are strongly linked to the quality of the computational mesh.

Figure 1 and Figure 2 illustrate the concept of mesh movement. The figures are examples of common FSI benchmark problems used to study the accuracy of the numerical solution techniques. The problems entail thin elastic beams undergoing flow-induced oscillations. Despite the success of mesh movement methods to deform the computational mesh, they remain fairly expensive, and can account for a significant percentage of the total



→ 1. Example of mesh movement for a slender elastic beam undergoing first mode oscillations (the colour scale is an indication of mesh quality, where red implies a good element and blue a degenerate element).

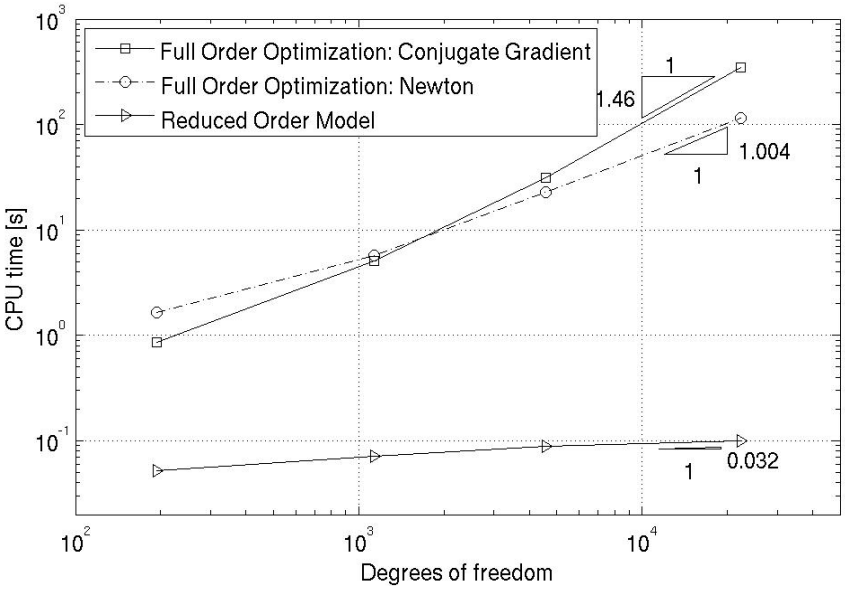


→ 2. Pressure plots for a common FSI benchmark simulation of flow over a fixed rectangle with a flexible elastic tail (the colour scale is an indication of pressure, where red and blue represent low and high pressures respectively).

CPU time required to perform a full FSI simulation. Depending on the complexity of the physics being solved, the total contribution of the mesh movement to the full costs can range from as low as 1% to as much as 50% of the full FSI simulation time.

The technique that was developed employs a reduced-order modelling (ROM) technique, known as proper orthogonal decomposition (POD). It is also commonly referred to as Kurhunnen-Loeve decomposition, principal-component analysis or singular-value decomposition. In essence, POD is a mathematical technique that allows a system to be decomposed into a subspace. In so doing, low-dimensional approximate descriptions of high-dimensional systems are generated.

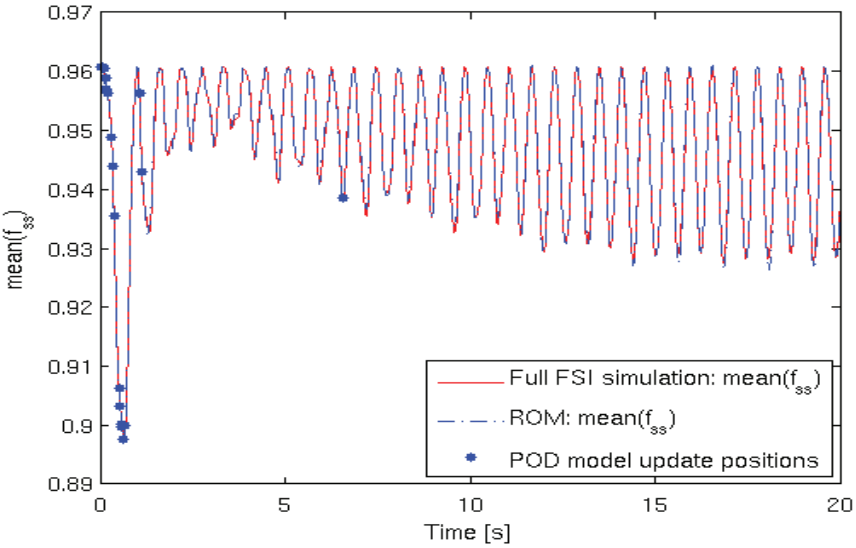
To get an idea of the potential savings offered by the implementation of POD to mesh movement, consider Figure 3, where a direct cost-scaling comparison is made between the POD model and



→ 3. CPU scaling, which compares the cost of full-order mesh movement, based on optimisation, to the cost of the POD-based ROM.

a mesh movement method based on optimisation. Not only is the POD model capable of reducing mesh movement costs, but it does so without any significant reductions in the quality of the original mesh movement scheme.

In order to develop an approximate model of a system using POD, the model has to be trained. The training process involves gathering a set of "snapshots" of the system, where each snapshot presents the full solution of



→ *4. Plot of the mean mesh quality for the benchmark problem of the oscillating flexible tail depicted in Figure 2 for 4 500 time steps: the mesh quality is measured using a quality metric defined so that a perfect and degenerate mesh attains a value of 1 and 0 respectively (the mesh movement is performed using both the full-order mesh movement and the adaptively trained POD-based ROM).*

the system for a given set of inputs. Applied to mesh movement, these snapshots present the mesh solution of the full-order mesh movement scheme for different boundary deformations. The POD model is then capable of reproducing information that closely resembles the information contained in the training snapshots.

Despite POD being able to provide exceptional approximations of systems at a mere fraction of the original cost, its limiting factor is the fact that it requires training. In the context of mesh movement, it is not particularly useful if a large set of expensive computations is necessary to develop a cheaper model, especially if the system parameters (such as the number of snapshots or the type of deformations the system may have to undergo) are not known prior to a simulation. To circumvent this problem, a novel adaptive training procedure was developed.

The training procedure allows the POD model to be trained through the course of a simulation only as it becomes necessary. Figure 4 illustrates the potential of the adaptive model. The plot shows the mesh quality produced by both a full-order mesh optimisation movement method and that of the adaptively trained POD model. The mesh quality is for the beam that is undergoing oscillatory motion across a total of 4 500 time steps in Figure 2.

In total, the adaptive POD model requires only 16 updates of snapshots, where each of these updates uses a single full-order mesh movement solution. This translates into a reduction in mesh movement costs for this particular problem from 4 500 full mesh movement computations to just 16. The negligible cost of the POD model implies time savings of three orders of magnitude, with essentially no loss in the produced mesh quality.

Overall, the work constitutes a distinct step towards making FSI technology computationally more affordable. The developed technology shows great potential, with a distinct possibility of being adopted into future FSI simulation codes.

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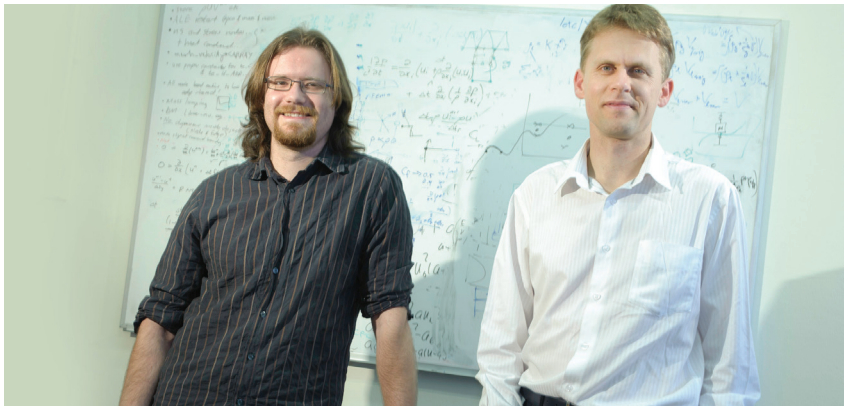
Alfred Bogaers *is a postgraduate student at the University of Pretoria. He received an award for the best student paper at the 8th South African Computational and Applied Mechanics (SACAM) conference in 2010.*
Dr Schalk Kok *and* ***Dr Arnaud Malan*** *are principal researchers at the CSIR. (Dr Kok was not available for a photograph.)*



→ *Alfred Bogaers (left) and Dr Arnaud Malan of the CSIR have developed a novel means to reduce the computational costs of mesh movement.*

About crises and methodological paradigms

by Dr Stefan Gruner

Since the seminal work on scientific paradigm shifts by Thomas Kuhn[1], the terms "paradigm" and "paradigm shift" have become so popular that they are nowadays used or misused in an inflationary manner at almost any occasion. This was also the case during the most recent economic turbulences. The hard global economic crisis of 2008/09 has tossed the sciences of economics into a deep internal and external crisis.

Externally, the sciences of economics as a whole came under heavy criticism from many members of the wider public[2]. Without much differentiation, ordinary people who lost their jobs and money pointed their fingers at those "MBA guys" in their fine shoes and Italian suits who seem to have single-handedly messed up the global economy.

Internally, in the faculties of economics, the crisis seems to have triggered some serious infighting between different "schools" and traditions of economics who blame each other for not having foreseen the emergence of that crisis.

For Germany, in particular, this discussion is documented in a series of articles in the newspaper *Frankfurter Allgemeine Zeitung*[3]. Without going into the details of those articles, one can summarise the feature as follows: There is a quarrel going on (particularly in Germany) between an "old school" of economics that is more philosophically and historically orientated, and a "new school" of economics that is more mathematically or formalistically orientated. This methodological quarrel is at the same time also a fight for scarce academic tenure positions (with an additional Freudian component of academic "sons" wanting to "kill" their academic "fathers", metaphorically speaking).

Thus, the crisis of the real economy triggered a crisis in the academic field of economics. The reasons why I mention this crisis of economics from an external perspective as an "IT guy" (in a computer science position) are the following:

First of all, the threads of IT (and its applications) are now deeply woven into the fabric of the sciences of economics, especially their new formalistic branch, with their (recently so disreputed) computer-model-based methodology. If the new school of economics were to lose the methodological dispute against the old school of "philosophical" economics in the aftermath of the current global economic crisis, then the "helper science" of IT would presumably suffer some consequences as well, be it in the form of idiological pressure on its own legitimation, or simply in the form of a shrinking demand for software and hardware equipment by the faculties and institutions of economics.

Secondly, we have already seen similar methodological "school" quarrels in two IT-related fields, namely in information science (IS) between what I call the "school of sociologists" versus the "school of technologists", and in the field of software engineering (SE) between the "school of formalists" and the so-called "agile alliance". Neither of these two IT-related methodological quarrels has yet ended decisively, from which I gather that the often-quoted "software crisis" has really not yet hit us hard and deep enough to enforce definitive decisions in this regard. My latest journal publication[4] delves deeper into this topic.

However, it is not only an external crisis that has the power to bring down the favourite methods that we invented in the lofty air of our academic methodology seminars. Some dialectic potential of evolutionary self-devaluation is already inherent in our methods themselves, which must make us very sceptical about any kind of what I like to call "method fetishism".

1 Kuhn, T. 2009. *The structure of scientific revolutions*. Books LLC Publ.

2 Brooks, A. Business Schools mull over Blame in Financial Crisis. http://www.npr.org/templates/story/story.php?storyId=103719186

3 *Frankfurter Allgemeine Zeitung*, special feature on economics: Dogmenstreit der Ökonomen. http://www.faz.net/s/RubB8DFB31915A443D98590B0D538FC0BEC/Tpl~Ecommon~SThemenseite.html

4 Gruner, S. 2010. Software Engineering between Technics and Science – Recent Discussions about the Foundations and the Scientificness of a Rising Discipline. *Journal for General Philosophy of Science*, Vol. 41, No. 1, pp. 237-260, Springer Verlag.

This is because some discovery D, made with the help of some method M, might "backfire" on the very applicability conditions of M, which must then be seen in the new light of D, which was not available before the actual application of M. Long before the notorious polemic by Paul Feyerabend against method[5], this was already seen very clearly by nobody less than Martin Heidegger, who wrote as long ago as 1927 (here my translation from the German original): "Especially when a method is genuine, i.e. when it truly enables access to the objects, the progress made on the grounds of that method (...) will necessarily lead to its outdatedness"[6].

In my experience, many postgraduate students are far too obsessed with their so-called "methodology chapter" for their dissertation in the context of some particular school of thought which stipulates their so-called "research paradigm". Following Thomas Kuhn strictly, however, we should keep in mind that we cannot simply choose between research "paradigms" in the way we can choose between tea or coffee for breakfast: new paradigms emerge from crises, and the emergences of crises are not fully under our voluntary control. If we can only make sure, following Heidegger, that our methods are "genuine" in the sense that they really provide "access to the objects", then we no longer need to worry too much about research paradigms and methodology chapters.

[5] Feyerabend, P. 1975. *Against Method*. 3rd edition. Verso Publ.
[6] Heidegger, M. 1975. *Die Grundprobleme der Phänomenologie*. Lecture at the University of Marburg, 1927. Frankfurt am Main: Vittorio Klostermann.

Dr Stefan Gruner *lectures at the University of Pretoria's Department of Computer Science. Beyond his technical topics of teaching and research, he is also interested in the philosophy, ethics and the history of science and technology. In addition to his degrees in computer science and software engineering, Stefan Gruner completed his master's degree in philosophy in 2010 with a thesis on Hegel's early metaphysics of nature.*

Extraordinary professor receives OBE Award

Prof Paul Sturges, an extraordinary professor in the Department of Information Science, has received an OBE (Officer of the Order of the British Empire) in the Queen's Birthday Honours list of 2010.

Prof Sturges was the Chair of the Committee on Free Access to Information and Freedom of Expression (FAIFE) of the International Federation of Library Associations and Institutions (IFLA) from 2003 to 2009. He has been involved in international librarianship for many years, and has contributed a tremendous amount through his work in the area of freedom of access to information and freedom of expression.

His work has concentrated on the value of access to information from the earliest development of human cognition through to the creation of fair and decent societies.

Particular highlights in his career include leading a project funded by the USA Department of Museums, Libraries and Archives on privacy in the digital library environment from 2000 to 2002, and authoring guidelines for public Internet access facilities on behalf of the Council of Europe from 1997 to 2001.

In addition to being Professor Extraordinary at the University of Pretoria, he is also Professor Emeritus at the University of Loughborough in the United Kingdom. He has been deeply involved with projects on African library and information-related issues since 1984.

Software testing in a small company

by Johan van Zyl

Let me begin by setting the record straight: I am not a tester and have never received any systematic training on testing. Thus, you might be asking yourself: how and why has this guy conducted a project on software testing? In this article, I will attempt to explain how I came about software testing, and I will make some interesting revelations about software testing in small companies, not only in South Africa, but around the world.

As part of my master's degree in information technology (M.IT), I had to do a research project. My fellow students and I were given free reins to choose any topic that interested us. I found this to be more difficult than choosing from a predetermined list of topics, but I was determined to research something that was relevant to my daily work.

In his book *Outliers – The Story of Success*, Malcolm Gladwell[1] states that it takes about 10 000 hours of practice to become an expert in something. Apparently, even Mozart's first works were not that great, and it was only after he reached this magical number of hours that his true genius came to light. I work for a small consulting and development company in South Africa, which focuses on integration and custom software development. I shall call it Company X.

One thing that always bothered me about Company X was the poor quality of the software that was produced. It seemed to me as if customers were never really satisfied with the product they received. You might think that many other factors, apart from testing, influenced that, and you would be right. The company uses the Waterfall Model because the management has not bought into the whole idea of agile development methods. Projects are late, over budget and of a questionable quality.

This led me and my project supervisor to believe that we could make a positive change by assessing the current testing process, or rather the lack of a suitable process, and then recommending an improved software testing process on the basis of these findings. My aim was to help Company X to establish a reasonable testing process based on well-known "best practices" and principles from scientific software engineering literature.

1 Gladwell, M. 2008. *Outliers – The Story of Success*. Little Brown and Company.

Small software companies (SSCs) with between one and 50 employees face many challenges in their pursuit of creating quality software. The first challenge is that they do not believe that the same processes and methods used by large software companies are applicable to them. Possible reasons for not adopting these methods are cost, lack of resources, time and complexity. The second challenge facing small software companies is that their processes and organisational structures are informal and often lead to a chaotic environment. This can be attributed to the fact that small companies must focus on time-to-market to survive and often neglect the more resource-intensive formal processes. The third challenge is a lack of skills and experience. Small software companies can often not afford to employ experienced software developers. The fourth challenge is that despite the many software process improvement (SPI) programs out there, such as CMM, CMMI and ISO/IEC15504, small software companies are either not aware of them or the software engineering practices implemented by these SPI programs are not focused on the needs and problems facing small companies.

You might think that these challenges are faced only by the local software market, but the literature suggests otherwise. A study conducted on the German software industry indicated that only 5% of all German software houses had a CMM maturity level of two or higher[2]. The other 95% had a CMM level of one.

My first goal was to get to know the testing process better. I wanted to understand how the software developers felt about testing, what they knew about software testing, and how the company perceived software

2 Broy, M. & Rombach, D. 2002. Software Engineering – Wurzeln, Stand und Perspektiven. *Informatik Spektrum*, Vol. 25, No.6, pp. 438-451, Springer Verlag.

testing. The answers to these questions were provided by way of a questionnaire, which formed the basis for further investigation. Once that was accomplished, my second goal was to use the abundance of software engineering literature available and provide a basic testing process[3].

Concrete problems in Company X

The first step in reaching these goals was to determine the problem areas in and around the testing process at Company X. These problems are by no means a South African phenomenon, but can be seen in many small software companies around the world.

The first problem was the lack of software testing knowledge. All the developers employed by Company X are university graduates. These developers were all employed without industry experience. I found that 75% of the developers did not know how to write a unit test. Software testing is currently not an individual module in the computer science or informatics curricula at many universities or technical colleges. Moreover, the management of the company did not provide the developers with an internal test training programme or external training opportunities. This led to projects that served as a training ground for these developers to build their skills. In turn, this resulted in missed deadlines and software fraught with defects. This is not a sustainable business model, as frustrated and unsatisfied customers will not return for future products. Furthermore, developers did not use any testing tools or frameworks such as Xunit, mainly because they did not know enough about testing and its importance in creating software of a high quality.

The last problem identified with regard to the knowledge and skills of the software developers was that they only performed dynamic testing[4], that is, testing that involves executable code. As is now known, static testing is just as important to detect defects early in the software process. This can be achieved by having regular code reviews, as well as reviewing the quality of requirements and design specifications.

The second part of my questionnaire was meant to yield some insight into the perceived commitment of the company towards testing. I wanted to determine how serious Company X was about providing the quality they promised in their mission statement. Here I quickly ascertained that the developers did not know what was expected of them in terms of testing. Typically, a company-wide testing policy will provide the employees with high-level testing objectives and principles that can be expanded further in a testing strategy per project. The testing strategy typically outlines the different testing levels, such as unit, integration, system and user-acceptance testing, as well as the activities to be performed at the different levels. There was also a lack of test documentation standards or templates that could be used during projects, such as testing plans.

Another problem that was identified was the lack of proper testing environments. Limited hardware was available and developers mainly tested the programs on their notebooks using virtual machines.

The main issue that this presented was that the production environment could never be properly replicated in a testing environment. This could lead to nasty surprises when it came to deployment during the project.

The current testing process in Company X is depicted in Figure 1. I used the software process engineering metamodel (SPEM) notation[5]. The workflow depicted in Figure 1 begins with the requirement specifications. Its work product serves as input into the implementation of features. A developer would take a requirement and implement it. Once it has been implemented, the developer would run the code to verify that the requirement is met. Should a defect exist in the code, the developer would attempt to fix the defect and run the code again. This code-and-fix approach would continue until all the features had been implemented and no apparent defects existed. The code would be packaged and released to the customer, who would often perform the most rigorous testing.

Test process improvement models

The test maturity model integration (TMMi) and the critical testing processes (CTP) are test process improvement models selected as the baseline for the newly suggested test process. The TMMi Foundation[6], a non-profit organisation created by test industry experts, developed the TMMi. The reason for choosing the TMMi is that it is fast gaining recognition as an industry standard, as was set out by its developers. It is based on the CMMi and the test maturity model (TMM). The CTP was developed by Rex Black[7] and was born out of 20 years' experience in the software testing industry. The CTP model contains 12 so-called "critical processes" that can be applied in any software organisation. The processes are presented as "lightweight checklists" and not as bureaucratic regulations.

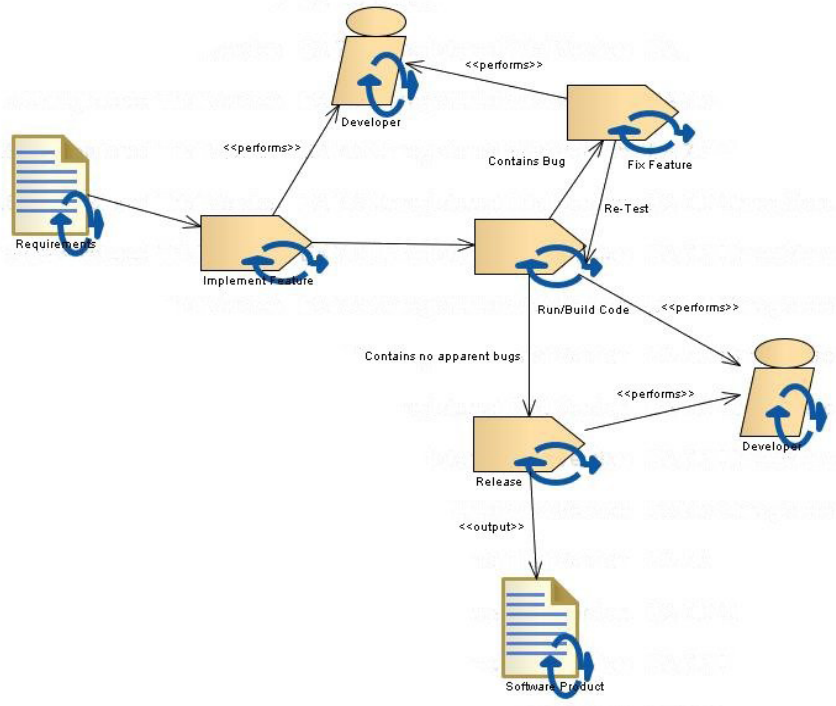
3 Van Zyl, J.M. 2010. Software Testing in a Small Company. Technical Report, University of Pretoria. http://ssfm.cs.up.ac.za/TR-JvZ-2010.pdf

4 ISTQB Standard Glossary of Terms used in Software Testing: International Software Qualifications. Board Report, v2.0, 2007, http://www.istqb.org/downloads/glossary-1.1.pdf

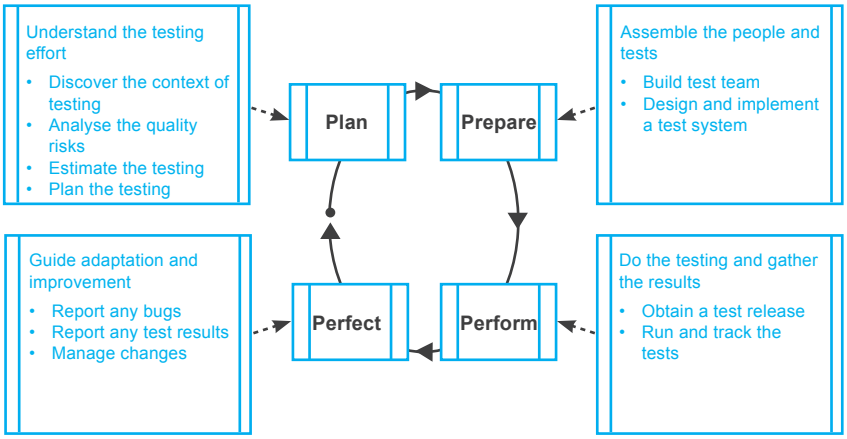
5 SPEM: Software Process Engineering Metamodel, volume 2; Object Management Group, 2008, http://www.omg.org/cgi-bin/doc?formal/08-04-01.pdf

6 TMMi Foundation: Test Maturity Model Integration (TMMi), Version 2, http://www.tmmifoundation.org/html/tmmiref.html

7 Black, R. 2004. *Critical testing processes – plan, prepare, perform, perfect*. Addison Wesley Longman Publ.



1. The current testing process in Company X.



2. Rex Black's critical testing processes.

Critical testing processes

The CTP comprises four phases. The first phase is concerned with planning the test effort. This includes a quality risk analysis, estimating the test effort and developing a plan for the test project. The deliverable of this phase is a test plan. The Prepare Phase commences upon completion of the Plan Phase. This phase includes the building of a test team, which either means employing new testers or training existing employees. According to Black, "only a team composed of qualified test professionals can succeed with the critical testing processes."

As you may have noticed, Company X does not employ a single dedicated tester. All test-related activities are performed by the software developers. The Prepare Phase is also concerned with building a test system that includes the creation of test suites to cover the risks identified in the Plan Phase, selecting the appropriate testing techniques based on the test conditions, and creating the test environment. The third phase of the CTP is the Perform Phase. The purpose of this phase is to execute the test cases developed and to record the test results. The final phase of the CTP is the Perfect Phase. The purpose of this phase is to adapt and improve the test process. This phase includes the bug reporting process, communication of the test results to relevant stakeholders, and the refinement of the applicable test process itself.

Test maturity model integration

The TMMi is a "heavyweight" model (compared to the more agile or "lightweight" CTP in which processes can be implemented as needed). It is structured more strongly and is very comprehensive. It follows the same staged approach as its CMMi uncle.

There are five levels of maturity, each consisting of different process areas. These process areas are made up of specific and generic goals that consist of specific and generic practices. The practices in each process area must be implemented before the maturity at that level can be attained. I only focused on TMMi levels two and three, as it can take up to two years to reach a level two maturity from the lowest level one.

These two levels include process areas such as test planning, test policy and strategy, test monitoring and control, test design and execution, and test organisation. Clear guidelines are provided on what is expected in each process area. Company X is currently at a TMMi level one. At this level, the test process is chaotic and undefined. There is no difference between testing and debugging.

Testing is mostly performed in an ad hoc manner after coding has been completed. I was shocked to see the similarities between the TMMi's description of a level one company and Company X. My goal was to elevate it to at least a level two maturity.

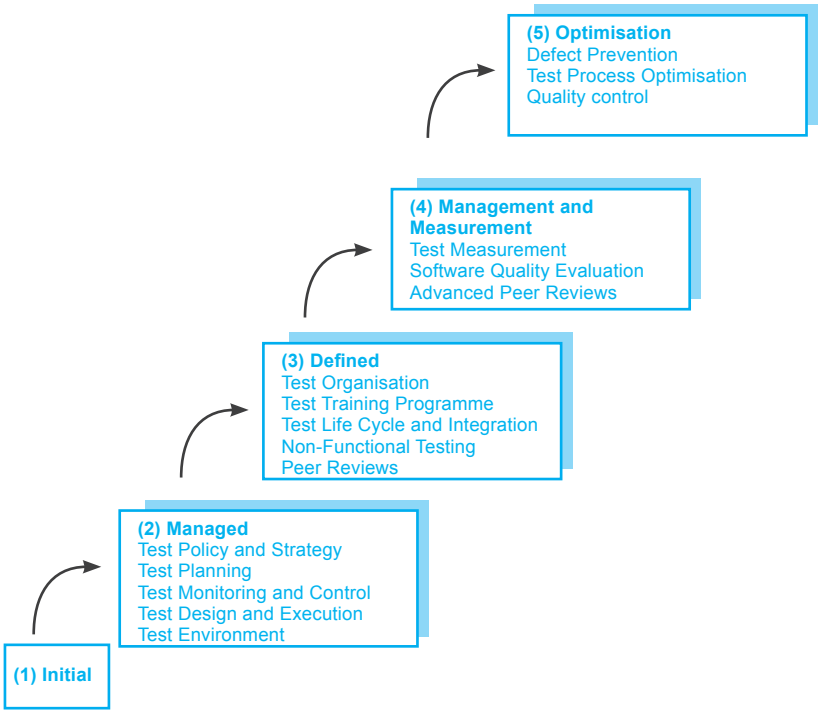
Based on the suggestions found in the literature and fruitful discussions with test industry experts, I devised a basic test process for Company X. This high-level overview of my suggestions improved the test process.

Improved test process

As my objective was to improve only the test process and not the entire software development process, I opted to incorporate the V-model[8] into the new test process for Company X. The V-model of software testing suits the Waterfall Model of software development and can be integrated without disrupting the core of the workflow of the entire development process. The V-model also allows for the early integration of the test activities into the software development process. The likeness of the new test process for Company X to the abstract V-model can be seen in Figure 4.

This diagram is also shown in SPEM notation and deserves further explanation. The icons that resemble envelopes represent the deliverables at different stages of the process. The icon that resembles a paper document at the top left is the test strategy, which serves as input to the test process. The left leg of the V consists of the software development phases, coupled with the process areas from the TMMi. It is clear that the Test Planning Phase follows the Requirement Phase and that a master test plan is produced as a deliverable of this phase.

8 Forsberg, K. & Mooz, H. 1998. System Engineering for Faster, Cheaper, Better. Technical Report, Center of Systems Management. Available online via Citeseer and Google Docs.



3. Rex Black's TMMi maturity levels.

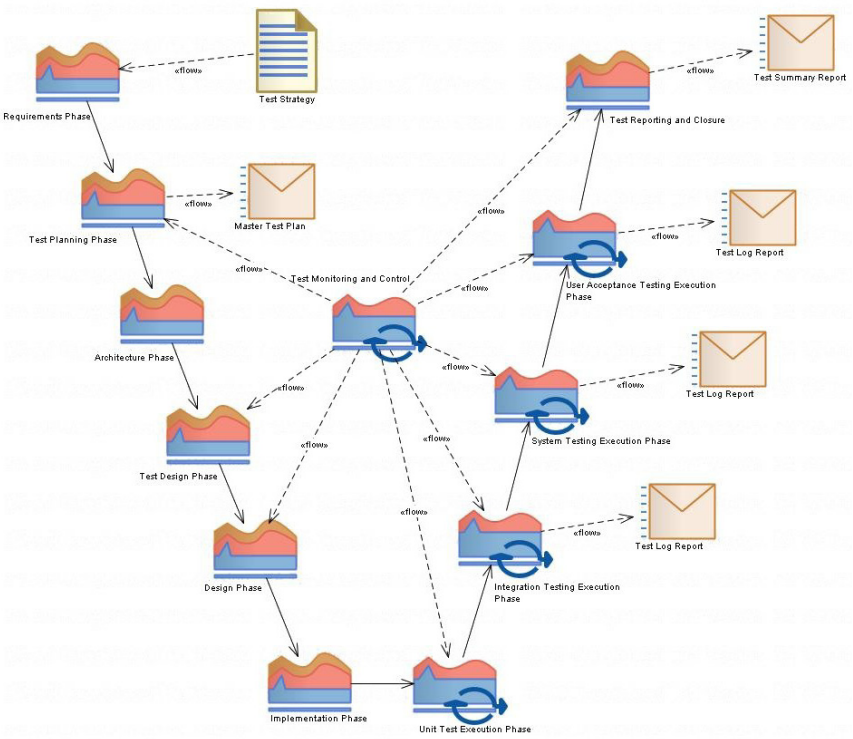
Test design is performed after the Architecture Phase. The whole process is continuously monitored and controlled, as can be seen from the icon in the centre of the process model. This is the monitoring and control process area adapted from the TMMi recommendations. The aim of this process area is to measure the test process with the use of metrics such as code coverage or the number of open defects. The reviewing of documentation and program code also forms part of this phase and helps to ensure that quality is achieved at the outset of the project.

The test execution phases (also adapted from TMMi) follow the Implementation Phase of the software development process. This includes the normal testing phases from the V-model (unit, integration, system and user-acceptance testing). Each phase is concluded with the creation of a test log to decide whether the entry and exit criteria of the respective levels have been met, and to track the progress of the entire test process.

The process is concluded with the test reporting and closure process area, where a test summary report is distributed to all stakeholders, the test environment is backed up for possible future use, and a test project "post-mortem" is conducted to determine where the process diverged from the test plan and how to improve the test process during the next project.

Looking back at this research project, I would have liked to have had a more agile process. This was not possible due to the current Waterfall process being followed in Company X. I can happily report that an agile approach is now being implemented, which will emphasise test-driven development (TDD). However, a recent paper[9] published on the benefits of TDD reported some remarkable results. It was found that TDD improved the internal code quality in some cases, but increased unwanted code complexity in others.

9 Siniaalto, M. & Abrahamsson, P. (2008). Does Test-Driven Development improve the Program Code? Alarming Results from a Comparative Case Study. Lecture Notes in Computer Science, Vol. 5082, pp. 143-156, Springer Verlag.



→ *4. Improved test process for Company X.*

The benefits of TDD were not as self-evident as previously expected and the ultimate verdict is still out.
I believe that there must be stronger collaboration between industry and tertiary institutions to deliver the right skills needed to the local IT market.
It came as a surprise to find that small companies play a big role in the global software economy, but many of them suffer from problems similar to those experienced by Company X.

Acknowledgements

This contribution is a slightly modified reprint of an article that appeared in the *Test Focus*, edited by Wayne Mallinson. Written permission was kindly given by the magazine, which is gratefully acknowledged.

I would also like to thank the people from the Special Interest Group in Software Testing (SIGiST) of the Computer Society of South Africa (CSSA) and the Johannesburg Centre for Software Engineering (JCSE) for the opportunity to present my findings at one of their public seminars in Johannesburg.A further thank you to my supervisor at the University of Pretoria, Stefan Gruner, for his support during my M.IT dissertation project.

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Last, but not least, he is enrolled for PhD studies in computer science (software engineering) at the University of Pretoria.

Advanced computing with cellular automata

by Andy Yang, Jamie Hirst, Pedro de Souza, Herah Khan and Andrew Shaw

Software development in today's competitive world is about more than just writing ("coding") a computer program. Software development is, however, a complex process that involves the capturing of detailed specifications and documentation, cooperating efficiently in task groups, and consulting with the client, thereby gaining an understanding of what the client expects, and fulfilling the client's requirements with a stable, high-quality product.

Students in the University of Pretoria's Department of Computer Science do a third-year module on software engineering, which gives them an opportunity to learn about all those skills and many more. This course also requires students to complete a practical year project, which incorporates and assesses the software development skills. One of the students' projects involved the design and programming of a cellular automata simulator.

Cellular automata

A cellular automaton (CA) is a regular grid of cells that form a "world". The grid has finite dimensions and each of its cells has its own internal state.

The project group was given the opportunity to work on a software simulator for cellular automata applications. The system made provision for triangular, rectangular and hexagonal worlds. Their software allowed the user to easily enter the local transformation rules for such worlds, to accurately simulate the desired phenomena, and to visualise the worlds in either two-dimensional or three-dimensional graphics, thus bringing a simulation to "life" in an aesthetically astonishing manner.

Internal states

Cellular automaton cells represent a world and each has a particular internal state. In a similar way, the cells in a cellular automaton also have internal states that can change over time while the automaton is active. In their software system, the students used integer numbers to represent those internal states. This provided the user with a very large number of possible cell states for world simulations, and allowed for very complex and feature-rich worlds in their cellular automata simulation environment.

Value ranges

The simulation of a cellular automaton on "raw data" can often look complex and confusing. However, by allowing the user to associate intuitive colours with ranges of internal state values, the software makes such simulations more meaningful, understandable, sensible and comprehensive to the user. In the students' software system, all value ranges are entered in a manner that is familiar to mathematics students, for example, $2<x<7$ is entered as (2;7), whereas $2<=x<7$ is entered as [2;7). The software system even supports the negative infinity value, which is represented as NEGINF, as well as the positive infinity value, which is represented as POSINF.

In order to assist the user in choosing a colour for a specific numeric range of states, the students programmed a panel, shown in Figure 1, which allows the user to slide the bars when changing the RGB colour values. Thus, the user is able to easily select the appropriate colour he or she desires, and the program automatically converts the RGB values to the popular hash colour schemes used in HTML when the user saves the chosen settings.

Transformation rules

The beauty of a cellular automaton and its ability to dynamically model so many different phenomena lie in its transition rule system. This rule system consists of a finite set of rather simple rules that are applied at many places simultaneously to advance a cellular world to its next configuration. In this way, one can evolve a cellular world.

A rule is typically generic in the sense that it applies to a set of cells, not just to one particular cell, and it consists of three main parts: the current values/states of a cell's

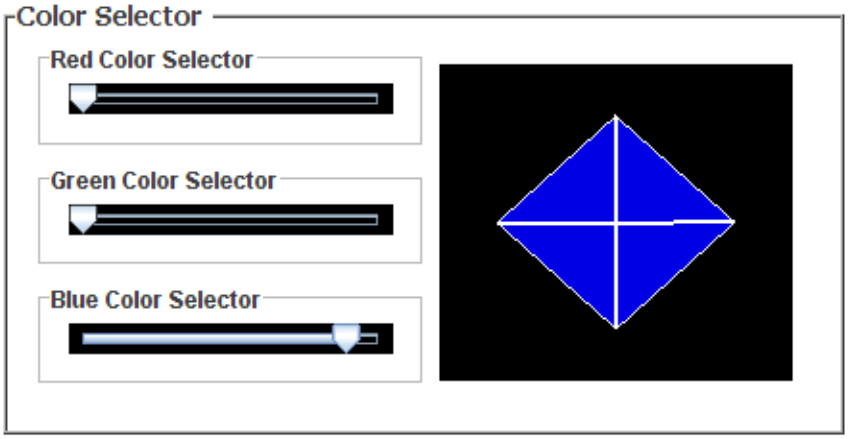
neighbours (application precondition), the current value/state of the cell itself (application precondition) and the value/state the cell will change to, should the two previous requirements be met for a rule (application postcondition). Hence, a rule will only be applied if the first two requirements hold, and the cell that matches the two requirements will be "evolved" to the new state, which is specified in the application postcondition mentioned above (everywhere, and simultaneously, in the entire cellular automaton).

In many situations, only certain values or states are of importance for a rule. To allow a rule to ignore the values or states of neighbours that are not of importance, the group made provision for a special symbol in the rule entering, namely the "*", which has the meaning of "any" or "accept all" (see Figure 2). It enables the user to focus only on those cell states or values that really matter (rather than the ones that do not). This "any" symbol, which was adopted from the theory of typed graph transformation systems and generalised cellular automata, allows the values or states specified in the first two application preconditions mentioned above.

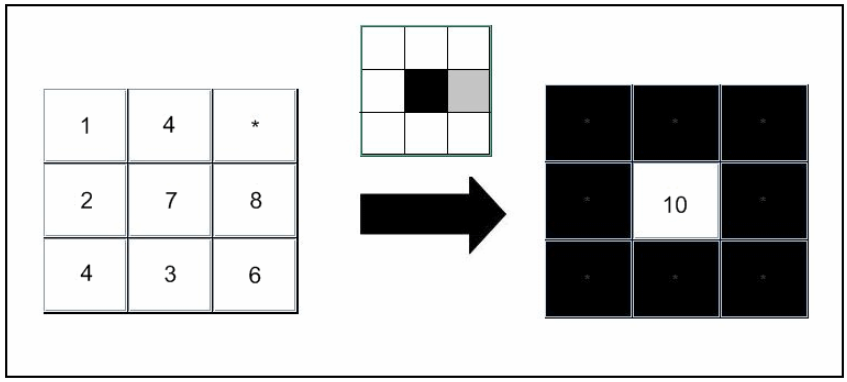
Multiprocessing

Multiprocessing is one of the most useful and complex capabilities of the latest computers. It can make a program far more efficient and helps to increase the speed at which a simulation takes place. Consequently, the students decided to implement their software system in such a way that it is suitable for multiprocessing.

Their software allows a user to choose between one, two, four and eight processors (CPUs). Consequently, it divides the rows (of a world) into the same number of segments and creates a processing thread for each segment. Each thread is then responsible for displaying and "evolving" the segment of cells allocated to it (see Figure 3). When this feature is utilised, the world in the students' simulations can evolve at a reasonably rapid pace.



→ *1. RGB changer.*



→ *2. Rule-entering panel.*

Simulation

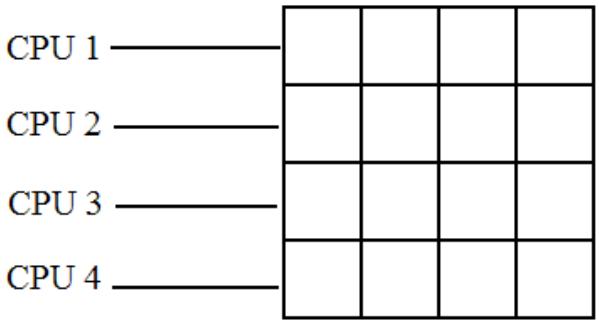
The graphical display of any software-based simulation is very important to the user, as it influences what the user can learn from performing this simulation. It is often desirable to view a simulation in a specific manner, from a particular perspective, height, angle, colour scheme or distance. The software tool developed by the students caters for this by allowing a user two-dimensional (2-D) and three-dimensional (3-D) modes.

Two-dimensional mode

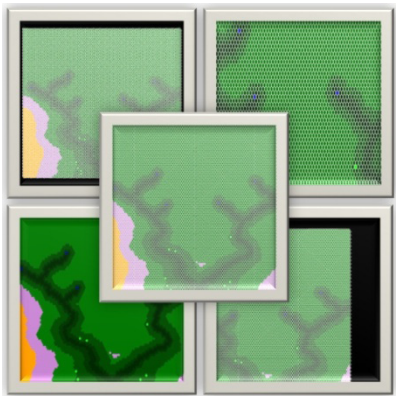
This interface mode allows the user to select multiple cells and easily adjust their values. Some phenomena are easier to view in a 2-D manner and such functionality is also provided in this view. The software allows users to edit and view the simulation however they want: zoom (in and out) and translate (up, down, left and right). See Figure 4.

Three-dimensional mode

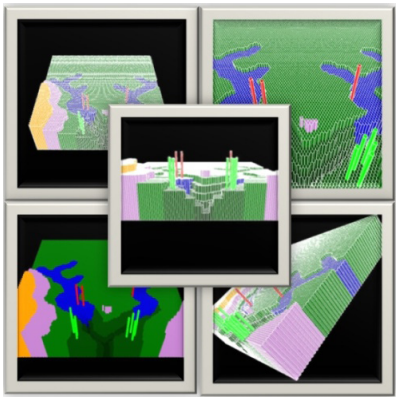
This interface mode is designed to run a simulation. It allows the user to rotate a world (up, down, left and right), zoom (in and out) and enables scaling, thus allowing the user to easily find the perfect way to view his or her simulation. See Figure 5.



→ *3. Division of world into four segments for four CPUs.*



→ *4. Two-dimensional viewing feature.*



→ *5. Three-dimensional viewing feature.*

Practical applications

When people think of cellular automata, they often think of Conway's *Game of Life*. This relates to physical phenomena such as algae growth or the spreading of a virus. However, since cellular automata are known to be Turing-complete, their applicability is constrained only by the theoretical limits of Turing-computability. Cellular automata can be thought of as an advanced form of a programming language, whereby the applications for which it can be used are mainly limited by the capability of the programmer to express his or her ideas.

Some interesting applications are possible in computer graphics nowadays. These are especially apparent in the field of computer games, where images need to be rendered at an efficient speed. In this particular field, a large amount of program code is usually required to determine the colours of particular pixels (in terms of textures, normals and lighting). Imagine being able to program an entire world while only worrying about a few simple sections and leaving the rest to the system. This will drastically reduce the amount of program code to be written by the programmer, whereby many mistakes will be avoided, as the underlying "engine" handles the rest, for example, choosing the correct materials, lighting and perhaps even the textures of a graphical scenario. See Figure 6.

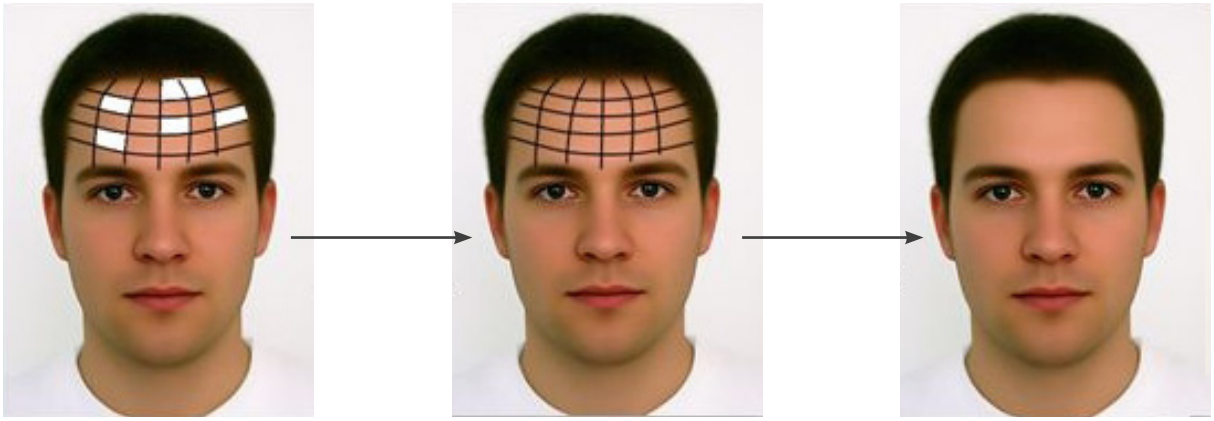
In the field of security, cellular automata can offer biometric authentication in an easy and simple manner. This can be done, for example, by dividing the eye or fingerprint into a grid of cells (world) and determining the relationship of each cell to its neighbours. A neural network could also be trained in this manner, through supervised learning. Afterwards, it could be used for a strong form of authentication. See Figure 7.

The project group's aim was to show how powerful and diversely usable a cellular automaton can be by illustrating this in a manner that non-experts would also understand and be able to appreciate. In order to do so, three main simulations were developed.

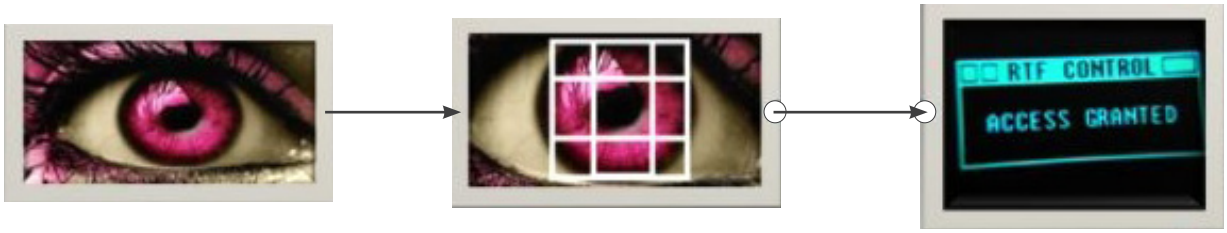
During the FIFA 2010 World Cup, many companies were looking for new and innovative ways to reach as many tourists as possible. To this end, the student project team presented a cellular automaton application, which offered any organisation the visual facility to reach new users or viewers in a new, intriguing and exciting manner. This would not only draw attention, but also have a lasting effect on all who see it. Think of a 3-D image in the middle of the football stadium that represents the flags of the countries of the teams that are playing, or a banner that forms new patterns for as long as one looks at it (see Figure 8).

In South Africa, many accommodation facilities are built sporadically, without much preceding research about their location. This is usually the case in rural areas and is often due to a lack of funding for such building projects. The aim of the group here was to show how a cellular automaton application could be used to analyse flood problems in landscapes (see Figure 9).

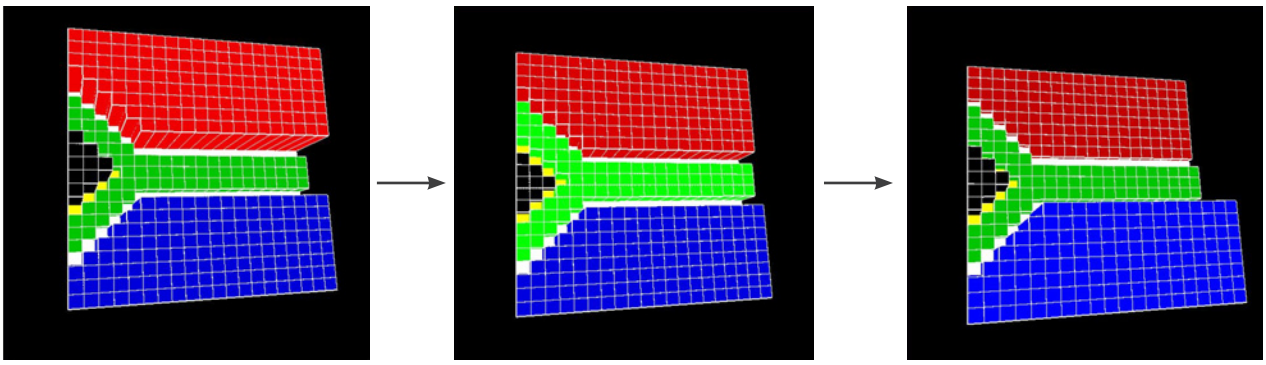
In many secondary schools in South Africa, learners are not sufficiently interested in pursuing scientific or computer science-related studies, perhaps due to their perceived difficulty of these subjects or a lack of prior exposure.



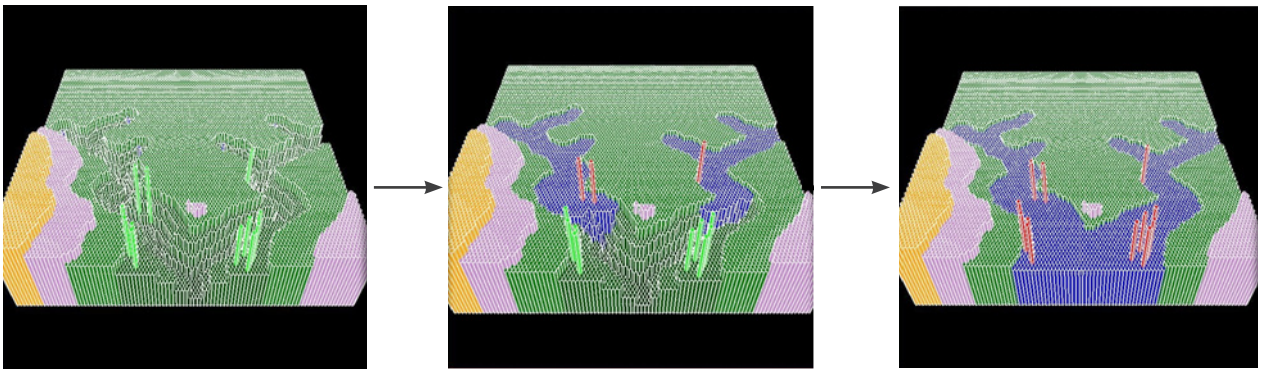
→ 6. Graphics simulation potential.



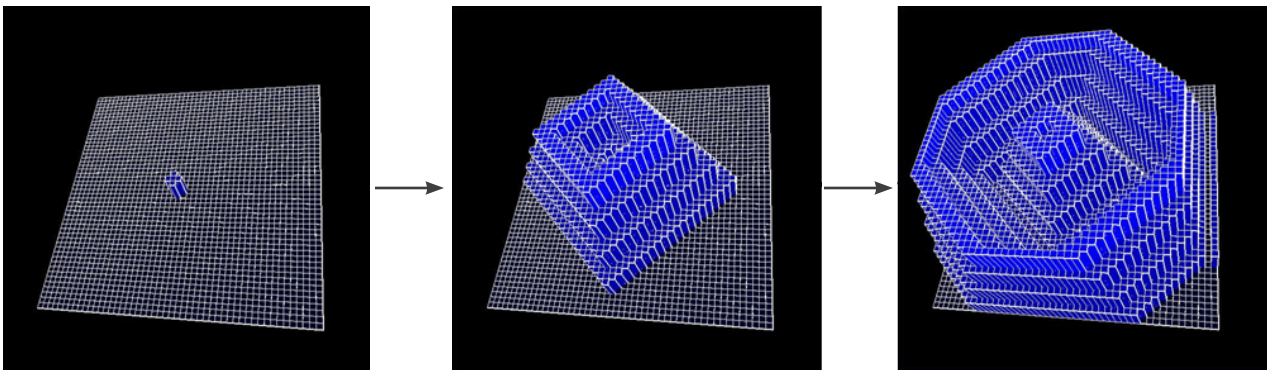
→ 7. Biometric authentication demonstration.



→ 8. Dynamic South African flag simulation (swaying).



→ 9. Flood plane simulation.



→ *10. Simulation of a ripple effect on a liquid surface.*

→ *11. Edge detection simulation.*

In this context, an intuitive cellular automaton visualisation can be used for educational purposes. The students designed a simulation of a ripple effect on a liquid surface (see Figure 10). This simulation allows a user to choose a place to make a drop and to see the wave impact it would have on the liquid surface. Similar simulations can be designed to show chemical bonding, chemical reactions or other phenomena that learners find hard to understand.

Another simulation is capable of discovering edges in digital images. This can be used for feature analysis, artificial intelligence and biometric authentication. For this cellular automaton application, the students developed a cellular automaton program that takes a photograph from a digital camera and converts it into a cellular automaton grid (world) (see Figure 11).

Acknowledgements

The student group would like to thank Morkel Theunissen for teaching them about design and development of complex software systems, Rushka Venter for all her help throughout the year, Rudi Penzhorn for his continuous guidance, support and assistance throughout this project, Retief Fourie for some additional interesting ideas, and last, but not least, Stefan Gruner for his scientific advice about the theory of cellular automata.

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The following students were involved in this project: ***Andy Yang***, ***Jamie Hirst***, ***Pedro de Souza***, ***Herah Khan*** *and* ***Andrew Shaw***. *Their software system won two prizes: the best engineered software engineering project of the year at third-year level for software engineering methodology and the best overall project of the year for software product quality.*

Evolving into centres of excellence

by Dr Helena Barnard

An entry-level car in the USA comes standard with air-conditioning, clock radio, power steering and a 1600 engine, not to mention a high standard of reliability! Consumers in advanced countries have a lot of money and many options to choose from, and they are very demanding.

The initial products of the automaker Hyundai were simply not acceptable to the USA market. The USA operations bled money. They only survived because of nearly a decade's worth of bankrolling by the South Korean government. Today, Hyundai is profitable, but it still serves the low end of the USA auto market. To overcome lingering perceptions of poor quality, vehicles are sold with a ten-year comprehensive warranty.

However, the USA experience has been invaluable. Over time, the combination of sophisticated customers, well-developed supplier networks, access to skilled researchers, engineers and technicians and a lot of hard work by Hyundai has resulted in a high-quality product. This has translated into a much stronger position for Hyundai, not only in the USA, but, perhaps more importantly, in their core markets, leading developing countries like India, China and South Africa. In other words, Hyundai's operations in the USA have become a centre of excellence that can be leveraged by the entire firm worldwide.

The experience of Hyundai in the USA is potentially relevant to firms from South Africa. Operations in the developed world can serve a crucial purpose as centres of excellence for firms from developing countries. To better understand such centres of excellence, I looked at the factors that affect the sharing of expertise between the subsidiary in the developed world (focusing on the USA) and its parent at home. My research suggests that when firms expand into more developed countries, they start a long and demanding, but potentially very rewarding, learning process.

It will no doubt frustrate managers – who thrive on making things happen – that many of the elements of the learning process cannot be hastened. For example, age and size matter. The longer a firm operates in the USA and the larger the subsidiary becomes, the greater the steady flow of knowledge to headquarters. In fact, when a firm first expands to the developed world, it is counterproductive to try to force the subsidiary to formally share its knowledge with the parent company. Initially, the subsidiary needs all available resources to simply survive in the more competitive market.

→ *Firms are more likely to succeed if they first develop international experience.*

At a strategic level, the match between the home and host country is important. If the institutions in the home and host countries are very different, it is hard to apply the lessons learnt abroad. Thus, Sasol is likely to find it easier to benefit from its presence in the USA than the Saudi Basic Industries Corporation (SABIC), one of the world's leading manufacturers of chemicals, fertilizers, plastics and metals in Saudi Arabia. Given our long-shared history, South African firms are likely to find the United Kingdom a more accessible host country than the USA.

In terms of industry, developing country firms paradoxically benefit more the less competitive the industry is in the developed host country. Why? The developed world benefits from a well-developed education system, solid technological infrastructure and a sophisticated customer base, and even its "less" competitive industries can give South African firms a run for their money. The globally leading industries of the developed world are simply so far ahead that they can crush most firms from developing countries. Think of a gifted matriculant being thrown into an MBA class. Although the student has the potential to eventually make a success of the MBA, the necessary background knowledge is still lacking.

The learning process in the developed world is not cheap. Business scholars talk about the "liability of foreignness". There are significant start-up costs, pressure on profit margins and the ever-present issue of currency volatility. Another important but often overlooked cost factor is the fact that firms abroad have few contacts in business. While we are on our home turf, we constantly use our connections to make things happen. Finding out which deals are really happening or how the competition is interpreting a new law is as easy as calling an old university buddy.

Lacking these contacts, firms abroad must rely on transactions, rather than relationships, to get access to knowledge. This is a heavy burden on firms; both in costs paid and in missed opportunities. Centres of excellence emerge when subsidiaries in the developed world recognise that apparently everyday transactions are, in fact, a gateway to building new relationships. They leverage their contacts with suppliers, distributors and employees to help them understand their demanding new location.

Of course, the lessons learnt by the subsidiary are only useful if they are shared with the rest of the firm. The most productive way of sharing knowledge is informally: working on projects together, engaging in joint problem-solving meetings, and even merely making regular phone calls and sending regular emails. If meaningful communication channels between the parent and subsidiary company exist, work-related insights will be shared. The single most useful action the parent can take is to assign a headquarters-based mentor to decision-makers in operations in the developed world. The subsidiary will then have a sounding board to bounce off ideas about the challenges of the demanding new market, and headquarters will have immediate insights into the lessons that are being learnt, or need to be learnt.

South Africa, China, Russia, India, Brazil – the leading developing countries of the world – are all emerging from (in most cases self-imposed) economic isolation. The internationalising firms from those countries are starting a learning process that the global leaders started a century ago. However, my research has left me optimistic about the potential of firms to benefit from expansion into more developed countries.

It is a challenge to operate in the developed world, and firms must be realistic about their financial and human resource base. Failure is a real possibility. Firms are more likely to succeed if they first develop international experience and strengthen their financial position in less demanding locations. Firms do succeed in the developed world, and when they do, their success tends to benefit the firm as a whole.

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Creativity and eureka in science and engineering

by Dr Hannes Steyn and Prof André Buys

Creativity lies at the core of all invention, innovation, entrepreneurship and leadership. At the heart of the creative process, in turn, lies the eureka experience: that precious and joyful event of inspired breakthrough insight.

An axiomatic principle of science and engineering is that one can only solve a problem once one understands its context and content really well, and one can only complete a design successfully once one knows and understands the requirements and the underlying technologies. The same is, of course, true for creativity and for eureka.

The roots of creativity

The root of the creativity of scientists and engineers is found in the human evolutionary past: in the creative struggle for survival and growth. In this sense, creativity has become the capacity to understand and employ the laws of nature in the struggle for survival and ascendancy. Today, one might as well speak of the survival of the most creative, as well as the fittest.

The Darwinian creative urge has evolved. As humans evolved from hunter-gatherers to farmers, due to the first disruptive technological revolution (the agricultural revolution), social structures changed perforce as people banded together to protect crops and herds against marauders. The agricultural revolution, therefore, not only introduced new technology, but also introduced a new level of competition and conflict, namely, the clan.

Different techno-historians describe the structure of technology revolutions and their attendant societal developments in different ways. The common theme is, however, the wave-like structure, and revolutionary and compressed nature. The evolution of human creativity in response to technology, struggle, competition and conflict is illustrated in Table 1.

Table 1: The evolutionary frame of creativity

Epoch	Revolution	Society	Competition
		Hunter-gatherer	Individuals
10kBC – 10kCE	Agriculture		
		Agrarian	Clans
± 1800	Industrial		
		Industrial	Nations
± 2000	Information		
		Information	Ideologies
± 2020	Biotechnology		
		Frantic?	Classes?

Human creativity does not only evolve because of the increasing complexity of technology. It also arises from the increasing complexity and intensity of competition and conflict. What is more, the succession of disruptive technological revolutions is compressed. An improvement in creativity should show a corresponding rapid exponential rise in the development of technology.

Rapid demand growth

Lest the crescendo-like technology development, as illustrated in Table 1, convey the idea that progress will carry on without limits, it must be said that the unfettered growth in global human numbers has become unsustainable. A sustainable society is a society that satisfies its resource requirements without endangering the sustainability of

→ *The human creative urge rises during adversity and conflict.*
Source: Wikimedia commons

future generations. Life on earth has become non-sustainable – the extinction rate of life forms increases, non-renewable resources decrease, natural habitat shrinks, humans no longer live in ecological harmony with their natural environment, the terror threat of weapons of mass destruction increases and the digital divide widens. In evolutionary terms, humans have, indeed, become the earth's ultimate infesting weed.

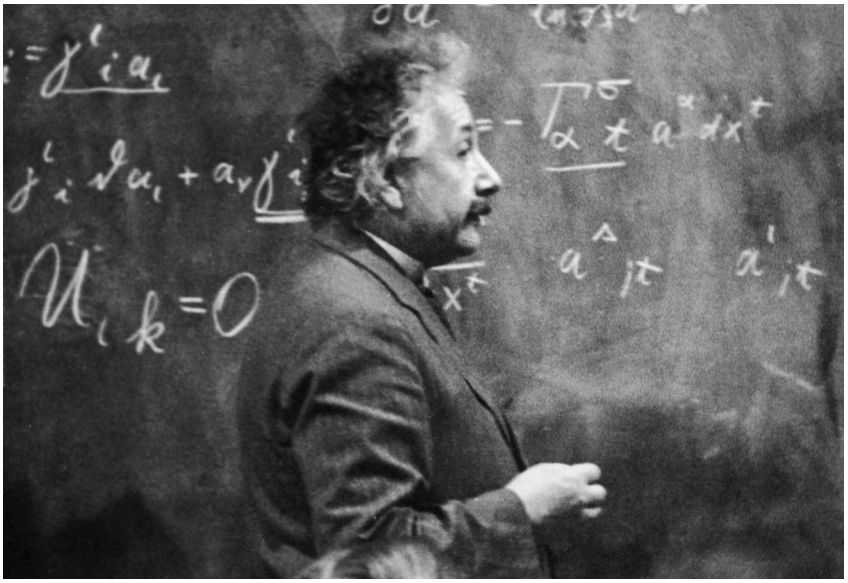
This is, of course, bad news for humanity, but is not necessarily bad news for life on earth. The earth has already experienced at least two mass extinctions (the first 245 million years ago and the second 65 million years ago) and life on earth has recovered stridently from both. The last mass extinction was caused by an asteroid impact on the Yucatán, creating an extraordinary climatic change. Millions of life forms disappeared, including the dinosaurs. The globe itself is, in fact, quite robust, and it actually belongs to the insects, which constitute the majority (72%) of all current earthly life forms. Today, signs of a third possible mass extinction are multiplying. After the third mass extinction, life will probably simply carry on, just like it did before.

Human life on the planet is converging on a crisis. This crisis may precipitate in the next decade or in the next century. Up to now, human creativity has always (at least over the last 10 000 centuries) risen to ensure the survival and growth of the human species. This time the crisis will probably not come from either space or the tectonic crust. It will be man-made and may very well trigger or accelerate another mass extinction. This time it is up to the human race to prevent or ameliorate and defer it; provided, of course, that human creativity, and hence the capacity for problem-solving, increases commensurately.

A shift in theory development

At the start of the 20th century, people interested in technology started to concern themselves with the nature of creativity. One of the first was Hermann von Helmholtz (in 1896), who identified three stages in creative technical work. He was a contemporary of that tireless innovator, Edison. Later came Karl Bühlinger (in 1907) with the isolation of the "a-ha! moment" and Henri Poincaré (in 1908) with his four-stage model of creative scientific work. These early insights were integrated by Graham Wallas (in 1926).

Jacques Hadamard used introspection to describe mathematical thought. His own thinking was largely wordless, often accompanied by images that represent the entire solution to a problem. He analysed the work of many of his peers and found the

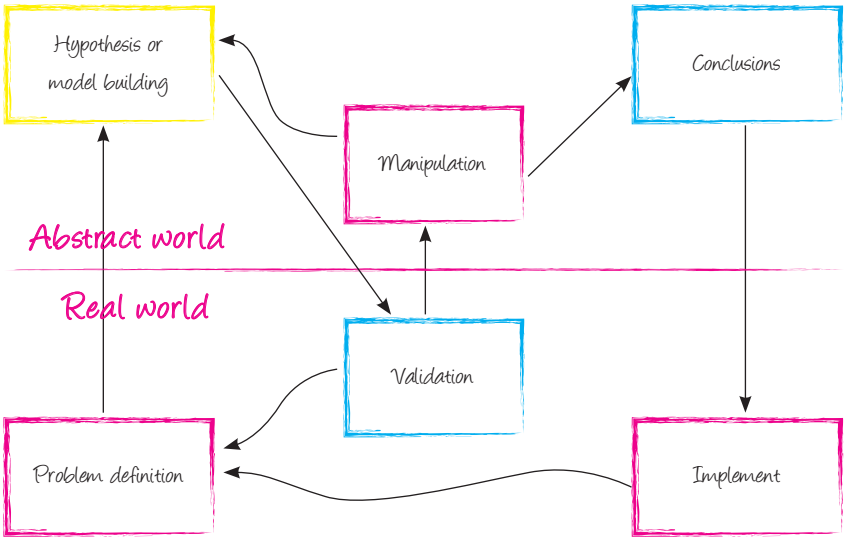


→ *Einstein was daydreaming in a chair in his patent office in Zürich when the holistic idea of the general theory of relativity suddenly dawned on him.*
Source: Wikimedia commons

same phenomenon. Einstein, for example, after years of fruitless calculations, suddenly had the solution to the general theory of relativity revealed to him in a dream, "like a giant die making an indelible impress, a huge map of the universe outlined itself in one clear vision".

The first formal analysis of the creative process from the point of view of psychology can be found in Joy Paul Guilford's 1950 address to the American Psychological Association. Guilford introduced the distinction between convergent and divergent thinking. However, others took a more pragmatic approach. Alex Osborne taught the technique of brainstorming. Genrikh Altshüller introduced his theory of inventive problem-solving and Edward De Bono has had some success since the 1960s with the ideas of lateral thinking, the "six thinking hats", etc.

Some theories suggest that creativity may be particularly susceptible to affective influence. Affective disorders, or disorders of the mood, include depression and bipolar illness. The elation (positive affect) following on breakthrough creative output is well known. Similarly well known (after the comparative work of Arnold Ludwig at the University of Kentucky) is the significant correlation between affective psychosis and creative achievement. Ellis Paul Torrance found a correlation between creativity and intelligence, beyond a threshold, in only a sample of highly intelligent people. Since 2000, authors such as Alice Flaherty and LR VanderVert have mapped the creative process on brain structure. This brief overview of inquiry into creativity displays a distinct transition over the last century from a focus on scientific creativity (Helmholtz, Poincaré, Edison, Einstein and Hadamard) during the first half of the 1900s to more general creativity during the second half of the 20th century.



→ *1. Schematic representation of the scientific method.*

The creative work of scientists and engineers

The work of scientists and engineers invariably follows the scientific method, which obeys an iterative hypothetic-deductive process and is based on the philosophical ideas of logical positivism that are best expressed by the philosophers Immanuel Kant and Ludwig Wittgenstein. The scientific method is broadly outlined in Figure 1, which can be readily understood by starting at the problem definition and following the arrows.

The curved arrows show some of the iterative review paths. Scientific knowledge propagates incrementally in concentric waves from the core of existing knowledge. The scientific method focuses on formal problem statements, as well as on measurement and experimentation. Peer review, traceability and transparency are important and so is the statistical significance of findings. Good science depends on a curious and open mind, but also on a healthy measure of scepticism.

When it comes to creativity, the procedural formats of problem-solving and design are vital, because they are based on the scientific method. And the scientific method is fundamental for technological progress. The philosopher René Descartes declared: "*Cogito ergo sum*" ("I think, therefore, I am" or "I think, therefore, I exist"). In short, without thinking, human existence is meaningless. It is creativity – that ultimate expression of intelligence – that distinguishes the human being from a cabbage or a rabbit.

In the practical sense, the scientific method culminates in the rigorous procedural formats for problem-solving, design and systems engineering. But the products, processes, services and businesses that are the usual subjects of science and engineering display life cycles. And it is this life cycle dimension that usually invokes the discipline of project management in the practical work of scientists and engineers. In project management, the design method is used over and over again in stage after life cycle stage, much like in a spiral; thus progressively creating models and specifications with

→ *The ideas of systems engineering and project management is used intensively in the defence environment, but is now also popular throughout science and engineering.*
Source: Cool toys, great pictures, USAF

increasing maturity. That is, with slow cost increase and rapid risk reduction. In this way, a mature design emerges and a cost-effective product comes to market.

A systems approach to creativity

In *The web of life*, Fritjof Capra (1996) introduces the holistic world view: a view of the world based on a new perception of reality. He calls it deep ecology. Capra stresses that the major problems of our time (pollution, climate change, runaway population growth, digital divide, decreasing biodiversity, global terrorism) cannot be understood in isolation. They are systemic and interconnected. From the systemic point of view, the only viable solutions are those that are sustainable. A sustainable society is one that satisfies its needs without diminishing the prospects of future generations.

Deep ecology and self-organisation shift the current cognition model based on informatics from cognition by symbols to cognition by connectivity; from information processing to the emergent (heuristic) properties of adaptive neural networks. The mind, thus, becomes a highly cooperative, interconnected system and the entire system acquires coherence in intricate patterns. Perception shifts from data processing to instant and ongoing neural pattern recognition. There is no doubt that the deep ecology ideas of Capra and his peers will be essential for new understanding in neuroscience and thus for creativity too. In a book by Richard Dawkings, published in 2008, Nicholas Humphrey (psychologist and evolutionist) describes the development of a model of consciousness.

He stands, observing and reflecting, at a rail. The first rail is that of the crib of a baby boy. He observes the baby thrashing around with arms flailing, hands grasping randomly and an occasional grimace flashing on his little face. He wonders what kind of an experience the boy is having. He then stands at a second rail, observing and reflecting again. This time it is the rail of the gallery in a concert hall. He looks down at the congregating orchestra. As they arrive, each player makes himself comfortable on the chair, arranges the scores on the music stand, starts to tune his instrument and plays a few sequences, softly, experimentally. For the moment each musician is playing for himself, oblivious to the cacophony arising from the rest of the orchestra, all the other musicians also tuning and experimenting with their instruments. Then, some sections try a few fleeting bars together.

But, they are all waiting for the conductor to appear, rap his baton on the podium and so bring the orchestra to order. Of course the conductor is an important figure in deciding on the repertoire, in setting the style, arranging, in leading rehearsals, in beginning and timing things. But once the orchestra plays, the conductor's role becomes mainly ceremonial, save for an encouragement here and a synchronisation there. Well, in a way, the boy is in that stage: the stage before the conductor arrives; the stage before the dawning of self-awareness. In much the same way, he finds himself surrounded by an interconnected web of sections: let's say one section of woodwinds, which we shall equate for the moment with the faculty of the senses. He has another section: let's say the strings, which we shall equate for the moment with memory. He has yet another section: let's say percussion, which we shall equate for the moment with logic or emotion, and so on. There is indeed a whole federation, as it were, of separate, independently growing mental faculties or subjectivities.

This foregoing federative model of awareness, verbalised by one of the most erudite modern exponents of neuroscience and promoted by the world's number one science writer, is probably as good as it gets, for now. Moreover, Humphrey's idea of awareness and its consequences for creativity fit neatly with the self-

organising system ideas of Capra and his peers. The Humphrey model of awareness provides a powerful holistic metaphor for creativity too. We have been searching for enhanced creativity in every nook and cranny – in IQ, in lateral thinking, in brainstorming, in thinking stereotypes, in dreaming, in doodling, in stimulation and even in madness, but our efforts have tended to specialisation and to exclusive (belief-like) recipes; to pot-luck, as it were. As so often happens in exploration, the rash analytical scalpel that we have applied to human creativity to date probably cut through tissue, nerve, vein and sinew alike, thus uncovering stump after bloody truncated stump, and missing – time after time – that beautiful systemic, grander and more pervasive whole.

Incremental theory expansion

In science and engineering, the eureka moment is usually embedded in a creative process that comprises three stages. The first stage is the incubation stage in which the problem is defined and both the quantitative and the qualitative aspects of the problem are thoroughly explored. Focused attention is often deliberately suspended to allow the subconscious access to the problem. The second stage is the eureka stage, in which the sudden breakthrough insight usually occurs under circumstances that are often unique and particular to the individual concerned. The final stage is the elaboration stage, in which the output of the eureka event is prepared for implementation. Elaboration usually entails the description of the eureka result in terms accessible to a wider circle of peers, ready for dissemination.

Without a common language and extensive use of written language, man is doomed to mediocrity. It is amazing that humans, those late-comers in the 4.6 billion-year-old evolutionary history of planet earth, were so tardy in their early development. After the discovery of writing some 5 000 years ago, things really happened at an accelerating rush. A mere 3 000 years after the advent of writing, the Roman Empire was in sway, the Christian Era had started and some prominent Egyptian, Chinese, Greek and Roman leaders recorded their philosophies, which are still taught and studied today. The importance of urbanisation and of the consequent development – 2 000 years later – of coded language (writing) led Hans Eysenck, the IQ guru, to state that "Einstein would not have prospered in an igloo, or Mozart in a kraal, or Shakespeare in a wigwam."

Young Einstein was troubled by his Bavarian high school's discipline. He later wrote that the spirit of learning and creative thought were lost in strict rote learning. Einstein was not only a keen violinist, but an avid sailor too. As a student in Bern, he often sailed on the lake. A companion of that time, Fräulein Markwalder (his landlady's daughter), noted that every time the wind died down, Einstein's notebook came out and he started writing, practically oblivious to the rest of the crew. But the moment the wind rose again, Einstein was immediately ready to sail and promptly put way his notebook.

This habit of making notes, designs, drawings and formulae, as well as keeping a journal and other manuscripts, is typical of highly creative technical people. They write, all the time. This habit is one of the reasons why we have so much on record from scientists such as Da Vinci, Newton, Poincaré, Darwin, Einstein and others. They probably did not write in anticipation of fame. They did it because it was an essential part of their trade.

That ever-present and stereotypical engineer's affectation, the Designer's Journal, which is usually a black hard-covered notebook (or electronic equivalent), is much, much more than a status symbol!

About his concurrent love for physics and music, Einstein said: "Both are born from the same source and complement each other." His oldest son remembered: "Whenever he felt that he had come to the end of the road or into some difficult situation in his work, he would take refuge in music, and that would, usually, resolve his difficulties." Einstein's sister remarked that playing music seemed to "put him in a peaceful state of mind, which facilitated his reflection." While puzzling over a physics problem, Einstein would play his violin until, suddenly, he would stand up and declare: "There, now I've got it!" A solution had suddenly appeared to him, his sister observed.

Writing (using coded speech) and playing the violin (using coded music) clearly had a major influence on the creativity of the world's most famous scientist, Albert Einstein. In this respect, it is noteworthy that Werner Heisenberg, of the uncertainty principle fame, was an accomplished pianist. But probably the most famous example of the science-and-art blend is Leonardo Da Vinci (1452–1519). Da Vinci was not only the creator of the *Mona Lisa* and *The Last Supper*. He was also a musician, a scientist, and a designer par excellence.

As you exercise your brain in logical and holistic thinking, it becomes second nature – you become mentally fit for that way of thinking. The saying (about neural hard-wiring) goes that neurons that fire together, grow together, so by simply thinking hard and often enough about a specific desirable reality, you start

The irascible Beethoven was renowned for his moroseness and disregard for authority; his handicap (deafness) was central in his creativity.

Source: Wikimedia commons

creating that reality. And, as success breeds more success, objective reality itself responds to your projection. This mechanism or control system was first called the power of positive thinking by the famous pastor, Dr Norman Vincent Peale. However, a lightweight, bubbling optimist does not convince with his or her positive, yet capricious projections. On the other hand, an optimistic visionary on the solid ground of a proud track record gets the attention every time. Such optimism and enthusiasm are infectious. This contagion is an important environmental feedback and reinforcing mechanism in the power of positive projection. By means of the positive projection of vision, the leader starts to create the reality of that vision.

Creating one's own reality by using the power of positive thinking is important for everyone, but for the leader, or inventor, innovator or entrepreneur, it is crucial. Good leaders envision a desired outcome with such clarity and such persuasive power that they rally and muster others to share it enthusiastically. In this way they mobilise and inspire the resources of a talented team, and the snow-balling momentum becomes unstoppable. They create a new reality. They are driven towards their goal by the compulsive rush of their creative energy, as if under a compelling force similar to gravity.

Edison said that genius (innovation, invention, entrepreneurship or leadership) is 1% inspiration and 99% perspiration. This remark is accurate enough and it points to the importance of the preparatory or incubation phase – the build-up of potential energy before its release. Holistically speaking, therefore, the build-up is more important (and certainly much more time-consuming) than the release.

In the theory development of this article, the various components have been verified either by anchoring them in literature or in industrial experience. In the examples of eureka moments investigated so far, the circumstances of the eureka occurrence remained similar. In some cases, they occurred under conditions of stimulation, in others without stimulation. But the circumstances always occurred at that borderline when the tug-of-war between the conscious and unconscious mind wavered in favour of the subconscious. This condition, in which inhibitions are suspended, thus allowed the (regular) space of convergent (left-brain) thinking to be invaded by divergent (right-brain) thinking.

In almost every case investigated, the onset of the eureka moment was sudden, holistic and brief. It was followed by joy and satisfaction.

In every case the eureka moment followed on a period of dedicated and persistent hard work or incubation. In most cases, there was some intentional suspension of focused attention, just as Henri Poincaré suggested. Every eureka moment was followed by verification and consolidation. This elaboration stage requires that the brilliant new insight, and perhaps even its outline implementation, be thought out logically and captured in a peer language, in a common and succinct vocabulary.

Creative productivity, particularly during the eureka event, is highly dependant on the individual's state of mind. Of course, moods can swing from melancholy to elation. In a really bad (morose and despondent) mood, a depressive patient will sometimes experience a debilitating lack of creativity and productivity. In a good (euphoric) mood, he or she will, however, be as sharp, energetic and enthusiastic as his or her genetic endowment allows. However, moderate human mood cycles are experienced by almost everyone. Some swings are diurnal, while others have a monthly or even seasonal nature. Clearly, for enhanced creativity, one needs those really positive moments.

Scientists and engineers employ an optimum blend of convergent and divergent thinking in their quest for creativity. The framework in Table 2 is useful in the preparation of eureka moments.

Table 2: Creativity paradigm

Creative output		Logic and reason	
		Beginner	Advanced
Envisioning centre	Beginner	The amateur	Unimaginative, plodding progress
	Advanced	Fantastic but impractical ideas	Invention, innovation, entrepreneurship and leadership

Adapted from Geyer (1987).

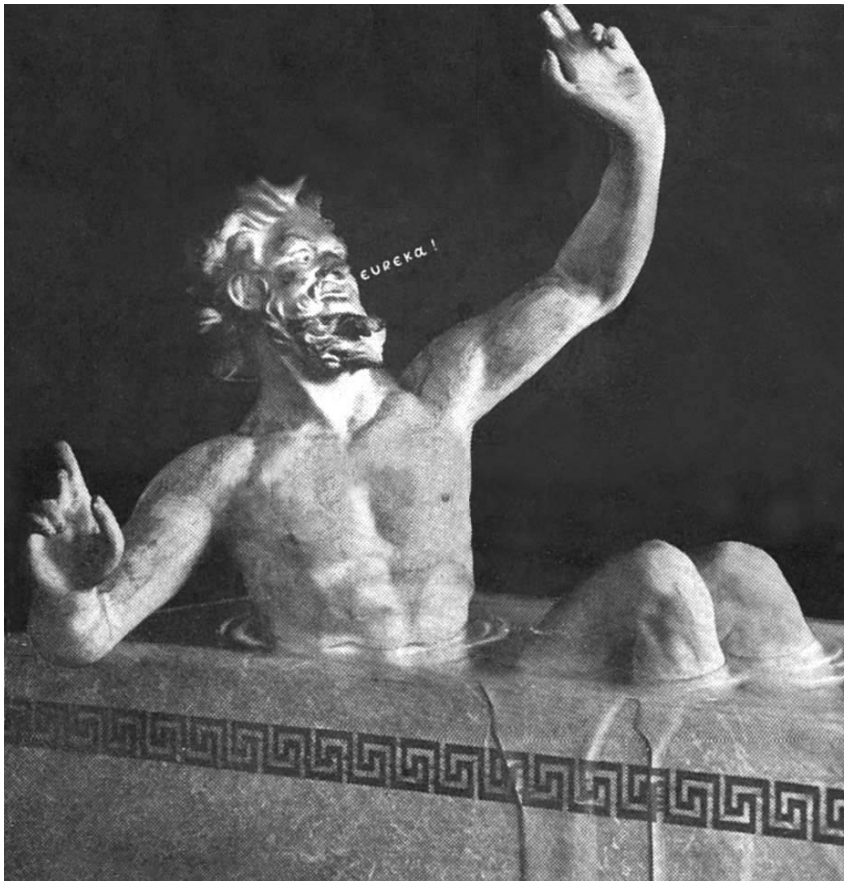
This fine balance between logic (serial processing) and vision (parallel processing) is akin to the best blend of science and art (or logic and holism). For optimum creativity, scientists and engineers need the wonder, imagination and flair of the artist, combined with the grim reason and perseverance of their own discipline.

Joy Paul Guilford and Erich Geyer were not the only ones to identify these two unique and important thinking styles. Friedrich Nietzche introduced the distinctions between the Apollonians and the Dionysians. On the one hand, the Apollonians favour logic, the analytical approach and a dispassionate weighing of evidence, and on the other hand, the Dionysians lean more towards intuition, synthesis and passion.

It has now become clear that, for optimum creativity, a careful blend of the two thinking styles is essential. Some critics say that scientists and engineers should develop the finer part of their lives, such as art, theatre, history, music and philosophy, to make of them more civilised human beings. However, the very blend of science and "the finer things in life" (the best synthesis of Nietzsche's Apollo and Dionysus) is also essential for optimum creativity. This supplement is not a "nice-to-have" cosmetic augmentation, but a vital ingredient in success in science and engineering.

Scientists, engineers, entrepreneurs and leaders often experience eureka-like breakthrough moments of exceptional insight in their work. Naturally, the explorer, detective and artist do too. In science and technology, the moments of brilliant new insight are so profound and delightful that scientists over the ages have given them a name: They are called "eureka moments". In the Greek language, "eureka" means "I have found it." The exclamation, "eureka!" was, reportedly first used by the mathematician Archimedes, some 2 200 years ago, when he stepped into a bath and noticed the attendant rise in the water level. This fluid displacement and buoyancy phenomenon became known as the Law of Archimedes.

Successor scientists followed by using the same exclamation during similar ecstatic moments of discovery. The exclamation "Eureka!" was initially used for "aha!" moments of invention or discovery, but since then, science and technology have progressed dramatically. Today, we know that not only invention, but also innovation, entrepreneurship and leadership all rely on moments of breakthrough visionary thinking. These climactic moments of brilliant thought have revolutionary technological and business consequences, much like the revolutionary consequences of the first discoveries.



→ *Archimedes discovered buoyancy in his bath. He also said "give me a place to stand and I shall move the earth."*

Source: Wikimedia commons

Eureka moments require a discontinuous (or transient) cognitive response and they deliver peaks of inspired, brilliant insight.

The experience of these precious moments is so climactic, exquisite and intoxicating that it can lead to addiction. It is as if the energy of all the foregoing toil is suddenly bunched up into a single ecstatic spurt of creative productivity. These moments are even more precious because of what they represent: the triggers of revolutionary progress. They represent the onset of exponential growth: growth in science, technology and business. Let's face it. If you have an intractable bent for addiction, you could become addicted to substances that are far worse than your creative juices.

Up to this point, it has been necessary to narrow the somewhat general definition of creativity down to its specific meaning in science and engineering, and to anchor this definition in its evolutionary roots. There is no evidence of a silver bullet solution. As always, creativity will demand total dedication, persistence and hard work.

Hopefully, some young scientists and engineers, who come to understand the complexity and urgency of the creativity crunch, will join the quest for improved creativity. Of course, whether or not the consequent growth in creative productivity will be up to the task of staving off the inclement global crisis remains to be seen.

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In a curious (but pleasant) reversal of fortune, ***Dr Hannes Steyn*** *studies for a PhD under the leadership of* ***Prof André Buys****. Prof Buys, in turn, worked under the leadership of Dr Steyn in Defence. This was after a successful career in the nuclear industry. In sharing the experience of industrial immersion, the authors have had the privilege of leading gifted technical people for most of their lives.*

The sky is the limit, unfortunately…

by Michael Neale

Mankind has already proven that the sky need not be the limit, but for all practical purposes it still is. We have set foot on another world. We continuously have people in orbit. We probe other worlds. We position telescopes in space and have even seen space tourists. However, all of these activities that prove that we can overcome the sky as a limit drain the earth of valuable resources: resources that might be better spent on building houses, creating jobs and saving the environment.

The sky is not the limit, merely an extremely expensive barrier to cross. To make the giant leap for mankind truly count, we need a way to traverse the barrier without gutting Planet Earth. We must find the resources we need in space and live off them; do what is called "in situ space resource utilisation" (ISRU).

Jan van Riebeeck and his settlers did not come to South Africa and expect constant supplies to be shipped from Europe. The early settlers had to farm to survive. They had to chop their own wood to repair ships, they had to mine to build our country, and our fellow countrymen had to earn our independence. And look at us now…

True, living off the land on a completely foreign and sometimes hostile piece of ground is more feasible than living off space. In space, one cannot find a food source, or breathe, for that matter. For example, it would be a daunting and long-term challenge to create the infrastructure needed for a self-sustained lunar colony. Yet, it is also a challenge that is exhilarating, stimulating and – most importantly – achievable through innovation.

Why bother?

There are numerous reasons for wanting to develop space resources, including the following:

- **Space exploration.** Earth cannot fund and supply a human presence across the solar system. It is vital to develop space resources for a sustainable human presence in space.
- **Human survival.** As long as humans are bound to a single planet, our fate depends on that of our vulnerable planet.
- **Scientific opportunities.** ISRU would go hand-in-hand with scientific advances. Once resources in space can be exploited, advanced research bases could be built, for example, telescopes on the far side of the moon could be constructed from lunar material.
- **Earth benefits.** ISRU would benefit the earth in terms of job opportunities, advances in technology, electricity supply from space-based solar panels, the supply of high-value materials and relief of the strain on earth's industries and environments.

In his book, *Mining the Sky*, JS Lewis describes the vast resource potential of our solar system. The moon has oxygen, iron, titanium, water, volatiles and a future fuel source, Helium-3. Although mineral concentrations comparable to those of the earth have not yet been found, this shows that the moon has the potential to be an industrial space port.

Metals and gases are abundant on asteroids, many of which come closer to the earth than the moon. Mars and its moons could also be sources of minerals and fuel, as well as being attractive targets for colonisation. Further away, the gas giants of our solar system harbour unimaginable amounts of valuable gases.

We are destroying the earth and the life on it to get to mineral resources, yet the resources on earth are insignificant compared to the riches available to us within our solar system. If we were to mine the mineral resources from space instead of on earth, it would help us protect the most valuable resource in our solar system, namely life.

Space Resources Roundtable

I recently had the honour of being awarded a scholarship by the Space Resources Centre at the Colorado

School of Mines. The condition of the scholarship was that I had to present a student paper at the first joint meeting of the Space Resources Roundtable and the Planetary and Terrestrial Mining Sciences Symposium (SRR & PTMSS).

This annual conference is a gathering of professionals from different fields, all interested in "living off the land" in space, or ISRU. The presentations revolved mainly around proposals and experimental results on how to explore, extract, beneficiate and utilise the wealth of resources found in space.

I attended this conference at the Colorado School of Mines from 8 to 10 July 2010 and intend going back every year.

An important aspect touched on at the conference was how to inspire young minds to get an education in science, technology, engineering or maths. One of the speakers does this by showing sixth graders how, with a proper education, they might one day be involved in building space colonies.

On a higher level of education, one presentation was on the lessons learnt by mechanical engineering students who had to build a robot capable of excavating lunar soil. A few universities in the USA have some final-year engineering students doing their design projects on building such lunar excavators. These robots eventually compete against each other at the NASA lunabotics competition.

A number of the speakers presented results from different aspects of one large experiment. This was NASA's lunar base analogue experiment, which was held early in 2010. In this experiment, scientists and engineers tested proposals for different components of a lunar base. This was done at a test site in Hawaii, where the inorganic, basaltic soil simulates important aspects of lunar soil. Some of the experiments were concentrating solar heat, melting soil for construction, incorporating hydrogen fuel cells, extracting oxygen from soil and self-thinking construction robots.

A definite highlight of the conference was the half-day technical demonstrations. This is where the speakers could demonstrate their projects and experiments. Most of the lunar base analogue experiments and a number of the student-built lunar excavators were showcased.

One of the main speakers presented his results on finding water ice on the moon. The Indian probe Chandrayaan-1 is currently busy mapping the lunar poles. The preliminary data from a NASA instrument on board confirmed that there is a lot of water ice on the moon. Previous studies, like the Lunar Crater Observation and Sensing Satellite (LCROSS) and the Lunar Reconnaissance Orbiter (LRO), showed that lunar water exists in some form, but the new results indicate that the ice is much more abundant and pure than previously expected. My presentation was a conceptual proposal on mining this ice.

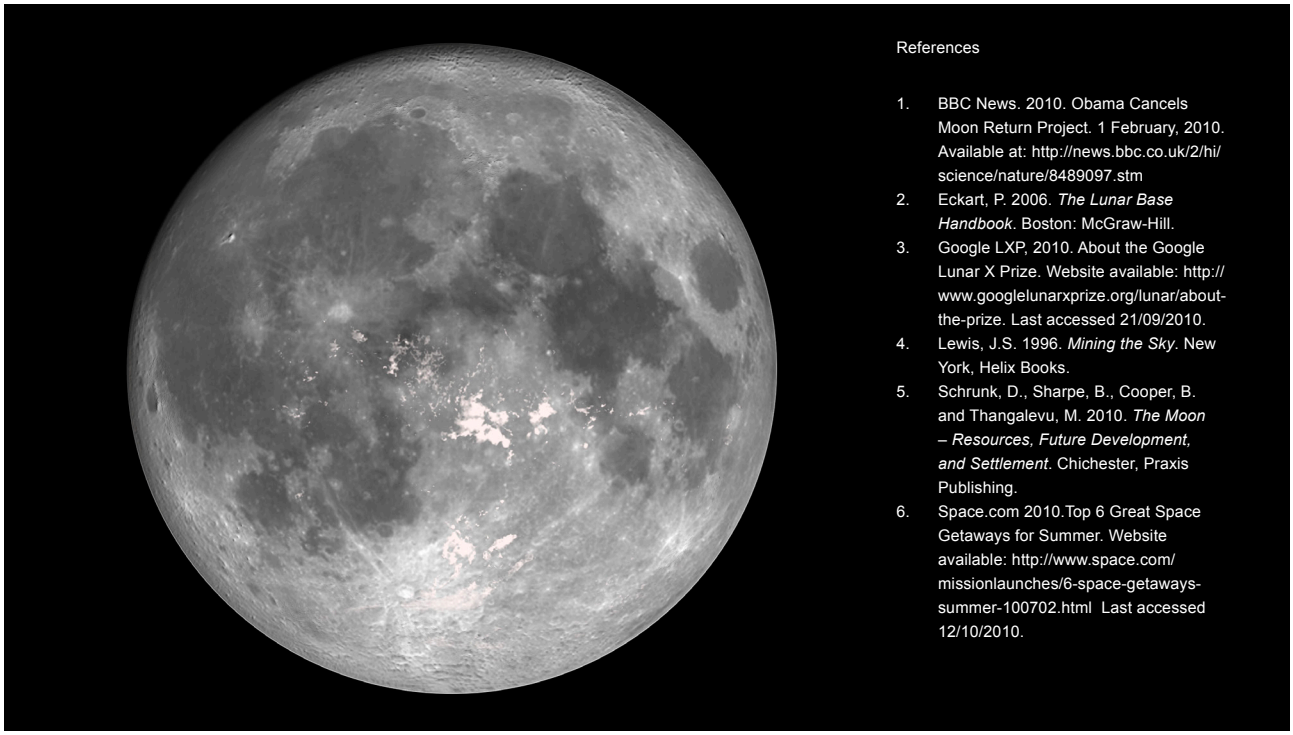
The ice is found in permanently shadowed craters, the slopes of which can be utilised to reduce ice transport. I showed three mining layouts, developed with assistance from VB Kom Consulting, that will channel the mined ice from the mining face towards a central point. The technical feasibility of the proposals is yet to be tested (and might result in a master's degree).

Mobilisation

In 2004, President Bush gave NASA the order to return humans to the moon by 2020, with the aim of extending the human presence to the rest of the solar system. When Obama assumed presidency, he supported this decision. However, the project was recently cancelled due to "lack of innovation". Instead, the plan is to put humans on asteroids and Mars. There is a lot of dispute over whether this is a good idea or not, as a sustainable moon base could have acted as an industrial outpost to supply material for Mars missions.

In the words of Jim Kohlenberger, "While we're cancelling Constellation [the lunar return project], we're not cancelling our ambitions." The cancellation of Constellation merely means that those who want to see ISRU operations on the moon will have less government money and will therefore have to obtain commercial support. This is arguably a good thing. If space missions could be more commercial and less governmental, the industry could be profitable. Profits could be ploughed back to develop the industry further.

There is already a growing awareness of and interest in commercialising space and its resources. At the moment, tourists can pay to go on zero-gravity flights, suborbital flights to space, time aboard the international space station and space walks. There are even offers to take tourists around the moon, although this has not happened yet.



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→ *There is vast resource potential in the solar system.*

These tourist excursions are far above the normal tourist's pay grade, but at least the seeds of a new industry have been sown.

Another example of commercialising space is the Google Lunar X-prize competition. Google is offering $30 million to the first commercial company to launch a rover to the moon and land it on the moon. Currently, 21 companies are competing to launch their rover to the moon first. Developing space in a commercial and industrial way as a platform for a space-faring human race is something that will happen. The question is just this: will we make it happen in our lifetimes?

A role for South Africa

Where does South Africa fit into the picture? We are not part of or able to compete with the supernations in a space race, but we can contribute. Dr Kris Zacny was born and raised in South Africa. To my mind, he is one of the champions of ISRU research, specifically in extraterrestrial robotic drilling. He works for Honeybee robotics, a company that does a lot of work for NASA. He has proven that South Africans are capable of making a contribution to this field.

This does not mean that all able South Africans should immigrate to the USA. South Africa is a strong mining country and has a number of astronomical facilities and experts. This, combined with our top-quality tertiary education, gives us the potential for substantial involvement in ISRU development. If we can get our academics educated about and interested in ISRU, there will be no need to leave the country.

ISRU development will require a multinational effort and I believe that South Africa can and should take up the challenge to overcome the limit we know as the sky. We must do what great minds do when confronted with an inconvenient barrier… innovate!

Michael Neale *is an honours student and academic instructor in the Department of Mining Engineering. He has had an interest in astronomy since he can remember and is a member of the Space Resources Roundtable. He intends establishing the South African Space Resources Association (SASRA) in the near future.*

Addressing shortcomings in the communication and provision of information to cancer patients

by Prof Ina Fourie

The expected growth in the number of cancer patients, the complexity of human information behaviour, and the ongoing frustrations and concerns reported by cancer patients due to a lack of information and inadequate communication of information reinforce the need for research to find ways of studying such needs in various cancer contexts and to find solutions. These may include interventions such as information portals, patient education, patient support groups and training health care professionals to use the Internet as an information resource in an appropriate manner to guide patients' information seeking.

The need to draw on different disciplines and research approaches seems very important to deepen insight and find solutions. The recent 7th Biennial Conference on Cancer, Culture and Literacy, presented by the Moffitt Cancer Centre at the Sheraton Sand Key Resort from 20 to 22 May 2010, again brought to the fore the dire need for information provision spanning cultures and languages, and the recognition of the impact of inadequate literacy levels when promoting screening for timely actions for cancers that may be prevented or cured if diagnosed at an early stage, for example, some breast, prostate and colon-rectal cancers.

A presentation entitled *How can studies on information behaviour expand the body of knowledge on cancer, culture and literacy?* attempted to awaken the interest of stakeholders working from a medical and health care background in considering the growing body of literature on information behaviour and information seeking, which is published in the domain of information science, and fully recognising and exploring what can be learned from health care and other supporting sciences.

Information behaviour is a subdiscipline of information science with its own theoretical base. It is seldom acknowledged in studies on cancer information needs and information-seeking behaviour. It includes studies that focus on cultural and language groups and covers studies about information needs, information seeking and information searching, and the dormant information needs and decisions not to react to information needs. It also covers the difficulty of recognising and adequately expressing information needs.

Studies on information behaviour inform the provision of information, for example, through libraries, and the design of systems to retrieve information, such as databases and portals. Such systems may support the provision and communication of cancer information to diverse cultural and language groups, as well as planning interventions for information provision and patient education, and health information literacy programmes. Various models on information behaviour and the subfields of information retrieval and information seeking were mentioned with reference to their implications, for example, Ingwersen's cognitive model, which is also relevant to those who are developing interventions.

Prof Ina Fourie *is a professor in the Department of Information Science,University of Pretoria. She teaches aspects of information retrieval, information behaviour and information literacy at graduate and undergraduate level. Her main research focus is information behaviour in contexts of cancer as well as palliative care.*

TuksBaja goes international

Engineering students from the University of Pretoria have been participating in the South African Sasol Baja SAE Competition since its inception 13 years ago. This is an annual event hosted by the Society of Automotive Engineering (SAE) and gives engineering students from different South African institutions an opportunity to design and manufacture, according to a specific set of rules, all-terrain vehicles that can compete against one another. All the teams are provided with the same 10 hp Briggs & Stratton engine.

→ The University of Pretoria has been participating in the South African Sasol Baja SAE Competition since its inception in 1997.

The competition consists of static judging, and a thorough safety and technical inspection. The cars are then put through rigorous tests for acceleration, hill-climbing ability, maneuverability and pulling ability. The competition culminates in a four-hour endurance race. The TuksBaja team is preparing to take part in the USA Baja competition in May 2011, which has a similar format to the national event.

The University's team consists of a group of dedicated students ranging from first-year to final-year students in different engineering disciplines, who gain hands-on experience solving real engineering problems. To ensure that the vehicle is ready for the USA competition, three final-year students are working on the TuksBaja vehicle as part of their final-year projects. These projects address the continuously variable transmission (CVT) setup, theoretical modelling of the vehicle dynamics and further development of the hydropneumatic suspension.

As participation in the American competition is a costly exercise, the team needs to ensure that the vehicle is capable of peak performance. During the 2009 December holiday, the team members identified three key areas of improvement. These were the drive train setup, suspension setup and reliability. The drive train consists of three reduction stages: the Polaris P-90 driving clutch and P-85 driving clutch, which forms the CVT, a belt reduction box and two hub reduction boxes, located at the hubs of the driving wheels.

The aim is to optimise the CVT that is implemented on the vehicle and improve the performance of the vehicle in the dynamic and endurance events to such an extent that participation in one of the Baja challenges to be held in the USA in 2011 becomes a viable option.

During the 2010 July holidays, the students performed extensive testing of different CVT configurations at the Gerotek vehicle testing facilities. Tests included performing hill climbs, and doing a skid pull and a 100-metre run. Different configurations of both the primary and secondary clutches were then compared to find the optimum configuration for participation in the Sasol Baja SAE challenge.

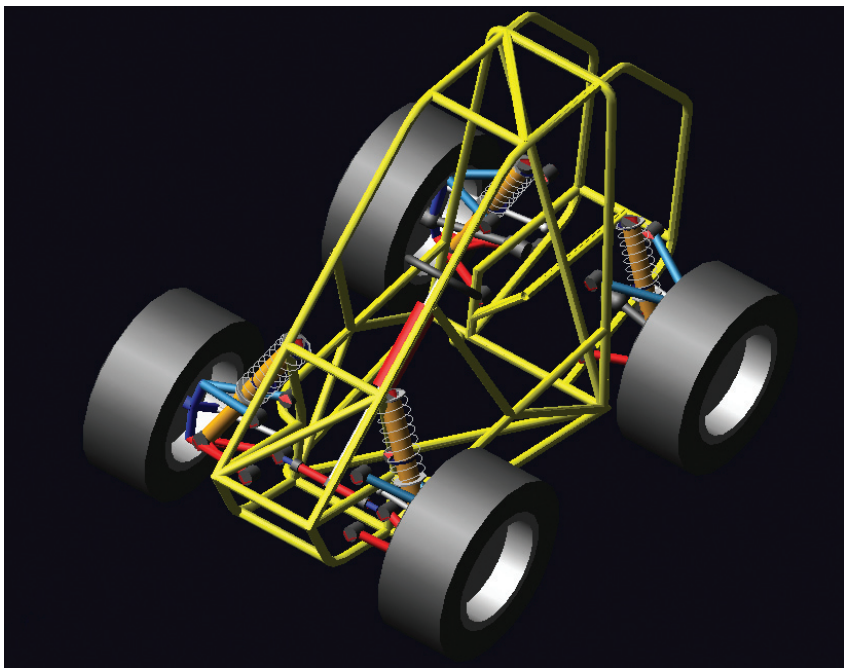
Variables investigated were flyweights used in the primary clutch, pressure springs used in the primary clutch and helix ramp angles implemented in the secondary clutch. The parameters monitored during testing were primary clutch rotational speed, secondary clutch rotational speed, vehicle speed, skid pull force and distance travelled, as well as the time taken to travel 30 metres from a standing start. The results were then processed and compared. Comparisons were made of different pressure springs for a specific weight and helix ramp, of different weights for a specific spring, and of different helix ramps for a specific weight and pressure spring.

To optimise performance in the various tests that form part of the competition, the damper system needs to be changed to conform to the changing road conditions. The road conditions vary from a concrete road during the speed and acceleration test to a muddy and rugged off-road track during the endurance race. The Tuks Baja is therefore equipped with a hydropneumatic spring damper system.

The advantage of this design is that the spring and damper characteristics can be changed quickly and easily. To alter the spring force, the gas pressure only needs to be increased or decreased. To change the damping coefficient, the damper pack dimensions, number of holes and orifice size need to be altered. Finding the best spring stiffness and damping coefficient through physical test is impractical and time-consuming. It is thus desirable to have a mathematical computer model, where various damping characteristics can be tested in the shortest time possible. This was achieved by creating a complete model of the car, using Adams/Car software.

The most important aspect of this research project was to create an accurate Adams model from the existing Baja. The better the mathematical model, the better the results will be. To achieve this, the dynamic properties of the Baja must be determined. The masses, centre of mass and moments of the sprung mass were determined experimentally. Due to the complex geometry of the unsprung mass, dynamic properties were taken from the CAD model. With this data, an Adams model was created.

To be sure that the model is an accurate representation of the prototype, the model needs to be verified by comparing data obtained experimentally to that acquired from an Adams simulation. If these two sets of data do not relate to each other, the Adams model must be refined until the two sets of data converge. With an accurate Adams model, different spring damper configurations can be tested and compared to find the optimum configuration of the hydropneumatic damper system. Applying these changes to the dampers will result in the mini Baja having optimum handling, ride comfort and jumping capabilities.

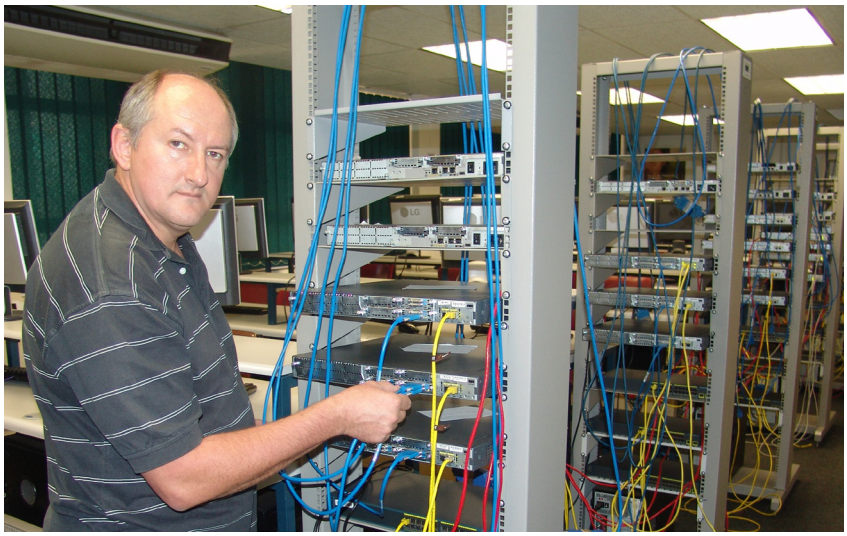


→ *The Adams TuksBaja model.*

Cisco Networking Academy makes a huge contribution to public service delivery

by Willem van Jaarsveld

"Average network fault turnaround times for the national government, education, defence and police networks have dropped from 25 hours to six hours. This is due to extensive training by the Cisco Networking Academy in the Computer Networking Group at the University of Pretoria (UP). Training was given to staff of the State Information Technology Agency (SITA) working at the National Operation Centre (NOC) in Centurion," says David Cloete, manager of the NOC.



→ Willem van Jaarsveld, director of the Cisco Regional Academy in the Department of Electrical, Electronic and Computer Engineering.

The SITA staff who participated in the Cisco networking training gained valuable knowledge and expertise in networking operation. These new skills are put to good use when networking faults need to be resolved in the shortest possible time. The turnaround time has been reduced to such an extent that it no longer disrupts service delivery for long periods.

During the recent opening of a Cisco local academy at the SITA training centre in Erasmuskloof, Pretoria, Emily Magoma-Nthite, Acting CEO of SITA, confirmed SITA's commitment to good service delivery and investment in human capital. The SITA-Cisco local academy will form part of SITA's learnership programme for young and upcoming networking specialists. This new facility, parented by the UP Computer Networking Group, will also be used for the further education and training of current SITA staff.

Aggrey Rantloane, Cisco Systems Regional Sales Manager: Public Sector, emphasised the important role the programme of the Cisco Networking Academy plays in the endeavour to eliminate the digital divide in Africa. By offering a high standard of training, complemented by numerous laboratory activities, the academy programme ensures well-qualified technicians, technologists and engineers to develop and support communication networks in Africa.

The sought-after Cisco-certified networking associate and professional (CCNA and CCNP) courses are taught as part of the undergraduate BEng Computer Engineering degree programme in the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria. With well-equipped networking laboratories and instructors, these courses are in high demand in industry.

For more information about the short courses, contact Amanda Mostert, Operations Manager at Continuing Education at the University of Pretoria Trust (CE at UP) on 012 420 5043 or amanda.ce@up.ac.za.

For an overview of the content of these courses, visit www.cisco.com/web/learning/netacad/course_catalog/index.html.

Optimal maintenance management enhances global competitiveness

Increasing awareness of the fact that optimal maintenance not only improves plant and infrastructure performance, but is essential to the global competiveness of South African enterprises is the driving force behind the establishment of a Centre of Excellence in Maintenance Engineering at the University of Pretoria.

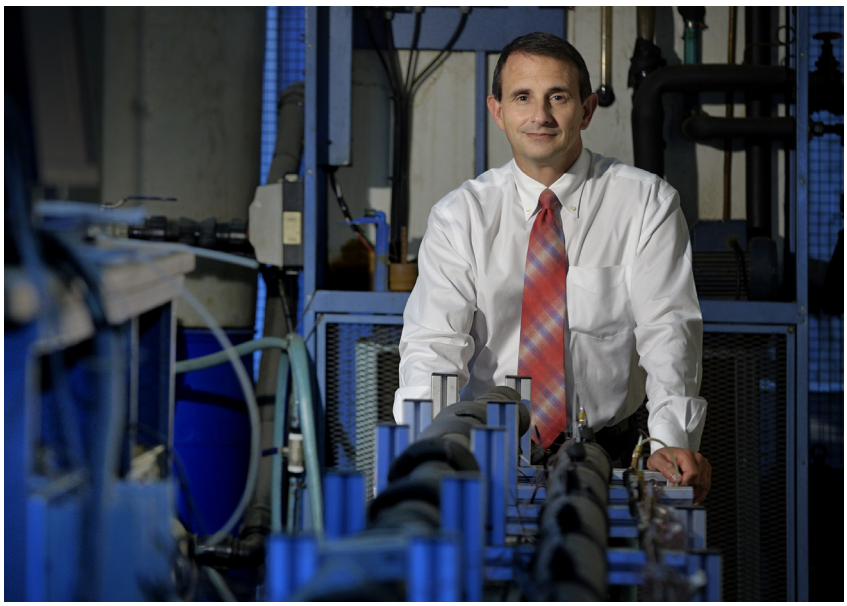
A maintenance engineering education and training programme was initiated in the Department of Mechanical and Aeronautical Engineering in 1994. However, this programme was downscaled in 2003 and effectively phased out in 2004 due to government funding policies.

Although the formal maintenance engineering programme was no longer presented, the department continued with its research programme, which supported maintenance-related issues. Projects in the field of condition-based maintenance have included master's projects such as gearbox vibration monitoring, the condition monitoring of electrical machines, dragline gearbox monitoring and rock bolt condition monitoring.

The most recent projects to be undertaken in this field include the development of a low-cost vibration monitoring system for gearboxes (MEng), the development of vibration monitoring techniques for varying speed and load machinery (PhD) and the development of prognostic methodologies for roller bearings (PhD).

The identification of an increasing industrial need resulted in a renewed interest in equipping engineering students to address maintenance issues in industry. This led to the establishment of a Centre of Excellence in Maintenance Engineering at the University of Pretoria in August 2010 after industry support was secured. It is located jointly in the Department of Mechanical and Aeronautical Engineering and the Graduate School of Technology Management.

In addition to modules such as Maintenance Practice, Condition-based Maintenance, Structural Integrity, Vibration Monitoring and Reliability Engineering, some new subjects are also being introduced. As maintenance actions are always measured against some cost value, Terotechnology examines the interaction of the cost principles, benefits and philosophies associated with maintenance decisions. Maintenance Management, on the other hand, examines the manangement principles and processes with which maintenance engineers work on a daily basis.

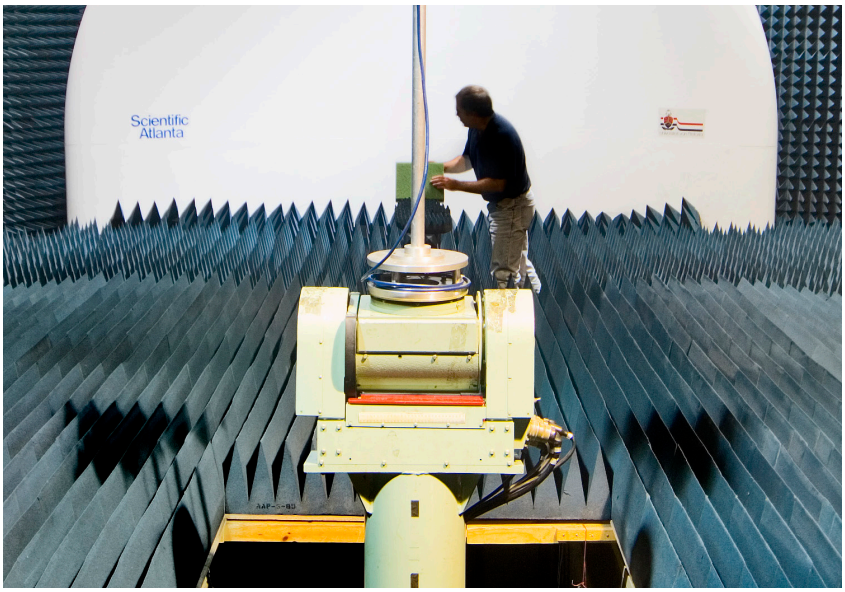


Prof Josua Meyer, chairperson of the School of Engineering.

Extending the capabilities of the Centre for Electromagnetism

by Prof Wimpie Odendaal

The Centre for Electromagnetism, which operates in the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology, is working towards replacing the obsolete 18 GHz network analyser in the compact antenna test range. Funds were raised to achieve this goal with the support of Prof Roelf Sandenbergh, Dean of the Faculty of Engineering, Built Environment and Information Technology. From a strategic point of view, extending the frequency range of the facility up to 40 GHz presents an opportunity for further exploration.



The compact antenna test range in the Centre for Electromagnetism.

"The high quality of research done by the experts at the centre enables us not only to service industry, but also to train future engineers to ensure the sustainability of the facility. A number of research outputs can be directly attributed to the consultation work performed by members of the centre. This places emphasis on the importance of continuing with collaborative efforts that encompass education, research and service," says Prof Sandenbergh.

The compact antenna test range is primarily a research facility that is used extensively by researchers in the Centre for Electromagnetism. It is used to measure antenna characteristics such as beam width, gain, side lobe levels and the polarisation of various sized antennas or antenna subsystems over a frequency range from 750 MHz to 40 GHz. Due to the facility's unique capabilities, the Centre for Electromagnetism is providing radio frequency and microwave free-field traceability to the local industrial community in partnership with the National Metrology Institute of South Africa. The compact antenna test range is ISO 17025:2005 accredited and it is therefore able to perform calibrations of power density meters or radiation hazard monitors and antennas.

With a view to industry's continued access to quality research and to the expertise available at the University of Pretoria, the campus company Business Enterprises at University of Pretoria (Pty) Ltd (BE at UP) has contributed financially to the upgrading of a network analyser at the centre to ensure the long-term viability of the facility.

At a ceremony held on 23 March 2010, the CEO of BE at UP, Deon Herbst, officially presented a cheque to the value of R200 000 to the centre for the upgrading of the facility. "The transfer of knowledge to industry remains our top priority and is also one of the main objectives of the University of Pretoria," said Herbst. "The relationship between BE at UP and the Centre for Electromagnetism focuses on high-quality knowledge transfer, which is why BE at UP takes pleasure in making a contribution to the upgrading of the research facility. We are positive that it will further improve the quality of our service delivery to clients," he concluded.

Staff members are appointed to leadership positions in industry associations

Two of the University's leading academics have been appointed to leadership positions in prominent industry associations. Prof Thokozani Majozi of the Department of Chemical Engineering has been elected as vice-president of the Engineering Council of South Africa (ECSA), while Prof Madeleine du Toit of the Department of Materials Science and Metallurgical Engineering has been appointed as president of the Southern African Institute of Welding (SAIW).

Prof Majozi is an associate professor in the Department of Chemical Engineering. His main research interest is batch process integration. His major contributions to research are the development of a continuous time framework for the synthesis of batch plants and a novel technique for near zero-effluent batch chemical facilities. Both these contributions have been adopted by industry.

He has received numerous awards for his research, including, most recently, the South African Institute of Chemical Engineering (SAIChE) Bill Neal-May Gold Medal Award for outstanding achievement and international recognition. This prestigious award is presented to an individual or group of individuals who have made a significant contribution to the chemical engineering discipline. In particular, the award recognises the international relevance of the contribution. The main criteria are unusually competent chemical engineering efforts carried out essentially in southern Africa, including commercial implementation (where relevant) and with an element of innovation.

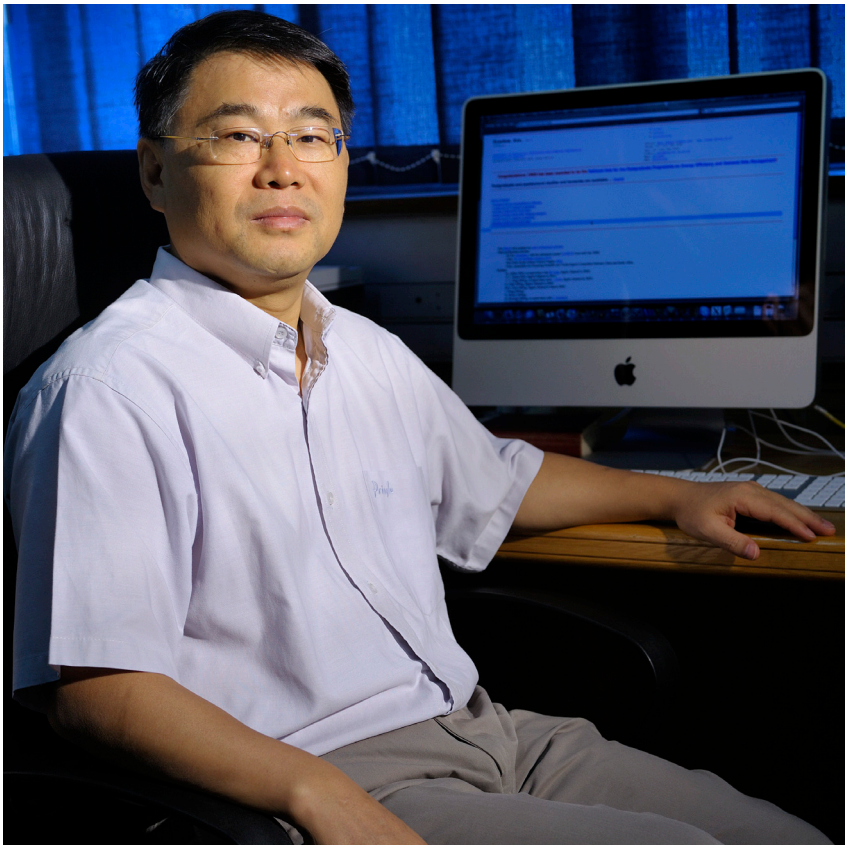
Prof Du Toit is head of the Department of Materials Science and Metallurgical Engineering. She is a registered professional engineer, as well as an international welding engineer and the first woman to hold this position. Her main research interests are welding engineering, welding metallurgy of stainless steels and the general physical metallurgy of steels and stainless steels.

She feels positive and energetic about her new role as president of the SAIW and looks forward to helping make positive changes, especially in assisting the institute in upgrading technology. She believes that many people in government could have a better understanding of what is happening in the South African welding industry and it is encouraging that many of the industry players are willing to be part of a process that brings government closer to welding. Prof Du Toit is a South African delegate to the International Institute of Welding (IIW) and a member of its technology management board.

Prof Madeleine du Toit, head of the Department of Materials Science and Metallurgical Engineering.

Engineers improve their research ratings

A researcher's rating with the National Research Foundation (NRF) is an indication of the quality of his or her research outputs in the recent past. It is undertaken by national and international peers and reviewers who are requested to critically scrutinise completed research, and it also gives an indication of the quality of a faculty's research and academic performance.



Prof Xiaohua Xia, A-rated researcher.

An A rating is the highest rating for individuals who are unequivocally recognised by their peers as leading international scholars in their field for the high quality and impact of their recent research outputs. B-rated researchers enjoy considerable international recognition by their peers for the high quality and impact of their recent research outputs.

The School of Engineering currently has two A-rated researchers, Prof Xiaohua Xia and Prof Brian Rand.

Rated researchers

Prof Xiaohua Xia of the Department of Electrical, Electronic and Computer Engineering received an A-rating from the NRF in 2009. He heads the South African National Hub for Energy Efficiency and Demand-side Management. His research interests include non-linear feedback control, observer design, time delay systems, hybrid systems, modelling and control of HIV/AIDS, and energy modelling and optimisation.

Prof Brian Rand of the Department of Chemical Engineering received an A-rating from the NRF in 2010. He is the current incumbent of the Department of Science and Technology (DST) Chair in Carbon Technology and Materials in the Institute of Applied Materials. His research interests are in carbon, graphite, nuclear graphite, refractories and ceramic processing. A major feature of his research has been the study of carbonaceous mesophase and its use in the fabrication and control of the structure of carbon fibres, composites and films. He has developed a novel approach to the transformation of pitch to carbon products.

The School of Engineering has a number of established B-rated researchers. These include Prof Johan Joubert (Electrical, Electronic and Computer Engineering), Prof Josua Meyer (Mechanical and Aeronautical Engineering), Prof Willie Nicol (Chemical Engineering), Prof Wimpie Odendaal (Centre for Electromagnetism), and Prof Jan Snyman (Mechanical and Aeronautical Engineering).

In the latest round of ratings by the NRF, another two researchers were recognised for the high quality and impact of their recent research outputs.

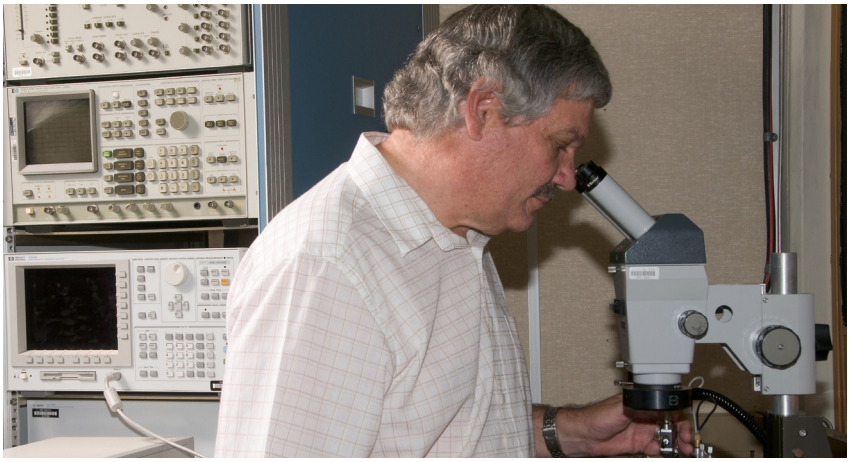
Prof Corné Olivier of the Department of Electrical, Electronic and Computer Engineering is a member of the Intelligent Systems Group, which is funded by the Unit for Defence Research at the Council for Scientific and Industrial Research (CSIR). His research interests are probabilistic reasoning within artificial intelligence, intent estimation, detecting change in low-resolution satellite data and images, and telecommunications and information theory.

Prof Monuko du Plessis is Director of the Carl and Emily Fuchs Institute for Microelectronics (CEFIM). He is the key inventor of the injection-enhanced silicon in avalanche (INSiAVA) technology and the principal research engineer leading the ongoing development work to refine this light-emitting technology for widespread use in industry.

Within the broader Faculty of Engineering, Built Environment and Information Technology, Prof Andries Engelbrecht and Prof Brian Watson of the Department of Computer Science also have a B-rating from the NRF.

Prof Brian Rand, A-rated researcher.

Prof Corné Olivier, B-rated researcher.

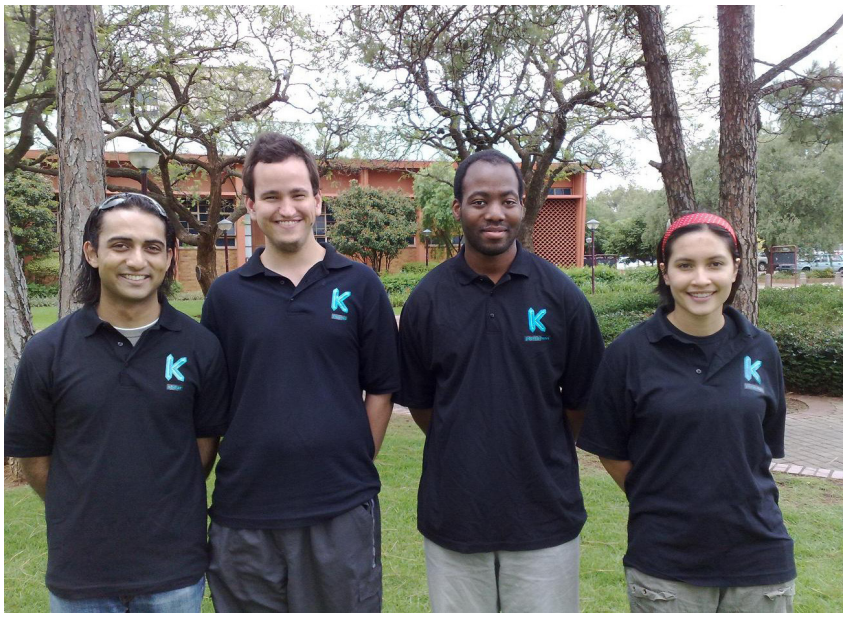


Prof Monuko du Plessis, B-rated researcher.

Krystal: a glimpse into the future of social networking

by Pierre Henri Kuate

Students in the Department of Computer Science were granted the opportunity to participate in the Microsoft© Imagine Cup, a competition for students, and won the Bright Blue Award for the development of a software product, known as Krystal, that was developed as part of their third-year curriculum.



→ The project group that developed Krystal (from the left to right): Abdur Khan, Thome Valentin, Pierre Henri Kuate and Jennifer Claire Brewster.

This project was inspired by the increase in the popularity of social networking sites such as Facebook and Myspace. The idea was to build a user-friendly software environment through which people could interact, learn and share information with each other. The system allows users to form groups, communicate in real time, share photographs, customise their "graffiti wall" and view their personal calendar. The software package even includes a bot game as a programming challenge and a custom-made Internet search engine with an indexer and relevance-ranking feature to find any information on the web.

The program was designed to fully utilise the Silverlight© software development platform to provide a rich, aesthetically pleasing and dynamic experience of usage. Creativity was an important point in the design of the system. Krystal features a window system that allows multiple activities to be performed simultaneously. All the subsystems come with a novel visual design to make them more pleasant and better to use.

As a software system, Krystal follows many design patterns that are taught in the academic software engineering literature. The Silverlight application was designed around the well-known MVC (model-view-control) metapattern in order to separate the external presentation from the internal data model. The underlying server uses the object-relational mapping tool NHibernate to communicate with the system's database.

Using their creativity and the features of Silverlight, the students were able to provide a unique experience for students to communicate and share information related to their studies.

During the department's annual Project Day at the end of the academic year, the project group gave a demonstration of their software, and also won a prize from the University.

The students found this to be an interesting experience. They learned much from the intermediate progress presentations made to to their lecturers.

Twins are top of civil engineering class

Twins Tercia and Talia da Sliva proved that engineering is no longer a man's world when they received their BEng degrees *cum laude* in April 2010. According to Prof Elsabé Kearsley, head of the Department of Civil Engineering, the top five students who graduated in 2010 were all women, and all passed with distinction.

They performed well throughout their four years of study, with Talia's average being a fraction higher than her sister's. This earned her the Vice-Chancellor and Principal's medal for the best student in the Faculty of Engineering, Built Environment and Information Technology. She was also the first female student in the history of the faculty to have received this honour.

In addition, Talia also received the medal of the Engineering Council of South Africa for the most outstanding achievement in the final year of study in civil engineering, the Stewart Scott International Prize for the most innovative research project of a final-year student in civil engineering, the BKS-DW de Vos medal for the best achievement in the final year, the prize of the South African Institute for Steel Construction for the best steel design and the ITS Prize for the best student in transportation planning.

She also received the Eskom Academic Award for being the top academic student out of all South African universities, having obtained the highest average marks during the final year of a four-year engineering degree relevant to Eskom.

Talia is currently employed by Jones and Wagner Consulting Engineering in Johannesburg, while Tercia works in the geotechnical department of BKS Consulting Engineers in Pretoria.

→ *Twin sisters Talia and Tercia da Silva were among the top five students in the civil engineering class who graduated from the University of Pretoria* cum laude *in April 2010.*

Student achievements reflect quality academic leadership

The achievements of students in the various departments of the Faculty of Engineering, Built Environment and Information Technology reflect positively on the quality of the academic leadership that is provided at the University of Pretoria. A master's student in Industrial and Systems Engineering received the bronze medal of the Southern Africa Association for the Advancement of Science (S_2A_3) for the best dissertation, while students in Electrical, Electronic and Computer Engineering came second in the student research paper competition of the Institute for Electrical and Electronics Engineers (IEEE) for the Europe, Middle East and Africa (EMEA) region. In addition, his supervisor, Prof Sunil Maharaj, received the Technology and Human Resources for Industry Programme (THRIP) award for technology.

→ *Ms Jacomine Grobler, recipient of the S_2A_3 bronze medal for the best dissertation at master's level in 2009.*

Ms Jacomine Grobler, a master's student who graduated from the Department of Industrial and Systems Engineering, has been awarded the prestigious S_2A_3 bronze medal for the best dissertation at master's level in 2009.

This medal is awarded annually to master's students at various universities in the country and is aimed at commending and encouraging local science and engineering students doing original research.

Jacomine completed her master's dissertation, entitled *Particle swarm optimisation and differential evolution for multi-objective multiple machine scheduling*, under the supervision of Prof Sarma Yadavalli, head of the Department of Industrial and Systems Engineering in the School of Engineering, and Prof Andries Engelbrecht, head of the Department of Computer Science in the School of Information Technology at the University of Pretoria.

Her dissertation focused on the development of a production scheduling algorithm to be used for the scheduling and allocation of tasks to resources in complex manufacturing environments. She worked closely with the Computational Intelligence Research Group and was invited to visit the Automated, Scheduling, Optimisation and Planning Research Group at the University of Nottingham in the United Kingdom, where she had the opportunity to present her work and exchange ideas with pioneers in the field.

She subsequently developed scheduling algorithms that resulted in improvements of up to 24% in terms of solution quality when compared to currently used algorithms.

Jacomine also presented papers at conferences in Hawaii, Singapore, Hong Kong and Norway. She currently works as an industrial engineer at Denel Dynamics and is studying towards her PhD.

Undergraduate students in the Department of Electrical, Electronic and Computer Engineering were also rewarded for their excellent research outputs. Danie Louw received the second prize for the Best Student Research Paper in IEEE Region 8

→ *Contributors to the paper that received second prize in the IEEE MELECON Research Paper Competition held in Malta were (from left): Philip Botha, Prof Sunil Maharaj and Danie Louw.*

(Europe, Middle East and Africa) for a research paper entitled *A low complexity soft-input soft-output MIMO detector which combines a sphere decoder with a Hopfield network*, on which he served as the lead author. His co-authors were Philip Botha and Prof Sunil Maharaj, also from the Department of Electrical, Electronic and Computer Engineering.

Following submissions from 26 student branches of the IEEE in 19 sections, six finalists were selected to present their papers at the 15th IEEE Mediterranean Electrotechnical Conference (MELECON) in Valletta, Malta on 26 April 2010. The University of Pretoria was the only finalist from Africa.

Their paper presented a reduced complexity soft-input soft-output multiple-input-multiple-output (MIMO) detector, which is intended to be used in conjunction with an error correction code. The detector combines a sphere decoder with a Hopfield network to calculate a max-log-map approximation. It is then combined with the error correction code in an iterative structure (turbo). The code used is a quasi-cyclic non-binary LDPC code. The simulation results demonstrate that with less computational complexity, the proposed system's performance equals that of an optimal sphere decoder-based detector.

DTI Award for Sentech Chair in Broadband Wireless Multimedia Communications

Prof Sunil Maharaj, who holds the Sentech Chair in Broadband Wireless Multimedia Communications (BWMC) in the Department of Electrical, Electronic and Computer Engineering, was the winner of the THRIP award for technology in the category Advanced Hi-Tech.

The THRIP project is funded by the Department of Trade and Industry (dti) and managed by the National Research Foundation (NRF) in the Department of Science of Technology (DST). It provides funding to support research initiatives that have industry participation and funding. In 2010, after a rigorous review of all funded research projects across the country, Prof Maharaj's work was placed in the top three in the category Advanced Hi-Tech.

He works in the field of broadband wireless communications. His research group comprises 23 students, who range from final-year Engineering Design Project students to PhD-level candidates.

Their research work has been largely in the area of MIMO systems and orthogonal frequency division multiplexing (OFDM) technology in wireless communication systems.

Their work has resulted in a provisional patent and the results of their research could have a major impact on next generation broadband wireless communication systems efficiencies.

Innovative Internet publishing by mining website

Business news publisher Creamer Media has launched geotargeted editions of its miningweekly.com news website.

→ *Kenneth Creamer, CEO of Creamer Media*

The CEO of Creamer Media, Kenneth Creamer says that the launch of the three new home pages is in line with the company's strategic objective to evolve into the leading provider of global mining news.

"We are committed to innovation. As we innovate, we find new ways of providing up-to-the minute mining news to a global audience," says Creamer.

The upgraded miningweekly.com site now includes separate editions for Africa, Europe, the Americas and Australasia.

Kenneth Creamer explains that readers will automatically be directed to the relevant geographical home page, which will make for speedy and relevant reading.

In addition to its main newsroom in Johannesburg, South Africa, Creamer Media has full-time journalists based in Toronto (Canada) and Perth (Australia), as well as a number of contributors in Malawi, Kenya, Zimbabwe, Zambia, Namibia and Argentina.

Mining Weekly publishing editor, Martin Creamer, says that, in addition to making the news geographically specific and providing articles with a longer life, the upgraded site also focuses on increasing the visual attractiveness for the reader. "Creamer Media launched the initial version of its website almost a decade ago. Since then, the company has continuously applied the power and versatility of the Internet to offer its readers news as it breaks, through the most relevant technology and mediums.

"The company is aggressive in its embrace of technology and ambitious in its plans of global expansion," said Martin Creamer.

Creamer Media sends two daily newsletters, *Africa, Europe, Australasia* and *North and South America* to almost 60 000 recipients daily.

The company also publishes *Engineering News*, *Polity* and *Research Channel Africa*.

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Way above standard

Standardisation is an increasingly important discipline in the modern world. A third-year student from the School of Engineering at the University of Pretoria received an award in the 2009 South African Bureau of Standards (SABS) Essay Competition for her thoughts on this intricate topic.

Standardisation in many technical fields is part and parcel of the knowledge that young professionals have to master. The SABS launched the SABS Essay Competition for undergraduate and postgraduate students to promote standardisation as a topic of investigation in tertiary academic institutions.

Ruanne van der Walt, a third-year student in electronic engineering, received a Highly Commended certificate as runner-up of the SABS Essay Competition. The theme of the competition was: *The utilisation of standards towards improving safety*. The winner of the competition, Paco Mendes of the University of the Witwatersrand, received a prize of R15 000 and R5 000 for the academic institution. The two runners-up, Ruanne and Yaacov Steinhauer of the University of Johannesburg, each received a cash prize of R5 000.

According to the judges, Ruanne gave an incisive overview of many of the key topics and issues related to safety and standards.

Ruanne's winning essay indicates how standards can increase safety in the workplace and at home.

According to Ruanne's essay, "Standards are the unsung heroes of South Africa. They fight for the people, preventing people from drowning, electrocution, head injuries and seafood poisoning."

The SABS defines a standard as a published document that lists established specifications and procedures to ensure that a material, product, method or service is fit for its purpose and performs in the manner for which it was designed and developed. The Compact Oxford English Dictionary defines safety

→ *Ruanne van der Walt (centre), a third-year student from the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria was awarded the second place for her essay on the utilisation of standards to improve safety. With her are Geraldine Monareng (executive corporate services of the SABS) and Vanida Lennon (standards executive of the SABS).*

as the state of being protected from danger, risk or injury. How do standards promote and improve safety?

According to Ruanne, the first idea that comes to mind is that standards prevent a consumer from being electrocuted in his or her pyjamas while making toast and touching the electrical plug by accident. The SABS standard sheet, 164 – 1:1992, plugs and socket outlets for households and similar purposes, ensures that the plugs of appliances do not give people a nasty early-morning shock or a shock at any time, provided the appliance is used correctly. However, appliance standards are not the only standards that exist for the protection of users. Standards exist for everything: from traffic cones to concrete floors, motorcycle helmets, lamp holders, personal floatation aids, air quality, child restraints in motor vehicles, and smoked snoek and prawns.

Manufacturers, designers and service providers can use standards as a resource. They should see standards as a tool with which they can improve their service or product instead of seeing them as a barrier to success.

The SABS website lists the benefits of standards. Standards ensure that people have easier access to and a greater choice of goods and services. They promote improved quality and reliability. Standards lower installation and start-up costs and ensure trust in one's business. Standards can create a competitive advantage by improving the quality of goods and services. They can also attract new customers.

Why then, askes Ruanne, if we have these great crusaders of public safety and business development, do we so seldom hear from them? How can one expect standards to be used to improve safety if their purpose and benefits are not clearly understood? Ruanne feels that a portion of the school curriculum should be allocated to inform learners of standards and the role of the SABS in this country.

The current National Curriculum Statement (NCS) for the Further Education and Training (FET) phase in schools includes a subject called Business Studies. In this subject, learners learn about various topics related to understanding and running a business. One of these topics involves steps in writing a business plan and how to establish a business.

"Learners will benefit from learning about standards as part of this topic because standards may have a substantial influence on product development and the use of standards can set one business apart from many others," says Ruanne.

The NCS includes other subjects, such as Design, and Engineering Graphics and Design, where standards may be introduced to learners. "Being in a technology and design field and only now realising how standards can be utilised to improve safety and promote technological advancement, I will be able to use standards to design new systems or to improve existing products and systems." says Ruanne.

Standards can be used to directly protect the public from danger, risk or potential harm. Business development, together with improving safety, is possible if standards are implemented and used as tools for advancement. However, none of the numerous business and safety advantages of standards can be utilised if standards are not well marketed in awareness campaigns in the near future.

Relationships at work

by Chris Heunis

When slogans like "winning with people", "our work force – our family", "people are our biggest asset" and "prevent injuries – we care" greet one as one enters the headquarters of trendsetting corporations, one cannot deny that relationship management is high on the scorecard.

These days, nobody questions the value of sound relationships at work. With the support industry cashing in on this evolving market, clients are confused about service offerings that involve coaching, mentoring and team building. Executives with effective soft skills will manage relationships through difficult times and will contribute to soaring productivity and retaining talent. This suggests that leaders with the "soft" knowhow will contribute to organisational stability and growth.

Research conducted by Gottman suggests that there is a strong link between work relationships and one's relationships at home. An abusive person at home will most likely display the same kind of behaviour at work. Gottman further suggests that in a marriage where a husband is not willing to share power with his wife, there is an 81% chance that it will end in divorce. This suggests that autocratic practices are doomed to fail.

Consider the following:

- Successful relationships accentuate the positive. Try to say "yes" as often as possible. Relationships deteriorate because of the way in which one reasons. Seek to understand.
- Do not be afraid to address a difference in opinion – embrace it and work through it.
- Good relationships are characterised by moments of attachment (vulnerability and intimacy). Do not misunderstand what is meant by "intimacy". This "moment" of intimacy can be characterised by a higher level of connectivity between two people. When both individuals share values like respect, integrity and openness, one should never avoid these moments. If one does, however, feel uncomfortable, check your values!
- Trivial moments filled with fun and laughter provide opportunities for profound connection, according to Gottman. For example, when one gives a small child a bath and he splashes, you can react in one of two ways. If you are impatient and short-tempered, you will miss an opportunity to meet the child in his world and on his terms. If you splash back and clean up later, you will have shared "intimacy" by connecting on a different level.
- Intimacy is the social glue that holds teams together by creating moments of truth between colleagues (through the medium of team building).
- Spread moments of intimacy equally between all your colleagues. This powerful moment becomes distorted when other team members do not share in the same level of openness. Those members will start to compete for your attention. If their attempts are unsuccessful, they will eventually lose interest. Those members who are excluded will group together and will jokingly gossip about this "unhealthy" or "romantic" relationship.

The importance of sound relationships at work will be realised as human resources move higher up the priority list of skills that are required for successful business leaders.

Chris Heunis *is the founder and executive director of the Team Building Institute.*

TBi

TEAM BUILDING INSTITUTE

Dr Siebert Benade (left) and Dr Chris Heunis (TBI) (right) celebrating the success of an eight-year business relationship between the GSTM and TBI.

"The programme offered by TBI to our master's students at the GSTM over the last eight years developed into an essential part of their development as people and managers. Participants... specifically gained from right-brain development towards whole-brain functioning."

Dr Siebert Benade - Graduate School of Technology Management, UP

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Lecturing and innovation

by Pieter de Villiers

Whenever we need to stay in touch with a moving object, the speed of that moving object determines the difficulties we experience in keeping up with it. This very simple statement holds extensive implications for the reality of our current world of business, research, lecturing and learning.

In a changing world, the simple principle that the speed of an object determines the difficulties in keeping up is applicable in such a way that it has become a serious threat to the sustainability of industries and many companies that are unable to keep up with the changes we experience. Universities are not free from such risks and challenges.

What do we lecture?

Universities usually teach the principles of science as a primary focus and the practical application of these principles as a secondary focus. Many principles of science have a history of stability. This is especially the case in natural sciences like physics and mathematics. In the social sciences, these principles are not as stable because of the nature and complexity of the human mind. The fact remains that universities should teach the fixed principles of science, as well as their application in real-life situations.

Let's look at two very simple examples. The law of gravity is known, well documented and described. This law is fixed. It does not change. We apply the principles of this law when we build an aeroplane or a bridge. Universities must teach both scientific laws and their applications. They cannot just teach students to design buildings, they must also teach them to use modern computer technologies instead of pencil and paper as instruments of work.

The challenge

If we agree to the fact that proper training must teach both the principles of science and the practical applications of these principles, we must also agree to the fact that lecturing should teach the most recent practical applications of science as used in the real world of business and life in general. This brings us to a critical focus point. Should a university teach the most recent practical applications of science? If they don't teach the most recent applications of science, universities will run the risk of delivering graduates with such outdated knowledge and skills that business will not be able to fully utilise the knowledge of these graduates. The reason is that the gap between what has been taught and the real world of applied science will be so big that young graduates will not have sufficient knowledge and experience when they enter the world of modern business.

The challenge is how a university should stay in sync with the changes in applied sciences, given the current pace of development. In simple terms, how do we ensure that our lecturing content reflects the most recent developments?

Some criticism

Consultants in many industries across many disciplines of science experience a serious gap between the scientific knowledge of newly trained students and the way in which scientific knowledge is applied in futuristic developments. In fact, it is the experience of industry that young graduates are very uncomfortable with anything that does not fit the (sometimes outdated) ideas being taught by universities.

Sophisticated consultants no longer investigate the strategic and operational design of a business by means of a process of personal engagement through interviews, questionnaires, data gathering and data processing. This is an outdated way of consulting. They use sophisticated artificial intelligence systems to map the strategic and operational design of a business. These systems are quick, efficient and delivered at a very low cost relative to the old methods. When doing this, industry experiences

young graduates to be totally out of their depth, consistently saying that a system-based analysis is not possible, reliable or complete. They do not know how these tools work or how they are developed and used. This is not an isolated case. Let us look at the arguments for not training students in the most recent innovations in business:

- Some new concepts, systems and products have not been tested properly and should only become part of training material once they have been tested and validated. The fact is that the process of testing and validating is so cumbersome and old-minded that futuristic companies do not have the time for it. If the thing works and makes sense, use it!
- There must be proper peer-group reviews and well-published research on the topic. This can happen in an academic environment, but not in business. The reasons are multiple. Losing your innovative edge by sharing critical intellectual property, wasting critical time to market and having to spend time and energy convincing meaningless critics are just some of the reasons.
- Universities do not have access to the most recent developments. This is most probably the best argument of all. Consultants are often faced with a situation where business leaders need help in the form of research and critical intellectual understanding of some of the challenges they face. They tend to refer these companies to their nearest university where such academics work. In the vast majority of cases, consultants realise that they either have no relationship with such a university or they show an unwillingness to work with the universities for fear of the access they have to grant these universities to their intellectual property. This is a serious challenge that deprives the economy of innovation to grow. (Consultants would prefer business to be much closer to academic institutions in order to prevent this. It will also be an important contribution to the capabilities of universities to lecture in collaboration with innovative development in industry and business.)

Is there a solution?

It must be emphasised that the predicament of "his master's voice" is fully understood. This predicament resides in the fact that lecturers tend to teach predominantly what their masters taught them. They will always be on good ground in terms of a responsible approach to their work if they stick to what is known and what has been tested.

Unfortunately, this is not good enough.

Consider the following:

- Get the innovators to lecture. Invite the innovators of new systems, products and applications to lecture on what they have done and teach the students to validate and test the innovators' products.
- Use students for research. Students should be used for research, even during their undergraduate years. Various assignments should be given with the outcome of finding the most recent ways in which things are being done against specific scientific underlying principles. These research results could, in turn, be used to inform faculties who to invite to present their innovations as part of a lecturing programme.
- Use innovative systems internally. Universities should use modern technologies and applications in order to demonstrate how innovative systems, processes and products are being utilised in business. Most universities will obviously think they do this. They do not. Some universities follow the most outdated methods and use old technologies when it comes to running the university as a business.

All the above are to be addressed by universities. The fact is that business has a critical role to play in this challenge. Business has to move much closer to the work being done by universities and use all the known methods of securing critical information as intellectual property and allow universities to work with them. If business does not take a much greater initiative in this regard, innovative success will never be optimal.

Any form of lecturing and teaching that does not stay in touch with innovation and progressive developments in our world is not worth the paper on which the learning material has been printed. For consultants, it will always be a thrill to experience areas where learning institutions have successfully trained their students on the most recent developments in the world of applied science, where business and the principles of science meet in order to take our world into the future. To all lecturers, faculties and universities making this an active strategy of their role in our world, congratulations and well done!

→ *Pieter de Villiers*